Low Interest Rates and the Distribution of Household Debt*

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Abstract

We study how changes in interest rates affect the distribution of debt within the population. In a model of borrowing with credit constraints and endogenous house prices, we show that less constrained and wealthier households increase their borrowing most when interest rates fall. We then use unique data on the universe of household credit in Belgium to document that older households with pre-existing housing wealth borrowed more as interest rates fell. Using regulatory data for identification, we find that a 1 percentage point fall in the interest rate is associated with a 7% increase in household debt.

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1. Introduction

Household debt increased substantially in most countries from 1980 to 2019. In the United States, household debt rose from 50 % to 75 % of GDP over this period. Other countries such as the United Kingdom, Switzerland, France or Canada experienced even stronger growth in household debt relative to GDP (Table 1). These patterns of rising household debt occurred as interest rates fell, with for instance 10 year real rates falling from 7.6% in 1982 to 0.5% in 2019 in the United States and the nominal fed funds rate falling from 14.2% to 1.55% over the same period.

The high level of household debt amid lower interest rates raises two concerns. A first concern is that high household debt can create risks to economic and financial stability. While debt can help households achieve their potential (Favilukis et al., 2017), an excessive indebtedness can increase the pro-cyclicality of the business cycle (Mian and Sufi, 2014). As households increase their leverage, their net worth becomes more sensitive to changes in asset prices, thereby threatening the stability of the financial system (Mian et al., 2017). Understanding the role of the interest rate in the increase in household debt is important to assess these risks. A second concern relates to the distributional implications of high household debt in the presence of credit constraints. If credit providers or regulators impose limits on the risk taking of households, the increase in household debt may be heterogeneous with some households being less able to borrow (Farhi and Werning, 2016; Svensson, 2019; Acharya et al., 2020).

How do changes in interest rates affect the distribution of household debt? While a number of authors have studied the sensitivity of household borrowing to the interest rate (Martins and Villanueva, 2006; DeFusco et al., 2020; Fuster and Willen, 2017), the implications of these estimates for the distribution of debt across households are less clear. If households face credit constraints, the response to lower rates is likely to differ across the population and the final outcome will depend both on the sensitivities of each type of borrower and on the prevalence of credit constraints in the population. These aspects have implications for models of the macroeconomy focusing on inequality (Greenwald et al., 2021; Gomez and Gouin-Bonenfant, 2020) or the transmission of monetary policy with heterogeneous agents (Auclert, 2019; Kaplan et al., 2018).

We tackle this question using both theory and new data on the universe of household debt in Belgium. In a benchmark model of borrowing with credit constraints, we show that a decline in the interest rate increases borrowing most for households that have accumulated some wealth and have future revenues to borrow against. This is consistent with stylized facts from the credit registry that show that the increase in household debt over the last decade is driven by borrowers aged between 45 and 54. To identify the role of the interest rate in household borrowing, we use the location of bank branches together with bank-level exposures to foreign countries to construct a 'Foreign GDP shock' instrument that shifts local credit supply but is independent of local economic conditions. Our estimates suggest that a 1 percentage point fall in the interest rate is associated with a 7% growth in household debt. To distinguish credit constrained households, we rely on the history and scope of the data to single out first-time borrowers, i.e. households that borrow for the first time in a given year. Our estimates suggest that first-time borrowers are more sensitive to interest rate changes than other borrowers. We argue that this could reflect changes in the access to credit as the most constrained borrowers are unable to borrow.

Our model extends the work of Stein (1995) to include endogenous house prices and borrowing by households. There are three periods. A continuum of households is endowed with some initial housing wealth as well as some labour income that is paid in the last period. For expositional purposes, we assume that the housing endowment is increasing with age and that the labour income endowment is decreasing with age. In the intermediate period, households consume housing and food - the residual good. Households can borrow in order to transfer their labour resources from the final to the intermediate period, subject to a credit constraint: for every unit consumed, households must make a down payment from their existing wealth. We show that the down-payment constraint leads middle aged households, with some existing housing wealth and future labour income, to borrow the most when interest rates fall. Younger households have more future labour income but are unable to borrow against this income because of a lack of resources for the down payment.

We then compare these predictions to the stylized facts using the household credit registry of the National Bank of Belgium (NBB). Belgium is an interesting laboratory to study the role of the interest rate as it is a small open economy in a large currency union. As in other countries, the aggregate household indebtedness in Belgium increased strongly as interest rates fell over the last decade, rising from 40% to 60% of GDP from 2006 to 2019. Belgium also offers unique credit data covering the universe of household borrowing from 2006 to 2018. We focus our analysis on mortgage debt which represents 95% of household borrowing and is the main driver of the increase in household debt.

We provide a series of stylized facts illustrating three features of the model: the distribution of credit by age, the evolution of the lending standards (or down-payment parameters) of banks and the potential identifiers of credit constrained households. We find that a shift occurred in the distribution of household debt across age groups over the last decade as older households increased their share of total credit. The share allocated to households between 25 and 35 years of age declined by around 10p.p. while the share of households above 45 increased by a similar amount.

In terms of lending standards, we do not find a significant deterioration in common indicators of risk at origination. The distribution of loan to value (LTV) ratios of newly originated loans or the debt service to income (DSTI) ratios have remained stable over the last decade despite the strong growth in credit. The stable LTV and DSTI ratios could reflect an allocation of credit directed to unconstrained households, who could already have some housing wealth and may have benefited from the growth in house prices.

To understand the allocation of the new credit, we decompose the credit flows into two categories: loans to first time borrowers and loans to other, non-first time borrowers. We define first-time borrowers as households who have no credit history at the time of the loan origination. The broad scope of our data allows to identify these borrowers more precisely than in previous studies such as Lee and Tracy (2018). In the model, one interpretation of first-time borrowers is that they are the credit constrained borrowers. The decomposition of credit growth suggests that loans to first time borrowers remained remarkably stable over the years, so that most of the new credit originated from non-first time borrowers.

We then quantify the role of the interest rates in household borrowing decisions, and how the sensitivity of borrowing to changes in interest rates varies for first-time and non-first time borrowers. The interest rate on individual mortgages depends on a wide range of variables that are mostly unobserved. These include for instance the future economic prospects of the household, the credit history or guarantees. To avoid a bias in our estimates, we construct a measure of the local interest rate using data on the physical location of bank branches and on interest rates for each bank at the national level. Instead of using the individual interest rates, this measure of local offered interest rate is less dependent on individual economic conditions (we use in addition only the location at the beginning of our sample).

We then instrument this local interest rate using foreign shocks to credit supply. The instrument is based on regulatory data on the international exposure of Belgian banks. As in the granular instrumental variables proposed by Gabaix and Koijen (2019), the idea is that shocks in foreign countries can affect local banks through their foreign lending. We use the exposure data to compute a foreign GDP growth shock for each bank, which we then combine with the branch locations to construct a local credit supply shock. We use this variable as an instrument for the local interest rate.

Our results suggest that a one percentage point decline in the interest rate is associated with a 7% increase in the debt of households. When we focus the sample on first-time borrowers only, we find that the elasticity increases to around 11%. Within the model, there are different ways to interpret the larger elasticity of first-time borrowers. One is that the credit constraints are relatively loose and they are able to secure the required downpayment through informal borrowing or past savings. Another interpretation is that the access to credit changes as interest rates fall, so that only the less constrained households can borrow. We provide some evidence supportive of this hypothesis: the share of the population with a mortgage increased significantly for most age groups over our sample period, while the share of younger households (aged 25 to 34) with a mortgage slightly declined. Regressions similarly confirm that lower rates are associated with lower access to credit for these households.

1.1. Related Literature.

Our work is related to a literature measuring the sensitivity of household borrowing to changes in the interest rate. For identification, these papers have relied on bunching around conforming loan limits (DeFusco et al., 2020), discontinuities around LTV thresholds (Best et al., 2020), mortgage subsidy reforms (Martins and Villanueva, 2006; Bhutta and Ringo, 2021) or survey analysis (Fuster and Zafar, 2021). Related to these papers but focusing instead on the mortgage payment (rather than the interest rate), Di Maggio et al. (2017), Fuster and Willen (2017) use exogenous changes in repayment schedules from Adjustable Rate Mortgages (ARM) to study borrower responses including leverage and consumption. Cloyne et al. (2019) use ARMs to study the response of household borrowing to changes in house prices.[1] Our identification strategy allows us to study the full population of borrowers (instead of e.g. only borrowers with a specific mortgage contract). The strategy relies on regulatory data on the exposure of banks to foreign countries, which create plausible shifts in the supply of credit in the spirit of the granular instrumental variables proposed by Gabaix and Koijen (2019) and of the credit supply shocks of Kashyap and Stein (2000); Khwaja and Mian (2008) or De Jonghe et al. (2020).

A second strand of the literature has focused on low interest rates and their implications for households, inequality and the financial system. Jorda et al. (2015) provide a historical perspective on the relationship between house prices, mortgage interest rates and mortgage debt. They find that loose monetary policy conditions often lead to booms in real estate lending, which in turn raises the risk of financial crises. Mian et al. (2017) echo this conclusion in a sample of 30 countries from 1960 to 2012, finding that low mortgage spreads are associated with an increase in the household debt to GDP ratio. Our work provides a disaggregated perspective on a recent case of strong growth in household debt.

[1] A related set of papers have studied the tax deduction of mortgage interest expenses, which is one of the main housing subsidies. Follain and Dunsky (1997), Ling and McGill (1998), Dunsky and Follain (2000) and Jappelli and Pistaferri (2007) for instance build on the seminal work of Poterba (1984) to study how the demand for mortgage credit changes with the tax subsidies, which influence the net interest rate paid by borrowers.

One important question when shifting from the aggregate debt series to the distribution of debt across the population is whether low interest rates contributed to the rise in inequality. Gomez and Gouin-Bonenfant (2020) argue that low interest rates decrease the return on capital but also make it cheaper to raise new capital. They show that the latter effect dominates in the case of the United States. A key challenge is then to understand whether credit constraints can prevent some households from reaping the benefits of the lower interest rates. This is one of the objectives of our paper. Greenwald et al. (2021) similarly emphasize that the impact of low rates on total wealth inequality (i.e. financial + human wealth) is lower than one would conclude looking only at financial wealth inequality. The reason is that the distribution of financial wealth and human wealth differ so the impact of lower interest rates on total inequality are milder. Our model also includes a human and a financial wealth distribution of households that respond to changes in the interest rate. We consider in addition the role of credit constraints: if households with a lot of human capital are unable to borrow, they will not benefit from the lower rates. Mian et al. (2021a,b) study the causes and consequences of the rise in household debt. Mian et al. (2021b) argue that the rise in top income shares has generated a savings glut of the rich, which in turn financed the increase in household and government debt. Mian et al. (2021a) then argue that the large debt levels have lowered aggregate demand and depressed the natural rate of interest. While the partial equilibrium nature of our analysis limits our ability to speak to this channel, the growth in borrowing from middle aged households with some pre-existing housing wealth is reminiscent of the findings of Adelino et al. (2016) that the middle class played a large role in the rise in aggregate household debt.

The low level of interest rates has also spurred a number of studies focusing on the impact on banks (Heider et al., 2021). Wang (2022) argues that the decline in interest rates has weakened the transmission of monetary policy and tightened the long-run provision of bank credit. Benetton et al. (2021) find that banks in the U.K. responded to the low interest rates by increasing origination fees. Gyöngyösi et al. (2019) use data from a household credit registry in Hungary to document how monetary policy affects credit supply. Our work complements theirs by focusing on the demand for credit by households and by documenting the response of households to interest rate shocks.

Our emphasis on credit constraints is related to a third strand of the literature that has aimed to understand the role of credit frictions in household borrowing. Attanasio et al. (2008) focus on the market for consumer loans and estimate the sensitivity of loan demand with respect to the interest rate and maturity. Einav et al. (2012) estimate a model with adverse selection and down payment requirements in the subprime auto loan market. Defusco (2018) uses a reform on real estate resale price controls to isolate the effect of collateral constraints. These papers emphasize the presence of credit constraints in household credit markets, a point that is shared by our work which also emphasizes the distributional implications. The issue of constraints in the access to credit has been central in the debate on macroprudential policies aimed at cooling housing markets (Claessens, 2015). Acharya et al. (2020), Peydró et al. (2020), Defusco et al. (2020) and Benetton (2021) show how macroprudential measures can affect lending. Our paper illustrates how the distribution of credit can evolve when credit constraints are stable and suggests that most of the credit growth is driven by unconstrained borrowers.

Finally, a number of papers in macroeconomics have highlighted the role of household credit in shaping the business cycle (Gertler and Gilchrist, 2018). Kaplan et al. (2018) explains that a key determinant of the direct transmission of monetary policy is intertemporal substitution, which occurs through credit markets. Kaplan et al. (2018) and Auclert (2019) have further emphasized that wealth or income inequality can also affect the transmission of monetary policy. Our focus on household borrowing at a disaggregated level can thus potentially shed light on the transmission of monetary policy where direct transmission may be more salient for some borrowers while credit constraints imply that indirect transmission is the primary channel for other borrowers.

The paper is structured as follows. We first present the model in section 2, including an analysis of the first-best outcome and the equilibrium with credit constraints. We describe the data and review key stylized facts in section 3. We then explain the empirical strategy in section 4 and discuss the estimation results and robustness analysis in section 5.

2. Model

To frame the analysis, we first explore a model of household borrowing under credit constraints, where households differ in their initial endowments of housing, financial and labour resources.

2.1. Setup

There are three periods indexed 0, 1 and 2. As in Stein (1995), a continuum of households $i \in [0, 1]$ receives an initial endowment and chooses a level of consumption of housing H_i and food F_i. The amount of housing in the economy is fixed to 1 and the housing stock is divisible. While Stein (1995) considers an exogenous distribution of debt and focuses on the implications for house prices, we endogenize the borrowing process as follows.

In period 0, the household receives a house of size H_i^0 and some financial assets (savings) worth K_i^0. The savings could be cash or a portfolio of financial securities that can be readily transformed to cash. The financial assets have a duration of d, so that a 1% fall in the interest rate leads to an increase of $d\%$ of the value of K_i^0.[2] We will sometimes refer to the housing and financial endowments as the capital endowment. In the final period 2, the household is paid a labour income (wage) W_i. The wage W_i could also be interpreted as the net savings, i.e. the difference between income and consumption over the whole lifetime in Auclert (2019). Households must consume in the interim period 1 and thus borrow in order to transfer their labour resources from period 2 to period 1. All amounts are in real value (net of inflation).

To guide the interpretation of the results, we assume that H_i^0 and K_i^0 are increasing in i, $\partial H_i^0/\partial i \geq 0$; $\partial K_i^0/\partial i \geq 0$ and that W_i is decreasing in i, $\partial W_i/\partial i \leq 0$. In this case, the index can be interpreted as the age of households. Young households (low i) have little housing or financial wealth but high future income. Old households (high i) on the other hand have accumulated more financial and housing wealth but have lower future income. While the assumption on the distribution of endowments allows to clarify the exposition, our results hold without this assumption.

In period 1, each household i chooses the amount of housing H_i and food F_i to maximize the Cobb-Douglas utility

$$\max_{H_i,F_i} U_i = \alpha \ln H_i + (1-\alpha) \ln F_i, \tag{1}$$

where α represents the taste of the household for housing. In order to fund the housing and food consumption in period 1, the household can sell its housing endowment at a unit price of P, it can sell its assets K_i^0 and it can borrow against its future (period 2) income at a gross interest rate R. The amount borrowed is thus equal to the consumption minus the financial and housing resources, $F_i + H_iP - H_i^0P - K_i^0$.

The lender imposes a Debt-Service To Income (DSTI) limit ρ so that total reimbursements in period 2 (principal and interest) must be less than a fraction ρ of the income earned:

$$R\left(F_i + H_iP - H_i^0P - K_i^0\right) \leq \rho W_i. \tag{2}$$

In addition to the DSTI constraint in equation (2), households face a constraint on the amount that can be borrowed relative to their financial and housing resources: the down-payment (or Loan-to-value) constraint. This constraint could result from a moral hazard problem as in Holmstrom and Tirole (1997) or a value-at-risk constraint as in Brunnermeier and Pedersen (2009). For each unit of down payment, households may consume up to an

[2] For instance, if the asset pays a risk-free unit of capital in period 2, the value in period 1 would be $1/R$ and the duration would be 1. A bank deposit or cash amount would have a duration of 0.

amount $1/\gamma$ where $\gamma \in [0,1]$. The parameter γ thus determines the share of consumption that must be financed by existing wealth in period 1 - in our case the housing wealth and the financial endowment. The downpayment constraint is

$$\gamma (H_i P + F_i) \leq H_i^0 P + K_i^0. \tag{3}$$

Finally, the supply of housing is normalized to one and the housing market clearing constraint is

$$1 = \int_0^1 H_i di. \tag{4}$$

Figure 1 summarizes the timeline. In period 0, households receive their housing and financial endowments. In period 1, they sell their existing house and financial assets and they borrow in order to fund their consumption of food and housing. In period 2, they receive their income W_i and pay back their debt.

2.2. No down-payment constraint

Consider first the model without the down-payment constraint. In this case, the resources available to households to purchase housing and food are composed of the proceeds from the sale of the housing and financial endowment, $H_i^0 P + K_i^0$, and the present value of transferrable future wages, $\rho W_i / R$. Households allocate a fraction α of their resources to housing and the remainder to food. Let $W = \int_0^1 W_i di$ be the aggregate labour income of all households and $K = \int_0^1 K_i^0 di$ be the sum of financial endowments. The equilibrium can in that case be summarized as follows.

Proposition 1 (Equilibrium with DSTI constraint)**.** *Without down-payment constraints, each household i allocates a fraction α of its resources $H_i^0 P + K_i^0 + \frac{\rho W_i}{R}$ to housing consumption and $(1-\alpha)$ to food consumption. House prices are equal to*

$$P = \frac{\alpha}{1-\alpha} \left(\frac{\rho W}{R} + K \right). \tag{5}$$

Proof. The households maximizes (1) subject to (2). The constraint may be rewritten as

$$F_i = \frac{\rho W_i}{R} - H_i P + H_i^0 P + K_i^0. \tag{6}$$

Plug F_i in the objective function:

$$\max_{H_i} U_i = \alpha \ln H_i + (1-\alpha) \ln \left(\frac{\rho W_i}{R} - H_i P + H_i^0 P + K_i^0 \right)$$

The FOC yields

$$H_i P = \alpha \left(\frac{\rho W_i}{R} + H_i^0 P + K_i^0 \right). \tag{7}$$

The amount of food is obtained by combining (2) and (7). House prices are pinned down by market clearing (4) and housing demand in equation (7). □

An increase in the preference for housing α or an increase in the financial or labour resources of households leads to higher house prices in proposition 1. A relaxing of the DSTI constraint which leads to an increase in ρ also increases house prices.

A fall in the interest rate affects households in three ways. First, it increases the present value of the wages that can be mobilized for borrowing, $\rho W_i/R$. This benefits the younger households more as they have a higher future wage income (since $\partial W_i/\partial i \leq 0$). If the value of the financial endowment K_i^0 is also sensitive to the interest rate and its duration d is positive, the lower interest rates will also increase the financial resources. The increased labour and financial resources will then increase the demand for housing, resulting in higher house prices. The higher house prices and asset values will benefit the older households more. In the special case where the duration of the financial asset is equal to one, we can show that all households benefit equally (in terms of available resources) from a fall in interest rates:

Proposition 2 (Distributional impact of interest rates without downpayment constraint)**.** *If there is no downpayment constraint and the duration of the financial endowment is $d = 1$, all households benefit equally from a fall in the interest rate, i.e.*

$$-\partial \log \left(\rho W_i/R + K_i^0 + H_i^0 P \right) / \partial \log (R) = 1 \forall i.$$

Proof. The total duration of the resources of the household is equal to the weighted average duration of the labour, housing and financial resources. The duration of the labour $\rho W_i/R$ and financial K_i^0 resources is equal to one. The duration of the housing resources will depend on house prices which are given by (5). Since house prices are a linear function of R^{-1}, the duration will also be equal to one when $d = 1$. □

Proposition 2 states that if the duration of the financial asset is equal to the duration of the labour resources (which have a duration of 1), then house prices will also have a duration of 1. A fall in the interest rate will then increase the resources available to households in period 1 by a same proportion for all households, regardless of the distribution of their wealth across financial, housing or labour resources.

If the duration of the financial resources is lower than the duration of the labour resources, younger households will benefit more as the rise in house prices will be lower than the appreciation in the value of labour resources. If instead the duration of the financial asset is higher than 1, the rise in asset prices will be higher than the rise in the present value of wages so households with more financial and housing wealth will benefit more.

This finding is consistent with the work of Auclert (2019) that highlighted the role of the interest rate exposure channel of monetary policy, where heterogeneous exposure to interest rate risk generates distributional effects of monetary policy. In Greenwald et al. (2021), a decline in the interest rate similarly affects both the value of financial wealth and human wealth. While lower rates increase inequality in financial wealth, it does not necessarily increase total inequality if human wealth and financial wealth are distributed differently across households. This is similar to the result of proposition 2 where young households have a lot of human wealth but little capital while older households have a lot of capital and little human wealth. If the duration of capital and human wealth are the same, both benefit to a similar extent if the interest rate falls.

Without the downpayment constraint, the borrowing of households exclusively reflects their human wealth and future labour resources. In our model, the distribution of debt decreases monotonically with age since households bring all their available labour income to the present ($\rho W_i/R$) and since younger households have higher future income ($\partial W_i/\partial i \leq 0$). If the interest rate falls, the bulk of the increase in aggregate debt will stem from the younger households if there are no downpayment constraints. Note that the DSTI constraint is binding for all households. As such, it can be interpreted as the budget constraint: it reduces the amount of future labour resources that can be transferred to the present.

2.3. Downpayment constraint

Let us now introduce the downpayment constraint of equation (3), so that households must pay down a fraction γ of their expenses in period 1 using their capital (housing and financial endowment). In this case households fall in one of two regimes. If the household has a lot of capital available relative to its labour resources, the downpayment constraint will not be a concern as the household has sufficient assets to use as collateral. If the capital of the household is low relative to its labour endowment, the household will however not be able to transfer all its labour income from period 2 to period 1 because of a lack of capital. The downpayment constraint will bind and the DSTI constraint will be slack. Since H_i^0 and K_i^0 are increasing in i and W_i is decreasing in i, there exists a threshold $\bar{i} \in [0,1]$ where households $i < \bar{i}$ are constrained while others are not.[3] When the household is constrained,

[3]The parameter conditions for an interior value of $\bar{i}$ are as follows. Let $\underline{H}$, $\underline{K}$ $\underline{W}$, $\overline{H}$, $\overline{K}$ and $\overline{W}$ be the housing, financial and wage endowments respectively for $i = 0$ and $i = 1$. Then $\bar{i} \in [0,1]$ if $\frac{1-\gamma}{\gamma}\left(\underline{H}P + \underline{K}\right) < \frac{\rho \underline{W}}{R}$ and $\frac{1-\gamma}{\gamma}\left(\overline{H}P + \overline{K}\right) > \frac{\rho \overline{W}}{R}$, where P solves (9).

the resources available are determined by the downpayment constraint. The allocation of the resources between food and housing are of shares α and $1-\alpha$ respectively. The next proposition summarizes the equilibrium with the downpayment constraint.

Proposition 3 (Equilibrium with DSTI and downpayment constraint)**.** *If $i > \bar{i}$, the housing and food consumption of household i is the same as in proposition 1. If $i \leq \bar{i}$, the household is resource constrained and housing and food consumption are given by*

$$\begin{cases} PH_i & = \alpha \left(\frac{H_i^0 P + K_i^0}{\gamma} \right) \\ F_i & = (1-\alpha) \left(\frac{H_i^0 P + K_i^0}{\gamma} \right) \end{cases}. \tag{8}$$

The price P solves

$$P = \int_0^{\bar{i}} \alpha \left(\frac{H_i^0 P + K_i^0}{\gamma} \right) di + \int_{\bar{i}}^1 \alpha \left(\frac{\rho W_i}{R} + H_i^0 P + K_i^0 \right) di. \tag{9}$$

The threshold $\bar{i}$ solves

$$\frac{1-\gamma}{\gamma} \left(H_{\bar{i}}^0 P + K_{\bar{i}}^0 \right) = \frac{\rho W_{\bar{i}}}{R}. \tag{10}$$

Proof. The household maximizes (1) subject to (2), (3) and (4). Constraints (2) and (3) can be rewritten as

$$H_i P + F_i \leq \frac{\rho W_i}{R} + H_i^0 P + K_i^0$$

$$H_i P + F_i \leq \frac{H_i^0 P + K_i^0}{\gamma}.$$

For a given consumption of housing and food and $i \neq \bar{i}$, one constraint will bind and the other constraint will be slack. The DSTI constraint (2) binds if

$$\frac{\rho W_i}{R} > \frac{1-\gamma}{\gamma} \left(H_i^0 P + K_i^0 \right) \tag{11}$$

and the downpayment constraint (3) binds otherwise. In the limit case where the left- and right-hand sides of 11 are equal, both constraints will bind. This is the threshold case where $i = \bar{i}$.

If $i > \bar{i}$, the downpayment constraint (3) is slack and the problem is the same as in proposition 1.

If $i < \bar{i}$, the DSTI constraint (2) is slack and the problem is

$$\max_{H_i, F_i} U_i = \alpha \ln H_i + (1-\alpha) \ln F_i,$$

such that

$$\gamma\left(H_iP+F_i\right)=H_i^0P+K_i^0.$$

Using the same steps as in proposition 1, we find that the household allocates a fraction α of its resources $\left(H_i^0P+K_i^0\right)/\gamma$ to housing and the rest to food.

House prices are such that the sum of housing demand of downpayment- and DSTI-constrained households is equal to the supply of housing in equation (4). □

Figure 2a illustrates the equilibrium with and without the downpayment constraint (propositions 1 and 3). We consider a linear distribution of housing endowments and wages where $H_i^0=2i$, $W_i=1-i$ and $K_i^0=0$. The blue line is the net present value of the period 2 labour income, which is also the amount borrowed in the case without downpayment constraint (proposition 1). In that case, younger households borrow most and the amount borrowed falls with age. The yellow line then shows the equilibrium with the downpayment constraint (proposition 3). The age threshold $\bar{i}$ is represented by the vertical dashed line. If the age of the borrower is above the threshold, the amount borrowed is the same as in the equilibrium without constraint (the blue line). If the age is below the threshold, the borrower is constrained: it lacks sufficient housing and financial resources to secure the amount that it would like to borrow. For constrained borrowers, the amount borrowed increases with age as the household accumulates more capital. With the downpayment constraint, the amount borrowed (and the labour resources transferred to period 1) is thus hump shaped. Households to the very left of the age distribution have no capital and thus cannot borrow. As age increases, they increase their borrowing up to a maximum at the threshold $\bar{i}$. The amount borrowed then falls with age as unconstrained borrowers transfer their labour resources, which fall with age.

Figure 2b then shows the impact of a fall in the interest rate, where the grey line is the outcome with a high interest rate and the blue and yellow lines are the outcome with a low rate. As before, a decline in the interest rate affects households through higher present value of labour income, a higher value of the financial endowment and higher house prices. The increase in debt of the unconstrained households, to the right of the threshold $\bar{i}$, is driven by the higher present value of the available labour income, $\rho W_i/R$, as in proposition 1. Constrained households to the left of the threshold also borrow more, but their borrowing is driven by the higher asset values that are then levered up to increase borrowing.

The flow of new credit to households is then the difference between the yellow line and the grey line in Figure 2b. While younger borrowers increased their borrowing most without the downpayment constraint, the constraint instead leads to a hump shaped response of credit over age so that middle-aged households now drive the bulk of credit growth. Younger households remain constrained by their lack of resources required to borrow, and their new borrowing is close to the borrowing with high rates. Older households on the other hand do not need to borrow much and therefore do not significantly change their borrowing behaviour. The increase in credit therefore originates from the middle-aged households who have accumulated some housing wealth but still expect substantial income resources in period 2. We record this in the next proposition, where the debt D_i is computed from proposition 3 as

$$D_i = F_i + H_i P - H_i^0 P - K_i^0.$$

Proposition 4 (Comparative statics)**.** *The increase in debt oustanding in case of a reduction in interest rates is higher for middle-aged households;* $D_i(R_2) - D_i(R_1)$ *for* $R_1 > R_2$ *is concave in* i *with a maximum at* $i = \bar{i}$*.*

Proof. Consider the case of high rates (indexed 1) and low rates (indexed 2), so $R_1 > R_2$, with respective debt levels $D_i(R_1)$ and $D_i(R_2)$. P_1 and P_2 and $K_{i,1}^0$ and $K_{i,2}^0$ are house prices and the value of capital endowments with R_1 and R_2. The other parameters γ, α, ρ and W_i are the same in both cases.

The debt increase with low rates is given by

$$D_i(R_2) - D_i(R_1) = \begin{cases} \rho W_i \left(\frac{1}{R_2} - \frac{1}{R_1}\right) & \text{if } i > \bar{i} \\ \frac{(1-\gamma)}{\gamma}\left(H_i^0(P_2 - P_1) + K_{i,2}^0 - K_{i,1}^0\right) & \text{if } i \leq \bar{i} \end{cases}. \tag{12}$$

If $i > \bar{i}$, the function is decreasing in i so $D_{\bar{i}}(R_2) - D_{\bar{i}}(R_1) > D_i(R_2) - D_i(R_1)\ \forall i > \bar{i}$. If $i < \bar{i}$, the function is increasing in i since $\partial H_i^0/\partial i > 0$ and $\partial K_i^0/\partial i > 0$. The function thus has a maximum at $i = \bar{i}$. □

It is interesting to contrast this result with the results of propositions 3 and 4 and the literature. A key argument of Greenwald et al. (2021) is that lower interest rates increase both the value of financial assets and the value of human wealth. If human and financial wealth are differently distributed across the population, total wealth inequality will rise less than financial wealth inequality. While this holds also in our model, a key condition for households to benefit from the higher human wealth is that they must be able to transfer it across periods. If downpayment constraints are significant, they are unable to benefit from the higher value of human wealth in period 1. As in Auclert (2019), the consumer responds to the change in interest rate but the mechanism differs depending on whether the borrower is credit constrained or not.

Proposition 4 focuses on the changes in the stock of debt across age groups. How does borrowing change in relative terms when rates fall? For instance, do households increase their borrowing by a same percentage? A second question is how changes in the interest rate will affect the share of the population that is downpayment-constrained. Let

$$\xi_i = -\frac{\partial \log D_i}{\partial \log R} \tag{13}$$

be the elasticity of borrowing to the interest rate. We can show that the elasticity is the same for all downpayment constrained borrowers and for unconstrained borrowers. If the elasticity of the former group is higher than that of the latter group, a fall in interest rates will reduce the threshold $\bar{i}$ and the share of constrained households. We summarize this in the next proposition.

Proposition 5 (Debt elasticity)**.** *The share of households constrained by the downpayment requirement $(\bar{i})$ is decreasing in R iff the interest rate elasticity of borrowing for dowmpayment-constrained borrowers is lower than that of unconstrained borrowers.*

$$\frac{\partial\left(\bar{i}\right)}{\partial R} < 0 \text{ iff } \xi_i > \xi_j \forall i < \bar{i},\ j > \bar{i}.$$

The elasticity of borrowing of constrained borrowers is higher than that of unconstrained borrowers iff the duration of the financial endowment is higher than one,

$$\xi_i > \xi_j \forall i < \bar{i},\ j > \bar{i} \text{ iff } d > 1.$$

Proof. The first part of the proposition can be recovered from the definition of $\bar{i}$:

$$\frac{1-\gamma}{\gamma}\left(H_{\bar{i}}^0 P + K_{\bar{i}}^0\right) = \frac{\rho W_{\bar{i}}}{R}. \tag{14}$$

The left hand side of (14) is the amount borrowed by constrained borrowers and the right hand side of (14) is the amount borrowed by unconstrained borrowers. If $\xi_i > \xi_j$ for $i < \bar{i},\ j > \bar{i}$, a fall in R will lead to a rise in the left hand term that is higher than that of the right hand term, so the threshold $\bar{i}$ falls.

The second part of the proposition can be shown by noting first that the unconstrained households have an elasticity of 1. The elasticity of borrowing of constrained households is

$$\frac{\partial \log D_i}{\partial \log R} = \frac{\partial \log P}{\partial \log R}\beta_H + d\left(1-\beta_H\right) \text{ if } i < \bar{i}$$

where β_H is the share of housing in the capital endowment ($\beta_H = H_i^0 P / \left(H_i^0 P + K_i^0\right)$. The elasticity of house prices $\frac{\partial \log P}{\partial \log R}$ is in turn greater than 1 if $d > 1$.

To see this, consider the case where $d = 1$. In this case, we can replace K_i^0 by $\tilde{K}_i^0 / R$ and the total capital K by $\tilde{K}$ with $\tilde{K}_i^0$ and $\tilde{K}$ being independent of R. The price of housing (3) can be rewritten as

$$P = \alpha \frac{1-\gamma}{\gamma} \int_0^{\bar{i}} \left(H_i^0 P + \frac{\tilde{K}_i^0}{R} \right) di + \alpha P + \alpha \frac{\tilde{K}}{R} + \alpha \int_{\bar{i}}^1 \left(\frac{\rho W_i}{R} \right) di$$

i.e.

$$PR = \frac{\alpha \frac{1-\gamma}{\gamma} \int_0^{\bar{i}} K_i^0 di + \alpha K + \alpha \rho \int_{\bar{i}}^1 W_i di}{(1-\alpha) - \alpha \frac{1-\gamma}{\gamma} \int_0^{\bar{i}} (H_i^0)\, di} \tag{15}$$

If we similarly replace the financial endowments in the threshold equation (10), we can obtain:

$$PR = \frac{\gamma}{1-\gamma} \frac{\rho W_{\bar{i}}}{H_{\bar{i}}^0} - \frac{\tilde{K}_{\bar{i}}^0}{H_{\bar{i}}^0} \tag{16}$$

The problem thus simplifies to two equations (15) and (16) with two unknows, $\bar{i}$ and PR. Let $\vartheta \in \mathbb{R}$ be the solution for PR, we have $P = \vartheta / R$ and the duration of housing is 1, i.e.

$$-\frac{\partial \log P}{\partial \log R} = 1.$$

If the duration d is greater than 1, the rise in the value of the capital endowment (housing and financial) will be larger than for $d = 1$. This will ease the downpayment constraint and further increase demand for housing, so house prices will rise more than if $d = 1$, and the price elasticity of housing will thus be greater than one. □

2.4. Empirical predictions

The model yields a number of predictions that can be mapped to the data. A first prediction is that the increase in debt across the age distribution is hump shaped: the increase in debt of younger and older borrowers is smaller than that of middle-aged borrowers. The muted response of borrowing by younger households in the model is a consequence of the downpayment constraint. When there are no such constraints, the distribution of household debt should instead be concentrated among the youngest households.

A second set of predictions relates to elasticity of borrowing to changes in interest rates for young (constrained) and old (unconstrained) borrowers. In the model, changes in interest rates impact the borrowing of these two types of households through different channels. The unconstrained households increase their borrowing because the cost of doing so has fallen and the current value of their future income has risen. The borrowing of constrained households is instead determined by the value of the collateral it uses as downpayment. Interest rates changes affect the value of its housing endowment and of its financial assets. The duration of the financial assets then plays a key role in determining the new borrowing capacity: if it is high, the constrained households will have a larger relaxation of the borrowing constraint and thus borrow more. Note that another interpretation could be that as interest rates fall they mobilize informal sources of capital such as transfers from relatives to increase their borrowing capacity. These aspects will determine whether the elasticity of borrowing is higher or lower for constrained or unconstrained households.

3. Stylized Facts

We now turn to the data to explore how the distribution of household debt changed over the last decades in Belgium. As we show in subsection 3.1, the behaviour of household debt in Belgium is similar to other countries with a substantial growth over the last decades. We then introduce the credit data used to study the distribution of household debt. We describe in more detail the evolution of credit and house prices in Belgium and the changes across different groups of borrowers. We then discuss how to identify the credit constrained borrowers.

3.1. International Perspective

Interest rates have declined steadily since the 1980s, and the rates on mortgages have been no exception. After reaching a high of 15% in the United States in 1980, the interest rate on 30-year mortgages fell to 10% in Germany and the U.S. by 1990. Ten years laters, mortgage rates were at around 7.5% in the euro area and the U.S., reaching 5% by 2010 and falling further since. Real rates have also fallen over the same period, as documented by Greenwald et al. (2021) and Marx et al. (2021).

Over the same period, the amount of household debt has increased substantially in most countries. As shown in Table 1, household debt to GDP went from 50% in 1980 to 75% in 2019 in the US. Countries such as France, Italy, Switzerland or Canada all experience strong increases in household debt to GDP. While the levels can differ across countries, with e.g. Canada or Switzerland having twice the debt levels of Belgium or France, the trend has been growth has been similar in these countries. Germany is perhaps the only exception to the strong growth as the ratio of household debt to GDP has fallen from 71% in 2000 to 54% in 2019, roughly the level of 1980.

3.2. Data

The main dataset that we use is the household credit registry of the NBB. The NBB maintains a credit registry for households as part of its mandate to prevent the overindebtedness of households. In addition to a production database that is consulted by banks when allocating new loans, the NBB also maintains an anonymized dataset which we use for our analysis. The registry includes data on all borrowing by residents in Belgium since 2006, including both mortgages and consumer loans. We focus on mortgage loans which account for 95% of total household borrowing. Mortgage debt also accounts for the bulk of the increase in household debt as the amount of consumer loans stayed broadly constant over our sample period.[4]

The registry data includes borrower characteristics such as the age, the gender and the municipality of residence (zip code) of the borrower. When a loan is allocated to multiple borrowers, we use the characteristics of a randomly selected lead borrower. The lead borrower is the same for all identical groups of borrowers so that e.g. couples with multiple loans are linked to the same borrower.

The loan characteristics in the registry include the total amount due, the maturity in months of the loan and the start date of reimbursements. It does not include however the current loan balance and we assume a linear amortization to compute the outstanding balance of the loans. We compute the outstanding amount at t years since issuance as the product of the remaining maturity as a share of the original maturity and the origination amount D_0. If the maturity of mortgage is of T years, the debt outstanding at t years since issuance is computed as:

$$D_t = D_0 \times \frac{T-t}{T}. \tag{17}$$

We verify in appendix A.1 that the aggregate stock of loans outstanding is consistent with alternative data series from the financial accounts. The correlation between the stock of loans - both new and existing - in our data and in the financial accounts is 98% (Figure A1 in appendix). At the bank level, the correlation between the registry and the financial accounts are of 99.5% (Figure A2). In appendix A.2, we verify the robustness of our figures to the assumption of linear amortization. We show that the differences with an annuity-based calculation of the outstanding balances are small because the average years since issuance of outstanding loans is small. In most years, more than 70% of mortgages have been issued less than 3 years in the past. The importance of loan renegotiation by households explains

[4] In 2006, consumer loans outstanding represented 7% of the total, or €8 billion. In December 2018 the amount outstanding had increased to €10.6 billion and the share in overall household debt had declined to 4.5% (Source: NBB.stat, loans and deposits).

the relatively low lifespan of mortgages. This in turn attenuates the role of the formula used to compute the outstanding balance.

The data includes around 1.6 million borrowers at the beginning of the sample, in 2007, and 1.9 million towards the end, in 2018 (Table 2). This represents around 15% of the total population for 2007. The weighted average age of borrowers increases from 39 to 41 years and borrowers generally have around 2 loans outstanding. The average amount borrower by households increased from €78,000 to €127,000 through our sample. The number of first time borrowers falls from 98,182 to 74,932 from 2007 to 2018, while the amount borrowed by these borrowers increased by 56%, from €135,000 to €204,000. The average age of first time borrowers falls slightly over time from 34 to 33 years.

The borrower characteristics in the credit registry include the age and the municipality of residence of the borrower. We use the information on the residence to merge the data with other databases. For the income, we use data on taxable income from the Finance ministry. The data provides the mean and median income by municipality and age group over our sample period. There are eight age groups: less than 25 years old, 25 to 34, 35 to 44, ..., 75 to 84 and above 84 years old.

We use data on real estate transactions from StatBel, the national statistical agency. For each municipality and year, the data includes the number of transactions and key moments of the price distributions. It also distinguishes among property types (house, apartments and villas). For each municipality, we compute a house price index following the Laspeyres methodology.

We also use a series of regulatory datasets and disaggregated statistics. The NBB collects data on the interest rates of new and outstanding loans of banks. We use the bank-level series to explore the role of interest rates as we explain in section 4. Finally, we also use data on credit flows used for the financial accounts, the bank balance sheets (Schema A) and the regulatory surveys on loan portfolios (Prêts Hypothécaires Leningen, PHL survey) to explore the evolution of bank lending standards and verify the accuracy of the outstanding amounts in the credit registry data.

3.3. Lending standards and distribution of household debt

Our sample is from 2006 to 2018. Interest rates fell substantially over this period, from a high of 6% in late 2008 to 1.5% in 2018. Mortgage rates in Belgium closely track the rates in the euro area which fell by similar magnitudes. Over the same period, household indebtedness increased strongly. The ratio of household debt to GDP increased from 40% in late 2004 to more than 60% in 2018. This is illustrated in Figure 3a. While Belgian households had a low level of indebtedness relative to the euro area average in 2004, the level of debt increased above that of the euro area in 2015. At the same time as household debt was going up, real estate prices also increased in Belgium. In particular, prices rose faster than the average disposable income of households and this rise was strongly correlated to the increase in household debt (Figure 3b).

At the aggregate level, lower interest rates were associated with higher household debt and higher house prices. A higher household debt need not increase leverage however if the assets of households also increases. In the case of Belgium, housing is the largest asset of most households. According to the Household Finance and Consumption Survey (HFCS), housing accounts for more than 75 % of the assets of households in the bottom 80 % of the wealth distribution. Households in the top 20 % of the wealth distribution have around 60 % of their assets invested in real estate, of which half is invested in real estate other than the main residence. The HFCS data suggests that the net wealth of households, defined as the total assets after deducting the debt, has remained stable from 2006 to 2018 at 200 % of GDP according to the NBB financial accounts. This suggests that the increase in household debt has thus increased the leverage of households and their exposure to potential declines in house prices.

On aggregate, households became more indebted as interest rates fell over the last decade. How is the increase in debt distributed within the population? Figure 4 explores a first dimension of heterogeneity across borrowers, age, which also plays a key role in the model. The figure shows the loan to income (LTI) ratios computed at the municipality level broken down by age groups, in 2006 and 2016. We observe a change in the pattern of household indebtedness over age. In 2006, the highest leverage of households was reached at a relatively young age (25-34), with leverage gradually declining for older age groups. In 2016, the peak in leverage is instead attained for the households aged 35 to 44. This is consistent with the prediction of our model of a "hump shaped" response to lower rates, and Figure 4 is in fact consistent with the model comparative statics in Figure 2.

Figure 5 provides an additional illustration of the increase in borrowing from older age groups. It shows the share of credit by age groups in 2006 and 2018. We find that the share allocated to households between 25 and 35 years old declined by around 10 percentage points while credit allocated to the age groups 45 and above increased their share by a similar amount.

In the comparative statics of Figure 2, the downpayment requirement γ remained constant. Could the increase in debt be driven by a change in credit standards by banks? We explore in Figure 6 two indicators of credit standards: the Loan To Value (LTV) ratio and the Debt Service To Income (DSTI) ratio of newly originated mortgages.

The LTV ratio measures the average size of the loan relative to the value of the house used as collateral. Figure 6a compares the distribution of the LTV ratios of new loans in 2009 with that of 2017. We find an increase in the share of loans with LTV between 80 and 110 percent. The share of loans with LTV higher than 110 percent however declined so that the share of loans with LTV higher than 80 percent stayed broadly stable.

Another measure of credit standards is the Debt Service To Income (DSTI) ratio which measures the share of disposable income allocated to the reimbursement of mortgages and the payment of interests. Lower interest rates could have conflicting effects on the DSTI ratios. On the one hand, it could lower interest payments and therefore the cost. On the other hand the higher borrowing amounts could increase the principal payments. Figure 6b shows the distribution of new loans in 2006 versus 2017 by DSTI categories. As for LTV ratios, the distribution remained rather stable with an increase in the density around 35%.

The maturity of the mortgages remained stable and around 17 years from 2006 to 2017. We find that the share of loans with maturities above 25 years declined, but this was compensated by a decline in shorter maturities of 10 to 15 years (Figure 7). In fact, the maturity of mortgages seems to be driven primarily by the age of the borrower. Borrowers aged less than 25 years borrow at maturities around 23 to 25 years, and the maturities then decline monotonically with age. The maturity of mortgages of borrowers older than 55 years is around 10 years (Figure 8).

The regulatory data suggests that the majority of mortgages in Belgium have a fixed rate. The share of fixed rate mortgages has declined somewhat between 2007 and 2017, falling from 82% to around 78%. The rate of default on mortgages is low and varies between 1 % and 1.2 % between 2006 and 2018.

3.4. Credit constraints and first-time borrowers

In the model, we use the age to distinguish constrained from unconstrained borrowers, assuming that older households have a larger housing endowment but a lower wage income. This provides an age cutoff below which households are constrained. In practice, income and endowment trajectories over age can differ across households and it is likely that within an age group, some households are constrained and others are not. An alternative way to identify constrained households is to focus on first time borrowers, i.e. borrowers in a given year that were previously absent from the database.

The broad scope of our data allows to identify first time borrowers with a higher precision than previously used measures. For instance, one approach used in the United States relies on the Universal Residential Loan Application forms, which include a question on ownership over the prior three years. This is often used to measure first time homebuyers, even though the history is of only three years. Lee and Tracy (2018) propose an alternative measure using data from the Federal Reserve Bank of New York Consumer Credit Panel, which is a 5 percent random sample of U.S. households with credit files derived from Equifax. Since the begining of our sample in 2006 also includes information on all loans outstanding, we are able to obtain a broader and more exhaustive measure of first time borrowers.[5]

Figure 9a shows that the age of first time borrowers is concentrated in the younger age group 25 to 34, so that an age-based proxy for financial constraints would be similar to focusing on first-time borrowers. However, the Figure also shows that some households also borrow for the first time at an older age (in particular 35 to 44 years).

A key issue to interpret results on first-time borrowers is the access to credit. In the model, housing is divisible and borrowers always purchase some housing and borrow, even if the amounts are small. In practice, housing is not divisible and there are limits to the extent that households can choose for a smaller or less expensive property. The average age of borrowers in Table 2 already gave a sense of the changes in access to credit for first-time borrowers relative to the general population. The average age of first-time borrowers fell slightly over the period, from 34 to 33, while the average age for all borrowers increased from 39 to 41. To explore the access of households to the credit markets, Figure 9b shows for the four main age categories in our data the share of households that have a mortgage. For the older age groups, the share of population that had a mortgage increased significantly. For instance, 28% of households aged 45 to 54 had in mortgage in 2018 while this figure was of 22% in 2006. The only category that did not see an increase in the share of borrowers is in fact the younger age group of 25 to 34 years, for which the fraction of borrowers slightly decreased. This suggests at the least that the access of younger borrowers to the credit market did not improve as interest rates fell.

The homeownership rate in Belgium is around 75% for households aged 35 to 65 (Table A2 in Appendix). For younger households aged 25 to 34, the homeownership rate is 51%. This suggests that around two thirds of owners buy their first property at the age of 25 to 34. Around a quarter of households in their later stages of life also owns properties that are not their main residence, but this fraction is low for the younger age groups whose housing wealth is concentrated in their main residence.

To understand the increase in household debt, we decompose the credit flows into two categories. For each year t, we distinguish loans D_{jt} issued to first time borrowers ($j = 1$), defined as borrowers who were previously absent from the database. We then compute the flow of credit to first time borrowers as

[5] Because the 2006 data only includes the loans outstanding, our measure of first time borrowers could capture borrowers who had reimbursed their loan before 2006 and took on a new loan after 2006. To account for this issue we run specifications of the regressions in section 4 without the first years in our sample where the bias is likely to be higher, and provide the breakdown by years of the credit flows in Table 3.

$$F_{1t} = D_{1t} - D_{1t-1}.$$

The other borrowers are non first time borrowers ($j = 2$), who had a loan outstanding before year t. We similarly compute the debt flows as:

$$F_{2t} = D_{2t} - D_{2t-1}.$$

The decomposition of credit stocks is shown in Table 3. From 2007 to 2018 the total stock of credit grew from €122 billion to €236 billion. We find that the amount of loans held by first time borrowers remained remarkably stable over this period, at around €12 billion. As a consequence, most of the credit growth originated from non first time borrowers, as shown in panel B of Table 3. First time borrowers accounted for only €2 billion of the €113 billion of increase in household debt from 2007 to 2018.

Recent work has emphasized the role of "investor borrowers" in the housing boom in the United States. DeFusco et al. (2020) for instance find that much of the rise and fall in volumes in the real estate market arose from changes in short-term investment. To explore whether the borrowing by non-first-time borrowers could be driven by a smaller group of investor borrowers, we decompose the stock of credit for different borrower groups depending on the debt percentile in Table 4. We sort all borrowers in increasing order of debt outstanding. The group <p10 includes the first 10% of borrowers, the second group (p10-p50) includes the next 10% to 50 % of borrowers, followed by the groups p50-p90, p90-p95 and the last 5% in the group >p95. Table 4 shows the total mortgage debt outstanding for the different groups. The table suggests that credit in the 5% of households with the largest debt outstanding did not increase more rapidly than the others, with a share that remained constant at around 20% of total credit between 2007 and 2018. These statistics suggest that "investor borrowers", or the concentration of large borrowing by a limited category of individuals, did not play a primary role in the overall increase in credit in the case of Belgium.

4. Empirical Framework

The previous section described a number of patterns regarding the distribution of credit in the last decades that are consistent with the model. To identify the specific role of the interest rate, we use a shift-share instrument, calculated as the weighted exposure of local banks to GDP growth in foreign countries. We first describe the identification challenge and our strategy. We then explain how we construct the local interest rate faced by the borrower, which is the main endogenous explanatory variable. We then describe the instrument for the interest rate. We finally discuss how we distinguish credit constrained borrowers using first-time borrowers.

4.1. Identification challenge

In the model, the response of borrowing by households takes two forms in equation (12). If the household is unconstrained, it is able to transfer all its future income to the present. The amount borrowed D_i is the net present value of the expected future income W_i,

$$D_i = \frac{W_i}{1+r}.$$

If the household is credit constrained, the amount borrowed is determined by the down-payment requirement γ and the resources available to the household. The resources consist of the housing endowment H_i^0 times the price of housing $P(r)$. The borrowing is

$$D_i = \frac{(1-\gamma)}{\gamma} H_i^0 P(r).$$

The term $(1-\gamma)/\gamma$ can be interpreted as a leverage multiplier. If the bank requires a down payment of 0.2 units for every unit consumed (so $\gamma = 0.2$), the household can borrow 4 units for every unit of available resource and the leverage multiplier is equal to 4. A change in the interest rate affects the borrowing by changing the value of the housing endowment, $P(r)$, which increases the borrowing capacity through the leverage multiplier.

In the data, we observe the amounts borrowed for each borrower i and year t. A specification that nests both the constrained and unconstrained cases is to estimate

$$\log D_{it} = \alpha_0 - \alpha_1 r_{it} + \alpha_2 \log H_i^0 + \alpha_3 \log W_i + \alpha_4 \log \frac{(1-\gamma)}{\gamma} + X_{it} + \epsilon_{it} \tag{18}$$

separately for constrained and unconstrained borrowers. This specification relates the amount borrowed D_{it} to the interest rate faced by the borrower, r_{it}. It controls for the housing wealth and the income of the household. X_{it} is a vector of borrower and period characteristics, including borrower and year fixed effects. The unobserved characteristics are ϵ_{it}.

The coefficient of interest is α_1 which measures the sensitivity of borrowing to changes in the interest rate. Estimating this parameter is challenging in practice since the interest rate r_{it} paid by the borrower is depends on circumstances such as the relationship between the borrower and the lender, individual prospects of the borrower, additional securities offered by the borrower or specific policies of the lender. In this case the unconfoundedness assumption is likely to be violated as some variables affecting the interest rate r_{it} will be unobserved.

We address this in two steps. First, instead of relying on the actual interest rate paid by the borrower, we construct a measure of the local interest rate offered by banks. We use this interest rate as the dependent variable r_{it} in equation (18). Second, we instrument the local interest rate with the weighted exposures of local banks to foreign growth shocks.

4.2. Measuring the local interest rate

At the loan level, the interest rate paid by the borrower on its mortgage generally depends on unobserved borrower characteristics such as future income prospects, private wealth, additional guarantees or private information available to the bank. If households with better economic prospects borrow more against lower rates, this could for instance bias our estimates downwards. To address this concern, we use a measure of the local interest rate faced by each borrower in its municipality instead of using the actual rate paid by the borrower. The interest rate at the municipality level is computed using the average interest rate of each bank at the national level and the geographic location of the bank branches.

We compute the local presence of the bank as the fraction of the total number of branches N_{bm} of bank $b \in \{1, \ldots, B\}$ in municipality $m \in \{1, \ldots, M\}$, divided by the total number of branches in m at the start of our sample ($t = 2006$):

$$\omega_{bm} = \frac{N_{bm}}{\sum_b N_{bm}}. \tag{19}$$

We set the market share to the 2006 level to avoid concerns that the local presence of banks will be determined by demand characteristics. The historical location of bank branches can predict the current location of bank branches, which in turn influence the supply of credit to borrowers.

Our focus on local credit supply builds on a large literature documenting that credit markets have a strong local component and that the physical distance between the borrower and the nearest branch is an important determinant of the credit supply available to households (Beck et al., 2018; Degryse and Ongena, 2005). Argyle et al. (2020) have shown that shopping for credit is costly and households tend to favour their local bank. If there are differences in pre-existing coverage of bank branches across municipalities, a shock at the bank level could create a contraction of credit in municipalities where this bank has a stronger presence. Figure 10 illustrates the differences in local market shares for two banks. While some banks have a national coverage, other banks are more focused on specific parts of the country. The shares also vary across neighbouring municipalities.

To compute the local interest rate, we use data on the average interest rate on mortgages for each bank at the country level. The data is from the NBB's survey on interest rates

(MFI Interest Rate statistics, MIR). For a given bank interest rate r_{bt} in year t we compute the local interest rate as

$$r_{mt} = \sum_{b=1}^{B} \omega_{bm} r_{bt}. \tag{20}$$

4.3. Foreign exposures and credit supply shocks

Our measure of the local interest rate addresses concerns regarding the determination of interest rates at the borrower level. The local interest rate could however still be dependent on local economic prospects that also influence demand. A bank that focuses on wealthy municipalities with strong economic prospects may for instance be able to offer more loans at lower rates than a bank that focuses on more vulnerable municipalities. To address this, we instrument the interest rates of banks using shocks to their foreign country loan portfolios. We use consolidated regulatory data to measure the exposures of banks to foreign countries to construct an instrument for bank credit shocks, in the spirit of the granular instrumental variables of Gabaix and Koijen (2019) and the shift-share instruments of Borusyak et al. (2022) and Goldsmith-Pinkham et al. (2020). Figure 11 illustrates the foreign exposures of Belgian banks. The largest countries by exposure are the Netherlands, the United Kingdom and the United States which together account for around 50% of total exposures. Consider a set of foreign countries indexed by $c \in \{1, \ldots, C\}$. Let g_{ct} be the GDP growth of foreign country c in year t. Let e_{bc} denote the exposure of bank b to country c in 2007, normalized so that $\sum_c e_{bc} = 1$. For each bank, we compute the bank foreign growth shock as

$$G_{bt} = \sum_{c=1}^{C} e_{bc} g_{ct}. \tag{21}$$

The exogeneity in the shares used to construct the instrument is an important component of the identification (Goldsmith-Pinkham et al., 2020). As for the local bank market shares, we fix the foreign exposures to their value at the beginning of our sample to avoid concerns of endogenous changes in the foreign exposures by banks over time that could be correlated with their local strategy. The average bank foreign growth shock in our data varies over time from a low of -4% in 2009 to a high of 6.7% in 2015. Within each year there are substantial differences in foreign growth shocks across banks as illustrated in Table 5.

To construct a local measure of the instrument, we use the branch locations as in equation (20). For each borrower i living in municipality $m(i)$ in year t, we compute the local foreign growth shock as a weighted average of bank-level shocks

$$Z_{it} = \sum_{b=1}^{B} \omega_{bm(i)} \times G_{bt}. \tag{22}$$

We then use this variable to instrument for the interest rate in equation (18) in a two stage least squares estimation procedure. The first-stage regression is

$$r_{it} = \beta_1 Z_{it} + \beta_2 \log H_i^0 + \beta_3 \log W_i + \beta_4 \log \frac{(1-\gamma)}{\gamma} + X_{it} + \nu_{it}.$$

A valid instrument must satisfy the exclusion restriction and must be relevant (Stock and Yogo, 2005). In our case, the exclusion restriction is that foreign economic shocks only affect the local economy through their impact on bank credit supply. This assumption is plausible in our setting since many of the foreign exposures of Belgian banks are with countries that are geographically remote. The share of exposures to countries outside the euro area is of 47%, for instance. Since Belgium is a small open economy with a strong exports sector, one additional concern regarding the instrument could be that the foreign lending networks are related to the trade networks of local firms. A foreign shock to banks would thus also affect the local economy and the demand for loans by households. To verify the robustness of our results to these concerns, we also estimate our model controlling for trade networks.

To further verify that the foreign shock is unrelated to local demand for loans, we perform a number of balance checks. The objective is to verify that the instrument is quasi-randomly assigned, i.e. that the exposure of local banks to foreign countries is plausibly random conditional on the observables that can be controlled for. The results of the balance checks are shown in Table 6, where we perform pairwise regressions of the instrument on a number of municipality characteristics, conditional on the set of fixed effects that we use in the main empirical specification. The analysis confirms that the correlation between the instrument and the local income or house prices are low and not statistically different from zero. We also compute in Table 6 the correlations of the instrument with the lending standards of banks (Loan to income and loan to value). Since credit constraints are an important determinant of borrowing by constrained borrowers, we must verify whether the credit constraints faced by borrowers change when banks face foreign shocks. We documented in section 3.3 that lending standards of banks were broadly stable over our sample period. The level of Tier 1 capital of banks in our sample is 15.4% of risk-weighted assets. The leverage ratio is at 5.6% and also satisfies the Basel III requirements. Through our sample period, the regulator also actively encouraged banks to lend prudently and increased the capital requirements of banks for real estate related exposures in December 2013 (Ferrari et al., 2016). The low correlation of the instrument and measures of credit constraints such as the LTI and the LTV ratios in Table 6 further confirms that banks do not change credit constraints such as downpayment requirements in response to foreign shocks.

The second condition for a valid instrument is that it is relevant in predicting the endogenous variable. Figure 12 illustrates the first stage relationship for banks and municipalities. The green dots indicate for each bank and year in our sample the foreign GDP shock and the difference between the bank rate r_{bt} and the average rate across all banks in year t. The blue dots show the first stage for municipalities, where the interest rate is computed using equation (20), substracting the year average. In both cases we observe a strong negative relationship between the foreign GDP shock and interest rates, which suggests that negative foreign shocks for banks are associated with higher interest rates in the domestic market.

Table 7 shows the results of the first stage regression estimated either at the bank level in specifications (1) and (2) or at the municipality level in specifications (3) and (4). While our sample includes 72 bank-year observations, the branch locations provide variation across municipalities and years for a total of 6,144 observations. The relationship between the average interest rate and the growth shock remains similar whether we use bank variation or municipality-level variation, with respective coefficients around -0.15 and -0.09. The relationships for the bank-level specifications are robust to including bank controls such as the leverage ratio or the share of deposits in total liabilities, and the municipality level specifications are robust to municipality controls such as the average income or real estate prices.

Following Stock and Yogo (2005), we test the relevance of the instrument by computing the F-statistics of the first stage regression in Table 7. The F-statistic in our baseline specification with municipality controls, year and region fixed effects is of 14.5, above the critical value of 11.32 of Stock and Yogo (2005) for a significance level of 5% and a maximal bias of the IV estimator relative to the OLS of 10%.

4.4. First-time borrowers and credit constraints

We use first-time borrowers as a proxy for constrained households. First-time borrowers are borrowers in year t who were previously absent from the database. The assumption, which we discussed in the previous section, is that households must accumulate some wealth before buying a house. When they have enough capital, households then borrow the maximum amount allowed by their credit constraint. Once the purchase is made, households accumulate further wealth and reimburse their mortgage, and thus become unconstrained. An illustration for this is given by the difference in LTV ratios of first time buyers and other buyers. While 30% of other buyers have LTVs higher than 90%, the share increases to 45% for first time buyers.[6] By estimating equation (18) separately for first-time and non-first time borrowers, we can thus assess the different sensitivities of constrained and unconstrained households to changes in the interest rate.

5. Results

We consider two levels of analysis in the second stage, at the municipality level or at the borrower level. The municipality level specifications allow to match the variation in interest rates, across municipalities and time. The borrower level specification instead allows for a more granular set of borrower controls, including borrower fixed effects.

5.1. *Municipality level specifications*

Consider a municipality m in year t. We regress the logarithm of total mortgage debt $\log(D_{mt})$ against the instrumented interest rate faced by households in the municipality, $\hat{r}_{mt}$:

$$\log(D_{mt}) = \alpha\hat{r}_{mt} + \beta_1 X_{mt} + \varepsilon_{mt} \tag{23}$$

where X_{mt} includes the observable municipality-year characteristics as well as the fixed effects. The unobserved characteristics are ε_{mt}.

The controls include the average income in the municipality, the property price index and a dummy for municipalities with a low volume in the real estate market. We also include the share of young in the population to account for differences in demographic patterns and the market concentration to account for potential market power of local banks. The specifications also include year fixed effects interacted with the region of the municipalities (Flanders, Wallonia or Brussels).

Table 8 shows the estimation results at the municipality level. After dropping municipalities that merged during our sample, we cover a total of 512 municipalities over 12 years from 2007 to 2018, giving us 6,144 observations. We focus on the period 2007-2018 for which we have the income data. To compute the debt per capita, we exclude credit issued by banks that do not provide interest rate information, representing around 15% of the outstanding, and we exclude borrowers below 25 and above 65 years old. The OLS specification in column (1) yields a negative and statistically significant relationship. The magnitude of the coefficient with the instrument in columns (2), (3) and (4) is broadly stable. The results suggest that a 1 p.p. decline in the interest rate is associated to a 9% increase in household indebtedness for all borrowers.

[6] NBB Financial Stability Report 2020.

5.2. *Average effect with borrower-level specifications*

We then use the full granularity of the data to exploit the variation over time for a given borrower. We consider the following specification

$$\log(D_{it}) = \alpha \hat{r}_{m(i)t} + \beta_1 X_{it} + \delta_i + \delta_{a(i)t} + \varepsilon_{it} \tag{24}$$

where D_{it} is the total debt of borrower i in year t and $r_{m(i)t}$ is the local interest rate faced by borrower i in its municipality $m(i)$. The specification includes borrower fixed effects δ_i as well as age group and year interaction effects $\delta_{a(i)t}$, where $a(i)$ is the age group of borrower i.

Table 9 shows the results at the borrower level using the full population with borrower fixed effects as well as age group - year interaction effects. The sample is from 2007 to 2018 with around 1.3 million borrowers per year and a total of 16.1 million borrower - years. As for the municipality level regressions, the coefficients for the IV specifications are negative so higher rates are associated with lower borrowing. The use of the instrument in columns (2), (3) and (4) increases the magnitude of the coefficients relative to the OLS regression in (1) which is not statistically different from zero. The borrower level coefficients are in line with the municipality level specification, implying that a 1 p.p. fall in interest rates is associated with a 7% increase in household indebtedness.

5.3. *First-time borrowers*

In the third specification, we focus on first time borrowers to understand the interest rate elasticity of borrowing of constrained households. Since borrowers can be categorized as "first time" only once in our sample, we cannot include borrower fixed effects. We instead estimate

$$\log(D_{it}) = \alpha r_{m(i)t} + \beta_1 X_{it} + \varepsilon_{it} \tag{25}$$

where $r_{m(i)t}$ is the local interest rate of the municipality $m(i)$ where i took on its first loan and t is the year in which the loan is taken. The controls X_{it} include age group $\times$ year interaction effects, region $\times$ year interaction effects as well as local income, market concentration, borrower age in years and property prices.

Table 10 shows the results of the specification focusing on first-time borrowers only. In this case, the IV estimates remain negative and statistically significant. The magnitude of the relationship increases relative to the specification with all borrowers in Table 9, to -11 for first-time borrowers versus -7 for all borrowers. In other words, the different specifications suggest that a 1 percentage point reduction in the interest rate is associated with a 7%

growth in household debt for all borrowers, while first-time borrowers are more sensitive to changes in interest rates as a 1 p.p. decline in interest rate is associated with a increase in borrowing of around 11%.

5.4. *Trade interlinkages robustness*

Our identification strategy assumes that the foreign GDP growth shocks are uncorrelated with the local state of the economy. The GDP shocks are then weighted using the exposure of banks to the different countries. One potential concern with this approach is that the lending interlinkages of banks could be related to the trade interlinkages of Belgian firms, which transmit foreign shocks to the local economy. A foreign GDP shock would then affect both the demand and the supply of credit. To address this concern, we estimate the baseline specifications with an additional control for trade-weighted foreign GDP growth. This variable is constructed using the share of exports to total exports as country weights. The results are broadly unchanged relative to the baseline estimations, as shown in Tables A3, A4 and A5 in appendix.

5.5. *Discussion*

The empirical analysis suggests that first-time borrowers are more sensitive to a decline in interest rates than the overall population of borrowers. Quantitatively, a 1% fall is associated with a 7% rise in borrowing for all borrowers versus 11% for first-time borrowers.

In the model this could be explained in a number of ways. A first reason could be that the borrowing constraints facing first-time borrowers are relatively limited. In the case without borrowing constraints, we indeed show that younger borrowers (such as first-time borrowers) are more responsive to interest rate changes since they have higher future income. A second explanation is that first-time borrowers may be able to overcome the downpayment constraints either by mobilizing informal resources (e.g. borrowing from relatives) or by investing their savings in high duration assets. A third explanation is that the composition of first-time borrowers changes as interest rates fall and some borrowers lose access to credit. This would be consistent with the decline in the share of young households that has a mortgage that we documented in Figure 9b.

To further gauge the relevance of borrower access to credit and how it relates to the interest rate, we regress in Table 11 the share of the population aged 25 to 34 that has a mortgage (i.e. the share of borrowers) against the interest rate, instrumented as in the previous municipality level specifications (Table 8). The regressions confirm that for this younger age group, a lower interest rate is associated with a lower fraction of the population with a mortgage.

The differences in the borrowing response across households is consistent with Di Maggio et al. (2017). They find that the consumption of borrowers with little housing wealth is almost twice as responsive to rate reductions as those of other borrowers. Their analysis however focuses on borrowers with Adjustable Rate Mortgages (ARM) where borrowers experience an exogenous reduction in the interest rate paid. Most borrowers then react to this income shock by reducing their leverage. Our identification strategy, using regulatory data on banks to construct credit supply shocks, allows to consider a more general response of household borrowing to changes in interest rates. An increase in debt in response to lower interest rates is also in line with most theoretical predictions (Campbell and Cocco, 2003).

Our results are also consistent with the work of Acharya et al. (2020) who study the introduction of macroprudential policies in Ireland. They show that the requirement of a maximum LTV ratios for the issuance of mortgages led to a reallocation of credit towards unconstrained borrowers. The measure however did not prevent aggregate credit growth. In our model, a cap on LTV ratios would be similar to a change in the down-payment constraint γ. If banks require a higher down payment, this reduces the borrowing of constrained borrowers while unconstrained borrowers remain unaffected. In our sample, we find that the lending standards of banks remained broadly stable (notwithstanding some year to year variation) and credit growth seems to have originated mostly from non-first-time borrowers. Since these borrowers already had a mortgage and thus some housing wealth, they are less likely to be constrained.

Our finding that the transmission of interest rates to borrowing varies within the population can further motivate an ongoing effort to include heterogeneity in macroeconomic models. Auclert (2019) or Kaplan et al. (2018) show for instance that the response of consumers with a high propensity to consume is a key transmission channel of monetary policy. Our analysis confirms that they are more responsive to changes in interest rates but access to credit is key.

The distributional focus of our work is also relevant for models of systemic risk indicators. The work of Schularick and Taylor (2012) for instance uses aggregate credit measures to construct early warning indicators of financial crises. The composition of credit could also matter as a credit growth driven by vulnerable borrowers would have different implications relative to a growth driven by unconstrained borrowers.

6. Conclusion

We explore the sensitivity of borrowing by households to changes in interest rates and how this sensitivity varies within the population. We first build a model of household borrowing with endogenous house prices and credit constraints. In the model, households differ in their endowments of housing wealth and labour income. Young households having little housing wealth and more future labour income whereas old households have more housing resources and fewer labour income. We show that middle aged households who have some pre-existing housing wealth increase their borrowing most in response to a fall in interest rates. These households have more resources to use as down payment whereas younger households with less resources face borrowing constraints.

We then use unique loan level data from Belgium to show that most of the increase in household debt over the last decade was driven by middle aged households who have some debt outstanding. While the loan to income ratios increased, we find that other indicators of credit standards such as debt service to income (DSTI) or loan to value (LTV) ratios remained broadly stable.

We finally estimate the elasticity of household borrowing to interest rates distinguishing the full population of borrowers and first-time borrowers. For identification, we construct an instrumental variable using foreign country exposures of banks and the location of bank branches. We find that a 1 p.p. decline in the interest rate is associated with a 7% increase in household debt and that first time borrowers respond more to changes in interest rates.

Our results emphasize the importance of heterogeneity in the response of households to lower interest rates. Our work provides first evidence on the evolution of household credit in Belgium over the last decades. It also opens up a number of avenues for future research including the determinants of relationships between borrowers and banks and understanding the normative trade-off between financial stability and access to credit.

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Table 1. Global household debt to GDP ratios since 1980

This table shows the ratio of household debt relative to GDP for 12 advanced economies. Columns 2 to 4 show the ratio in percentage points and column 5 shows the relative growth between 2019 and 1980. Source: IMF Global Debt Database except for Switzerland in 1980 from the Jordà-Schularick-Taylor Macrohistory Database.

Country	Year			Growth
	1980	2000	2019	(1980-2019)
Switzerland	67	103	129	+93%
Canada	46	59	101	+120%
Sweden	48	47	89	+85%
United Kingdom	30	64	84	+180%
United States	50	71	75	+50%
Belgium	33	41	62	+88%
France	22	34	62	+182%
Japan	47	71	61	+30%
Spain	24	45	57	+138%
Germany	52	71	54	+4%
Italy	6	23	41	+583%

Table 2. Overview of mortgage credit registry

This table provides an overview of the mortgage credit registry. We consider two groups of households: *All borrowers* includes all households with a mortgage outstanding. *First-time borrowers* only includes households that borrow for the first time in a given year. *Households*: number of households with a mortgage outstanding. *Age*: Average age of lead borrower in household weighted by the outstanding amount borrowed by each household. *Loans*: Average number of loans per household, weighted by the outstanding amount borrowed by each household. *Amount*: average total amount borrowed for each borrower.

Characteristic	Year		
	2007	2013	2018
All borrowers			
Borrower count	1,574,737	1,731,767	1,858,961
Age average	39	40	41
Loans per borrower	2	2	2
Amount per borrower	77,607	102,020	126,701
First-time borrowers			
Borrower count	98,182	64,556	74,932
Age average	34	33	33
Loans per borrower	1	1	1
Amount per borrower	135,258	162,696	203,865

Table 3. Decomposition of mortgage debt by borrower type

This table shows the breakdown of total mortgage debt for first-time and non-first-time borrowers. Panel *A* decomposes the stock of debt and panel *B* provides the flows over specific periods, computed as the difference in stocks.

Panel A. Credit stocks in billion euros

Year	Total credit	First time borrowers	Non-first time borr.
2007	122.2	13.3	108.9
2010	151.8	12.5	139.3
2014	186.0	12.1	173.9
2018	235.5	15.3	220.3

Panel B. Credit flows in billion euros

Period	Total credit	First time borrowers	Non-first time borr.
2007-2010	29.6	-0.8	30.3
2010-2014	34.2	-0.5	34.7
2014-2018	49.5	3.2	46.3
Total	113.3	2.0	111.3

Table 4. Distribution of mortgage debt by household indebtedness

This table shows the distribution of the mortgage debt outstanding for different groups of borrower indebtedness. We sort borrower by their debt outstanding, then consider in panel *A* the groups of borrowers below the 10th debt percentile, from the 10th to the 50th percentile, from 50th to 90th, 90th to 95th and above the 95th percentile. Panel A shows the total mortgage debt oustanding for each group in billion euros as well as the share of each group in %. Panel B shows the debt per borrower for the main percentiles.

Panel A. Amount outstanding in billion euros and share in percent

Year	Total Credit	Indebtedness percentile range 0 to 10	10 to 50	50 to 90	90 to 95	95 to 100
Amount						
2007	122	1	19	61	15	27
2012	171	1	26	88	20	36
2018	236	1	39	121	27	48
Share						
2007	100	1	15	50	12	22
2012	100	1	15	51	12	21
2018	100	1	17	51	11	20

Panel B. Amount outstanding per borrower in euros

Year	Total borrowers	Indebtedness percentile 10	50	90	95
2007	1,574,737	8,853	54,000	165,000	214,286
2012	1,717,914	11,984	73,150	210,000	265,073
2018	1,858,961	12,603	100,000	257,500	326,843

Table 5. Foreign growth shock

This table shows summary statistics of the foreign GDP growth shock computed using foreign exposures of banks. Panel *A* documents the foreign GDP shock computed at the bank level from equation (21). Panel *B* shows the foreign growth shocks computed at the municipality level as in equation (22). The sample includes 6 banks per year and 512 municipalities with bank branches, as in the regression table 7.

Year	Observations	Mean	Standard Deviation	Min	Max
Panel A: Bank level					
2007	6	3.4	0.4	2.9	4.1
2008-2009	12	-1.6	2.3	-4.0	1.2
2010-2012	18	1.3	1.0	-0.7	2.6
2013-2014	12	1.6	1.0	0.2	3.1
2015-2018	24	3.0	1.2	1.8	6.7
All years	72	1.6	2.1	-4.0	6.7
Panel B: Municipality level					
2007	512	3.5	0.2	3.1	4.1
2008-2009	1,024	-1.5	2.1	-3.8	0.9
2010-2012	1,536	1.5	0.9	-0.1	2.6
2013-2014	1,024	1.7	0.8	0.7	3.1
2015-2018	2,048	2.9	0.8	1.8	6.7
All years	6,144	1.7	1.9	-3.8	6.7

Table 6. Balance checks for municipality level specification

This table shows the coefficients and robust standard errors from pairwise regressions of the instrument, the average foreign GDP growth of banks in m and t, on the control variables. All variables are taken in logs. *Mean income* is the average income in m and t; *Property price* is the average price of real estate in m and t; *Low volume* is a dummy for municipalities with a low volume of real estate transactions; *Share of young* is the share of population aged between 25-34 years; *Market concentration* is the Herfindahl index computed as the sum of squares of bank market shares; *Loan to income* is the debt per capita divided by the average income in m and t; *Loan to value* is debt per capita divided by the average price of real estate in m and t; *Average age* is the average age of population in in m and t. Robust standard errors.

	Coefficient	Std. Dev.	Confidence Interval
Mean income	0.169	0.136	[-0.130, 0.469]
Property price	0.143	0.125	[-0.132, 0.418]
Low volume dummy	0.023	0.014	[-0.009, 0.055]
Share of young	-0.004	0.012	[-0.031, 0.023]
Market concentration	-0.005	0.026	[-0.062, 0.053]
Loan to income	0.291	0.201	[-0.151, 0.733]
Loan to value	0.136	0.088	[-0.057, 0.329]
Average age	0.121	0.071	[-0.035, 0.277]

Table 7. First stage regression: Interest rates and foreign growth

This table shows the results of the first stage regression of the interest rate on the foreign growth shock instrument. Columns (1) and (2) show the specifications at the bank level and columns (3) and (4) the specification at the municipality level. In column (2), bank characteristics include the common equity to assets ratio, the loans to assets ratio, the deposits to assets ratio and the ratio of loans to deposits. In column (4), municipality characteristics include the average income, the property price index, an indicator for low volume in the real estate market, the share of the population aged between 25-34 years, and market concentration computed as the sum of squares of bank market shares. Sample : 2007-2018. Robust standard errors.

	Interest Rate			
	Bank level		Municipality level	
	(1)	(2)	(3)	(4)
Foreign growth	-0.151*	-0.126*	-0.091**	-0.087**
	(0.063)	(0.050)	(0.032)	(0.031)
Observations	72	72	6,144	6,144
Bank controls	No	Yes	No	No
Municipality controls	No	No	No	Yes
Year F.E.	Yes	Yes	Yes	Yes
Region F.E.	No	No	Yes	Yes
F-Stat	5.738	2.207	8.229	14.534
R^2	0.961	0.965	0.996	0.996

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8. Interest rate sensitivity of debt at municipality level

This table shows the sensitivity of mortgage borrowing to the interest rate estimated at the municipality level as in equation (23). The dependent variable is the logarithm of total mortgage debt for each municipality and year. We instrument the interest rate r_{mt} in municipality m and year t with the average foreign GDP growth of banks in m and t (see table 7 for the first-stage estimation results). The dependent variable is the log of debt per capita in m and t. *Mean income* is the average income in m and t; *Population* is the total population in m and t; *Property price* is the average price of real estate in m and t; *Market concentration* is the Herfindahl index computed as the sum of squares of bank market shares in m and t. All specifications include year times region interaction effects. Robust standard errors clustered at the region-year level. Sample 2007-2018.

	Debt			
	OLS	IV		
	(1)	(2)	(3)	(4)
Interest rate	-9.776***	-9.856***	-8.983***	-8.839***
	(0.778)	(1.821)	(1.797)	(1.877)
Mean income	1.204***	1.257***	1.283***	1.223***
	(0.050)	(0.063)	(0.065)	(0.062)
Population	0.959***	0.971***	0.975***	0.960***
	(0.004)	(0.003)	(0.003)	(0.005)
Property price	0.069***		0.100***	0.081***
	(0.010)		(0.024)	(0.027)
Market concentration	-1.241***			-1.242***
	(0.153)			(0.156)
Observations	6,144	6,144	6,144	6,144
Region × Year	Yes	Yes	Yes	Yes
R^2	0.981	0.978	0.978	0.980

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9. Interest rate sensitivity of debt at borrower level (all borrowers)

This table shows the sensitivity of mortgage borrowing to the interest rate estimated at the borrower level as in equation (24). Column (1) shows the OLS specification without instrument. Columns (2) to (4) show the second stage of the IV estimation under different specifications. All variables are taken in logs. *Population* is the population of the municipality; *Mean income* is the average income in the municipality of borrower i and year t; *Market concentration* is the sum of squares of bank market shares; *Population age* is the average age of the population in the municipality; *Property price* is the average price of real estate; *Borrower age* is the age of the borrower in years. The specifications include borrower fixed effects and age group times year interaction effects. Robust standard errors clustered at the borrower-level. Sample: all borrowers aged between 25 and 65 years. Sample 2007-2018.

	Debt			
	OLS	IV		
	(1)	(2)	(3)	(4)
Interest rate	0.034	-6.616*	-7.372**	-7.366**
	(0.340)	(3.521)	(3.478)	(3.478)
Population	-0.048***	-0.048***	-0.048***	-0.048***
	(0.000)	(0.001)	(0.000)	(0.000)
Mean income	0.155***	0.155***	0.154***	0.154***
	(0.003)	(0.003)	(0.003)	(0.003)
Market concentration	0.108***	0.080***	0.072***	0.071***
	(0.014)	(0.023)	(0.022)	(0.022)
Population age	0.008***	0.008***	0.008***	0.008***
	(0.000)	(0.000)	(0.000)	(0.000)
Property price	-0.014***		-0.012***	-0.012***
	(0.002)		(0.002)	(0.002)
Borrower age	-0.374***			-0.374***
	(0.006)			(0.006)
Observations	16,088,898	16,088,898	16,088,898	16,088,898
Age Group × Year	Yes	Yes	Yes	Yes
Borrower	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10. Interest rate sensitivity of debt at borrower level (first-time borrowers)

This table shows the sensitivity of mortgage borrowing to the interest rate for first time borrowers as in equation (25). The estimation is done at the borrower level for first-time borrowers only. Column (1) shows the OLS specification without instrument. Columns (2) and (3) show the second stage of the IV specification. *Mean income* is the average income in the municipality of borrower i in year t; *Herfindahl index* is the market concentration index computed as the sum of squares of bank market shares; *Property price* is the average price of real estate in $m(i)$ and t. The specifications include year fixed effects. Robust standard errors clustered at the year level. Sample: first time borrowers aged between 25 and 65 years from 2007 to 2018.

	Debt			
	OLS	IV		
	(1)	(2)	(3)	(4)
Interest rate	8.726***	-12.398***	-12.097***	-10.928***
	(1.339)	(3.578)	(3.577)	(3.582)
Mean income	0.628***	0.639***	0.638***	0.626***
	(0.006)	(0.005)	(0.005)	(0.006)
Market concentration	-1.331***	-1.382***	-1.384***	-1.421***
	(0.029)	(0.032)	(0.032)	(0.032)
Borrower age	-0.004***		-0.004***	-0.004***
	(0.000)		(0.000)	(0.000)
Property price	-0.064***			-0.062***
	(0.004)			(0.004)
Observations	738,529	738,529	738,529	738,529
Age Group × Year	Yes	Yes	Yes	Yes
Region × Year	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11. Access to borrowing

The dependent variable is the share of the population aged 25 to 34 that has a mortgage outstanding in a given municipality and year. Municipality controls include labour market characteristics (unemployment, share of employment in agriculture, in industry and in construction) and bank characteristics (the average leverage ratio of banks in the municipality). Robust standard errors clustered at the year level.

	Share of borrowers in population			
	OLS	IV		
	(1)	(2)	(3)	(4)
Interest rate	129.099*	240.881**	237.189*	242.416*
	(70.258)	(96.612)	(129.821)	(129.024)
Mean income	17.609***	19.584***	17.560***	17.618***
	(0.512)	(0.626)	(0.546)	(0.507)
Population	-1.208***	-1.292***	-1.214***	-1.212***
	(0.037)	(0.030)	(0.035)	(0.036)
Property price	3.708***		3.702***	3.707***
	(0.290)		(0.284)	(0.291)
Market concentration	0.382			0.721
	(1.717)			(1.716)
Observations	6,144	6,144	6,144	6,144
Municipality controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

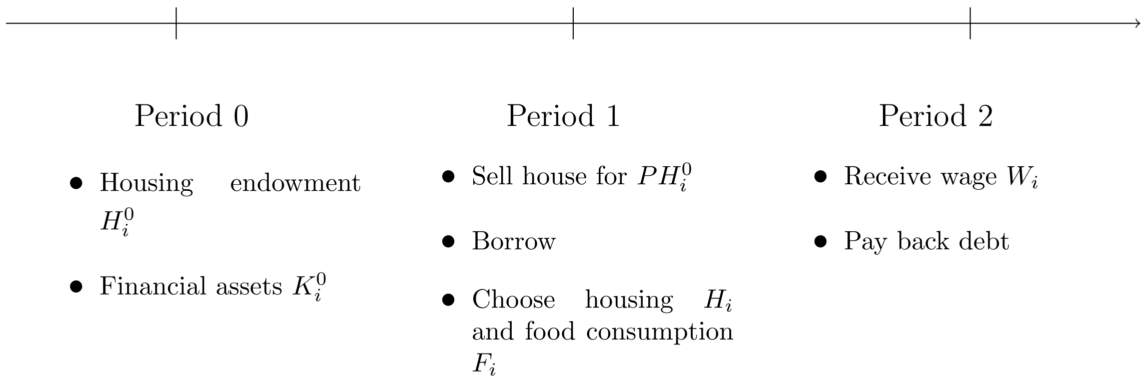
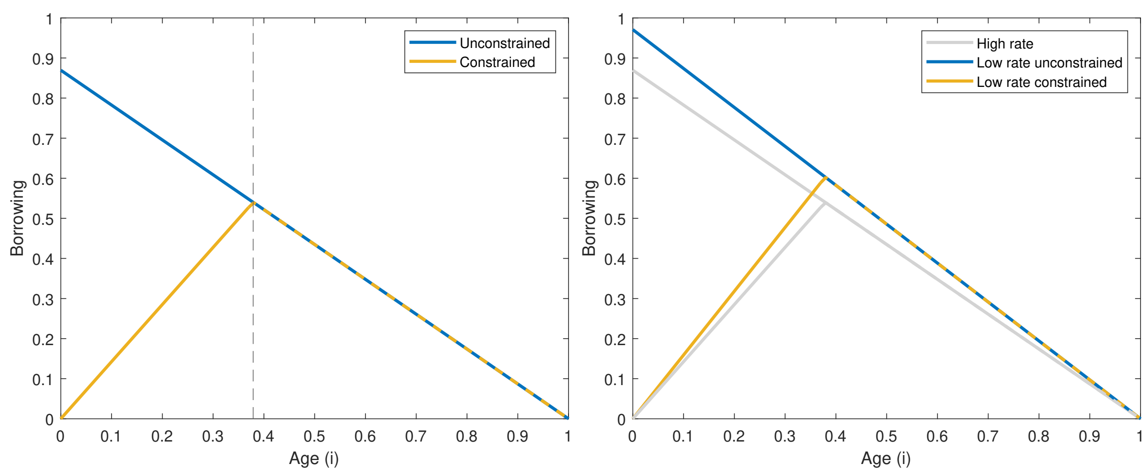


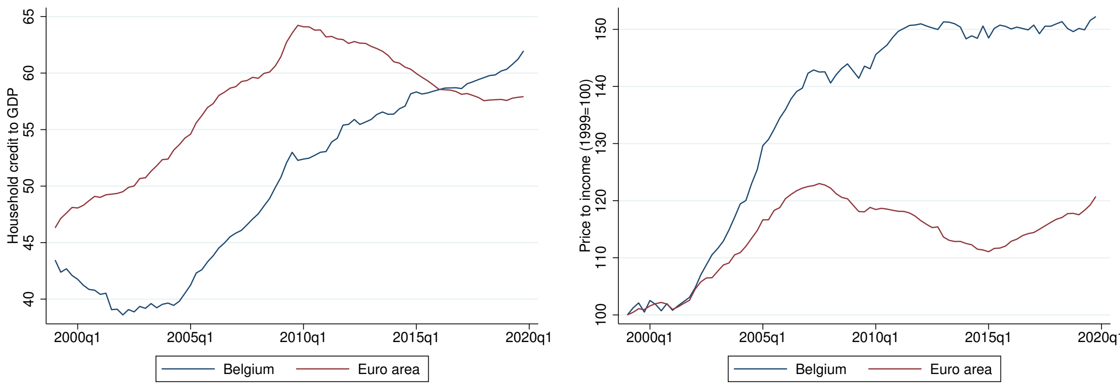
Figure 1. Model timing



(a) Baseline rate R_1 (b) Rate $R_2 < R_1$

Figure 2. Interest rate counterfactuals

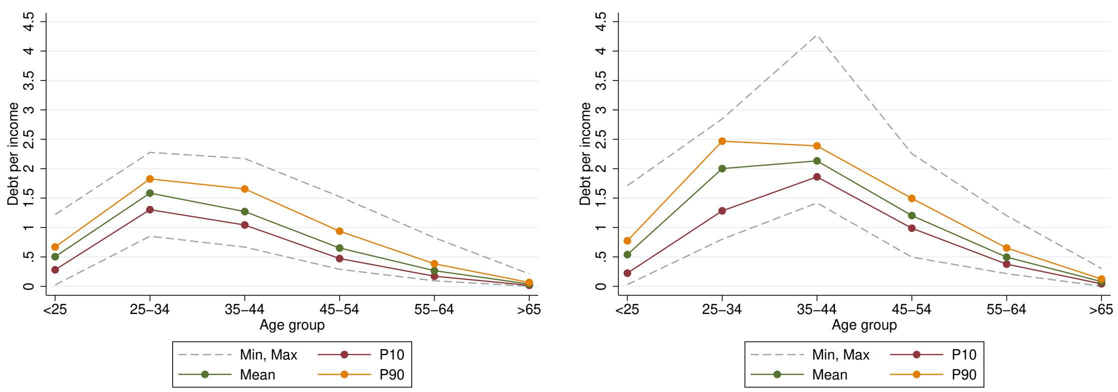
Figure 2a is a numerical simulation of the model with linear endowments $H_i^0 = 2i$, $\rho W_i = 1 - i$ and $K_i^0 = 0$. The blue line shows household borrowing in the unconstrained, first-best case. The orange line shows the amount borrowed with a downpayment constraint. Figure 2b illustrates comparative statics of borrowing with a lower interest rate $R_2 < R_1$. The parameters used are $\gamma = 0.25$, $\alpha = 0.3$, $R_1 = 1.15$ and $R_2 = 1.03$.



(a) Household debt to GDP (b) Price to income

Figure 3. Household debt to GDP ratio and house price to disposable income ratio in Belgium and the Euro area

Figure 3a shows the ratio of household debt to GDP in Belgium and the euro area (Source: ECB Quarterly Sector Accounts and Main Aggregates statistics). Figure 3b shows the ratio of house prices to disposable income in Belgium and the euro area (Source: OECD Housing Prices).



(a) Year 2007 (b) Year 2018

Figure 4. Ratio of total mortgage debt to annual income across municipalities in Belgium

These figures show the distribution of debt to income across municipalities and age groups in 2007 (Figure 4a) and 2018 (Figure 4b). The figures show the 10th and 90th percentile, the minimum and maximum of debt to income across municipalities for each age group. The mean is the national average. Percentiles are computed across municipalities using population weights.

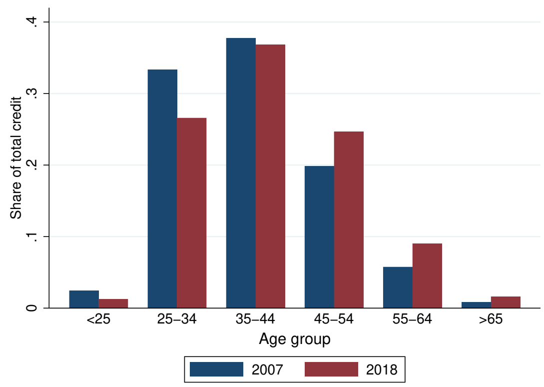
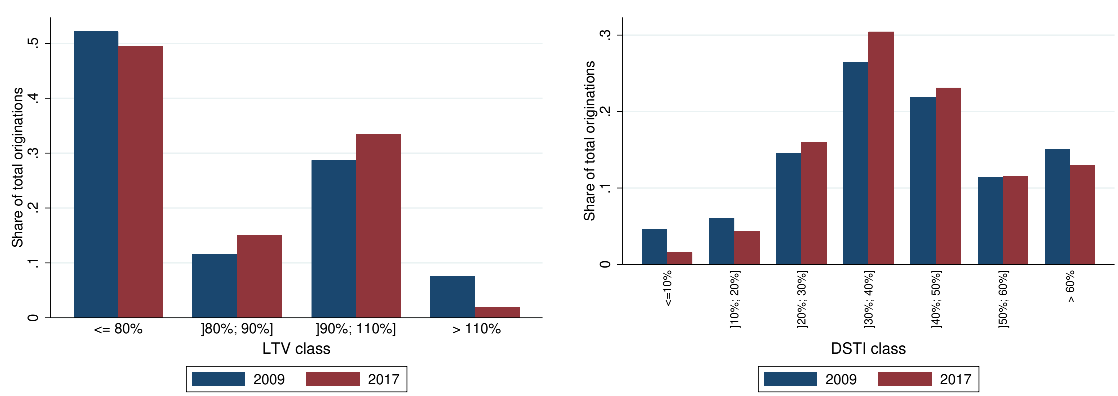


Figure 5. Distribution of credit across age groups in 2007 and 2018

This figure shows the share of total mortgage credit outstanding allocated to the different age groups in 2007 and 2018.

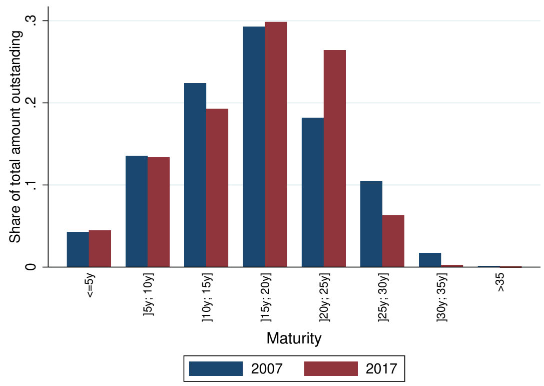


(a) Loan-to-value ratio

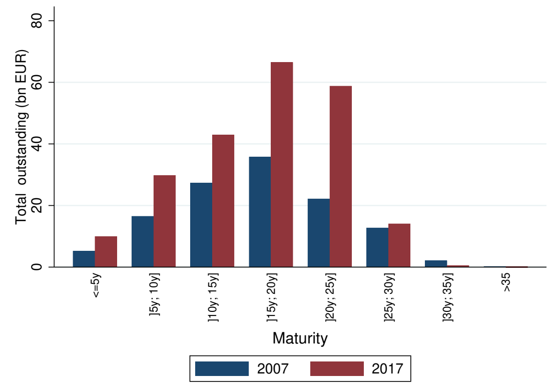
(b) Debt service to income ratio

Figure 6. Indicators of loan quality at origination

Figure 6a shows the distribution of the loan-to-value ratio of mortgages at origination in 2009 and 2017. Figure 6b shows the distribution of the debt service to income ratio of mortgages at origination in 2009 and 2017. Source: NBB PHL Residential Real Estate Survey.



(a) Share



(b) Amount

Figure 7. Maturity structure of outstanding mortgages

This figure shows the maturity structure of outstanding morgage loans in 2007 and 2017. The left hand side figure shows the share of each maturity group in the total and the right hand side figure shows the outstanding amount in euros. Loan maturities are grouped in ranges: below 5 years, from 5 to 10 years, 15 to 20, 20 to 25, 25 to 30 and above 30 years.

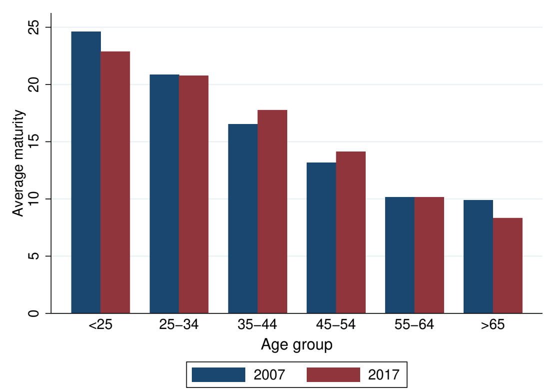
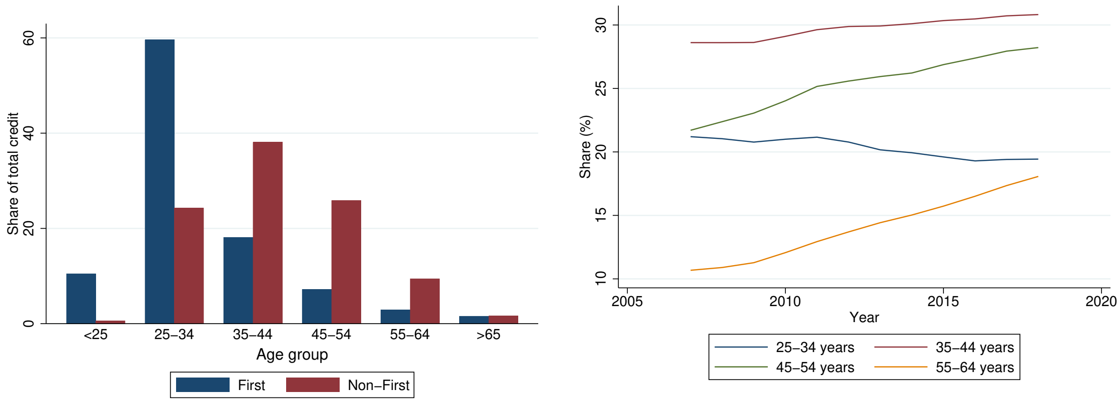


Figure 8. Average maturity of outstanding mortgages by age group in 2007 and 2017.

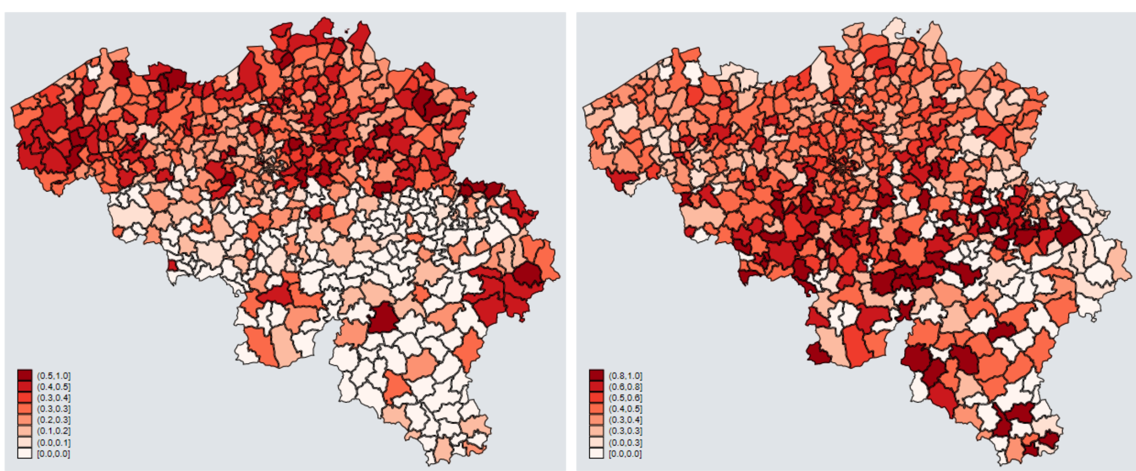
This figure shows the valued weighted average maturity of mortgage loans outstanding by age group in 2007 and 2017. Source: KCP.



(a) Credit by age and borrower type in 2018

(b) Share of population with a mortgage outstanding by age group

Figure 9. Distribution of credit by age group and borrower type and average age by borrower type
Figure 9a shows the share of outstanding mortgage credit to first time and non-first time borrowers in 2018, broken down by age group. Figure 9b shows for each age category the average ratio of the number of borrowers with a credit outstanding to the total population.



(a) Bank A

(b) Bank B

Figure 10. Branch market share of two banks
The market share is computed as the number of branches of a bank relative to total branches in a municipality. Source: Banque Carrefour des Entreprises.

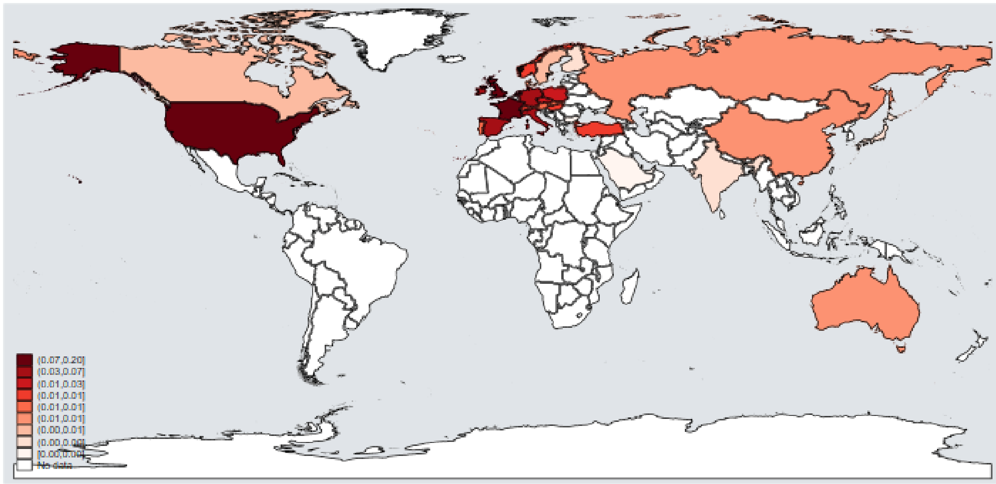


Figure 11. International exposures of Belgian banks

International exposures are computed as the share of foreign exposures out of total foreign exposures. Foreign country exposures are international financial claims of domestic bank head offices on a worldwide consolidated immediate borrower basis, i.e. including the exposures of own foreign offices but excluding inter-office positions. Source: NBB Schema A.

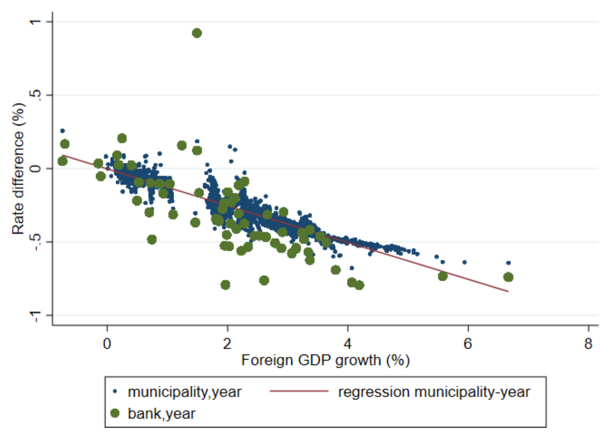


Figure 12. First stage relationship between interest rates and foreign GDP growth

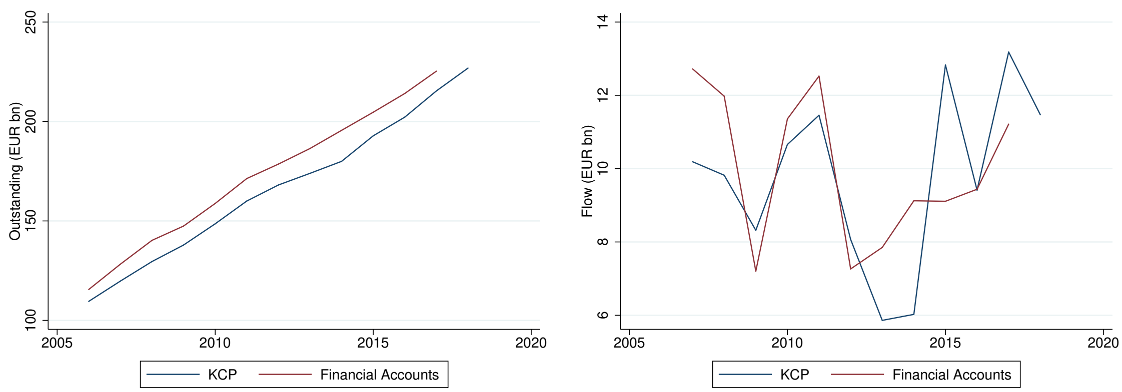
This figure shows the relationship between interest rates and foreign GDP growth which we use as the first stage regression. The green points are observations at the bank and year level and the blue points are observations at the municipality and year level. For the bank-level observations, the foreign growth shock is computed as G_{bt} in equation (21). The interest rate is the bank rate r_{bt} in equation (20) minus the year fixed effects, i.e. we regress $r_{bt} = G_{bt} + \delta_t + \epsilon_{bt}$ and plot $r_{bt} - \hat{\delta}_t$ on the y-axis. For the municipality-level observations, the foreign growth shock is computed as Z_{mt} in equation (22). The interest rate is the bank rate r_{mt} in equation (20) minus the year fixed effects, i.e. we regress $r_{mt} = Z_{mt} + \delta_t + \epsilon_{mt}$ and plot $r_{bt} - \hat{\delta}_t$ on the y-axis. The regression line shows the linear fit between the interest rate and the foreign growth shock at the municipality level. The sample period is from 2007 to 2017, excluding the year 2009.

Appendix to "Low Interest Rates and the Distribution of Household Debt"

A. Data consistency

A.1. Comparison with other databases

Figures A1 and A2 illustrate the comparison of the credit registry data with data from the financial accounts explained in section 3.



(a) Stocks

(b) Flows

Figure A1. Comparison of aggregate mortgage credit stocks and flows using the credit registry data and the financial accounts
These figures compare the stocks and flows of outstanding mortgages in Belgium using the credit registry and the financial accounts statistics. Figure A1a shows the stocks of mortgages outstanding for each series and figure A1b shows the flows. Figures are in billion euros.

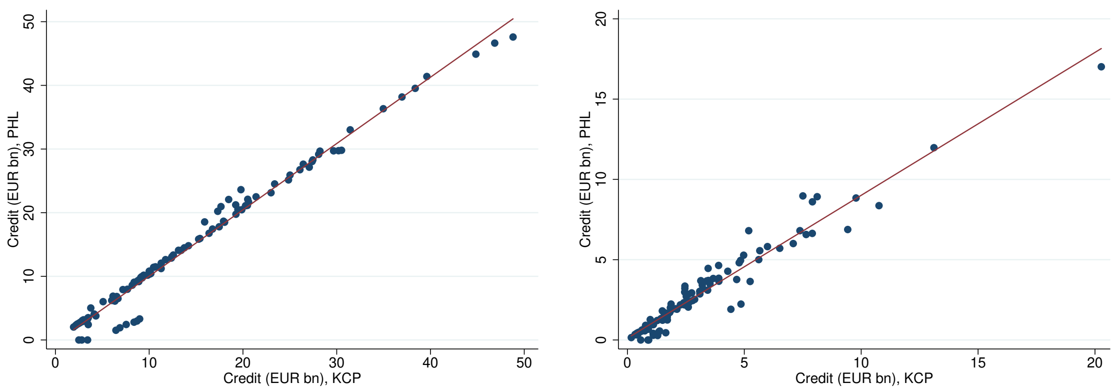
A.2. Annuity-based calculation of outstanding amounts

As explained in section 3, we recover the outstanding balance of a mortgage from the amount at origination using a linear approximation, defining the outstanding debt balance D_t as

$$D_t = D_0 \times \frac{T - t}{T},$$

where D_0 is the debt amount at origination, T is the maturity in years and t is the years since issuance.

In this subsection, we compare the amount outstanding using the linear approximation to the amounts computed using an annuity-based amortization of the mortgages. With annuity-based contracts, the borrower reimburses a fixed amount for the full duration of the



(a) Total credit

(b) New credit

Figure A2. Comparison of mortgages outstanding by banks

These figures compare the total mortgages outstanding at the bank-level for the 10 largest banks using data from the credit registry (x-axis) and the regulatory survey of mortgage portfolios (NBB PHL Residential Real Estate Survey, y-axis). Figure A2a includes all mortgages outstanding while figure A2b focuses on new loans originated in a given year. Figures are in billion euros and annual from 2007 to 2017.

mortgage, and this amount includes both the interest payments and the reimbursement of the principal amount. If the interest rate on the mortgage is r and the annual payment to be made is C, the mortgage at origination is such that

$$D_0 = \frac{C}{r}\left(1 - \frac{1}{(1+r)^T}\right).$$

Using the interest rate in the year of issuance, we can therefore compute the annual payment as

$$C = \frac{D_0 \times r}{1 - \frac{1}{(1+r)^T}}.$$

and the amount outstanding in period t is equal to

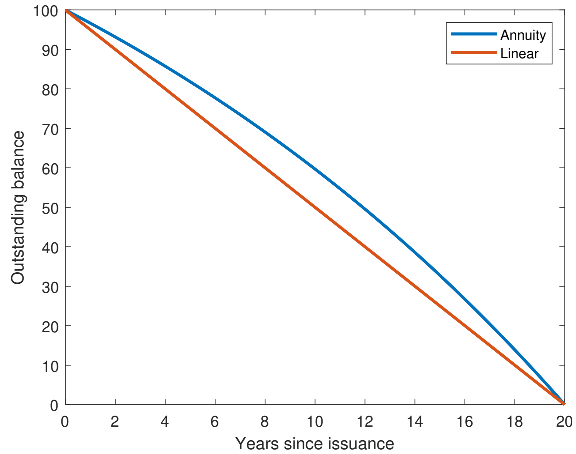
$$D_t = \frac{C}{r}\left(1 - \frac{1}{(1+r)^{T-t}}\right). \tag{26}$$

Figure A3 illustrates the differences in outstanding balances using the linear and annuity approximations for a 20 year mortgage with a 4% interest rate. The largest difference between the two formulas arises in the middle of the life of the mortgage. In the early years of the loan, the difference is smaller.

To verify the robustness of our results to the assumption of a linear amortization, we compute the outstanding balances using an annuity based amortization. For the annuity-based balance, we use the interest rate on 10 year government debt in the year of issuance. Table

Figure A3. Amount outstanding with annuity-based or linear amortization

This figure compares the outstanding balance of a mortgage worth 100 at origination, issued with a 20 year maturity at an interest rate of 4%. “Annuity” is the balance computed using an annuity-based amortization of the mortgage while “Linear” is a linear amortization.



A1 compares the amount outstanding using the two methodologies. The difference ranges from €6 to 12 billion across years. The outstanding amount using the linear approximation is around 5% lower than the amount with the annuity formula.

One reason for the relatively small differences is that the average years since issuance is low. This is illustrated in Figure A4 which shows the share of total mortgages outstanding for different ranges of years since issuance. While the average maturity of mortgages at origination is around 15 years, more than 70% of mortgages have an average life smaller than 3 years. This reflects the importance of refinancing, as borrowers frequently renegotiate the terms of their debt with banks. The frequent refinancing of mortgages then minimizes the differences between the use of an annuity-based amortization and a linear amortization, since the differences are small at the early years of the mortgage.

B. Additional tables

Table A2 shows the home ownership rates for different age groups. Tables A3, A4 and A5 show alternative specifications of the baseline.

Table A1. Mortgages outstanding with linear and annuity-based amortization

This table compares the total outstanding value of mortgages using a linear amortization as in equation 17 and an annuity-based amortization as in equation 26. Amounts are in euro billion.

Year	Amortization		Difference
	Annuity	Linear	
2006	116	109	6
2007	127	120	7
2008	138	130	8
2009	149	140	9
2010	161	151	10
2011	174	163	11
2012	182	171	11
2013	188	176	12
2014	198	186	12
2015	207	196	10
2016	217	207	10
2017	232	223	9
2018	245	236	9

Figure A4. Years since issuance of outstanding mortgages

This figure provides a breakdown of outstanding mortgages by years since issuance from 2006 to 2018.

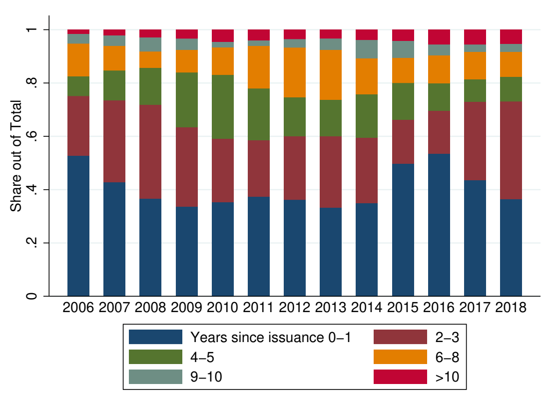


Table A2. Homeownership and age

The table shows the share of households who own their main residence, other real estate or both. source: HFCS, Third wave (2017).

Age	Share of households that own		
	Main residence	Other real estate	Both
Under 25	0 %	0 %	0 %
25 to 34	51 %	8 %	7 %
35 to 44	73 %	12 %	9 %
45 to 54	75 %	22 %	18 %
55 to 64	74 %	27 %	24 %
Over 65	69 %	21 %	17 %

Table A3. Trade interlinkages robustness (Municipality level)

This table shows the sensitivity of mortgage borrowing to the interest rate estimated at the municipality level as in the specifications of Table 8, but accounting for trade interlinkages. The trade-weighted foreign growth is the weighted average foreign GDP growth using the share of exports to each country as weights. Other variables are identical to those of Table 8.

	Debt			
	OLS	IV		
	(1)	(2)	(3)	(4)
Interest rate	-9.802***	-6.554***	-5.325**	-6.776***
	(0.850)	(2.192)	(2.297)	(1.935)
Mean income	1.204***	1.309***	1.346***	1.259***
	(0.050)	(0.071)	(0.074)	(0.062)
Population	0.959***	0.972***	0.977***	0.961***
	(0.004)	(0.003)	(0.003)	(0.005)
Trade-weighted foreign growth	-0.571	12.830	12.807	7.228
	(5.579)	(8.646)	(7.835)	(7.417)
Property price	0.069***		0.141***	0.105***
	(0.010)		(0.033)	(0.029)
Market concentration	-1.241***			-1.234***
	(0.154)			(0.161)
Observations	6,144	6,144	6,144	6,144
Region × Year	Yes	Yes	Yes	Yes
R^2	0.981	0.977	0.977	0.980

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4. Trade interlinkages robustness (All borrowers)

This table shows the sensitivity of mortgage borrowing to the interest rate estimated at the borrower level as in the specifications of Table 9, but accounting for trade interlinkages. The trade-weighted foreign growth is the weighted average foreign GDP growth using the share of exports to each country as weights. Other variables are identical to those of Table 9.

	Debt			
	OLS	IV		
	(1)	(2)	(3)	(4)
Interest rate	0.480	-4.584**	-5.036**	-5.041**
	(0.377)	(1.987)	(1.971)	(1.971)
Population	-0.048***	-0.048***	-0.048***	-0.048***
	(0.000)	(0.000)	(0.000)	(0.000)
Mean income	0.155***	0.156***	0.154***	0.154***
	(0.003)	(0.003)	(0.003)	(0.003)
Market concentration	0.106***	0.096***	0.091***	0.089***
	(0.014)	(0.015)	(0.015)	(0.015)
Population age	0.008***	0.008***	0.008***	0.008***
	(0.000)	(0.000)	(0.000)	(0.000)
Trade-weighted foreign growth	3.157***	-3.612	-4.199	-4.179
	(1.158)	(2.839)	(2.820)	(2.820)
Property price	-0.014***		-0.013***	-0.013***
	(0.002)		(0.002)	(0.002)
Borrower age	-0.374***			-0.374***
	(0.006)			(0.006)
Observations	16,088,898	16,088,898	16,088,898	16,088,898
Age Group × Year	Yes	Yes	Yes	Yes
Borrower	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5. Trade interlinkages robustness (First-time borrowers)

This table shows the sensitivity of mortgage borrowing to the interest rate estimated at the borrower level and for first-time borrowers only as in the specifications of Table 10, but accounting for trade interlinkages. The trade-weighted foreign growth is the weighted average foreign GDP growth using the share of exports to each country as weights. Other variables are identical to those of Table 10.

	Debt			
	OLS	IV		
	(1)	(2)	(3)	(4)
Interest rate	8.600***	-14.637***	-14.382***	-13.829***
	(1.346)	(3.714)	(3.714)	(3.715)
Mean income	0.628***	0.639***	0.639***	0.627***
	(0.006)	(0.005)	(0.005)	(0.006)
Market concentration	-1.329***	-1.385***	-1.388***	-1.425***
	(0.029)	(0.032)	(0.032)	(0.032)
Trade-weighted foreign growth	5.390	11.658*	11.893**	15.122**
	(5.807)	(6.001)	(6.000)	(6.000)
Borrower age	-0.004***		-0.004***	-0.004***
	(0.000)		(0.000)	(0.000)
Property price	-0.064***			-0.062***
	(0.004)			(0.004)
Observations	738,529	738,529	738,529	738,529
Age Group × Year	Yes	Yes	Yes	Yes
Region × Year	Yes	Yes	Yes	Yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$