

Essays on the Economics of Debt, Default and Housing Markets



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Dedicated to Eileen and my parents, Mary and Stephen

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 60,000 words including appendices, bibliography, footnotes, tables and equations and has fewer than 150 figures.

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Abstract

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This thesis is composed of three chapters on different topics of macro-finance. Thematically, they are linked by their focus on household credit constraints - be they exogenous regulatory constraints, as in Chapter 1, or endogenous constraints as in Chapters 2 and 3.

The first chapter is joint work with Juan Castellanos Silvan and Gonzalo Paz-Pardo. We propose a joint model of the aggregate housing and rental markets in which both house prices and rents are determined endogenously. The key part of the model is that households can choose their housing tenure status (renters, homeowners, or landlords) depending on their age, wealth, and income. We show how the reliance on heterogeneous household landlords generates an upward sloping supply curve for rented accommodation. With the model in hand, it can be used to study the introduction in Ireland in 2015 of macroprudential policies that limited loan-to-value (LTV) and loan-to-income (LTI) ratios of newly originated mortgages. The introduction of stringent LTV and LTI ratios mitigates house price growth, but increases rents and reduces homeownership rates. As a result, middle-income households are negatively affected.

The second chapter stays with the theme of housing markets but introduces endogenous default. The main innovation is to consider delinquency as an important stage of default. In some European countries, mortgage delinquency rates are much higher than foreclosure rates. The stock of delinquent mortgages peaked at 9% of GDP in the Eurozone periphery and the average length of a delinquency spell was over 10 months. This fact has been largely neglected in the macro-finance literature. This chapter provides a framework for understanding why high levels of persistent mortgage delinquency can emerge as an equilibrium outcome during a housing market crisis. Banks tolerate delinquency because the gain to foreclosing is less than the option value of continuing with the delinquent loan. By nesting a straightforward

game between debt-distressed households and banks within a quantitative macro-housing model, the option to enter delinquency is shown to significantly attenuate (by roughly half) the consumption drop during a crisis. Importantly, I show that the ability of households to gain insurance through delinquency is significantly impacted by the degree of recourse available to banks upon foreclosure. The model features realistic lifecycle dynamics, tenure choice between renting and owning, endogenous liquidity in the housing market and defaultable, long-term debt.

The third and final chapter leaves housing markets behind but sticks with the theme of default, credit risk, and interest rates. Using the Brazilian administrative credit registry data with the universe of all consumer loans originated by banks in the country from 2013 to 2019, the chapter documents high borrowing interest rates, which vary systematically with individual characteristics. In particular, even after controlling for several observable individual attributes - such as income, debt, occupation, and default probabilities, low-income individuals pay higher interest rates than high-income borrowers. We quantitatively analyze a consumer credit market with these characteristics observed in Brazil in a model with endogenous default, and where consumers face idiosyncratic income and expenditure shocks. We perform counterfactual analyses to assess the impact of different financial reforms on borrowing rates, consumption inequality, consumption insurance, and welfare. We find that reforms aiming to reduce intermediation costs and bank market power have sizeable average and distributional welfare implications.

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Table of contents

List of figures	xv
List of tables	xix
1 Aggregate and distributional effects of credit shocks on housing and rental markets	1
1.1 Introduction	2
1.2 Model	7
1.2.1 Production	7
1.2.2 Households	8
1.2.3 Equilibrium	11
1.3 A macro-prudential reform: the case of Ireland	12
1.3.1 Empirical evidence	12
1.3.2 Parametrizing the model	14
1.3.3 The reform through the lens of the model: exploring the mechanisms	18
1.4 Conclusion	25
References	27
Appendix A Appendix to Chapter 1	35
A.1 Alternative models	35
A.1.1 Model with a single quality	35
A.1.2 Model with a quality ladder: the baseline	36
A.1.3 Model with two housing technologies	37
A.1.4 Parameterizing the alternative models	38
A.2 Robustness	40
A.2.1 Aggregate housing supply elasticity	40
A.3 Solution method	43

A.3.1	General equilibrium	43
A.4	Additional model-generated figures	45
A.5	Additional data facts	46
A.5.1	Structure of the Irish rental sector	46
2	Falling Behind:	
	Delinquency and Foreclosure in a Housing Crisis	49
2.1	Introduction	50
2.2	Basic Facts About Mortgage Delinquency	55
2.3	Model	59
2.3.1	Environment	59
2.3.2	Households	59
2.3.3	Banks	61
2.3.4	Household Decision Problem	64
2.3.5	Housing Markets, Rental Markets and Production	69
2.3.6	Equilibrium	71
2.3.7	Illustration of Mechanism	72
2.4	Calibration	75
2.4.1	Untargeted Moments	80
2.5	Understanding Delinquencies In A Crisis	83
2.5.1	House Prices, Delinquency and Foreclosure	83
2.5.2	The Relationship Between Delinquency, House Prices and Consumption	86
2.5.3	The Importance of the Lifecycle and Income Process	87
2.6	Recourse and Delinquency	90
2.7	The Effects of Loan Repricing	94
2.8	Delinquency Costs and Benefits in Steady State	99
2.9	Conclusion	102
	References	103
	Appendix B Appendix to Chapter 2	111
3	Consumer Loans, Heterogeneous Interest Rates, and Inequality	135
3.1	Introduction	135
3.2	Empirical Analysis	138
3.3	Model	146

3.3.1	Environment	146
3.3.2	Saving and Borrowing Decisions	146
3.3.3	The Default Decision	147
3.3.4	Welfare	150
3.4	Fitting the Model to the Data	150
3.5	Counterfactuals	155
3.5.1	Benchmark Counterfactual: No wedges	155
3.5.2	Portability	161
3.5.3	Payroll Expansion	166
3.6	Conclusion	173
References		175
Appendix C Appendix to Chapter 3		183
C.1	Data Appendix	183
C.1.1	Description of Data Sets and Summary Statistics	183
C.1.2	Bankruptcy	189
C.1.3	Description of Data Moments	189
C.1.4	Wedges	190
C.1.5	Summary of All Different Loan Types	193
C.1.6	Wedges	196
C.1.7	Interest Rates and Individual Characteristics by Risk	198

List of figures

1.1	Ratio of coefficients for house prices and rents, by year	14
1.2	Housing status (number of properties)	19
1.3	Supply and demand in the rental market	20
1.4	Homeownership Rate	21
1.5	Transition Dynamics	23
1.6	A decomposition of the lifetime CEV – the role of rental prices	24
1.7	CEV – the role of housing tenure	25
A.1	Effects of the Reform as a Function of the Supply Elasticity	40
A.2	CEV – the role of housing supply elasticity	42
A.3	Transition Dynamics – some extra variables	45
A.4	An alternative decomposition of the CEV – the role of house prices .	45
A.5	Irish rental sector structure	46
A.6	Share of property transactions, by type of buyer and year.	47
2.1	Housing Markets in Eurozone Periphery	55
2.2	Delinquency & Foreclosure In Eurozone Periphery	56
2.3	Housing Markets in Eurozone Periphery	57
2.5	Delinquent Accounts Behaviour	58
2.7	Decision Tree for Mortgager	65
2.8	Mortgager Response to Income Shock	73
2.9	Mortgager Response to Income and House Price Shocks	74
2.10	Decline in Employment Over Crisis	75
2.11	Homeownership and Financial Wealth	81
2.12	Evolution of Crisis	82
2.13	Delinquency Behaviour	83
2.14	Delinquency and House Prices	84
2.15	Delinquency and House Prices	85

2.16	Consumption and House Prices	87
2.17	Age-Dependent Income Process	88
2.18	Credit Rationing by Income Process	88
2.19	Median Reservation Payment by Age	89
2.20	Age-Dependent Income Process	90
2.21	Recourse and Risk Pricing	91
2.22	Recourse and Delinquency in a Crisis	93
2.23	Recourse and Delinquency in a Crisis	94
2.24	Repricing - Lender vs. Market	96
2.25	Interest Rate Premia 2012-19	97
2.27	Repricing in a Crisis	98
2.28	Bank Thresholds and Equilibrium Outcomes	100
2.29	Welfare Facing Different Shocks	101
B.1	Histogram of Loan-to-Value Ratios	114
B.2	Histogram of Maturities	114
B.3	Histogram of Interest Rates	115
B.4	Crisis With TFP Shock Instead of Skewness Shock	119
B.5	Crisis With Only Skewness Shock	120
B.6	Changing the Persistence of the Shock	121
B.7	Arrears Balances by Months in Arrears	122
B.8	Arrears Balances by LTV	123
B.9	Consumption and House Prices With Recalibrated Foreclosure Only	125
B.10	Recourse and Non-Recourse With Recalibration	127
B.11	Recourse and Non-Recourse With Recalibration	129
3.1	Loan interest rate densities by income groups; spreads and default-adjusted spreads by income groups	140
3.2	Loan interest rate densities by income groups; spreads and default-adjusted spreads by income groups	152
3.3	Model Interest Rates and Wedges	154
3.4	Assets and Debt Use by Age and Income	154
3.5	Consumer Welfare Gains From Removing All Wedges - by Sector and Income Decile	156
3.6	Change to Consumption Profiles - No-Wedge Benchmark	157
3.7	Effects of Removal of All Wedges on Lifetime Consumption Averages and Standard Deviations	158

3.8	Change to Debt and Asset Profiles from Removing of All Wedges . . .	159
3.9	Path for Typical Default Event - Baseline vs. No-Wedge Benchmark . .	160
3.10	Consumer Welfare Gains From Portability Reform - by Sector and Income Decile	162
3.11	Change to Consumption Profiles - Portability Reform	163
3.12	Effects of Portability Reform on Lifetime Consumption Averages and Standard Deviations	164
3.13	Change to Debt and Asset Profiles from Portability Reform	165
3.14	Path for Typical Default Event - Baseline vs. Portability Reform . . .	166
3.15	Consumer Welfare Gains From Payroll Expansion - by Sector and Income Decile	167
3.16	Change to Consumption Profiles - Payroll Expansion	168
3.17	Effects of Payroll Expansion on Lifetime Consumption Averages and Standard Deviations	169
3.18	Change to Debt and Asset Profiles from Payroll Expansion	170
3.19	Path for Typical Default Event - Baseline vs. Expanded Payroll (base- line wedges)	171
3.20	Path for Typical Default Event - Baseline vs. Expanded Payroll (equal wedges)	172
C.1	Default rates by income groups	188
C.2	Default rates by income groups	188
C.3	Percentage of different loan types	193

List of tables

1.1	Effect of lending limits on house and rental prices	13
1.2	Parameter values	17
1.3	Targeted and untargeted moments	18
1.4	Quantity and price effects across steady states	21
A.1	Effects of credit tightening under different assumptions on housing supply	36
A.2	Targeted and untargeted moments under different model assumptions	39
2.1	Income Garnishment in Default for Spain	77
2.2	Parameter Values.	78
2.3	Model Fit on Targeted Moments	79
2.4	Model Fit on Untargeted Moments	80
B.1	Sample Means	113
B.2	Moment Estimates	115
B.3	Recalibrated Parameter Values.	124
B.4	Recalibrated Fit on Targeted Moments	125
B.5	Recalibrated Parameter Values.	126
B.6	Recalibrated Fit on Targeted Moments	127
B.7	Recalibrated Parameter Values.	128
B.8	Recalibrated Fit on Targeted Moments	129
B.9	Estimate of effect of interest rate resets on spreads	133
3.1	Interest rates and individual characteristics - Personal loans	142
3.2	Interest rates and individual characteristics - Payroll loans	144
3.3	Calibrated Parameters	153
3.4	Model Fit	153
3.5	Baseline vs Counterfactuals Comparison	155

C.1	Summary Statistics - Personal Loans	185
C.2	Summary Statistics - Payroll Loans	187
C.3	Wedges and individual characteristics - Personal loans	191
C.4	Wedges and individual characteristics - Payroll loans	192
C.5	Summary Statistics - Consumer Loan (ex-housing and earmarked credit)	194
C.6	Wedges and individual characteristics - Personal loans	196
C.7	Wedges and individual characteristics - Payroll loans	197
C.8	Interest Rates and Individual Characteristics by Risk (AA and A) - Personal loans	199
C.9	Interest Rates and Individual Characteristics by Risk (AA and A) - Payroll loans	200
C.10	Interest Rates and Individual Characteristics by Risk (B, C and D) - Personal loans	201
C.11	Interest Rates and Individual Characteristics by Risk (B, C and D) - Payroll loans	202
C.12	Interest Rates and Individual Characteristics by Risk (E, F and G) - Personal loans	203
C.13	Interest Rates and Individual Characteristics by Risk (E, F and G) - Payroll loans	204

Chapter 1

Aggregate and distributional effects of credit shocks on housing and rental markets

This chapter is the product of joint work with Juan Castellanos Silvan and Gonzalo Paz-Pardo

Abstract

We propose a joint model of the aggregate housing and rental markets in which both house prices and rents are determined endogenously. Households can choose their housing tenure status (renters, homeowners, or landlords) depending on their age, wealth, and income. We use our model to study the introduction in Ireland in 2015 of macroprudential policies that limited loan-to-value (LTV) and loan-to-income (LTI) ratios of newly originated mortgages. The introduction of stringent LTV and LTI ratios mitigates house price growth, but increases rents and reduces homeownership rates. As a result, middle-income households are negatively affected.

Keywords: House Prices, Rental Prices, Homeownership, Life-cycle, Housing Affordability, Credit Conditions, Macroprudential Policy

JEL classification: D15, E21, E30, E51, G51

1.1 Introduction

Housing has a dual nature as an investment asset and as a consumption good. It represents the majority of wealth for most households and even those who don't own a home must consume housing services, which they usually obtain by buying them in the rental market. Because of their economic and political relevance, housing and rental markets are usually very closely regulated and subject to a wide range of tax advantages, subsidies and restrictions.

Understanding the dynamics of house prices and rental rates, together with their impact on household welfare, requires a joint study of both markets. Interventions that make renting less attractive might encourage households into homeownership, thus potentially raising house prices and lowering rental rates, whilst financial shocks that limit the availability of credit might have the opposite impact. The sizes of these effects depend on the segmentation between the markets for owner-occupied and buy-to-let properties (Greenwald and Guren, 2021a), but also on the responsiveness of the landlord sector to rental and house prices and the differences in quality between owned and rented accommodation, amongst other factors.

In this paper, we develop an equilibrium model of the rental and housing sectors with several key features. First, households differ in their age, income, and wealth, and make endogenous housing tenure choices that lead them to be renters, homeowners, or landlords. Households can borrow through long-term mortgages for which downpayment and other constraints only bind at origination. Second, both rental and housing markets must be in equilibrium, which imply that house prices and rental prices must adjust to clear both markets as a result of potential shocks, but they may do so in different directions. This differs from standard assumptions in the macro-housing literature, in which the rental sector is either non-existent, has a fixed price, or is owned by a stylized foreign risk-neutral investor, thus implying that rents must either stay fixed or co-move with house prices. Third, we consider different scenarios for the convertibility of owner-occupied housing and rental accommodation, and show how they generate different implications for house prices, rents and their ratio.

We use our model to study the effects of a shock to the availability of credit for households, in the form of a borrower-based macroprudential policy intervention that imposes maximum loan-to-value (LTV) and loan-to-income (LTI) ratios to newly originated mortgages. We motivate our analysis with the reform introduced in Ireland in 2015, which set the minimum downpayment on a house to 20% and

the maximum ratio of mortgages to household income to 3.5. Acharya et al. (2022) find that this reform reduced house price growth in areas where the limits were particularly binding. We extend their analysis to rents and find that it had the opposite effect: rental prices increased in those areas where the reform was more binding.

We show that we can rationalize this empirical observation through the lens of the model with the following intuition: in the presence of binding constraints to mortgage credit, prospective homeowners need to postpone or cancel their home buying decisions and stay renters for longer. Thus, more landlords need to enter the market, buy housing and provide it for rent. As long as the supply curve for rental housing at constant house prices is upward sloping, rents must go up to clear the market because the next marginal landlord must be compensated above the previous one in order to step in and provide additional rental housing. On the other hand, the effect on house prices depends on the relative qualities of rental and owner-occupied housing and the ease of convertibility amongst the two. If, as is true in the data for Ireland and most countries, rental housing is of smaller size or lower quality than owner-occupied housing, the increase in the share of renters will have a negative impact on average housing prices. In any case, the homeownership rate goes down.

These opposing effects on rental and house prices crucially hinge on the fact that we allow for *landlord heterogeneity*, a feature that is not present in models with a fully deep-pocketed and risk neutral investor who provides rental housing at user cost, nor in models in which the homeownership rate is fixed at 100% and there are no renters. The structure of our landlord sector is consistent with data from the Irish rental market, in which more than half of rental properties are owned by small landlords with one or two properties and less than 10 percent of properties are owned by large owners with 50+ properties (see Appendix A.5.1 for details).

Calibrating our model and replicating the Irish macroprudential reform, we find that it generates an 8.06% increase in rents and a 0.64% decrease in house prices. Moreover, it reduces the homeownership rate by 2.79 percentage points, with most of it being concentrated among households in the middle of the income distribution and between 35 to 55 years old. Finally, it also generates an increase in concentration in the housing and rental markets, with wealthier landlords holding a larger share of all rental properties (38% pre-reform vs. 39.3% post-reform). In terms of welfare, our model reveals that constraining housing credit is particularly harmful for renters, middle aged households and those in the middle of the income distribution because they find it more difficult to obtain a mortgage and therefore they need to postpone

or cancel their buying decision while paying higher rental prices. Nonetheless, the aforementioned increase in rents and reduction of house prices benefit (prospective) landlords and households in the top of the income distribution since buying is cheaper, the constraints do not bind for these households, and the cash flow they obtain from their investment is higher.

Our results provide the first measure of the costs imposed on households by macroprudential policies through both the rental and housing sectors. However, given that we do not model aggregate uncertainty, cyclical buildup of risk or household's defaults, we cannot measure the benefits of those policies and, as a result, we are silent on optimal LTV or LTI ratios.

Although we have focused on the 2015 Irish macroprudential reform, our framework is more general and can be used to study the effects of other shocks in other economies. For instance, it suits itself naturally to study the effects on the housing and rental markets of monetary policy or fiscal policies such as mortgage subsidies, taxes associated with property purchases, etc. Landlord heterogeneity and the existence of many small landlords are not exclusive to the Irish economy, but a common feature of many European countries. In the United States, where institutional investors are quite developed, individual investors are still very relevant for the determination of housing and rental prices: on aggregate, private individual investors own 71.6% of all rental properties (Pew Research, 2021), with 14 million of them owning between 1 and 4 properties.

Related Literature Our paper contributes to studies of housing in macroeconomics (see Piazzesi and Schneider (2016) for a broad review), and in particular to recent papers that, inspired by the housing boom and bust associated to the 2008 global financial crisis, have analysed house price dynamics and their close relationship with credit, beliefs about future prices and fluctuations in liquidity. We contribute to it by focusing on the rental sector and studying its implications for welfare and aggregate dynamics.

In a general equilibrium model, Favilukis, Ludvigson and Nieuwerburgh (2017) show that a relaxation of financing constraints can lead to a large boom in house prices. Justiniano et al. (2019) focus on the role of the increase in the aggregate amount of credit supply in the economy, which they relate with the low mortgage rates that prevailed during this period. However, these models assume that all households are homeowners, and thus they lack the additional margin of adjustment through changes in housing tenure.

Kaplan et al. (2020a), instead, find that credit conditions had a very small role in house price movements. In their framework, the key driver of the movements in house prices and rents is the change in house price beliefs. They allow households to rent, but assume that a deep-pocketed rental sector is ready to provide rental housing at user cost, thus linking directly the evolution of rents and house prices. Their extension with household-landlords is closest to our framework, but they do not study its implications for rental rates and how they interact with house prices.

Garriga and Hedlund (2020a) focus on the role of endogenous liquidity in housing markets and find that it amplifies the effect of credit shocks on housing prices. In their model, households can rent and the markets for rental and owner-occupied housing are segmented. In particular, they assume that very large dwellings are not available for rent, which in turn weakens the connection between rents and house prices present in the user cost framework.

In a recent paper, Greenwald and Guren (2021a) rationalise the conflicting findings of these different contributions by showing that, in a model in which rental and owner-occupied properties are identical (no market segmentation), increases in homeownership rates do not impact house price-to-rent ratios because households buy housing from deep-pocketed landlords that do not use credit. As a result, changes in credit conditions do not affect house prices. Instead, if the markets for rental and owner-occupied housing are segmented (i.e., they are different goods), the increase in demand by borrowers as a result of a credit shock raises house prices. Arslan et al. (2020) follow this intuition and present a model with partially segmented housing markets and focus on the bank lending channel associated to credit supply shocks.

Our contribution builds on the intuition that assumptions about the rental sector are key for house price dynamics, but we extend it further by developing a model with full heterogeneity in which the decision to become a landlord is endogenous, as in Sommer and Sullivan (2018), who focus on the tax treatment of housing. Landlords in our model are heterogeneous in their age, income and wealth, which generates a positively sloping rental supply function at a given house price. Unlike Sommer and Sullivan (2018), our mortgages are long-term and have both loan-to-income and loan-to-value constraints that only bind at origination, which is key for the question we are considering. We find that, although the effects of a negative credit shock on house prices do depend on the assumptions about segmentation as shown in Greenwald and Guren (2021a), the impact on rental rates is unequivocally positive.

Our modeling of housing and mortgages is based on Paz-Pardo (2021), which we extend to a general equilibrium setting where both house prices and rents are endogenously determined. We use this framework to connect the evolution of housing markets with distributional outcomes, such as Kiyotaki et al. (2011), focusing on an application related to macroprudential policy. The endogenous determination of rents and housing prices is novel to macro applications that study the effect of credit shocks, but is also present in state-of-the-art equilibrium models of local housing markets, such as Favilukis et al. (2022), who focus on rent stabilization policies. Chambers et al. (2009) study the aggregate implications of mortgage choice in a model with endogenous rents, but exogenously fixed house prices through technology.

A broad literature has studied the benefits of macroprudential policies in terms of financial and macroeconomic stability from a modeling perspective, e.g. Lambertini et al. (2013) or Farhi and Werning (2016). More recently, Ferrero et al. (2023) have also studied the joint optimal macro-prudential and monetary policy mix and put forward the idea of countercyclical borrower-based macro-prudential policies. Muñoz and Smets (2022) show that these countercyclical rules may trigger a reallocation of credit to the large real estate funds that operate in the rental market and consequently countercyclical LTV measures on institutional investors may be desirable for macroeconomic stability. Nonetheless, fewer have studied their negative consequences on household's welfare. One example is Queiró and Oliveira (2022) who study the effects of the loan-to-value and payment-to-income constraints implemented in Portugal in 2018 through a model à la Kaplan et al. (2020a), and find that the reform is welfare reducing due to changes in homeownership and the quality of housing rather than through changes in prices.

Some other recent contributions have studied the effect of these reforms from an empirical perspective. Acharya et al. (2022) study the Irish reform in which we will base our empirical experiment, and using geographical heterogeneity in the intensity of the treatment find that the reform was successful in cooling the most tensioned housing markets, reallocating credit to rural areas and to higher-income borrowers. Van Bakkum et al. (2019) study the introduction of a loan-to-value limit in the Netherlands and find that it reduced mortgage leverage, but also, consistently with the implications of our model, the share of renters that transition into homeownership.

Overview The rest of the paper is structured as follows. In section 1.2, we present the model. In section 1.3, we analyze the Irish macroprudential reform of 2015. First, by presenting some empirical evidence in section 1.3.1; and then by using a calibrated version of the model to analyze the effects on quantities and prices as well as on welfare. Parametrization is discussed in section 1.3.2, while model results are presented in section 1.3.3. Finally, section 1.4 concludes.

1.2 Model

In this section, we present a heterogeneous-agent life-cycle model with housing and rental markets in which landlords choose their status endogenously. As a result, households in our model economy differ in their age, income, asset holdings and housing status. Renters and landlords meet in the rental market and determine the equilibrium rental rate. In the production side, there is a final good sector that produces non-durable goods and a construction sector that produces new houses.

1.2.1 Production

There are two production sectors in the economy: a final-good and a construction sector. They produce non-durable consumption goods and houses, respectively.

Final-good sector The competitive final-good sector operates a linear technology

$$Y_c = A_c N \tag{1.1}$$

where A_c is the constant aggregate labor productivity and N are the units of labor services. Profit maximization yields an equilibrium wage $w = A_c$.

Construction sector The competitive construction sector operates a Cobb-Douglas technology

$$Y_h = A_h L^\alpha S^{1-\alpha} \tag{1.2}$$

where L is the amount of buildable land (housing permits), S is the quantity of structures and $\alpha \in (0, 1)$ is the constant share of land in production.

We assume that housing permits are fixed and are priced competitively, so that the housing developer solves the following static problem

$$\max_S p^h A_h \bar{L}^\alpha S^{1-\alpha} - p_L \bar{L} - S \quad (1.3)$$

where p_L is the equilibrium price of buildable land, and the price of structures (non-durables) is normalized to unity. Profit maximization implies the following housing investment function:

$$Y_h = A_h^{1/\alpha} ((1 - \alpha) p_h)^{(1-\alpha)/\alpha} \bar{L} \quad (1.4)$$

and consequently the elasticity of aggregate housing supply to house prices equals to $(1 - \alpha)/\alpha$. For a detailed derivation of equation (1.4) see Appendix A.1.2. As we shall see, equation (1.4) and the housing market clearing condition pins down the equilibrium per unit price of housing, p_h . However, this is not the final transaction price since we further assume that housing is discrete and it can be of two types: owner-occupied (OO) or buy-to-let (BLT) housing. As a result, we let the transaction price be a multiple of the per unit price: $p^h(\mathcal{H}_j) = \mathcal{H}_j p_h$ for $j \in \{oo, btl\}$ reflecting that these two types of housing are characterized by different qualities or sizes.

1.2.2 Households

Demographics Household's age is indexed by $j = 1, \dots, J$. In the first $J^{ret} - 1$ periods they work. Thereafter they are retired until they die with certainty after age J .

Preferences Households derive utility from non-durable consumption and housing services. They value these streams of consumption according to

$$\mathbb{E}_0 \left\{ \sum_{j=1}^J \beta^{j-1} U(c_j, s_j(h)) \right\} \quad (1.5)$$

where $\beta > 0$ is the discount factor, $c > 0$ is consumption of non-durables and $s(h)$ is the consumption of housing services which depends on the type of the house where the household resides and acts as a multiplicative shifter. The per-period utility

function is given by

$$U(c, s(h)) = \frac{(c s(h))^{1-\gamma}}{1-\gamma} \quad (1.6)$$

where $\gamma > 0$ captures both risk aversion and intertemporal elasticity of substitution. As standard in the literature, we assume that the housing service flow for homeowners is larger than for renters living in the same house.

Endowments Working-age households receive an idiosyncratic labor income endowment. We assume that it has a deterministic component that depends on age and a stochastic, persistent component. That is

$$\log y = \log A_c + f(j) + \eta \quad (1.7)$$

where A_c is an index of aggregate productivity, $f(j)$ is a polynomial in age and η represents the stochastic persistent component of earnings. We estimate the earnings process non-linearly as in De Nardi et al. (2020) (see Section 1.3.2 for details). Retired households receive a fixed fraction of their labor income in the last period prior to retirement for the rest of their lifetime.

Households are born with an initial endowment of liquid wealth that is drawn from a log-normal distribution. We also assume that they start their life as renters and thus have no housing wealth.

Liquid assets Households can save in a one-period risk-free bond, $a \geq 0$ that yields a constant interest rate, r , which is determined in the world market and therefore is exogenous.

Housing choices Households can also save through buying houses, which serve a dual role as assets and source of consumption flows. Households who do not own a house must rent one in the market at the unit rental rate p^r . Homeowners do not have to pay rent. When a homeowner buys additional houses as an investment, she rents them out in the market and receives p^r per period per housing unit. Note that these assumptions allow us to distinguish between renters (who own zero houses), homeowners (who own exactly one house) and landlords (who own more than one house). As anticipated above, we further assume that there are two types of houses

which differ in their quality \mathcal{H}_j and that the final transaction price payed or received by households depends on it, i.e. $p^h(\mathcal{H}_j) = \mathcal{H}_j p^h$ and $p^r(\mathcal{H}_j) = \mathcal{H}_j p^r$.

Housing is illiquid since buying and selling housing units is costly. Thus, we assume that households pay a proportional transaction cost, $\tau^h p^h(\mathcal{H}_j)$, that depends on the value of the house being bought or sold. These capture real estate agent fees, taxation and other administrative costs. Houses are also costly to maintain. Therefore, home-owners and landlords pay maintenance costs to keep up with their depreciation, $\delta^h p^h(\mathcal{H}_j)$, where δ^h is the depreciation rate.

Since, in principle, households can differ in both the number of houses and size of each house they own, we introduce the vector \vec{H} of housing sizes $[\mathcal{H}_1, \dots, \mathcal{H}_h]$ and adopt the notation $\vec{H}(h)$ to denote a household with h houses of size $\mathbf{H} = [\mathcal{H}_1, \dots, \mathcal{H}_h]$, where \vec{H} is of length h . For houses who rent (and, therefore, own no houses, we let $\vec{H} = h = 0$. We also use $p^h(\vec{H})$ denote the vector of prices corresponding to each house in \vec{H} .

Mortgages The purchase of a house can be financed through a mortgage at a fixed rate $r(1 + \kappa)$, where $(1 + \kappa)$ is the is the intermediation wedge between the mortgage rate and the risk-free rate. To reduce the dimensionality of the problem, we treat mortgages as negative asset holdings $a \leq 0$, which prevents mortgagors from simultaneously having liquid assets. In other words, a denotes the net asset position.

At origination, the borrower must satisfy two constraints. First, a maximum loan-to-value (LTV) limit, which imposes that the size of the mortgage has to be smaller than a fraction of the value of the house. And second, for the case of a household becoming an owner occupier, a loan-to-income (LTI) requirement which stipulates that the household not borrow more than a multiple of its current income. Formally,

$$a' \geq -\lambda_{LTV} p^h(\vec{H}') \cdot \vec{H}' \quad (1.8)$$

$$a' \geq -\lambda_{LTI} y \quad (1.9)$$

where $\lambda_{LTV} < 1$ and $\lambda_{LTI} > 1$. As in reality, these two constraints do not bind after origination, so households do not need to renegotiate their mortgages every period and thus are not subject to these constraints every period.

After origination the borrower chooses the repayment schedule freely. Nevertheless, we impose that all debts must be paid before the terminal age J , i.e. $a_J = 0$ and

that a minimum amortization payment must be made in each period, together with interest payments. As in Kaplan et al. (2020a), the minimum payment is determined by the constant-amortization formula

$$m_j = \frac{r(1+\kappa)(1+r(1+\kappa))^{J-j}}{(1+r(1+\kappa))^{J-j} - 1} \quad (1.10)$$

Household's Problem A household of age j , income y , with housing portfolio \vec{H} and a assets solves the following dynamic program

$$V(a, \vec{H}, y, j) = \max_{a', \vec{H}'} \left\{ \frac{(c s(\vec{H}))^{1-\gamma}}{1-\gamma} + \sigma_\varepsilon \varepsilon(\vec{H}) + \beta \text{EV} \left(a', \vec{H}', y', j+1 \right) \right\}$$

s.t.

$$c + a' + p^h(\vec{H}') \cdot \vec{H}' + \tau^h p^h(\vec{H}) \cdot |\vec{H}' - \vec{H}| + \delta^h p^h(\vec{H}) \cdot \vec{H} \leq$$

$$y + (1 + r(1 + \mathbb{I}_{a' < 0} \kappa)) a + p^h(\vec{H}) \cdot \vec{H} + p_r(h - 1)$$

$$a' \geq \begin{cases} -\mathbb{I}_{h' > 1} \lambda_{LTV} p^h(\vec{H}) \cdot \vec{H} + \mathbb{I}_{h'=1} \max \left\{ -\lambda_{LTV} p^h(\vec{H}) \cdot \vec{H}, -\lambda_{LTI} y \right\} & \text{if } h' > h \\ a(1 + r(1 + \kappa) - m(j)) & \text{if } h > 0 \text{ and } a < 0 \\ 0 & \text{otherwise} \end{cases} \quad (1.11)$$

where $\sigma_\varepsilon \varepsilon(h)$ are choice-specific random taste shocks that are *i.i.d.* Extreme Value Type I distributed with scale parameter σ_ε . These represent shocks to the utility of homeownership (i.e., they are alike to moving shocks), but are also computationally convenient as they help to smooth out expected value functions (Iskhakov et al., 2017).

1.2.3 Equilibrium

A competitive equilibrium in this economy consists of a value function $\{V\}$, policy functions for the households $\{c, a', \vec{H}'\}$, policy functions for the firms $\{N, L, S\}$ and prices $\{w, p_h, p_r, p_l\}$ that jointly solve the household, final-good firm and construc-

tion firm problems, and satisfy the following market clearing conditions

$$\text{Housing production: } Y_h = (\delta_h + 1/T)H \quad (1.12)$$

$$\text{Aggregate housing: } H = \sum_{n=1}^N \mathcal{H}_n H_n^{sh} \quad \text{where} \quad \sum_{n=1}^N H_n^{sh} = 1 \quad (1.13)$$

$$\text{Total production: } Y = Y_c + Y_h \quad (1.14)$$

$$\text{Resources: } Y = C + S \quad (1.15)$$

for a given risk free rate r .

1.3 A macro-prudential reform: the case of Ireland

Macro-prudential regulations that limit household leverage in the residential mortgage market have been widely used by policymakers to smooth the house price and credit cycles. We study the case of Ireland, whose central bank introduced these measures for the first time in February 2015 after a first discussion in October 2014. In particular, the Central Bank of Ireland established a maximum LTI limit of 3.5 and several LTV limits depending on the borrower type. For primary dwellings (PD) the limit was set to 80% of the value of the house; for first-time-buyers (FTBs), the limit was more generous: 90% for the first 220,000 and 80% for the excess amount; and for buy-to-let (BTL) properties the threshold was more stringent and set to 70%. Additionally, a share of the total amount of lending offered by banks was exempt of the limits (15% of all lending for LTV limits and 20% of all lending for LTI limits).

The prompt implementation of the reform, paired with data availability, makes Ireland a compelling case study. We now turn to showing the effects that the reform had on house prices and rents in the data, which we will use as motivating evidence for the calibrated version of our model.

1.3.1 Empirical evidence

Using data for the universe of originated mortgages in Ireland, Acharya et al. (2022) study the 2015 reform and find that it generated a reduction in house price growth. In order to control for potentially confounding effects in macroeconomic aggregates, they develop a *distance* measure that correlates with exposure to the macro-prudential reform. In counties where house prices were high with respect to incomes, many mortgages were originated before the reform at or above the limits: these are

low-distance areas where the reform is expected to have stronger effects. Instead, in counties where house prices were relatively low with respect to incomes, the reform was closer to non-binding and thus expected to have low to no effects. Consistently, they find that the distance measure positively correlates with house price growth around the reform: house prices grew more in areas where the constraints were less binding, while house price growth moderated in areas where the intervention was more binding.

We extend their framework to look at the effects on rents. We use the distance measure they computed and merge it with house price and rental data extracted from daft.ie (Lyons, 2018). Following their empirical implementation, we measure changes in house prices and rents between the third quarter of 2014 and the last quarter of 2016 and regress them on the aforementioned distance measure. That is,

$$\Delta HP_i = \beta_0 + \beta_1 \text{Distance}_i + \epsilon_i \quad (1.16)$$

$$\Delta HR_i = \gamma_0 + \gamma_1 \text{Distance}_i + v_i \quad (1.17)$$

Table 1.1 shows the results. We replicate the positive coefficient they obtain for house prices, but we find that the effect on rents was the opposite: rents increased by more in areas where the macro-prudential intervention had stronger effects. This movement of rents and house prices in opposite directions is restricted to the time around the implementation of this policy and is not present for the rest of our sample period. Figure 1.1 shows the ratio of coefficients β_1 and γ_1 in Equations (1.16) and (1.17) if we estimate them in different sample periods (x-axis). Specifically, we keep the same time window as in our main regression (9-quarter changes) and report the coefficients as a function of the central part of the window. We keep the distance measure fixed to its value in Acharya et al. (2022), which corresponds to 2014.

Table 1.1: Effect of lending limits on house and rental prices

	Δ House prices	Δ Rents
Distance	0.289 (0.068)	-0.171 (0.039)
Obs.	54	54
R^2	0.34	0.31

The unconditional average and median of this coefficient is positive, reflecting that, in general, house prices and rents tend to comove, which is consistent with theories that set the value of a house to the expected discounted value of future rents. However, around our credit shock the fact that there are constrained renters who can't buy breaks this long-run relationship and generates effects going in opposite directions. The fact that this negative coefficient is limited to the time around the reform is a model implication, and is reassuring that the distance measure does not capture other relevant, time-invariant omitted variables (such as urban vs. rural, for example) which were themselves driving the relationship between house prices and rents.

In short, this placebo test confirms that our findings are not driven by time-invariant omitted variables which are correlated with the distance measure and reinforces the idea that the credit shock induced a decoupling of the usually positive relationship between the evolution of house prices and rents.

1.3.2 Parametrizing the model

In this section, we parametrize our model to be consistent with the cross sectional features of the Irish economy and use it for a twofold purpose. First, to understand the opposite effects on house prices and rents of the macroprudential reform; and second, to further analyze the distributional effects and the costs imposed on households by these reforms, taking into account a broad life-cycle perspective.

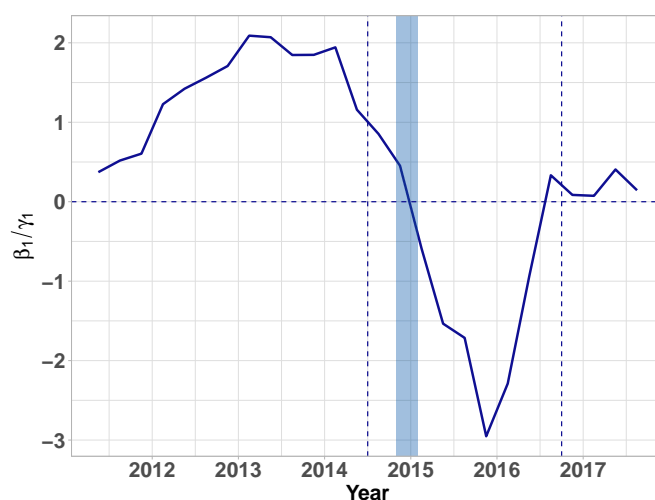


Fig. 1.1: Ratio of coefficients for house prices and rents, by year

As standard in the macroeconomic literature, we assign some of these parameters externally, while others are chosen internally with the objective of minimizing the distance between a collection of data and model moments.

Earnings Process

We estimate our earnings process on a combination of Household Finance and Consumption Survey (HFCS) data and European Union Statistics on Income and Living Conditions (EU-SILC) data. The HFCS, which takes place every three years, collects rich data on the income and wealth of European households, including their homeownership status, rental income, etc., which we also use as targets for our model. We use the HFCS to extract the average age-earnings profile in the Irish economy after taking into account year effects. However, in the case of Ireland the HFCS lacks a panel component, so we resort to EU-SILC data to study the annual fluctuations of income. Although it is targeted to produce statistics on poverty and living conditions, it is nationally representative. We use the longitudinal version of the survey (between 2005-2019) and after dropping households with low attachment to the labour force (below 1,500 per year of labour market income) we are left with 1,270 observations to estimate our earnings process.

Our measure of income in the data is disposable household income after both taxes and transfers. To filter out potential measurement error in the survey whilst keeping potentially relevant rich features of earnings dynamics, we use the procedure described in Arellano et al. (2017) to extract out a transitory component and keep the persistent component of earnings.

Applying this procedure allows us to estimate earnings dynamics under flexible assumptions, and in particular incorporating potential age-dependence, non-normalities and non-linearities in earnings dynamics. The first element is of particular relevance for our question. Most households become homeowners when they are relatively young, still changing jobs and potentially subject to large fluctuations to their labour market income. A standard earnings process in which earnings are a random walk is a poor representation of the earnings risk faced by households at this particular age. Middle-aged households with stable jobs, instead, have much higher persistence, but significant negative skewness risk (e.g., through job loss). For a detailed description of the method and the economic implications of flexible earnings dynamics, see De Nardi et al. (2020).

Externally calibrated parameters

The model period is one year. Households enter the economy at age 25, they retire with certainty at age 65 and live until age 95. This means that $J^{ret} = 41$ and $J = 71$. There is no population growth. We set the CRRA risk aversion coefficient, γ , to 2, a common value in the literature. The scale parameter of the taste shock, σ_ε , is within the range suggested by Iskhakov et al. (2017) and equal to 0.05.

We restrict the number of housing qualities to just two - one "small" house primarily for renters (although it can also be bought) and one "large" house which we assume can only be lived in if it is owner-occupied. The house qualities, $\{\tilde{h}_{oo}, \tilde{h}_{btl}\}$, are chosen to replicate the owner-occupied to buy-to-let house price ratio, which is 1.21 in the data. The housing depreciation rate, a cost borne by households, is set to be 1.2% per year and it is within the range of typical values used in the literature. The transaction cost for selling or buying a house τ^h equals 4% of its value. The maximum loan-to-value, λ_{LTV} , and loan-to-income, λ_{LTI} , ratios are 1.0 and 6.0, respectively. This is consistent with the evidence in Kelly et al. (2018) that estimate the 98th percentile of observed LTI and LTVs ratios on quarterly mortgage data during the period 2003 to 2011.¹

The risk-free rate on liquid savings r is set to 2%. The mortgage rate equals the risk-free rate times an intermediation wedge $(1 + \kappa)$, which takes a value of 1.02, i.e. we assume a 2% spread on mortgage borrowing.

The final good aggregate productivity shifter, A_c , is set to 1.25. The share of land, α , used in production in the housing sector is fixed to 0.33 and the amount of buildable land, \bar{L} , is equal to 1.

Internally calibrated parameters, targets and model fit

The remaining three parameters: the discount factor β , the homeownership utility premium $s(h > 0)$, and the scaling factor in housing production A_h , are jointly set to match four moments of the data. In particular, we try to match the average wealth to income ratio, which is around 7 in the HFCS; the homeownership rate that was around 80% before the 2008 crisis according to EU-SILC; a house price to income ratio of 5 that is consistent with the data in the Central Statistics Office (CSO); and the house price to rent ratio that is computed using data from the Residence Tenancies Board (RTB) and the CSO.

¹Note that prior to the 2015 reform, there was no institutional limits. Therefore, these limits were unofficially imposed by Irish banks and were based on their own risk assessment.

The first block of Table 1.3 shows the exact value of these moments in the data as well as their model counterparts which are obtained using the parameters reproduced in the last block of Table 1.2. The model is able to match the average homeownership rate, the average house price to income ratio, and the house price to rent ratio reasonably well. However, it under-predicts the average wealth to income ratio since we do not model the stock market nor include bequest motives.

The model is also able to replicate the share of landlords in the economy, both at the aggregate level and along the age distribution. In the model, the share of landlords with two rented out properties (the upper bound) is 3.97%, while in the data 5.11% of landlords own two or more rental properties. The model also does a great job in capturing the life cycle dynamics as shown in Figure 1.2. It is only at the middle of the life-cycle when some households can afford a second or third home, which later in old-age they sell to finance retirement. In both the model and the data, the share of renters decreases with age, and many households are able to access homeownership earlier in life. During the retirement period, the model overpredicts

Table 1.2: Parameter values

Parameter	Interpretation	Value
<i>Externally calibrated:</i>		
J^{ret}	Working life (years)	41
J	Length of life (years)	71
γ	Risk aversion coefficient	2.0
σ_ε	Scale parameter (taste shock)	0.05
$\{\tilde{h}_{oo}, \tilde{h}_{btl}\}$	Housing qualities	{1.036, 0.8562}
δ^h	Housing depreciation rate	0.012
τ^h	Proportional transaction cost	0.04
λ_{LTV}	Maximum loan-to-value ratio	1.0
λ_{LTI}	Maximum loan-to-income ratio	6.0
r	Risk-free rate	0.02
κ	Intermediation wedge	0.02
A_c	Aggregate labor productivity	1.25
\bar{L}	Amount of land	1.0
α	Share of land in production	0.33
<i>Internally calibrated:</i>		
β	Discount factor	0.9375
$s(h > 0)$	Utility premium from ownership	1.6
A_h	Scaling factor in housing production	0.12

Table 1.3: Targeted and untargeted moments

Moment	Model	Data	Source
<i>Targeted:</i>			
Wealth to income ratio	5.32	6.78	HFCS
Homeownership rate	79.13%	80%	EU-SILC
Avg. house price to income ratio	4.90	5.0	CSO
House price to rents ratio	23.00	22.58	RTB/CSO
<i>Untargeted:</i>			
Rents to avg. income ratio	0.2132	0.2216	RTB/CSO
Share of households with 3+ properties	3.97%	5.11%	HFCS

the share of renters and the extent to which landlords sell their properties to finance retirement. This mismatch is a standard feature of life-cycle models who do not model a set of relevant features of retiree saving behaviour, including precautionary savings related to medical costs or long-term care, bequest motives, etc. (Nakajima and Telyukova, 2020).

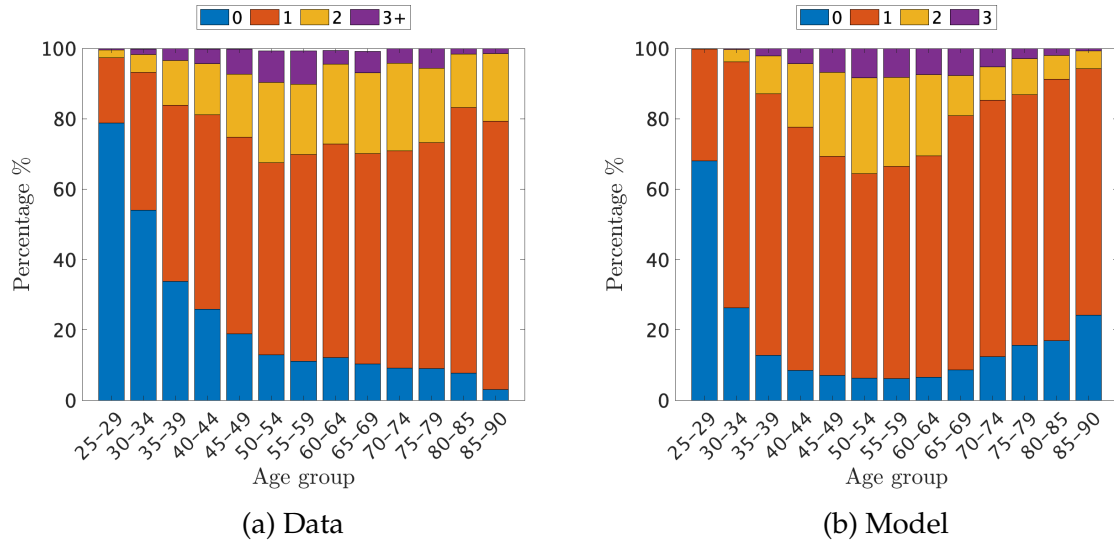
In any case, these life-cycle patterns are endogenously captured by the model without explicitly targeting them, which is reassuring about the validity of the model as a laboratory to study the distributional effects of the macro-prudential reform discussed above.

1.3.3 The reform through the lens of the model: exploring the mechanisms

Intuition: a supply and demand explanation

Before we turn into the results of the model, i.e. how the Irish macroprudential reform affected house and rental prices, homeownership rates and welfare, we present the intuition through a supply and demand illustration. We use the share of renters (demand) or the share of landlords adjusted by the number of properties they own (supply) on the x-axis and the rent-to-price ratio on the y-axis.

As shown in Figure 1.3, rental demand is downward sloping because increases in the rental to house price ratio incentivize homeownership and consequently less and less households are willing to be renters. On the other hand, such increase makes buying buy-to-let properties more attractive and more and more households are willing to be landlords. This results in an upward sloping rental supply curve. As standard, the intersection of these two curves form an equilibrium which determines



Note: The blue bars (0 properties owned) denotes renters. Those with 2 or more (yellow and purple) are landlords and those who own one property (red) are owner-occupiers.

Fig. 1.2: Housing status (number of properties)

the price. As illustrated in panel (a), such equilibrium requires that the share of renters equals that of houses offered by landlords in our model economy, which in turn determines the rental rate and the average house price.

Now, consider the impact of a credit reduction associated for example to the introduction of macroprudential mortgage limits. On impact the reform primarily affects potential buyers that were close to the borrowing limit before and that now do not qualify for a mortgage. These households are not able to buy a house anymore, and therefore need to rent. This shifts the demand curve outwards as shown by the blue dash line in panel (b) of Figure 1.3.

In a model with perfectly elastic rental supply (red dotted line), the increase in rental demand only translates into a reduction of the homeownership rate since the share of renters goes up. Prices do not move because deep-pocketed landlords are willing to buy as many houses as needed at the present value of rents to meet rental demand. As shown in Greenwald and Guren (2021a), this is why in the baseline model of Kaplan et al. (2020a) credit conditions do not affect house prices.

As discussed above rental supply is upward sloping in our model. Consequently, an increase in rental demand associated with the reduction in credit results not only in changes in the homeownership rate but also in an increase in the rent to price ratio.

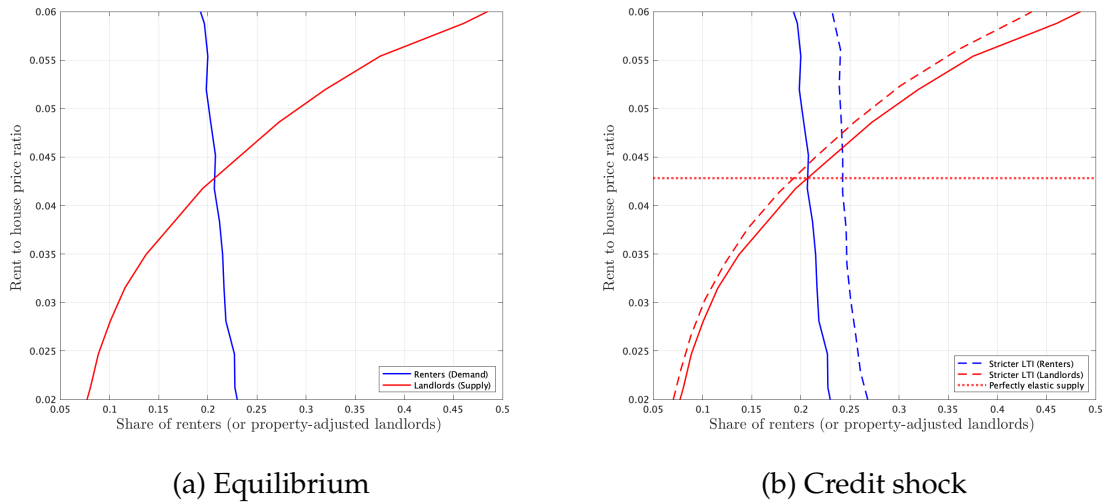


Fig. 1.3: Supply and demand in the rental market

This increase in the price ratio is slightly amplified in our model because landlords also use credit to buy additional rental properties, which slightly shifts rental supply inwards (red dashed line).

Overall, a reduction in credit results in an increase of the rent to price ratio and a reduction of the homeownership rate because rental demand shifts outwards, rental supply is upward sloping and (potential) landlords are a bit sensitive to credit conditions.

Steady state comparison

We first study the aggregate effects of the macroprudential reform if it were to be permanent. We do so by comparing two steady state equilibria that only differ in their institutional parameters. First, the LTI and LTV limits are those specified in Section 1.3.2 for the *pre-reform* economy. Second, the model is solved using the LTI and LTV limits established by the Central Bank of Ireland in 2015 for the *post-reform* economy. In particular, we simplify some of its aspects and directly impose $\lambda_{LTI}^{post} = 3.5$ and $\lambda_{LTV}^{post} = 0.8$. Results are shown in the first two columns of Table 1.4.

The more stringent borrowing limits lead to an increase in the rent-to-price ratio and to a reduction of the home-ownership rate in the long run, as shown graphically above. In particular, the homeownership falls 2.79 percentage points while the rent-to-price ratio increases by 8.76%. As we showed empirically in Section 1.3.1, the macroprudential reform had opposite effects on house prices and rents.

Table 1.4: Quantity and price effects across steady states

	Pre-Reform	Post-Reform	Only LTI
Rent-to-Price	4.38%	4.73%	4.73%
Average house price to income	4.90	4.87	4.87
Rent to Income	0.21	0.23	0.23
Homeownership rate	79.13%	76.34%	76.36%
Share of households with 3 properties	3.97%	4.65%	4.66%
Share of houses in hands of 3-property landlords	38.06%	39.29%	39.47%

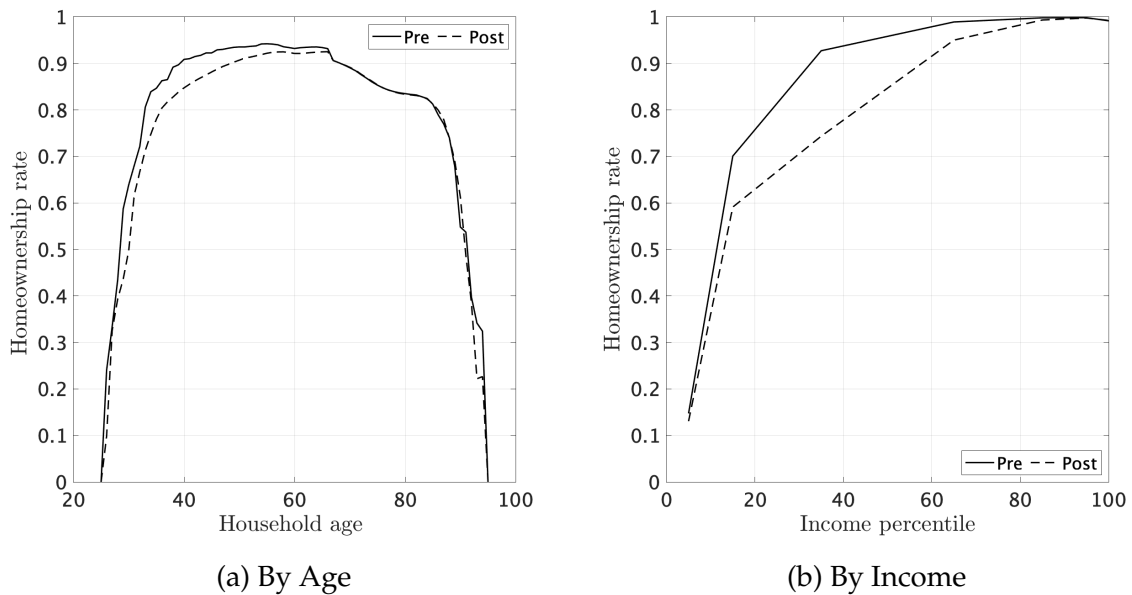


Fig. 1.4: Homeownership Rate

Consequently, the increase in the rent to price ratio could be originated by an increase in rents or a drop in house prices. Importantly, our model is able to disentangle the two. We find that rental rates rise by 8.06% while house prices fall by 0.65%. Thus, our model is consistent with the negative empirical correlation of macroprudential borrowing limits and house prices, as well as the positive empirical correlation of these limits and rental prices.

Regarding the fall in the homeownership rate, we find that it is concentrated among middle aged households and those in the middle of the income distribution (see Figure 1.4). These results are very intuitive. Very poor households cannot afford to purchase a house independently of the credit conditions while the very rich are

typically unconstrained or they do not need a mortgage. As a result, the reform has very little to no impact on their choices. However, for middle income households, that typically finance their housing purchases through mortgage borrowing, the tightening of these conditions have direct/partial equilibrium effects because they do not longer qualify for a mortgage and indirect/general equilibrium effects because higher equilibrium rental prices make it harder to save for downpayment.

Since there is a reduction in the homeownership rate, the share of renters must rise in the *post-reform* economy. As shown in the last two rows of Table 1.4, this extra demand for rental units is met by existing and new landlords. In fact, the share of landlords with two rental properties increases by 0.68 p.p., and the share of rental properties in hands of the wealthiest landlords rise from 38.06% to 39.29%. Thus, the reform lead to a higher degree of concentration in the rental market.

Finally, we decompose the effects of each of the two borrowing limits by solving for a third steady state equilibrium in which only the new LTI limit is imposed. Results are shown in the third column of Table 1.4. Given the similarity of this equilibrium with the *post-reform*, we can conclude that most of the effects are originated by the tighter LTI limits since it is the one that typically binds given the Irish institutional framework and parametrization.

Welfare effects along the transition

We now consider the effects of the transition from the (initial) *pre-reform* steady state to the (final) *post-reform* steady state. That is, agents unexpectedly observe that LTV and LTI limits become more stringent with the LTI limit dropping from 6 to 3.5 and the LTV limit falling from 100% to 80%. The reduction of these limits is permanent and it is perceived as such by the agents in the economy.

Transition paths Figure 1.5 show the transition paths for rents, average house prices and homeownership rates in deviations from the initial steady state. After the introduction of the regulatory LTV and LTI limits, homeownership rate falls by 1.8 p.p. upon impact since there is a significant mass of households that at the new limits do not qualify for a mortgage and consequently are forced to obtain housing services in the rental market. This increase in rental demand puts upward pressure in rental prices which immediately rise by 6%. Similarly, average house prices also react upon impact and fall by 1.7%. These price changes incentivize (prospective) landlords to buy additional rental houses, bringing back up the average house price to its new steady state level, which is 0.6% lower than in absence of the reform. In

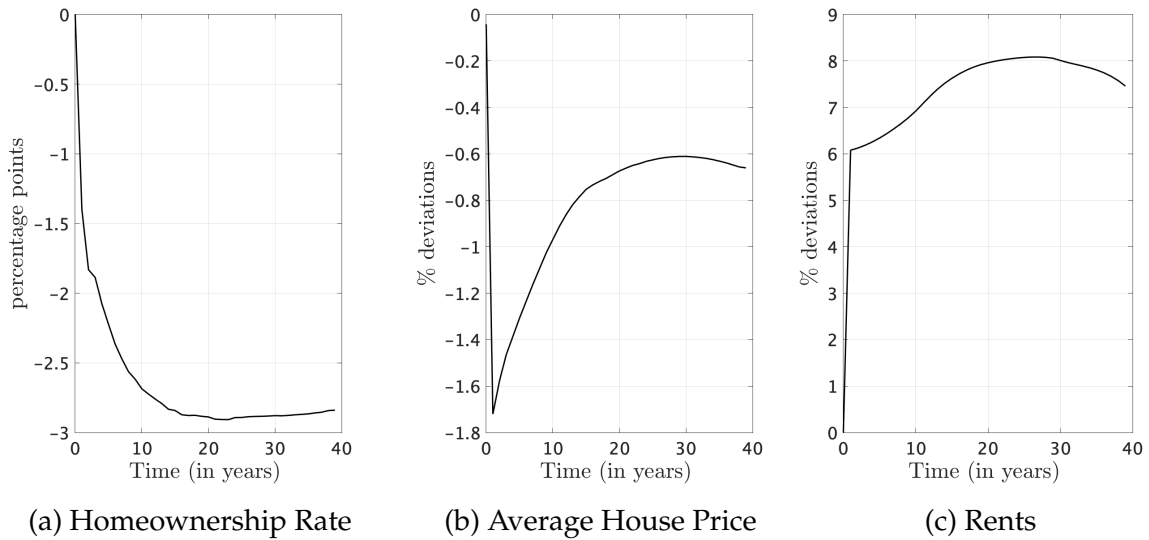


Fig. 1.5: Transition Dynamics

any case, rental prices continue adjusting upwards in subsequent periods because saving for downpayment is more difficult as a bigger fraction of income is destined to obtain housing services in the rental market, which in turn forces homeownership to keep adjusting downwards putting upward pressure on rents despite the slow increase in supply, specially coming from new landlords.

In Figure A.4 in the appendix we also depict the evolution of the share of landlords with 2 or 3 properties as well as that of owner-occupied and buy-to-let housing prices.

Welfare We evaluate the distributional effects of the macroprudential reform through the traditional lifetime consumption equivalent variation (CEV) measure. This metric informs us about how much consumption (in percentage) needs to change in the pre-reform economy such that the households are indifferent between living in the pre-reform steady state and living through the transition induced by the policy reform. Formally, for a given set of state variables $x = (a, y, h, j)$, the consumption equivalent variation $g(x)$ is computed as

$$V_0(x; g) \equiv (1 + g)^{1-\gamma} V_0(x) = V_1(x) \quad \implies \quad g(x) = \left[\frac{V_1(x)}{V_0(x)} \right]^{\frac{1}{1-\gamma}} - 1 \quad (1.18)$$

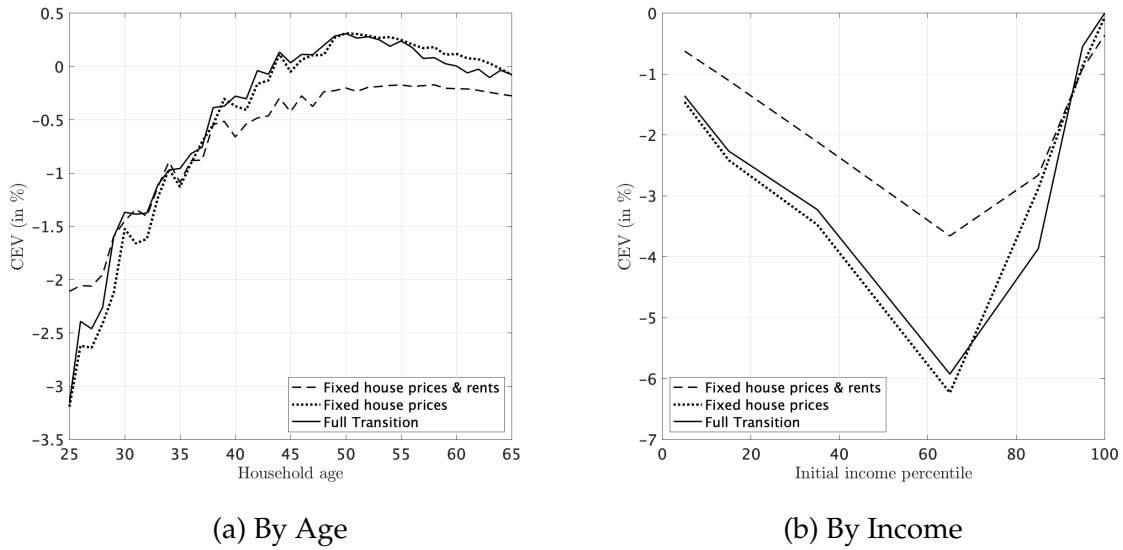


Fig. 1.6: A decomposition of the lifetime CEV – the role of rental prices

where we are using the fact that the utility function is CRRA. From (1.18) it is easy to realize that a negative value of $g(x)$ is associated with agents being worse-off by the introduction of the reform.

Figure 1.6 shows this metric along the age distribution (left) and along the income distribution at the initial age (right) for three different scenarios. In the first scenario, we compute the CEV at constant prices. That is, we fix both rental and house prices to its pre-reform values and evaluate the welfare effects of constraining mortgage borrowing along the transition. As expected, such intervention is welfare reducing. More interestingly, and as shown by the dashed line, these losses are particularly large for the young and those in the middle of the income distribution.

The second scenario, depicted by the dotted line, shows the effects of rental price movements. In particular, to evaluate its welfare effects, on top of those induced by changing the LTI and LTV limits, we feed in the equilibrium path for rents while still keep the house prices at their pre-reform values. As revealed by the distance between the dashed and dotted lines, the sharp jump in rental prices harms the young who are typically renters, while it benefits the middle-aged who are more likely to be landlords. Along the income distribution, the change in rental prices severely affects those in the bottom and middle of the income distribution since they must pay higher rental prices. Moreover, prospective homeowners will need to cancel or postpone their house buying decisions since rental payments constitute

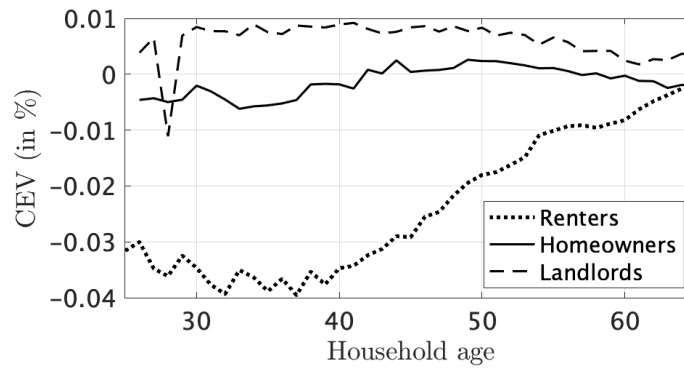


Fig. 1.7: CEV – the role of housing tenure

now a larger fraction of their expenses, making impossible, in some cases, to save enough for downpayment.

Finally, the third scenario shows the overall welfare effects in which both rental and house prices behave as in Figure 1.5. This is depicted by the solid line, which follows closely the dotted line. That is, the drop in house prices in isolation does not have a big impact on average welfare by age. Nevertheless, it has more clear distributional implications along the income distribution: those in the middle-lower part of the income distribution are better off because they can now buy a house at a cheaper price, while those at 70-90 percentiles of the income distribution are slightly worse off since their houses have lost some value, and therefore provide less cushion for unexpected income shocks.

The aforementioned decomposition of welfare effect has highlighted the importance of housing status on the bearing of the welfare costs of the macro prudential reform. Therefore, we also analyze the welfare effects for renters, homeowners and landlords in Figure 1.7. This figure confirms that the macroprudential reform benefits landlords, harms renters and has a small impact on homeowners on average.

1.4 Conclusion

In this paper, we empirically show that the introduction of LTI and LTV limits in Ireland in 2015 had opposite effects on house prices and rents. To rationalize this finding, we build a life-cycle incomplete markets model with *heterogenous landlords*, which allows us to disentangle the effects of these borrowing-based macroprudential policies on both housing and rental markets.

Viewed through the lens of the model, the 2015 Irish macroprudential reform led to the intended reduction in house prices, but at the cost of increasing rental rates and reducing the homeownership rate. Moreover, it also increased the concentration in the rental market as the share of rental housing in hands of the wealthiest landlords increased.

These aggregate effects impacted households differently. The young, the middle-income and the renters suffer the most from the reform because they have to pay higher rents and are forced to postpone or cancel their buying decisions. On the other hand, top income earners, soon-to-be retirees and landlords slightly benefited because these agents are not constrained by the new borrowing limits and can buy additional housing at lower prices.

Our model does not include aggregate uncertainty, cyclical buildup of risk or household default. Embedding our framework in a model that incorporates the benefits of macroprudential regulations would be an interesting next step with which to study optimal LTV and LTI ratios. Besides, in our model all of the heterogeneous landlords are relatively small. As Muñoz and Smets (2022) show, the role of institutional investors matters to study the effects of macroprudential policies. Thus, a fruitful area for future work would be to study the relative role of these two different types of investors, their heterogeneity across housing markets, countries and over time, and their macroeconomic implications.

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Appendix A

Appendix to Chapter 1

This Appendix is organized as follows. Section A.1 describes alternative models which differ in their assumptions about the housing market. These additional models are useful to validate the robustness of our results to changes in these key assumptions. Section A.2 analyzes how sensitive our results are to various choices within the baseline model. Section A.3 outlines the algorithms used for the computation of the equilibrium. Section A.4 contains some additional plots, while section A.5 presents additional data facts that support our modeling choices.

A.1 Alternative models

A.1.1 Model with a single quality

In this version of the model, we assume that there is only one house quality, which directly implies that the the aggregate amount of housing does not change. In fact, one can normalize it to unity, i.e. $H = 1$. In this case, it is possible to find the equilibrium house price analytically through the housing producer's first order condition:

$$p_h(1 - \alpha)A_h \left(\frac{\bar{L}}{S}\right)^\alpha - 1 = 0 \Leftrightarrow p_h = \frac{1}{A_h(1 - \alpha)} \left(\frac{S}{\bar{L}}\right)^\alpha \quad (\text{A.1})$$

and the housing market clearing condition,

$$A_h \bar{L}^\alpha S^{1-\alpha} = \delta_h H \Leftrightarrow S = \left(\frac{1}{A_h} \delta_h \bar{L}^{-\alpha}\right)^{\frac{1}{1-\alpha}} \quad (\text{A.2})$$

Table A.1: Effects of credit tightening under different assumptions on housing supply

	Single quality	Quality Ladder	Two Techn.
Δ Rent-to-Price	5.98 %	8.76 %	23.58 %
Δ Average house price to income	0.0 %	-0.65 %	-0.58 %
Δ Owner-occupied house price to income	0.0 %	-0.14 %	-2.14 %
Δ Buy-to-let house price to income	0.0 %	-0.14 %	8.11 %
Δ Rent to Income	5.98 %	8.06 %	22.86 %
Δ Homeownership rate	-2.34 p.p.	-2.79 p.p.	-2.88 p.p.
Δ Share of households with 3 properties	0.58 p.p.	0.68 p.p.	1.01 p.p.
Δ Share of houses in hands of 3-property landlords	0.81 p.p.	1.24 p.p.	-4.42 p.p.

since after substituting equation (A.2) into (A.1), the per unit house price is simply a function of model parameters α , A_h and δ_h , as well as the amount of buildable land used in production, which is also fixed by assumption.

Importantly, note that in this case a change in mortgage credit conditions, i.e. changes in λ_{LTV} and λ_{LTI} , won't affect the equilibrium house price, p_h . In our model, however, this does not imply that the relative price of housing versus that of renting does not change as we move credit conditions. In fact, it does! As shown in Table A.1 below, the rent to price ratio increases by 5.98%. Nevertheless, this change corresponds entirely to the increase in rental prices associated to the higher rental demand. In other words, the change in the ownership composition of the housing stock, which moves from homeowners to landlords, does not affect house prices because owner-occupied and buy to let properties are assumed to be identical, i.e. there is no segmentation.

This is still an important result because we are able to generate movements in the rent to house price ratio in response to a change in credit conditions even without the need to impose some degree of segmentation between the two markets. The key element of the model that generates this behavior is the presence of small heterogeneous landlords that weight costs and benefits before buying an additional house and rent it out. In particular, this feature generates an upward sloping rental supply curve (see Figure 1.3) which is key in generating changes in both prices and quantities as credit tightens.

A.1.2 Model with a quality ladder: the baseline

In this version of the model we assume that houses differ in their quality or size. For simplicity, we further assume that there are only two types: owner-occupied (OO)

and buy-to-let (BTL) with the former being larger or of better quality than the latter, i.e. $\tilde{h}_{oo} > \tilde{h}_{btl}$. We calibrate these two parameters to match the owner-occupied to rental house price ratio in the data.

An implication of this assumption is that the aggregate amount of housing is now endogenous and in fact given by: $H = \tilde{h}_{oo}H_{oo} + \tilde{h}_{btl}(1 - H_{oo})$ where H_{oo} also denotes the homeownership rate. As a result movements in credit conditions also generate changes in house prices through a composition effect. Since a credit tightening reduces the homeownership rate, the total aggregate amount of housing also drops because there are fewer high quality owner-occupied houses relative to lower quality rental houses. This drop in aggregate housing affects the per unit house price through equation (A.3) below

$$p_h = \frac{1}{1 - \alpha} \left(\frac{1}{A_h} \right)^{\frac{1}{1-\alpha}} \left(\frac{\delta_h H}{\bar{L}} \right)^{\frac{\alpha}{1-\alpha}} \quad (\text{A.3})$$

which we have obtained after substituting the housing investment function (1.4) into equilibrium condition that states that all depreciated houses must be refurbished: $Y_h = \delta_h H + (1/T)\tilde{h}_{oo}$. Equilibrium condition (1.4) is obtained by solving for S in the housing good producer first order condition and then plug it into the housing technology $Y_h = A_h \bar{L}^\alpha S^{1-\alpha}$.

In short, in a model with landlord heterogeneity, allowing for a quality ladder in the housing market is a way of generating changes in both house prices and rents in response to a credit shock, as shown in the second column of Table A.1.

A.1.3 Model with two housing technologies

In the baseline model, the housing good producer uses the same production function to build both owner-occupied and buy to let properties. Alternatively, one could also assume that this is not the case since these are two completely different goods (full segmentation). Hence, in this version of the model, we assume that both owner-occupied and buy-to-let housing producers are independent of each other. Nevertheless, we further assume that they use the same Cobb-Douglas technology but with different degrees of efficiency. As a result, the equilibrium house prices for each housing sector $j = \{oo, btl\}$ are given by:

$$p_h^j = \frac{1}{(1 - \alpha)} \left(\frac{1}{A_h^j} \right)^{\frac{1}{1-\alpha}} (\delta_h H_j)^{\frac{\alpha}{1-\alpha}} \quad (\text{A.4})$$

where now the efficiency units in production is industry specific, A_h^j , and the total stock of housing is split between the two industries, i.e. $H = H_{oo} + H_{btl}$.

In this specification, the values of A_h^{oo} and A_h^{btl} are key to determine the price relationship between owner-occupied and buy-to-let properties. Therefore, we calibrate these two values such that the equilibrium house price ratio in the pre-reform economy equals to that in the data.¹ In fact, it is easy to show that:

$$\frac{A_h^{oo}}{A_h^{btl}} = \left(\frac{p_h^{btl}}{p_h^{oo}} \right)^{1-\alpha} \left(\frac{H_{oo}}{1 - H_{oo}} \right)^\alpha \quad (\text{A.5})$$

which allows us to pin down their ratio directly from the data, conditional on a specific value of the share of buildable land used in production.² In any case, it is important to note that house prices in this economy differ not only because the efficiency parameters do not coincide, but also because the share of each housing good in the total housing stock differs.

Bearing that in mind, we now turn to the results of our main experiment. Under these assumptions, a tightening of the credit conditions also generates an increase in the rent to house price ratio (23.58%) as well as a reduction in the homeownership rate (-2.88 p.p.). Unlike in the baseline, owner-occupied and buy-to-let property prices move in opposite directions since the drop in homeownership rate leads to a reduction in owner-occupied house prices, while the increase in the rental share induces an increase in buy-to-let property prices. As a result, the effect on average house prices will depend upon the strength of each of these two channels and the equilibrium quantities of the two housing goods. For the model parametrization considered, and explain below, owner-occupied house prices drop by -2.14%, while buy-to-let house prices rise by 8.11%. However, since there are a lot more owner-occupied houses in the economy (approx. 80%), the average house price to income ratio slightly decrease (-0.58%) in response to a credit tightening.

A.1.4 Parameterizing the alternative models

We calibrate the alternative models to have a fairer comparison of the effects of the reform among the different versions of our model economy. In particular, we choose

¹On average owner-occupied housing is 1.21 times more expensive than buy-to-let properties.

²Note that H_{oo} corresponds to the home-ownership rate since every household must buy an owner-occupied property before purchasing additional buy-to-let properties. Thus, the two ratios in the RHS of equation (A.5) are observable.

the same three parameters: discount factor, β , utility premium from homeownership, $s(h)$, and the scaling factor in housing production, A_h , to jointly match the wealth to income ratio, the homeownership rate, the house price to income ratio and the house price to rent ratio.³

Table A.2 reports the model fit under each of the three assumptions. The three versions of the model under-predict the wealth to income ratio. Nonetheless, the model with one single quality is closer to this target in part due to higher levels of housing wealth. In this set up both the homeownership rate and the average house price to income ratio are slightly above target, while they are below target for the models with two different house prices. The house price to income ratio is matched reasonably well in all three versions of the model.

In terms of untargeted moments, the share of households with three properties is under-predicted in all three versions since we cap the maximum number of houses owned by a household to three. In any case, the model with a single quality predicts a larger share of households with three properties, which may be explained by the higher equilibrium rental price in this economy as it incentives saving in housing instead of in bonds. Nevertheless, the rent to income ratio is also accurately predicted by the other two versions of the model. Finally, all the three versions of the model are also able to replicate average housing status along the age distribution despite not reported here.

Table A.2: Targeted and untargeted moments under different model assumptions

Moment	Data	Single quality	Quality ladder	Two Tech.
<i>Targeted:</i>				
Wealth to income ratio	6.78	6.00	5.32	4.96
Homeownership rate	80.00%	80.14%	79.13%	79.41%
Average house price to income ratio	5.00	5.23	4.90	4.78
House price to rents ratio	22.58	22.56	23.00	22.54
<i>Untargeted:</i>				
Rents to income ratio	0.2216	0.2319	0.2132	0.2124
Share of households with 3+ properties	5.11%	4.18%	3.97%	3.52%

³Note that in the model with two housing technologies we pick A_h^{oo} and let A_h^{bit} be determined by the relationship in (A.5).

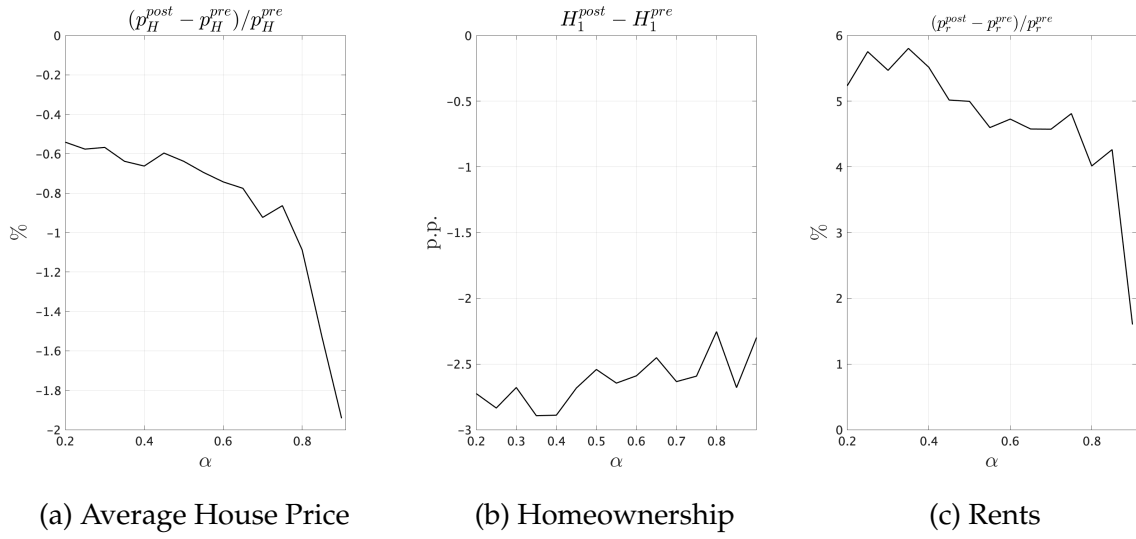


Fig. A.1: Effects of the Reform as a Function of the Supply Elasticity

A.2 Robustness

A.2.1 Aggregate housing supply elasticity

We have discussed in Appendix A.1.2 that in the baseline model house prices change in response to a credit tightening because the amount of aggregate housing varies endogenously with the equilibrium homeownership rate. Moreover, we also know from the market clearing conditions that the amount of aggregate housing is proportional to the housing production. Thus, in this section we study how the elasticity of aggregate housing supply affects our results.

This elasticity is governed by the share of land used in production α . To see this, compute the elasticity of housing production with respect to the per unit house price:

$$\begin{aligned}
 \frac{\partial Y_h p_h}{\partial p_h Y_h} &= A_h^{1/\alpha} \bar{L} \frac{1-\alpha}{\alpha} ((1-\alpha) p_h)^{\frac{1-\alpha}{\alpha}-1} (1-\alpha) \frac{p_h}{Y_h} \\
 &= \frac{1-\alpha}{\alpha} ((1-\alpha) p_h)^{-1} (1-\alpha) p_h \\
 &= \frac{1-\alpha}{\alpha}
 \end{aligned} \tag{A.6}$$

Therefore, we modify the value of α and recompute the effect of the reform across steady states. In doing so, we make sure that the house price in the pre-

reform economy does not change and modify the efficiency of housing production A_h accordingly. Figure A.1 shows the changes in the average house price, the homeownership rate and the rental rate across steady states for various elasticity levels.

Recall that a credit tightening forces some households to postpone or cancel their buying decisions which in turn leads to a higher share of renters in the economy. Remember as well that in the model with a quality ladder, movements in the share of renters are the only driver of movements in average house prices. It is purely a composition effect: less high quality owner occupied houses relative to low quality buy-to-let properties implies a fall in average house prices. Therefore, for large values of α , i.e. for economies in which housing investment is less sensitive to prices changes, one would need a bigger drop in average house prices to accommodate the same change in the housing stock. In other words, if the housing producer does not react as much to changes in credit conditions then house prices have to drop more to clear the markets – see panel (a). In panel (b), we show that the change in homeownership rate is higher the higher the elasticity of housing supply, even though the slope is pretty flat. Finally, panel (c) shows that rental prices rise more in economies with high aggregate housing supply elasticity. This is partly explained by the lower fall in house prices which doesn't allow many new landlords to step in and provide additional rental houses. As a result, rental prices need to increase more to clear the rental market. Moreover, the larger drop in the homeownership rate in the economies with high aggregate housing supply elasticity also puts more pressure into the rental market: there is a larger share of households competing for a rental home since they cannot afford to buy their own at the new limits, which combined with the small changes in rental supply puts upward pressure on rental prices.

Finally, we also compute the consumption equivalent variation (CEV) across steady states for a new born with zero assets and zero housing wealth. The solid black line in Figure A.2 depicts this average CEV for economies with different housing supply elasticity. As expected, the welfare loss is more severe in economies with high housing supply elasticity (low α) because the rise in rental prices is larger, the fall in house prices is tiny and there is a large drop in homeownership.

We also compute these welfare numbers in an economy with fixed rental and housing prices (dashed line) and show that, as one would have expected, the CEV is constant across different values of the housing supply elasticity. An obvious implication of this result is that the response of real estate prices to a credit tightening,

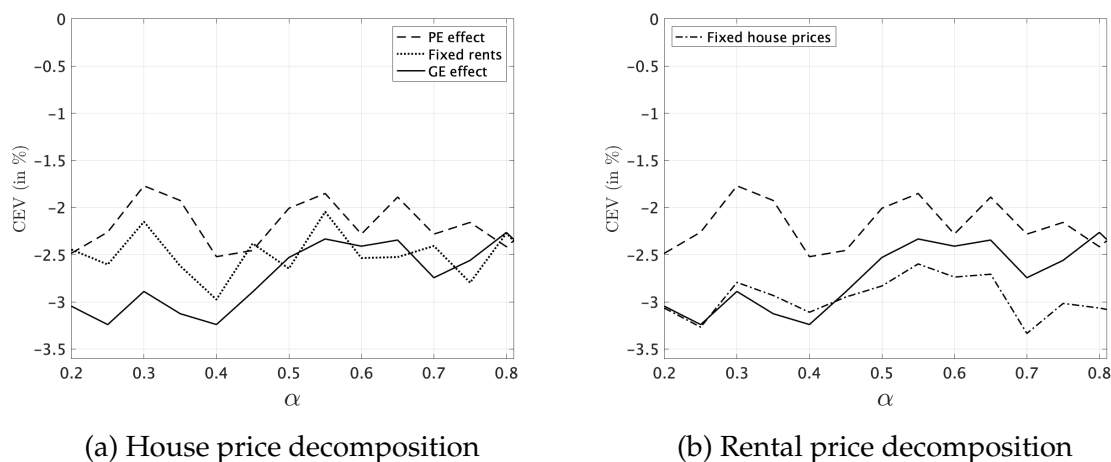


Fig. A.2: CEV – the role of housing supply elasticity

which in itself depends on the housing supply elasticity, is essential in assessing who are the ultimate winners and losers from the reform.

Finally, since we are interested on how much of these differences in welfare effects can be attributed to changes in rents and how much corresponds to house prices, we also compute the CEV under fixed rental prices (dotted line) and fixed house prices (dash dotted line). Starting from panel (a) and comparing the solid line and the dotted line we see that the gap between these two lines is wider for low values of α . In this region, the rise in rental prices is the largest making welfare losses more severe. Moving to panel (b) and comparing the dashed dotted line with the solid line, we can observe that the gap between these two lines is wide for high values of α . In this case, however, the solid line is on top since the larger fall in house prices when the housing supply is very elastic makes the effects of the reform less harmful.

A.3 Solution method

The solution of the model consists of two main loops: an inner loop that solves the household problem given structural parameters and prices, and an outer loop that recovers the equilibrium distribution and prices. In what follows, we describe each of them in detail.

A.3.1 General equilibrium

Algorithm 1 explains how to recover the equilibrium house price p_h^* and rental rates p_r^* , as well as the equilibrium distribution of households in the model economy, $\mu^*(\cdot)$. It works as follows. First, we start by guessing a value for the rental price and

Input:

Vector of parameters: Θ
 Rental price guess: p_r^{guess}
 House price guess: p_h^{guess}

Output:

Equilibrium rental rate: p_r
 Equilibrium avg. house price: p_h^{avg}
 Stationary distribution: $\mu(\cdot)$

```

 $p_r^1 \leftarrow p_r^{guess}, H^1 \leftarrow H^{guess};$ 
 $p_h^1 \leftarrow H^1;$ 
for  $i = 1 : \text{max iter}$  do
   $\phi^a(\cdot), \phi^h(\cdot) \leftarrow$  Algorithm 2: Household problem;
   $\mu(\cdot) \leftarrow \phi^a(\cdot), \phi^h(\cdot), \mu_0;$ 
   $R^d, R^s, H \leftarrow \mu(\cdot);$ 
  if  $\max\{abs(R^d - R^s), abs(H^i - H)\} < tol$  then
    return  $p_r^i, p_h^i, \mu(\cdot)$ 
  else
    if  $R^d > R^s$  then
       $p_r^{i+1} > p_r^i$ 
    else
       $p_r^{i+1} < p_r^i$ 
    end
     $H^{i+1} \leftarrow \xi H^i + (1 - \xi)H;$ 
  end
end

```

Algorithm 1: General Equilibrium

the housing stock. Note that the latter allows us to compute the per unit price of housing analytically through the market clearing conditions. Given house and rental prices, it is possible to solve the household problem for which we use the algorithm described below. As a result, we obtain the asset and housing tenure policies, which are probabilistic distributions since we use extreme value I shocks. These policies are then used to back out the stationary distribution over asset, income, housing tenure and age. In the next step, we use the stationary distribution to compute the share of renters, homeowners, and landlords in our model economy. We check if the disequilibrium in the rental and housing markets is below a predetermined tolerance level. If that is the case, we exit the algorithm since we have found an approximate equilibrium. Otherwise, we update our guesses for the rental price and the housing stock and start over again from the household problem.

A.4 Additional model-generated figures

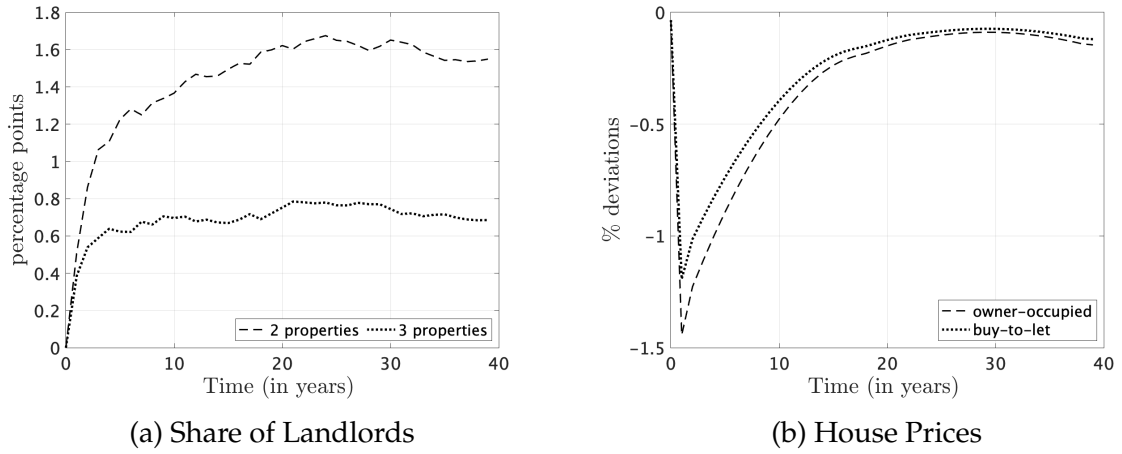


Fig. A.3: Transition Dynamics – some extra variables

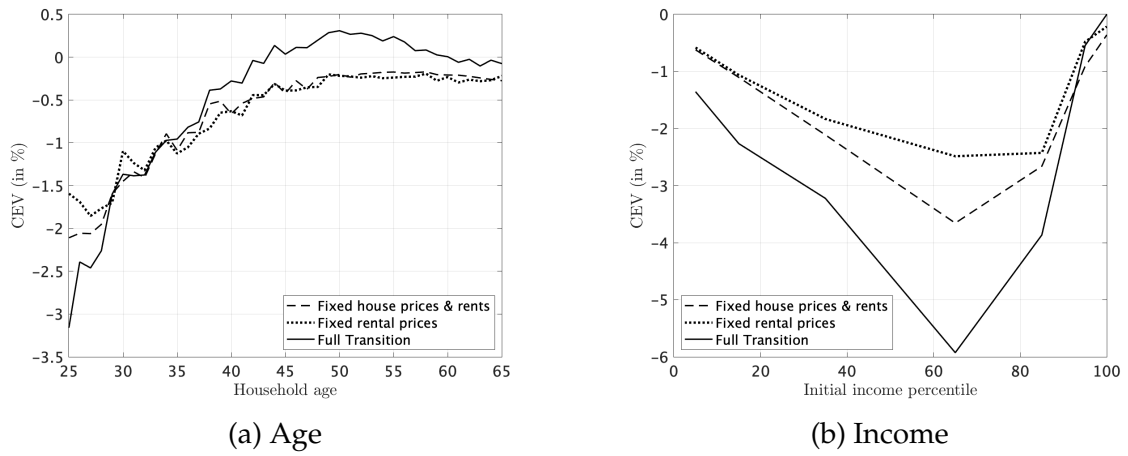
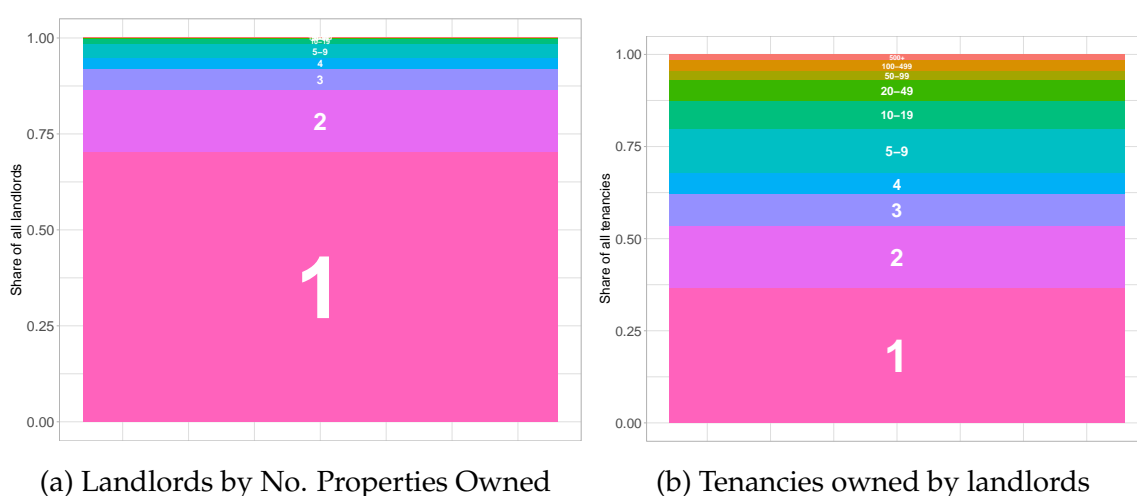


Fig. A.4: An alternative decomposition of the CEV – the role of house prices

A.5 Additional data facts

A.5.1 Structure of the Irish rental sector

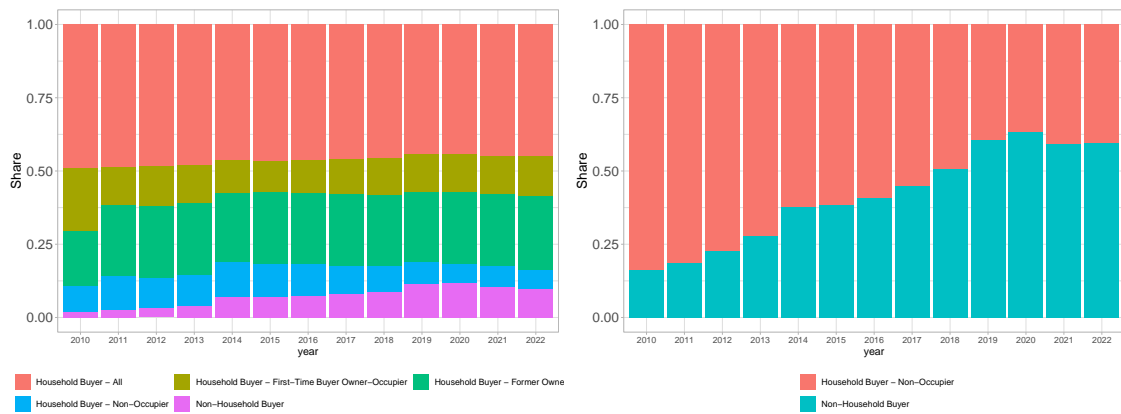
In the Irish rental sector, the vast majority of houses to rent are owned by relatively small landlords. Figure A.5, right panel, shows that around 37% of all rental properties are owned by people that only own that property, and the next 15% is owned by people that only own two. In contrast, big investors with more than 50 properties represent less than 10 percent of all rentals.



Source: Department of Finance (2019)

Fig. A.5: Irish rental sector structure

Despite their small aggregate size, non-household and other rich investors have grown over time, and concentrated in particular housing markets, such as newer developments around Dublin and other cities. In Figure A.6 we show that, although they are still a small share of all transactions (left hand side) they do buy a significant amount of non-owner-occupied housing (right hand side). However, around the time of the reform around 60% of transacted non-owner-occupied housing was bought by household buyers.



(a) All properties

(b) Bought by non-owner-occupiers

Source: Irish Central Statistics Office.

Fig. A.6: Share of property transactions, by type of buyer and year.

Chapter 2

Falling Behind: Delinquency and Foreclosure in a Housing Crisis

Abstract

In some European countries, mortgage delinquency rates are much higher than foreclosure rates. The stock of delinquent mortgages peaked at 9% of GDP in the Eurozone periphery and the average length of a delinquency spell was over 10 months. This fact has been largely neglected in the macro-finance literature. This paper provides a framework for understanding why high levels of persistent mortgage delinquency can emerge as an equilibrium outcome during a housing market crisis. Banks tolerate delinquency because the gain to foreclosing is less than the option value of continuing with the delinquent loan. By nesting a straightforward game between debt-distressed households and banks within a quantitative macro-housing model, the option to enter delinquency is shown to significantly attenuate (by roughly half) the consumption drop during a crisis. Importantly, I show that the ability of households to gain insurance through delinquency is significantly impacted by the degree of recourse available to banks upon foreclosure. The model features realistic lifecycle dynamics, tenure choice between renting and owning, endogenous liquidity in the housing market and defaultable, long-term debt.

2.1 Introduction

Mortgages account for the vast majority of household debt in Europe. In the Eurozone periphery outstanding mortgages peaked at 65% of GDP. Entering into a mortgage contract is the largest financial commitment a household is likely to make. The consequences of this contract going wrong are, therefore, important. This paper documents that one of the most important ways households and banks in Europe deal with debt distress is through delinquency - where households persistently breach their mortgage contract by underpaying. Back of the envelope calculations suggest that in the Eurozone periphery, the stock of delinquent mortgages in the aftermath of the Great Financial Crisis reached 9% of GDP. By contrast, foreclosures - what we more conventionally think of as mortgage default - were comparatively underused: the foreclosure rate peaked at less than 2%. Why did European countries deal with their housing crises in this way and how did it affect the dynamics of these crises?

Despite their importance, economics lacks a framework for thinking about the macroeconomic consequences of mortgage delinquency. This paper provides such a framework. I describe a model where delinquency emerges as an equilibrium outcome because the bank's gains to foreclosure are less than the continuation value of the mortgage. This makes it a useful insurance tool for households in negative equity. When this simple framework is embedded in a quantitative model, I show that it can match key stylised facts about delinquency. In particular, the model accounts for the fact that delinquency spells are often long (10 months on average) and that those accounts 90 days past due still have relatively high recovery rates (40% recover within a year). I then consider how delinquency impacts a housing crisis. Through simulating a Spanish-style housing crash, delinquency is shown to attenuate the drop in consumption and house prices during a crisis. Consumption drops by 50.5% less in a crisis where delinquency is prevalent relative to the standard assumption which rules out delinquency. Importantly, these results are sensitive to the foreclosure regime.

One of the themes of this paper is that delinquency should not only be thought of as a stage households move through on their way to foreclosure. In many cases, it is a substitute to foreclosure. Debt-distressed mortgagors can use sometimes lengthy delinquency spells to smooth consumption in bad times and hold onto their home at the same time. Mortgage delinquency can be an effective insurance tool for a couple of reasons.

First, households effectively get to use a line of credit that does not charge them high interest rates. This makes mortgages different from other commonly studied debt contracts, such as consumer loans or sovereign bonds - where market determined interest rates are often explosive. As a long-term contract, there are limits on how much banks can change interest rates and even when they do, banks moderate those changes because they internalize the impact they have on default probability. Given this limitation, banks, naturally, want to limit high risk borrowers' use of this credit line. Unable to 'discipline' borrowers with high risk premia, they try to limit exposure by enforcing a minimum repayment schedule. As I will show, delinquency emerges because banks' ability to enforce that repayment schedule is limited.

Secondly, mortgages are collateralized and the lender must choose whether to seize that collateral. In principle, this puts the lender in a strong position once the contract is breached. In practice, households who know that lenders are reluctant to foreclose can exploit this fact by refusing to repay and running up an arrears balance. These arrears are more sustainable when house prices are low and foreclosure is unpalatable. The contribution of the core mechanism in this paper is to show how banks' ability to credit-ration households changes during a crisis and maps to quantitatively reasonable delinquency dynamics.

The fact that the bank's outside option - foreclosure - is unattractive when house prices are low means that some of the risk of a collapse in house prices is shared between the household and the bank. The household effectively gains insurance against falling into negative equity at the same time as a negative income shock. All households with mortgages are typical 'wealthy hand-to-mouth' agents who can struggle to smooth consumption in response to income shocks even with positive net worth and higher than average incomes. This is because their housing wealth is difficult to liquidate and mortgage payments take up 22% of household gross incomes on average.¹ Nonetheless, households whose house is worth more than their mortgage still have the option to sell their homes. By contrast, households who fall into negative equity are extremely vulnerable to income shocks. They must either make steep cuts to consumption to keep up with their mortgage repayments, or they must breach their mortgage contract in some way. Since low prices make foreclosure unattractive for the bank, space emerges for the household to use delinquency, underpay their mortgage, and smooth consumption.

¹Data from HFCS for Spain, Ireland, Portugal and Italy. Rents occupy 11% of gross incomes.

With an understanding of the role delinquency plays during the crisis in hand, we can then ask whether the foreclosure regime matters. In particular, does the fact that banks in European countries have recourse to pursue households for debt owed over and above the value of the house make any difference?² I find that a strong recourse regime leads to low rates of foreclosure and high rates of delinquency. Weak recourse regimes push more households into foreclosure and lead to fewer delinquency spells that last for less time.

What is the mechanism behind this result? Strong recourse make the process of foreclosure extremely painful for the household.³ Only highly indebted households with persistent and large negative shocks opt for foreclosure. Recognising this, banks tolerate households underpaying their mortgage and running up large arrears balances - in effect allowing them an extra line of credit. I find that the benefits of maintaining access to this credit makes households prefer a foreclosure regime with strong recourse, even after learning that house prices have dropped substantially.

One of the reasons households value mortgage delinquency as a line of credit is the low interest rates attaching to mortgages. Banks allow delinquent households to continue to use this line of credit at low interest rates. Over 2012-19, delinquent borrowers in the Eurozone periphery faced interest rates just 0.6p.p. higher than performing borrowers. When given the chance to reset mortgage rates in the model, banks don't punish delinquent households with punitive interest rates. This is because banks internalize the damage high interest rates do to the household's debt sustainability, so any interest rate repricing mid-loan is moderate. The fact that mortgage interest rates are generally not repriced to the household's riskiness makes mortgage delinquency an even more useful insurance tool.

On a macro level, foreclosures create a negative market externality. During a crisis, demand for houses drops and there is a rush to sell from households unable to afford their mortgages. Housing markets become illiquid and housing transactions actually drop. Large numbers of foreclosed properties flooding onto the market exacerbate the problem, forcing house prices to drop further, pushing more households into negative equity and precipitating further foreclosures. Extended periods of delinquency can intervene in this process by giving households the space to recover or, at the very least, the time to sell and repay. By keeping people in their

²Foreclosure regimes are often characterised by their degree of 'recourse'. In a non-recourse regime a household whose house is foreclosed is no longer liable for the debt, even if the value of the house is less than the outstanding debt. In a regime with strong recourse, the lenders have powers to compel the household to continue repaying even after foreclosure.

³For example, in Spain recourse takes the form of direct wage garnishment - households have a fraction of their income taken at source.

homes, delinquency keeps those houses off the market and attenuates the drop in prices by 25.2%.

The model captures these dynamics by including a housing market featuring directed search and matching frictions where households seeking to sell must choose a list price. The probability of making a sale is then a decreasing function of that list price. The model features tenure choice between renting and owning, a rich household balance sheet with liquid savings, illiquid savings (houses) and debt (mortgages). The results show how the drop - and subsequent recovery - in house prices transmits to consumption. The effect of concurrent drops in income and house prices - the 'double trigger' - on aggregate consumption is roughly half as bad in a model with delinquency compared to a model without.

The difference is accounted for by a number of factors, one of which is the smaller drop in house prices. Added to this, households who can use delinquency can absorb income shocks by running up their debt in the form of arrears. Knowing this, they have less reason to increase their precautionary savings when risk is elevated. Interestingly, with delinquency the game between the bank and the household changes - allowing more or less credit - as house prices change. This effect of this on consumption tends to lean against the wealth effect from changes in house prices. So, on impact when prices fall it first cushions the drop in consumption as the bank's value of foreclosure is very low. As prices rise, foreclosure becomes more attractive and household's access to delinquent credit balances is curtailed. I discuss this in detail in section 5.

Related Literature

This paper touches on and extends several strands of literature related to debt, default and housing markets. Firstly, this paper follows in the tradition of the quantitative literature of default on unsecured debt starting with Chatterjee et al. (2007a), Livshits et al. (2010) and Athreya et al. (2009). There is now also an extensive literature incorporating mortgage default following Campbell and Cocco (2015), Mitman (2016) and more recently Ganong and Noel (2020). All of the literature in this area models default as a single one-shot event rather than an ongoing, slow process which can be reversed as here. Perhaps the closest paper to the present one is Athreya et al. (2018) who consider the effectiveness of penalty rates in deterring late payments on consumer debt. In a similar vein, Benjamin and Mateos-Planas (2012) consider the difference between formal and informal default. What is different here

is that we are modelling the lender's incentive to end the debt contract by seizing the collateral - a feature that characterises mortgage debt in particular.

From a more theoretical perspective, there is a large literature on optimal debt contracts with collateral including Hart and Moore (1994) and Hart and Moore (1998) who consider an investor and lender where the lender must choose whether to seize the collateral of the investor. On the optimal design of mortgages there is a recent contribution from Piskorski and Tchisty (2017) who study the design of state-contingent mortgage contracts in a two-period model. On the more quantitative side, Guren et al. (2021) compare the relative merits of state-contingent interest regimes. They focus on the benefits of allowing mortgage payments to drop through explicitly contracted contingencies - such as a drop in house prices. The present paper looks at the implicit state contingency that arises from the game between households and banks. An implication of the model is that a drop in house prices will facilitate lower mortgage payments by households.

Kaplan et al. (2020*b*), who also model default, are part of the literature seeking to explore the relative importance of various channels on house prices, finding that credit conditions and foreclosures play only a small role relative to house price expectations. Importantly, they find that neither the number foreclosures nor credit conditions have significant effects on equilibrium house prices. Recently, Garriga and Hedlund (2020*b*) show how modelling the housing market as one of directed search means that foreclosures can significantly amplify the decline in house prices during a crash. Their paper follows a tradition of using search and matching frictions including Wheaton (1990) and Piazzesi and Schneider (2009). I leverage that insight to show how substituting away from foreclosure and into delinquency can not only improve household consumption smoothing, but also improve the functioning of the housing market in a crisis.

Papers focusing on credit conditions' effect on house prices include Landvoigt et al. (2015), Justiniano et al. (2015), Favilukis, Ludvigson and Van Nieuwerburgh (2017) and Greenwald and Guren (2021*b*) who emphasise the role of market segmentation between the rental market and owner-occupier market in determining the responsiveness of house prices to credit shocks. Among other things, the present paper provides a simple way to nest both the user-cost framework favoured by Kaplan et al. (2020*b*) with very high elasticity of supply of rental accommodation, and the perfect segmentation favoured in other papers.

The rest of this paper is organised as follows. Section 2 sets out some key stylised facts about delinquency and the dynamics of delinquent accounts below the headline numbers. Section 3 sets out a model of delinquency where, unlike previous papers, foreclosure is the result of joint decisions by the household and bank. Section 4 describes the calibration of that model and Section 5 documents the delinquency, consumption and house price dynamics during a simulated crisis. The question of recourse regime is taken up in Section 6, while the impact of loan repricing is addressed in Section 7. Section 8 considers the interest premium households pay in steady state for access to foreclosure and section 9 concludes.

2.2 Basic Facts About Mortgage Delinquency

This paper is motivated in part by the experience of the Eurozone periphery of Spain, Italy, Portugal and Ireland in the aftermath of the Global Financial Crisis and Eurozone sovereign debt crisis. These countries all had high levels of homeownership before the crisis (Figure 2.1) and experienced deep and prolonged recessions with very large drops in house prices. High home-ownership rates together with large swings in house prices suggest that a households in these countries are extremely exposed to double-trigger events. Understanding what tools they use to weather these events is an important research question and policy in this area can have potentially large effects on welfare and wealth accumulation.

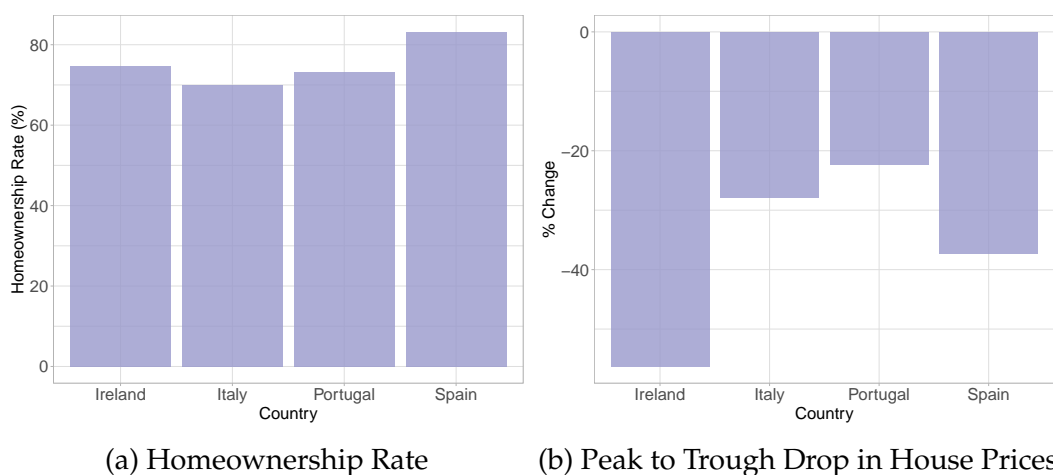
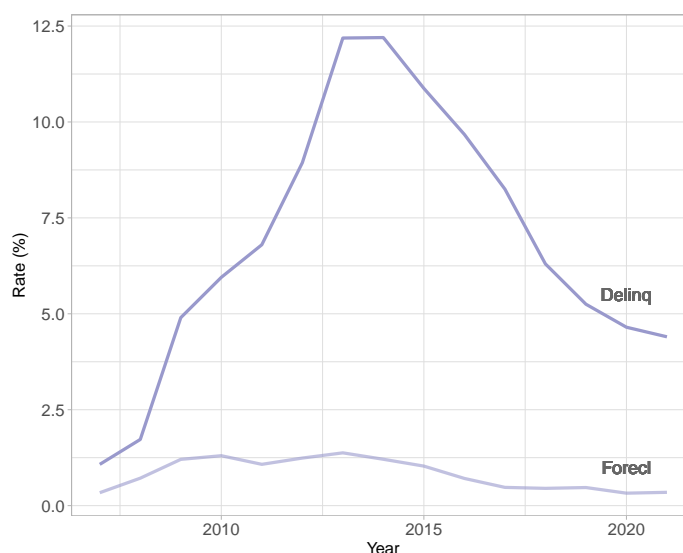


Fig. 2.1: Housing Markets in Eurozone Periphery

Figure 2.2 shows the reaction of delinquency rates - here defined as mortgages considered as non-performing - and the foreclosure rate. The figure plots the

weighted average of both rates across the Eurozone periphery countries under consideration. The striking rise in delinquent mortgages - peaking at over 13 percent in 2014 - dwarfs the numbers entering foreclosure. The foreclosures rate does rise - in fact it roughly quadruples - but the magnitudes are small when compared to the peak in, for example, the US where foreclosure starts peaked at 6 percent.



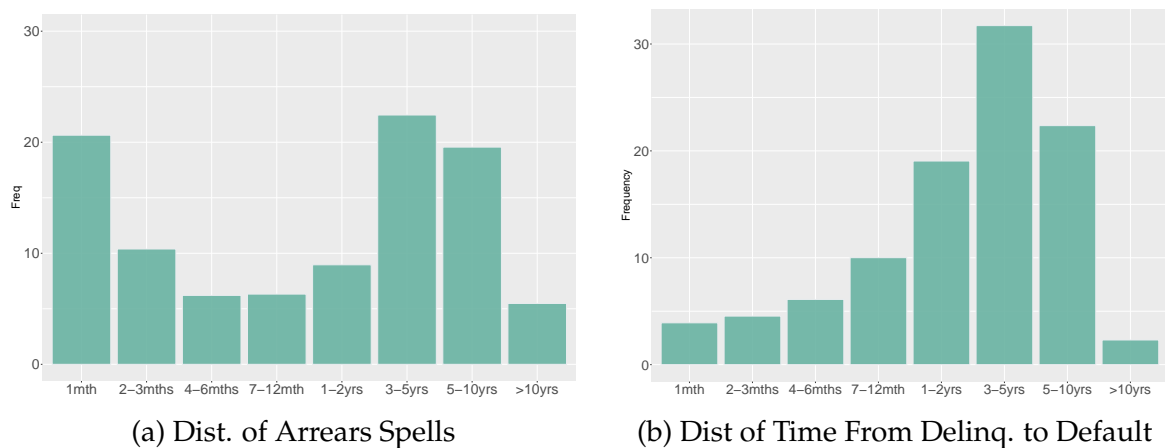
Note: Weighted averages across Eurozone Periphery countries (ES, IT, PT, IE) over 2012-19. Source for foreclosures is a combination of the national statistics offices of the respective countries (INE (Spain), INE (Portugal), Istat, CSO) and the respective ministries of justice. Source for delinquent accounts is ECB securitised mortgages data. Arrears spells are defined as periods of time in which the arrears balance is rising quarter-on-quarter.

Fig. 2.2: Delinquency & Foreclosure In Eurozone Periphery

One of the reasons for the size and persistence of delinquent accounts is the amount of time borrowers' accounts are in persistent arrears. To look into the underlying dynamics of mortgage delinquencies, I use a loan-level dataset from the ECB covering the universe of securitised mortgages in all four countries from 2012-19.⁴ The data is a panel and allows us to observe mortgage accounts that are accumulating arrears balances over time by underpaying their mortgage.

Figure 2.3a establishes a basic fact about delinquency: it can last for a very long time. Again aggregating over the Eurozone periphery, Panel (a) shows the distribution of the length of time an account is consistently adding to their mortgage arrears balance each quarter. Each arrears episode is taken as one observation of

⁴Appendix B contains further discussion of the dataset and compares the data to other mortgage data from surveys.

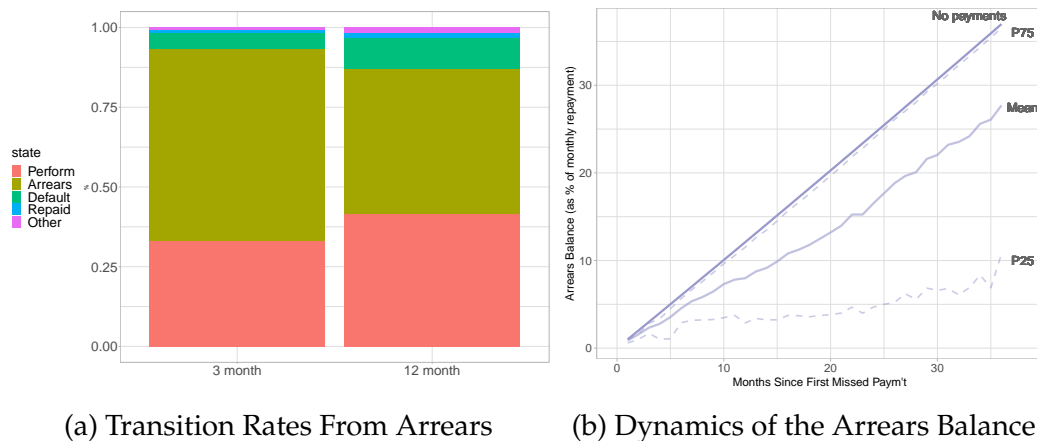


Note: Weighted averages across Eurozone Periphery countries over 2012-19. Source is ECB securitised mortgages data. Arrears spells are defined as periods of time in which the arrears balance is rising quarter-on-quarter. Left panel shows the distribution of arrears/delinquency spells irrespective of how or whether than delinquency is resolved. Right panel shows the distribution of arrears spells that have ended in default/foreclosure.

Fig. 2.3: Housing Markets in Eurozone Periphery

the length of an arrears spell. The data covers arrears spells from 2012-19. As you might expect, a large number of these spells end after only a few months. However, a large number persist for many months and extend into multiple years. This group includes all households who cannot sustain 3 months of full repayments in a row. Figure 2.3b plots the amount of time that has passed since the account first began accumulating arrears up to the point where it enters outright default and foreclosure litigation begins. It shows that very few mortgages enter default after just a few months and it generally takes a long period of arrears accumulation before a foreclosure occurs.

The key question that arises from this is whether these long delinquency spells are really accounts that are destined for foreclosure but for some reason the bank is waiting before initiating proceedings. This would imply that delinquency is just a 'waiting room for foreclosure' and not really worth studying separately. It is therefore useful to establish another basic fact: recovery rates from arrears are high. Figure 2.5a shows the transition shares for mortgages that have just become 90 days past due (the traditional date for assuming a mortgage is in 'default') over the period 2012-19 in the Eurozone periphery. The most likely state for one of these mortgages to be in in 3 months time is actually continuing arrears. This is consistent with the lengthy delinquency spells in Figure 2.3a. Nonetheless, approximately 1/3 of



Note: (a) Aggregating across Eurozone periphery. Transition rates are for mortgages observed crossing the 90 days past due threshold. (b) Arrears balances are for mortgages that reach each number of months past due and expressed relative to payment due.

Fig. 2.5: Delinquent Accounts Behaviour

these mortgages will have returned to performing after one quarter. A little over 2/5 will be performing again after a year. Compared to the shares entering default (admittedly, an absorbing state) these recovery rates are high. This may help explain why banks continue to tolerate arrears of a year or more: the option value of waiting and giving borrowers a chance to recover is high.

Another reason for banks to tolerate arrears is displayed in Figure 2.5b which plots the number of months since a borrower first missed a payment on the x-axis against the arrears balance as a proportion (note: not percentage) of the monthly repayment. The top line, labelled 'No repayment' represents what would happen to the arrears balance if the borrower made no payments whatsoever.⁵ Below this line are the mean arrears balance along with the 75th and 25th percentiles. Clearly, a large number of people are indeed making virtually no repayments since the 75th percentile is so close to the No payments case. At the same time, the majority are clearly making some payments and the 25th percentile is doing enough to seriously stall the rise in the arrears balance.

This data points to a picture of delinquency that is not just the time that passes between a household deciding to default and a foreclosure occurring. This paper takes the view that it is a state households use to try to smooth through income shocks. Households choose not to pay down their debts but smooth consumption by running up arrears balances and gambling for redemption. Inevitably, some

⁵This is slightly above the 45-degree line due to the accrual of interest.

households lose this gamble on a future recover and end up being foreclosed on with an even higher debt level. But it appears enough recover to make lengthy arrears an outcome that lenders are prepared to tolerate. The following section describes a model where lengthy arrears spells can become the equilibrium outcome.

2.3 Model

2.3.1 Environment

The model is a heterogenous agent, lifecycle model where households live for finite lives of length T that are divided into working age and retirement. Households can either save for retirement by accumulating interest bearing assets b_t or by purchasing a house financed by a mortgage a_t . Houses are discrete, indivisible goods that can either be rented or bought.

Mortgages are long-term, defaultable debt-contracts with a minimum repayment schedule that ensures the mortgage will be repaid within a household's lifetime. Importantly, households can hold both liquid savings and mortgage debt simultaneously. Households may choose to repay early by overpaying relative to this. Borrowers can breach the terms of the contract in two ways: by defaulting, declaring bankruptcy and triggering a foreclosure, or by refusing to meet the repayment schedule and, thereby, accumulating arrears. If a household enters delinquency/arrears, a bank will have the right to foreclose on the house and it must decide whether to trigger the foreclosure or allow the delinquency to continue. Foreclosure has two elements. Firstly, it means the bank takes possession of the house and attempts to sell it. Secondly, the household is subject to wage garnishment.

The housing market in the baseline is modelled with directed search. In this way, houses listed for sale on the market may not attract a buyer right away. The probability of matching with a buyer is a function of market tightness. During a house price collapse, markets become slack and the time-on-the-market for listed houses can become long.

2.3.2 Households

Households supply labour from period 1 to period $T^{ret} - 1$ and are retired from period T^{ret} to period T when they die with certainty. They can have mortgage size a_t with savings b_t . They have a housing status which means they either rent a house

of size h^r , or they own a house of size $h \in H$. The household receives idiosyncratic labour income endowments $w_t y_{i,t}$ that are a function of their age τ . These are determined by the process:

$$y_{i,t} = y_\tau + \epsilon_{i,t} + \sigma_\tau^e e_{i,t} \quad (2.1)$$

$$\epsilon_{i,t} = \rho_\tau \epsilon_{i,t-1} + \sigma_\tau^u u_{i,t} \quad (2.2)$$

$$u_{i,t}, e_{i,t} \sim N(0,1) \quad (2.3)$$

$$(2.4)$$

The first component is a deterministic function of age. The second term represents persistent shocks following an AR(1) process where the persistence and variance of the shocks are age dependent. The final term is the transitory income shocks where again the variance is age dependent. During retirement, households receive a constant risk-free income stream.

Households have preferences over housing and consumption given by

$$u(c_t, h_t) = \begin{cases} \frac{c_t^{1-\sigma}}{1-\sigma} & h_t = h^r \\ \frac{c_t^{1-\sigma}}{1-\sigma} + \zeta h_t & h_t \in \{h_1^o, \dots, h_N^o\} \end{cases} \quad (2.5)$$

where the cases reflect a preference for ownership such that if a household moves from the renting state, h^r to owning a house of size h_n^o then they receive extra utility ζh_n^o . This means that ownership delivers a utility benefit but does not affect the marginal utility of the consumption good. Those who do not own, must pay rent p_t^r . We can write their budget constraints as

$$c_t + b_{t+1} + p_t^r = w_t y_t + (1 + r_t) b_t \quad (2.6)$$

where w_t is the aggregate wage and r_t is the return on deposits.⁶ Homeowners do not pay rent but must finance their mortgage a_t and pay housing maintenance costs δh_t . Their budget constraint is otherwise the same:

$$c_t + b_{t+1} - a_{t+1} + \delta^h h_t = w_t y_t + (1 + r_t) b_t - (1 + r_t^m) a_t \quad (2.7)$$

⁶Since homelessness is not an option, it is at least possible that households cannot afford positive consumption after paying rent. To avoid this, I assume that rents cannot consume more than 1/2 household income and that if it does, a government rent supplement will pay the difference. In practice, this happens in very few cases.

where $r_t^m > r_t$ is the interest rate on mortgages. One of the key features of mortgages is that the interest rate does not change due to changes in the idiosyncratic features of the household. This means that unlike in the bond market or in the case of revolving loans, lenders do not have the ability to reprice the loans in response to a borrower's deteriorating creditworthiness. To protect themselves from excessive exposure to risk, lenders therefore require that borrowers agree to a minimum repayment schedule. This repayment schedule is assumed to be the one that guarantees full repayment by the end of the household's life. This is given by:

$$\underline{m}_t = \frac{r_t^m (1 + r_t^m)^{T-\tau}}{(1 + r_t^m)^{T-\tau} - 1} \quad (2.8)$$

A borrower making a payment of size m_t will then have a law of motion of debt $a_{t+1} = (1 + r_t^m - m_t)a_t$. Borrowers can overpay relative to the repayment schedule. They can only increase their debt if they refinance - and thereby have their loans repriced - or if they choose to accrue arrears. They accrue arrears by choosing to pay $m_t < \underline{m}$.

Mortgages can be in one of three states s_t : performing (P), delinquent (D), and foreclosed (F). To economise on notation, I will sometimes refer to the household's idiosyncratic state as $X_t = \{a_t, b_t, h_t, y_t, s_t, \tau\}$.⁷

2.3.3 Banks

Banks are modelled as deep-pocketed, risk-neutral investors. Banks only lend against collateral (houses) and they earn a fixed spread between the mortgage rate and deposit rate, $r_t^m > r_t$. Banks do not charge different interest rates to borrowers of different riskiness. Instead, we follow Kaplan et al. (2020b), Garriga and Hedlund (2020b) and others by stipulating that a borrower who takes out a mortgage with principal balance a receives only $q(X_t)a$ units of the numeraire good in the period the mortgage is originated. The mortgage pricing function q depends on the characteristics of the borrower, X_t .

Despite not being able to adjust the interest rate charged to households period-by-period, banks do continue to price mortgages at the marked-to-market price. How a mortgage is priced depends on whether the mortgage is performing, delinquent, or foreclosed on.

⁷Homeowners without debt and renters are, trivially, assumed to be performing.

Performing Mortgages

For performing mortgages, the (pre-dividend) marked-to-market price is a function of the period-by-period revenue stream m_t , and the bank's expectation of what state the mortgage will be in tomorrow:

$$q_t(X_t) = m_t + \frac{1}{(1 + r_t)} (1 + r_t^m - m_t) \mathbb{E}_t \left\{ \rho_{t+1}^{repay} + \rho_{t+1}^{forecl} F_{t+1}(X_{t+1}) + \rho_{t+1}^{delinq} D(X_{t+1}) + \rho_{t+1}^{perf} q(X_{t+1}) \right\} \quad (2.9)$$

The indicator functions ρ^i take the value 1 if the event in the superscript takes place. We can take each in turn. If the household repays in full - either by selling or refinancing - in the next period, the bank receives $(1 + r_t^m)$ per unit of debt. If a foreclosure occurs, the bank will receive value F defined below. If the household chooses delinquency, the bank's continuation value is D , also defined below. Finally, if the mortgage continues to be performing, the bank receives q again in the next period.

Foreclosed Mortgages

The value of foreclosure to the bank is composed of two parts: the collateral and the wage garnishment of the household. Once the house is foreclosed on, the ownership of the house is transferred to the bank who must then attempt to sell it. If the mortgage account has positive equity, the bank returns this positive equity to the household. In this case, the bank is essentially buying out the household's remaining equity. If the mortgage account is in negative equity, the household remains liable for this and will end up servicing it through wage garnishment. In Spain, borrowers in default surrender a legally specified fraction of their income, $\alpha(y_t)$. The household does not keep paying this forever but exits the foreclosed state F with probability θ . This implies that the bank either recovers the full amount owed, or the discounted sum of payments made by the household before they escape the foreclosure state.

This is summarised as:⁸

$$f_t^1 = \min \left\{ a_t - p_t^h h_t, \mathbb{E} \sum_{j=0}^{T-\tau} \left(\frac{1-\theta}{1+r} \right)^j \alpha(y_{t+j}) y_{t+j} \right\} \quad (2.10)$$

The collateral component of foreclosure is the right to sell the house. The bank attempts to do this by choosing a list price p_t^{list} . Due to the version of directed search used to model the housing market, this implies a probability of sale, η , that is a direct function of the difference between the list price and the shadow price p_t^h . The larger the discount the bank offers relative to the shadow price, the higher the probability of sale (see below for derivation of this function). If the bank fails to sell, it pays the house maintenance cost and tries again in the next period. So we can write,

$$f_t^2 = \max_{p_t^{list}} \left\{ \eta^{sell}(p_t^{list}, p_t^h) (1 - \Delta) p_t^{list} h_t + \right. \\ \left. (1 - \eta^{sell}(p_t^{list}, p_t^h)) \left(-\delta^h h_t + \mathbb{E}_t \left[\frac{1}{1+r} f_{t+1}^2(p_{t+1}^h, a_{t+1}) \right] \right) \right\} \quad (2.11)$$

In the first line on the right-hand side we have the probability of a sale times the return on that sale, adjusted for the bank's cost of foreclosure. In the second line we have the probability of failing to make a sale times the maintenance costs for another period, plus the discounted expected value of the problem in the next period. At the point of foreclosure, the bank expects to get the sum of the benefit from wage garnishment and the value of assuming ownership:

$$F_t(X_t) = \frac{f_t^1 + f_t^2}{a_t}$$

Delinquency

We are finally in a position to describe the value of delinquency. What is novel about this is that the bank exercises a choice over whether to allow delinquency to

⁸This is implicitly assuming that the foreclosed sum has the risk-free rate attached to it. Since the bank discounts at the same rate, the bank is indifferent between receiving the remaining debt as a lump sum or as a stream of payments over multiple periods. This simplifies the above expression considerably.

continue, or whether to trigger a foreclosure. So we have that,

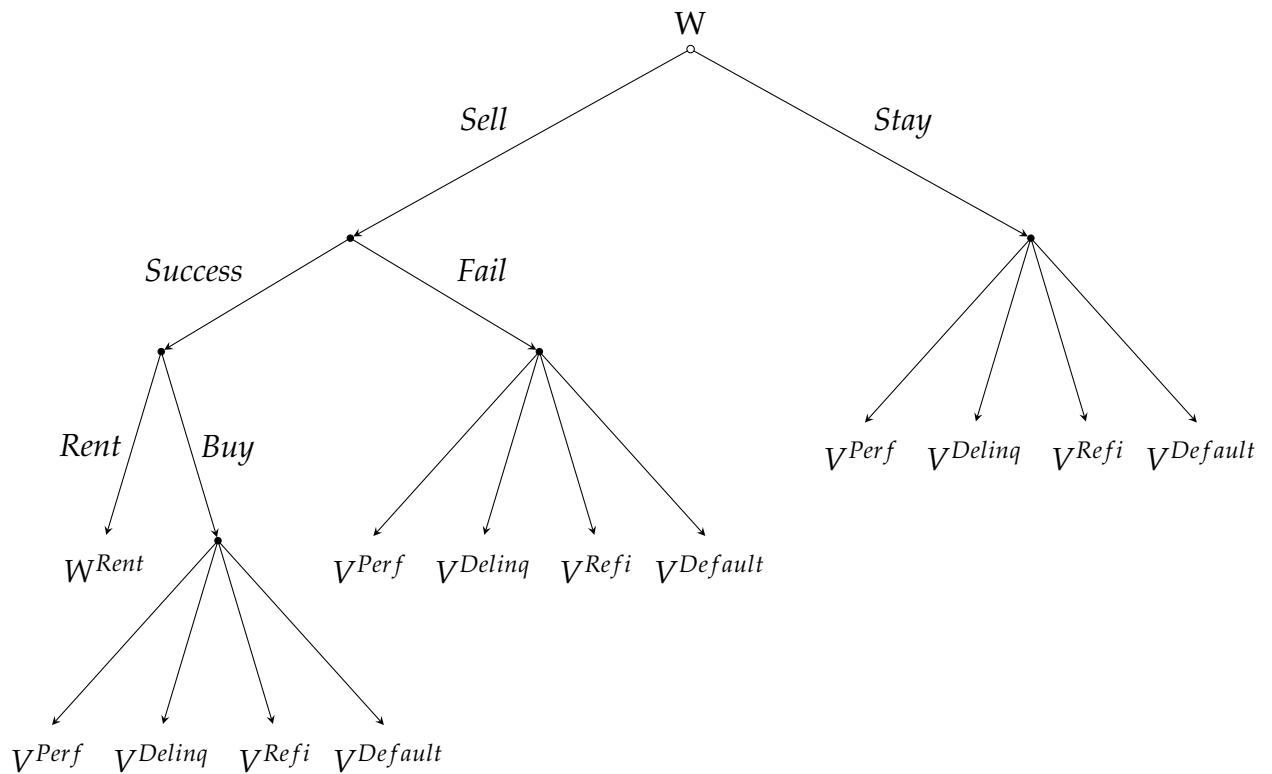
$$D(X_t) = \max \left\{ F_t(X_t), m_t^{delinq} + \frac{1}{1+r} (1 + r_t^m - m_t^{delinq}) \mathbb{E} \left[\rho_{t+1}^{repay} + \rho_{t+1}^{forecl} F_{t+1}(X_{t+1}) + \rho_{t+1}^{delinq} D(X_{t+1}) + \rho_{t+1}^{perf} q(X_{t+1}) \right] \right\} \quad (2.12)$$

This mimics the value of performing mortgages with a couple of important differences. Firstly, the presence of $F(X_t)$ indicates that the bank has gained the right to end the contract and trigger a foreclosure. Secondly, the payment the bank receives each period is now $m_t^{delinq} \geq 0$ rather than $m_t = \underline{m}_t$. We can identify three cases: (i) Foreclosure is better than delinquency of any kind. In this case, the bank will foreclose at the first opportunity the household gives it. Most models of mortgage default implicitly assume that this case always obtains (ii) Foreclosure is worse than delinquency, even if the household repays nothing. Foreclosure here is so painful that allowing the delinquent household to run up their debt is preferable. This would be equivalent to a complete payment holiday. (iii) The household has some leeway to underpay but it cannot just pay nothing. In this intermediate case, we can define a reservation payment m^{res} such that $D(m^{res}) = F$. Delinquency is only sustainable in the present period if the household is prepared to meet this repayment level.

2.3.4 Household Decision Problem

As discussed above, households make a tenure choice over whether to live in rented accommodation or owner-occupied housing. They can use mortgages a_t to finance their house and they can save in liquid assets (deposits). Renters face a simple set of choices. First they choose whether to buy a house or not. If they choose to remain renters, they then choose how much deposits b_t , to hold. If they choose to buy a house, they must also choose how large a mortgage to take.

Matters are slightly more complicated for homeowners and it is easiest to think about a households' decision problems as taking place in several stages which are set out in Figure 2.7. First the agent must choose whether or not to try to sell their current house or whether to stay in it. Homeowners who decide to sell must choose what price to list their house at. If they succeed in selling at that price, they then get to choose whether to buy a different house or become renters. Homeowners who do not sell (or fail to sell), must then decide what status they want their mortgage



Note: Decision tree for homeowner with a mortgage. Choosing to sell leads to success or failure with endogenous probability. At each terminal node, households reach a discrete state summarizing tenure choice and loan (if any) performance state. The value at the terminal node is the value of making optimal consumption/savings choices.

Fig. 2.7: Decision Tree for Mortgager

(if any) to be in. They can choose to pay at least the minimum repayment, they can choose to refinance (in which case they must choose their new debt level), they can choose to enter delinquency (in which case they choose a repayment level below the fixed repayment), or they can choose to default. After this, homeowners must choose how much liquid savings to hold. With this summary in mind, we can now examine the decisions in more detail.

Renters

Households who enter the period as renters must choose whether to seek to buy a house for owner occupation:

$$W^{Rent}(b_t, y_t, \tau) = \max\{V^{Rent}(b_t, y_t, \tau), R^{Buy}(b_t, h_1, y_t, \tau), \dots, R^{Buy}(b_t, h_N, y_t, \tau)\} \quad (2.13)$$

where V^{Rent} is the value of staying as a renter and choosing consumption-saving optimally:

$$V^{Rent}(b_t, y_t, \tau) = \max_{c_t, b_{t+1}} \{u(c_t, h^r) + \beta \mathbb{E}W^{Rent}(b_{t+1}, y_{t+1}, \tau + 1)\} \quad (2.14)$$

$$\text{subject to:} \quad c_t + b_{t+1} + p_t^r = w_t y_t + (1 + r_t) b_t \\ b_{t+1} \geq 0$$

R^{Buy} is the value of buying a house and then making decisions over savings, debt and consumption:

$$R^{Buy}(b_t, h_t, y_t, \tau) = \max_{c_t, b_{t+1}, a_{t+1}} \{u(c_t, h_t) + \beta \mathbb{E}R^{Own}(b_{t+1}, a_{t+1}, y_{t+1}, \tau + 1)\} \quad (2.15)$$

$$\text{subject to:} \quad c_t + b_{t+1} + p_t^h h_t = w_t y_t + (1 + r_t) b_t + q_t a_{t+1}$$

Homeowners' Tenure Decision

At the top of the tree in Figure 2.7, households who enter the period as owners must choose whether to seek to sell their house or stay:

$$W^{Own}(a_t, b_t, h_t, y_t, \tau) = \max\{R^{Sell}, R^{Own}\}$$

Those who opt to sell must choose a list price and face probability η of successfully making a sale:

$$R^{Sell}(a_t, b_t, h_t, y_t, \tau) = \max_{p_t^{list}} \{\eta(p_t^h, p_t^{list}) W^{Rent}(b_t + p_t^{list} h_t - a_t, y_t, \tau) \\ + (1 - \eta(p_t^h, p_t^{list})) R^{Stay}(a_t, b_t, h_t, y_t, \tau)\}$$

If they succeed in selling their house, the household becomes a renter and solves the renter's problem above. Households who sell can still end the period as home-

owners if they choose to buy another house. Households who begin the period as homeowners can also end as homeowners by choosing not to sell, or choosing to try to sell but failing. Those who do end the period as owners choose what to do with their mortgage (if any):

$$R^{Own}(a_t, b_t, h_t, y_t, \tau) = \max\{V^{Perform}, V^{Delinq}, V^{Refi}, V^{Default}\}$$

Homeowners' Saving Decisions

At the bottom of the tree in Figure 2.7 are the households who end the period as homeowners. They make their final decision over saving and spending depending on whether they are performing, delinquent, defaulters or refinancers. For households who choose to perform, their problem is given by

$$V^{Perform}(a_t, b_t, y_t, h_t, \tau) = \max_{c_t, b_{t+1}, a_{t+1}} \{u(c_t, h_t) + \beta \mathbb{E}W^{Own}(a_{t+1}, b_{t+1}, h_t, y_{t+1}, \tau + 1)\} \quad (2.16)$$

subject to:

$$c_t - a_{t+1} + b_{t+1} + \delta^h h_t = w_t y_t - (1 + r_t^m) a_t + (1 + r_t) b_t \quad (2.17)$$

$$a_{t+1} = (1 + r_t^m - m_t) a_t \quad (2.18)$$

$$m_t \geq \underline{m} \quad (2.19)$$

$$b_{t+1} \geq 0 \quad (2.20)$$

Refinancing is essentially equivalent to taking out a new mortgage and fully repaying the old one. The new mortgage is repriced at the point of refinancing. This involves contracting a new mortgage balance a_{t+1} , receiving $q_t a_{t+1}$ and repaying $(1 + r_t^m) a_t$. Households who are refinancing make a double savings choice :

$$V^{Refi}(a_t, b_t, y_t, h_t, \tau) = \max_{c_t, a_{t+1}, b_{t+1}} \{u(c_t, h_t) + \beta \mathbb{E}W^{Own}(a_{t+1}, b_{t+1}, h_t, y_{t+1}, \tau + 1)\} \quad (2.21)$$

subject to:

$$c_t - q_t a_{t+1} + b_{t+1} + \delta^h h_t = w_t y_t - (1 + r_t^m) a_t + (1 + r_t) b_t \quad (2.22)$$

$$b_{t+1} \geq 0 \quad (2.23)$$

Households who choose delinquency solve a similar problem to those in the performing state but now they can pay less than the contractual repayment:

$$V^{Delinq}(a_t, b_t, y_t, h_t, \tau) = \max_{c_t, m_t, b_{t+1}} \{u(c_t, h_t) + \beta E W^{Own}(a_{t+1}, b_{t+1}, h_t, y_{t+1}, \tau + 1)\} \quad (2.24)$$

subject to:

$$c_t - a_{t+1} + b_{t+1} + \delta^h h_t = w_t y_t - (1 + r_t^m + \chi) a_t + (1 + r_t) b_t \quad (2.25)$$

$$a_{t+1} = (1 + r_t^m + \chi - m_t) a_t \quad (2.26)$$

$$m_t \geq m^{res} \quad (2.27)$$

$$b_{t+1} \geq 0 \quad (2.28)$$

The continuing constraint on the mortgage payment means that delinquency must be preferable to foreclosure from the bank's perspective. To ensure that creditworthy households do not use delinquency instead of refinancing, delinquency incurs a penalty cost each period χ .

Finally, we must deal with the consequences of foreclosure. The foreclosure state lasts for a random number of periods and ends with exogenous probability θ . During that time the household is subject to a fixed utility penalty Γ . As discussed above, if the household is in positive equity, it receives that positive equity from the bank: $b_t = p_t^h h_t - a_t$. However, if it is in negative equity it remains liable for the remaining $a_t - p_t^h h_t$ while in the foreclosure state through a series of income garnishments. These income garnishments happen until the household escapes the foreclosure state with probability θ or they have repaid the residual debt, whichever happens sooner. The law of motion for this residual debt is

$$a_{t+1} = (1 + r) a_t - \alpha(y_t) w_t y_t \quad (2.29)$$

These garnishment fractions are allowed to be a function of the income shock.

While in the foreclosure state, the household cannot get another mortgage. The problem is:

$$V^{def}(a_t, b_t, y_t, \tau) = \max_{c_t, b_{t+1}} \{u(c_t, h_t) - \Gamma^u + \theta \beta E[W^{rent}(b_{t+1}, y_{\tau+1}, \tau + 1)]\} + \\ (1 - \theta) \beta E[V^{def}(a_{t+1}, b_{t+1}, y_{\tau+1}, \tau + 1)] \quad (2.30)$$

subject to:

$$c_t + b_{t+1} + p_t^r = w_t y_t + (1 + r_t) b_t + (1 - \alpha(y_t)) w_t y_t \quad (2.31)$$

$$a_{t+1} = \max\{0, (1 + r) a_t - \alpha(y_t) w_t y_t\} \quad (2.32)$$

$$b_{t+1} \geq 0 \quad (2.33)$$

2.3.5 Housing Markets, Rental Markets and Production

Housing Markets

The housing market is modelled with matching frictions similar to Garriga and Hedlund (2020b)⁹. For tractability, buyers and sellers are intermediated by real-estate agents/brokers who enter the market after paying entry cost κh . The probability that a seller matches with a broker η_t is a function of market tightness θ_t (i.e. the ratio of brokers to sellers). A broker who successfully enters a submarket and matches with a seller who has listed at price p_t^{list} can then sell to buyers at the market price p_t^h . The broker then earns net revenue $p_t^h h_t - p_t^{list} h_t$. Free entry of brokers into each submarket implies that the following zero-profit condition holds:

$$\frac{\eta_t}{\theta_t} (p_t^h - p_t^{list}) = \kappa$$

The matching function is the standard Cobb-Douglas type and so generates matching probabilities $\eta_t = \min\{1, (\theta_t)^{\gamma_s}\}$. Using this to eliminate θ_t from the zero-profit conditions, we see that the probability of a match in given submarket is a function of the difference between the list price and the shadow price of a unit of housing.

$$\eta_t = \min \left\{ 1, \max \left\{ 0, \left(\frac{p_t^h - p_t^{list}}{\kappa} \right)^{\frac{\gamma}{1-\gamma}} \right\} \right\} \quad (2.34)$$

This result is due to the role of brokers and gives us the important result that market tightness depends only on the price index p_t^h and not on the cross-sectional distribution of assets, income and houses. The lower the shadow price, the more sellers are forced to lower their list price (or equivalently, enter a submarket with a lower price). Modelling the housing market this way generate two effects. Firstly, it

⁹Unlike Garriga and Hedlund (2020b) I assume the brokers can costlessly match with buyers. The search and matching friction is, therefore, one-sided in the sense that sellers must find a buyer for their house but buyers can always immediately find a house to buy.

leads to larger swings in house prices as the market becomes slack and sellers have to discount their houses by more in order to make a sale. Secondly, it means that the time on the market can be lengthy meaning that distressed borrowers cannot immediately liquidate their homes and repay their mortgage.

Production

Final goods are produced by firms using a production function that is linear in labour

$$Y^c = A_t^c N_t^c$$

where A_t^c is normalised to 1 in steady-state. There are also firms specialising in the production of houses who use a production function using a combination of land (in fixed supply each period) and labour:

$$Y_t^h = A_t^h (N_t^h)^\alpha (L)^{1-\alpha} \quad (2.35)$$

This generates an upward sloping supply of housing. The housing stock then evolves according to:

$$H_{t+1} = H_t(1 - \delta^h) + Y_t^h \quad (2.36)$$

Finally, the total supply of labour to the final goods and construction sectors must sum to the total labour endowment which is supplied inelastically (and normalised to 1): $N_t^h + N_t^c = N = 1$.

Rental Market

To try to capture the correlation between rents and house prices in a downturn, I extend the user cost framework of Kaplan et al. (2020b) by assuming that a rental company buys houses and rents them out but is subject to an adjustment cost. As pointed out by Greenwald and Guren (2021b) and others, there is substantial market segmentation between the owner-occupied housing market and the rental market such that previously owner-occupied houses cannot be frictionlessly incorporated into the rental market and vice-versa. Under the pure user-cost framework, house price fluctuations are dampened by the presence of a rental sector that will buy/sell

large quantities of housing to maintain the user-cost relationship between rents and house prices.

This criticism can be accounted for by incorporating a non-linear adjustment cost for the rental company similar to the way capital adjustment costs are modelled. The rental company solves:

$$J(H_{t-1}^r) = \max_{H_t^r} \left\{ p_t^r (1 - \psi) H_t^r - p_t^h \left[H_t^r - (1 - \delta^h) H_{t-1}^r + \frac{\phi}{2} \left(\frac{H_t^r}{\bar{H}^r} - 1 \right)^2 \right] \right. \quad (2.37)$$

$$\left. + \frac{1}{1+r} \mathbb{E}[J(H_t^r)] \right\} \quad (2.38)$$

The adjust cost penalises the rental company for deviating from \bar{H}^r . The first-order condition for this is

$$\frac{p_t^r}{p_t^h} = \frac{1}{1-\psi} \left[1 + \frac{\phi}{\bar{H}^r} \left(\frac{H_t^r}{\bar{H}^r} - 1 \right) - \frac{1-\delta^h}{1+r} \mathbb{E} \left(\frac{p_{t+1}^h}{p_t^h} \right) \right]$$

Here ϕ measures deviation from pure user-cost framework and determines how easily houses sold in the owner-occupier market can be integrated into the rental market. Intuitively, housing units moving between the rental and owner-occupier market will require some modifications and the cost to the rental firm of undertaking these modifications is increasing in the number of units that need to be modified.

2.3.6 Equilibrium

An equilibrium consists of value and policy functions for households and lenders, a market tightness function θ , prices p^h, p^r, w, r , distributions Φ of households and Ψ of foreclosed houses such that housing, rental and labour markets clear.

In particular, equilibrium in the housing market requires that the number of houses sold is equal to the number of houses bought. The number of houses sold $S(p_t^h)$ is a function of the number of new houses produced, the number of houses successfully hold by banks and the number of houses successfully sold by households. Note that the requirement to succeed in selling implies that the number of houses on the market can exceed the number of buyers. We can write the number of houses sold as:

$$S_t(p_t^h) = Y_t^h(p_t^h) + S_t^B(p_t^h) + S_t^{HH}(p_t^h) \quad (2.39)$$

For banks, their optimal list price is a function of the house size, the outstanding debt and the household's income. To ease notation I suppress this dependence and write:

$$S_t^B(p_t^h) = \sum_{h \in H} \int_{a_t} \left\{ h \eta(p_t^{list*}, p_t^h) d\Psi_t(\cdot, h) \right\} \quad (2.40)$$

Houses sold by households is given by:

$$S_t^{HH}(p_t^h) = \sum_{h \in H} \left\{ \int h \rho^{sell} \eta(p_t^{list*}, p_t^h) d\Phi_t(\cdot, h) \right\} \quad (2.41)$$

Houses bought consists of all houses bought by households, and the net demand from the rental firm.

$$\mathbb{D}_t(p_t^h) = D_t^{HH}(p_t^h) + (H_t^r - H_{t-1}^r) \quad (2.42)$$

where the number of houses bought by households is given by:

$$D_t^{HH}(p_t^h) = \sum_{h \in H} \left\{ \int h \rho^{sell} d\Phi(\cdot, h) \right\} \quad (2.43)$$

The equilibrium house price ensures that the number of houses sold is equal to the number of houses demanded:

$$\mathbb{D}_t(p_t^h) = S_t(p_t^h) \quad (2.44)$$

2.3.7 Illustration of Mechanism

Before moving on to the calibration and a consideration of aggregate dynamics, it is worth pausing to illustrate the mechanism of consumption smoothing at work for an individual household subject to a persistent income drop. The focus is on a single household rather than the aggregate so it should be understood as purely illustrative. Figure 2.8 shows the case where an income drop happens in the stationary equilibrium. A lot of the action is happening in the top-middle panel. Here, the top black dot-dash line represents the contractual mortgage repayment \underline{m}_t , while the bottom black dashed line is the bank's reserve payment. These two lines together form a corridor in which arrears are sustainable. Above this corridor, the household is performing; below it the bank will foreclose. At the beginning of the

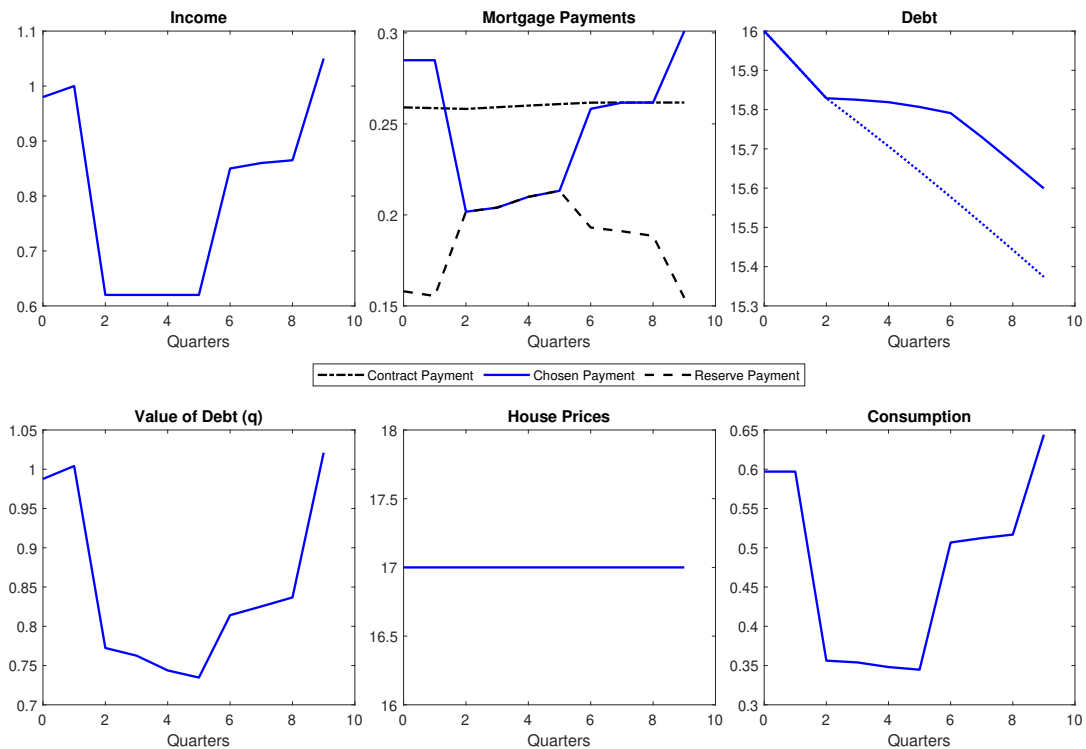


Fig. 2.8: Mortgager Response to Income Shock

period, the household is paying more than the contractual repayment, indicating that they are on course to pay down their mortgage before the end of life. A large income shock occurs and two things happen. The first is that the bank's reservation payment jumps up, reflecting the fact that the value of the mortgage has dropped due to the decline in income. The second is that the household cuts their consumption so that the constraint on $m_t \geq m^{res}$ is binding. Note that this is still substantially below the contractual mortgage repayment where, in a model of pure default with no recourse to delinquency, the household would have to choose to either stay above this level or default. In this example, the reservation payment is enough to keep debt at close to a constant level. Once the income shock reverts, the reservation payment drops and the household increases their repayment, eventually rising back above the contractual level.

Figure 2.9 shows the case where we subject the same household to the same income shock but also exogenously shock house prices. In the case shown, house prices drop by 20 percent before reverting in an AR(1) fashion with persistence of 0.8. Naturally, an exogenous house price shock implies that these dynamics are partial equilibrium responses. The key change is in the reservation payment which

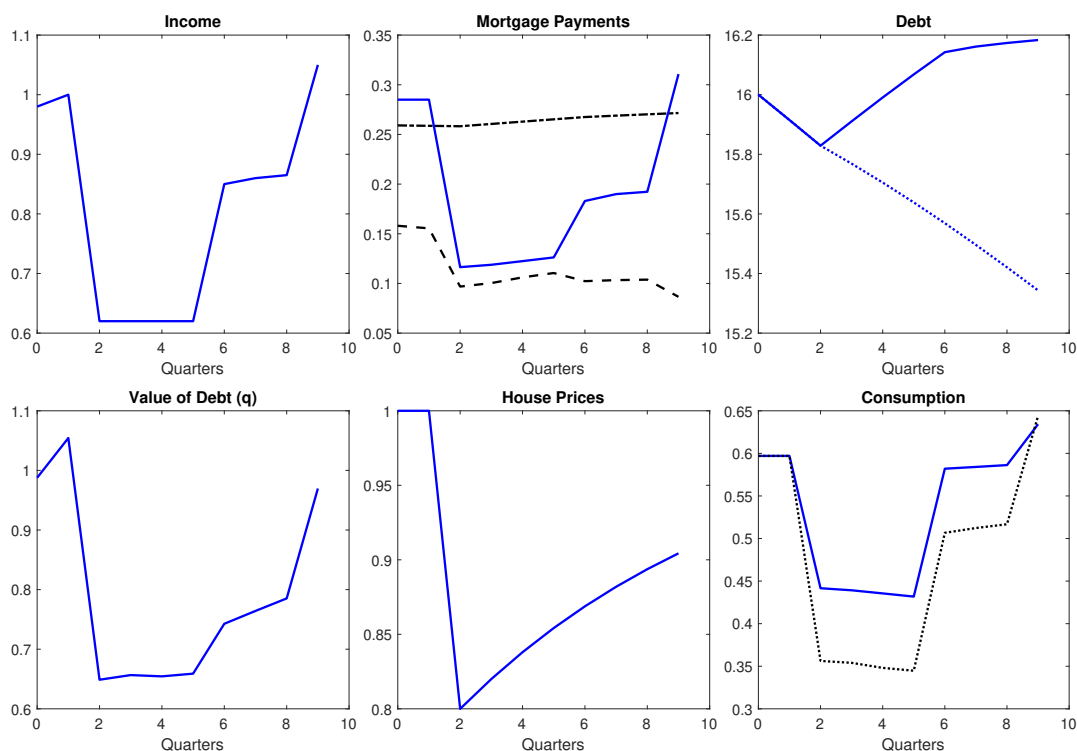


Fig. 2.9: Mortgager Response to Income and House Price Shocks

no longer jumps up in response to the household's deteriorating income. The value of foreclosing on the house has dropped so the homeowner has more room to cut their repayment. Importantly, the optimal choice of mortgage repayment is actually not binding. The consumption responses are compared in the bottom-right panel. The figure also shows that the cut in mortgage repayment is significant enough that debt is actually rising during this time.

Together, these examples convey how state-contingency is built into the model. Households who receive an income shock are afforded some room to smooth their consumption in response. But less room than they had before the income shock, because being on a lower income makes the loan less valuable. When the income shock coincides with a price shock, it (perversely) affords extra room to the household. In the next section we move from the individual household level to aggregate dynamics.

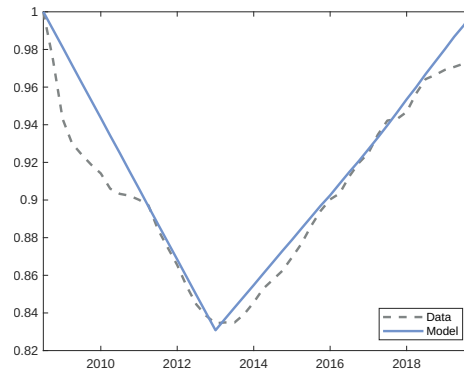


Fig. 2.10: Decline in Employment Over Crisis

2.4 Calibration

Having laid out the model in the previous section, this section describes the model calibration in steady-state and the crisis experiment to be undertaken. I compare the model fit against a set of targeted moments and then compare the model's performance against untargeted data. The calibration of the model is performed along three dimensions. Firstly, there is a group of parameters that are set using external sources or common values in the literature. Secondly, there is a set of parameters used to target steady-state moments. Finally, I target two parameters using the transition path during the crisis. The model is calibrated to quarterly frequency. Before moving to the calibration, it is worth briefly discussing how the crisis is simulated.

Crisis Experiment — The economy is pushed into a crisis by means of two unanticipated shocks. The first, is a credit shock that leads to the exogenous imposition of a maximum loan-to-value ratio of 0.9. This is supposed to account for the reduced risk appetite from banks owing to the financial crisis. The second is a skewness shock to the steady-state earnings process such that the probability of falling into the lowest persistent income state (equivalent to unemployment) is exogenously increased. The size of the skewness shock is calibrated to match the decline in employment in Spain over 2008Q3-2012Q4. After this, the shock is reversed until employment returns to the baseline level. Figure 2.10 shows the path of effective labour supply in the model plotted against hours worked per person in the labour force for Spain. Once the shock occurs, agents know that the shock will remain in place for this period of 18 quarters and will enter recovery immediately afterwards.¹⁰ Once the shock

¹⁰I perform robustness to the duration of the shock in Appendix B

is underway, agents are able to forecast the evolution of the aggregate state with perfect foresight.

The calibration of the shock uses the fact that even though agents supply raw labour inelastically, the effective labour they can supply is subject to idiosyncratic persistent shocks. As more households start to receive more negative productivity shocks, the total amount of effective labour being supplied drops but evenly and slowly across the population. Nonetheless, the introduction of downside uncertainty causes an immediate pull-back in consumption and a drop in house prices. Appendix B contrasts the same experiment with a persistent TFP shock. In summary, the size of the response is much smaller for the TFP shock because the contraction in incomes is spread evenly across the population. With the skewness shock, some households' incomes fall dramatically. The serious deterioration in incomes means these household cannot afford the minimum repayment and mortgage delinquency or foreclosure becomes necessary.

Income Process — The idiosyncratic productivity shocks are set to match the income process taken from Garcia-Cabo and Madera (2019). However, these processes are estimated at an annual frequency. To convert them to a quarterly frequency, I follow Garriga and Hedlund (2020b) by assuming that the households play a lottery in which with probability $3/4$ they do not receive a new persistent shock, whereas with probability $1/4$ they draw from the transition matrix calibrated to the persistent income process estimated in Garcia-Cabo and Madera (2019). Therefore, households expect to receive one persistent shock per year. For the transitory shocks, I assume that the annual transitory shock is actually the sum of four, i.i.d. quarterly shocks and choose the standard deviations of these shocks so that the corresponding annual variance in income matches those reported in Garcia-Cabo and Madera (2019). Households are assumed to begin their lives as renters but I assume the distribution of savings matches the net financial wealth holdings observed for 25 year-olds in the HFCS.

Wage Garnishment — In Spain, this wage garnishment is set in law and operates similar to an extra income tax. Income below minimum wage is not garnished. Between 1-2 minimum wages, the marginal garnishment is 30 per cent. This keeps increasing until a household earns more than 5 minimum wages, at which point the garnishment is 90 per cent.

Externally Set — Among the other externally set parameters are the household intertemporal substitution σ which is set at the standard value of 2, the maintenance

Table 2.1: Income Garnishment in Default for Spain

Income Level	Marginal Rate	Implied Avg Rate
Less than Min. Wage	0%	0%
1-2 Min. Wage	30%	10%
2-3 Min. Wage	50%	22%
3-4 Min. Wage	60%	31%
4-5 Min. Wage	75%	39%
More than 5 Min. Wage	90%	47%

Notes: From Article 607 of Consolidated Legislation on Civil Procedure, Law 1/2000 of January 7th (<https://www.boe.es/buscar/act.php?id=BOE-A-2000-323>). The average rates assume the middle of the specified range.

costs of houses is set according to estimates from the Spanish Ministry of Finance. The entry cost for real-estate agents κ determines the maximum price discount before it becomes certain that the house is sold. The parameter is particularly relevant for banks seeking to sell foreclosed property quickly. For this we can draw on a number of sources. The Spanish Realtors Association report that typical price discounts for foreclosed houses at auction are 30%. Property website Idealista have separate listings for foreclosed properties. After controlling for size in metres squared, and location, the average discount on a foreclosed house in 2021 was 22%. Finally, the ECB RMBS database reports the banks' realised loss after sale of a property. The median implied discount relative to market value over 2012-19 was 19% and the 90th percentile was 29%. I take 25% as a reasonable number in the middle of this range.

Since Spain is taken to be a small-open economy, the interest rate is set to the ECB rate in the pre-crisis period 2003-07 adjust for inflation as measured by the HICP. Doing this yields an average annualised real rate of 0.485 percent. The purpose of χ is to ensure that borrowers who could refinance at $q = 1$ never find it optimal to use delinquency. We set it at the minimum value necessary to make this true. I find this to be 0.007.

Labour's share of income from housing production is set to the standard value of $2/3$. In terms of housing types, the model assumes there is only one type of rented accommodation and three types of owner-occupied houses. The smallest owner-occupied house is assumed to be equivalent to a rented house and this size is normalised to 1. Spain's Ministry of Ministry of Transport, Mobility and Urban Agenda report that the median rented house is 75m^2 . The median owned house is

92m² and the 90th percentile of owner-occupied housing housing size is 152m². As such, we take the second and third points in the owner-occupied housing grid to be 1.24 and 2.03

Table 2.2: Parameter Values.

Parameter	Value	Description	Source/Reason
Household			
β	0.9896	Discount factor	Calibrated
σ	2	Intertemp. subst.	Standard
ζ	0.0151	Pref. for ownership	Calibrated
Production			
δ^h	0.005	Housing maintenance costs	Finance Ministry
A^h	0.2234	Housing production	Calibrated
α	0.6667	Labour share in production	Standard
ψ	0.6102	Operating cost of rental company	Calibrated
ϕ	0.0082	Adj. cost for rental company	Calibrated
Housing Market			
κ	1.5124	Max price list discount	Discounts on forecl. sales
γ	0.6553	Match function	Calibrated
θ	0.0512	Time in default	Calibrated
Γ^u	0.8345	Non-pecuniary forecl. cost	Calibrated
Δ	0.2183	Bank loss on forecl.	Calibrated
Interest Rates			
r	0.485	Deposit rate (annual %)	ECB rate
r_t^m	2.811	Mortgage rate (annual %)	ECB MIR
χ	0.007	Delinquency penalty	Discourage delinq.

Internally Calibrated — The calibrated parameters are, of course, jointly determined but we can think of the household discount factor β pinning down the median net wealth-to-income ratio, which in the Spanish Household Finances Survey (EFF) averages 4.53 over 2002-08. The preference for ownership ζ is chosen to target a homeownership rate of 80.6, as is the case in the EFF. The productivity of housing production and the operating cost of the rental company help to pin down the house price-to-income ratio, which is 6.1 according to data from the OECD, and the price-to-rent ratio, which averages 13.11 in data from the property website Idealista. The rental company adjustment cost is calibrated so that the correlation between

Table 2.3: Model Fit on Targeted Moments

Moment	Model Value	Empirical Value
Median Net Wealth-to-Income Ratio	4.61	4.53
Homeownership Rate (%)	80.1	80.6
Price-to-Income Ratio	5.95	6.10
Price-to-Rent Ratio	13.11	13.11
Time on the Market (quarters)	1.67	1.67
Foreclosures (% , annual)	0.34	0.31
Delinquency Rate (%)	2.10	1.94
$Corr(Delinq., Forecl.)$	0.85	0.84
$Corr(p^h, p^r)$	0.88	0.88

rents and house prices along the transition of the baseline crisis experiment matches that found in the data. The amount of time houses spend on the market should be pinned down by the match function, characterized by γ . Data from Idealista points to an average time on the market of 5 months or 1.67 quarters. I calibrate r^m to target the average spread on mortgages relative to the risk-free rate. Because of the presence of q , the mortgage pricing at origination, the actual cost of credit is different from simply the period interest rate r_t^m . The rate on mortgages is taken to be the average rate on total loans for house purchases in Spain from the ECB's MIR dataset. The resulting spread $r_t^m - r_t$ is an annualised 1.23 percent.

The steady-state foreclosure rate of 0.34 percent and arrears rates of 1.9 percent are pinned down by the cost of foreclosure to the household in the form of the utility penalty for foreclosure, Γ^u and the probability of exiting the default flag θ . A large part of the action in the model happens in transition away from steady-state. To discipline this aspect of the model, I use Δ to match the correlation of delinquencies and foreclosures in the data. The logic of using Δ is that it shifts the value of foreclosure and, thereby changes the banks' willingness to foreclose versus tolerate delinquency. The full set of parameters for this exercise are set out in Table 2.2.

The resulting model fit is set out in Table 2.3. It is worth noting here that in addition to the parameters directly influencing the cost of foreclosures for the bank and the household, the matching process also has a significant impact on the model's ability to hit the foreclosure rate. The reason is that households cannot immediately sell their homes without making discounts on the price. This differentiates this

model from one where households are immediately able to sell their house. In these cases, only households that are in negative equity face a reasonable prospect of being foreclosed. With a average time on the market of 5 months, households who can no longer pay their mortgage, face a reasonable prospect of having to wait multiple periods before they can sell. There will be a measure of households in positive equity who end up defaulting while trying to sell their homes.

2.4.1 Untargeted Moments

This subsection compares a range of model outputs against empirical counterparts that were not targeted in the calibration. I start by comparing steady-state outcomes before moving to crisis behaviour.

Loan Characteristics & Affordability Ratios — Table 2.4 sets out loan characteristics. It shows the 10th, 50th and 90th percentiles for loan-to-value ratios and payment-to-income ratios. The model performs well along LTV ratios but doesn't match the extremely high LTV ratios of the most indebted households. The model payment-to-income-ratios are more tightly clustered than the data and the median is too low. However, the PTI for the model is actually the minimum repayment assuming repayment by end-of-life so we should expect this to be lower than the payment actually chosen by the household.

Table 2.4: Model Fit on Untargeted Moments

Moment	Model Value	Empirical Value
P10 LTV Ratio	0.411	0.453
P50 LTV Ratio	0.756	0.799
P90 LTV Ratio	1.03	1.11
Mortgage Maturity (years)	20.3 ^a	23.4
Rent-to-Income Ratio	0.14	0.11
P10 PTI	0.121 ^b	0.085
P50 PTI	0.165 ^b	0.210
P90 PTI	0.381 ^b	0.467

Notes: Data is from HFCS for mortgages originated pre-crisis. (a) The model maturity is the average time actually taken to repay the loan whereas the empirical counterpart is the average maturity agreed at origination. (b) The mortgage payment-to-income ratio for the model corresponds to the minimum payment.

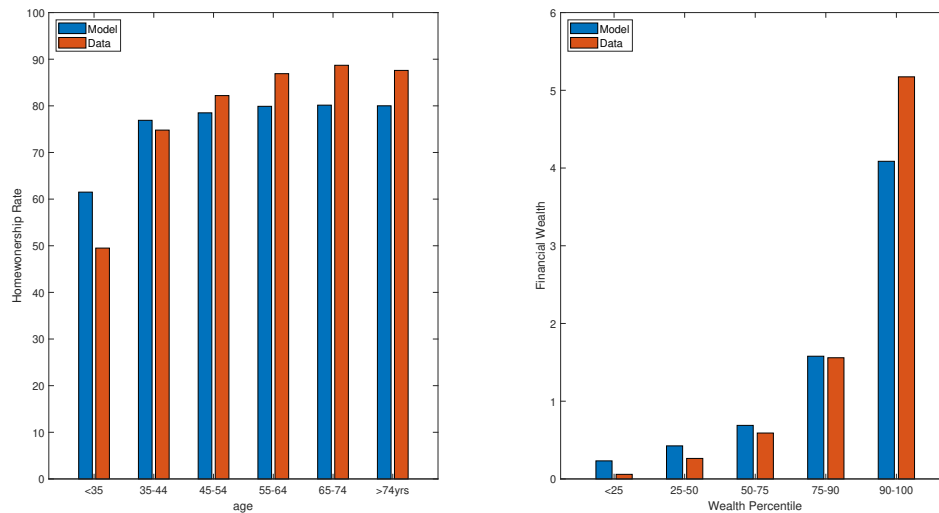


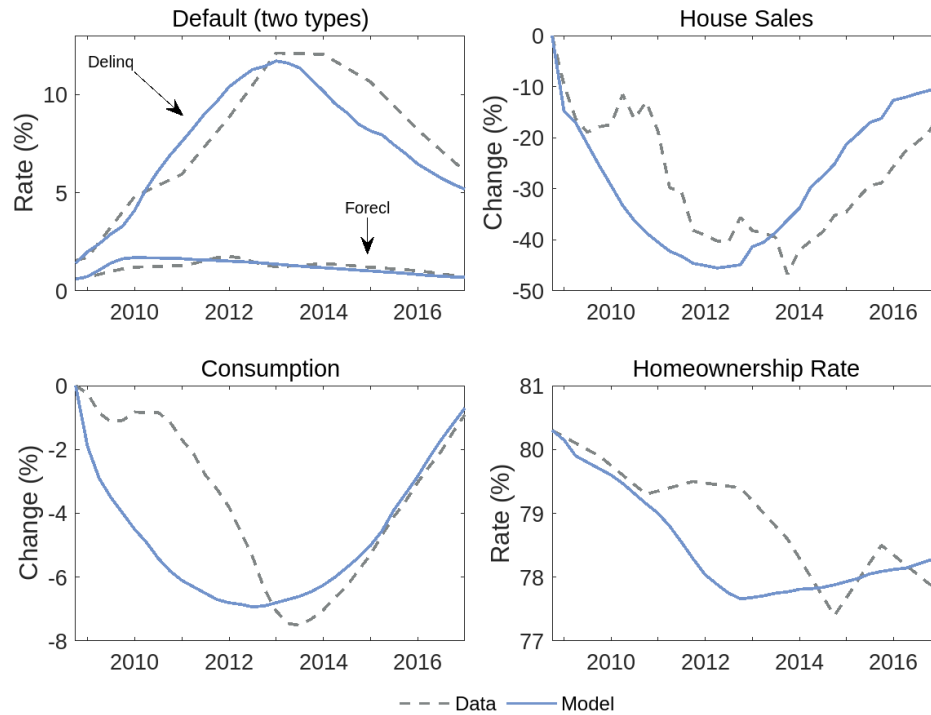
Fig. 2.11: Homeownership and Financial Wealth

Cross-Sectional Wealth & Housing — Figure 2.11 compares the cross-sectional results of the model to the data. In the left panel I compare the model generated homeownership rates across ages. The model's performance is decent although it predicts higher levels of homeownership among the young, particularly the under 35 cohort, than we observe in the data. On the other hand, it predicts too low a homeownership rate for the old as the model prediction is of an almost flat profile from 50 years old on, whereas in the data, the homeownership rate keeps rising.

The right panel of Figure 2.11 shows the median wealth across the wealth distribution. Again, the model performs well except at the top of the distribution where it struggles to match the level of financial wealth of the top decile. There is also a small degree of overshooting for the lower parts of the distribution.

Evolution of Crisis — Figure 2.12 plots the responses of some of the key variables in the crisis and compares the model simulation to the data. The first noteworthy point is that the model correctly channels mortgage 'defaults' into delinquencies rather than foreclosures. The magnitudes are broadly right even though the model peaks occur earlier than the peaks in the data - a feature that also appears throughout the other plots.

Housing sales fall sharply during the crisis. This feature of the model output is generated by the drying up of liquidity in the housing market. Too many sellers are chasing too few buyers (intermediated by brokers) so the probability of making a sale drops sharply and the time a house spends on the market becomes long (see below).



Note: Model output vs. data. Sources: INE, ECB, Eurostat and Spanish Ministry of Justice. Foreclosure rates are annualised.

Fig. 2.12: Evolution of Crisis

The completion of these sales, therefore, take a long time and the home-ownership rate drops slowly.

When it comes to consumption, the magnitude of the drop is roughly right but the model forecasts consumption to drop much more quickly than it does. This may be because in the simulation, agents have perfect foresight of the depth and persistence of the crisis whereas in reality this was much more uncertain. In addition, fiscal stabilisers in Spain may have cushioned much of the initial blow but as Spain became embroiled in the Eurozone sovereign-debt crisis it was forced to embark on an austerity programme, removing some of these buffers.

Underlying Behaviour of Delinquencies — To get a better sense of how delinquencies evolve in the model Figure 2.13a plots the rate at which accounts transition from delinquency back to performing in the model versus the data. This is a key metric in the determination of the reservation payment and therefore, the scope for utilising delinquency at all. The comparison is made for Spanish data over the period 2012-19, meaning that we are only observing transitions just before the trough in employment

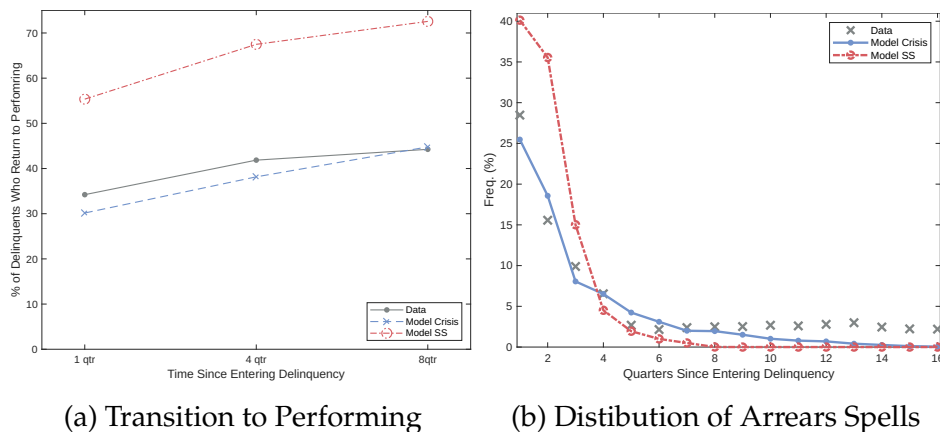


Fig. 2.13: Delinquency Behaviour

and house prices, and through the recovery. Figure 2.13a plots the model transitions in steady state and during the full duration of the crisis, and compares these to the data. Figure 2.13b shows the distribution of arrears spells, again comparing the model during the crisis window to the data. The behaviour is quite similar, although the fraction of delinquency cases that make it to more than three years (12 quarters) is lower in the model simulations than in the data. Some further model fits are shown in Appendix D.

2.5 Understanding Delinquencies In A Crisis

The previous section set out how the model was parameterized and assessed its performance in steady state and during a housing crash. The present section tries to explore the mechanisms at play beneath the headline numbers. I first try to show how delinquencies and foreclosures are connected to house prices. Then I move on to discuss how these issues spill over into consumption. Lastly, I show how the insurance on offer from delinquency is dependent on getting a good characterisation of the income process.

2.5.1 House Prices, Delinquency and Foreclosure

This section explores the two-way relationship between house prices and delinquency. The first effect runs from house prices to the willingness of the bank to foreclose. Figure 2.14 plots the crisis episode of the baseline and compares it to a partial equilibrium case where house prices are kept fixed even as incomes drop.

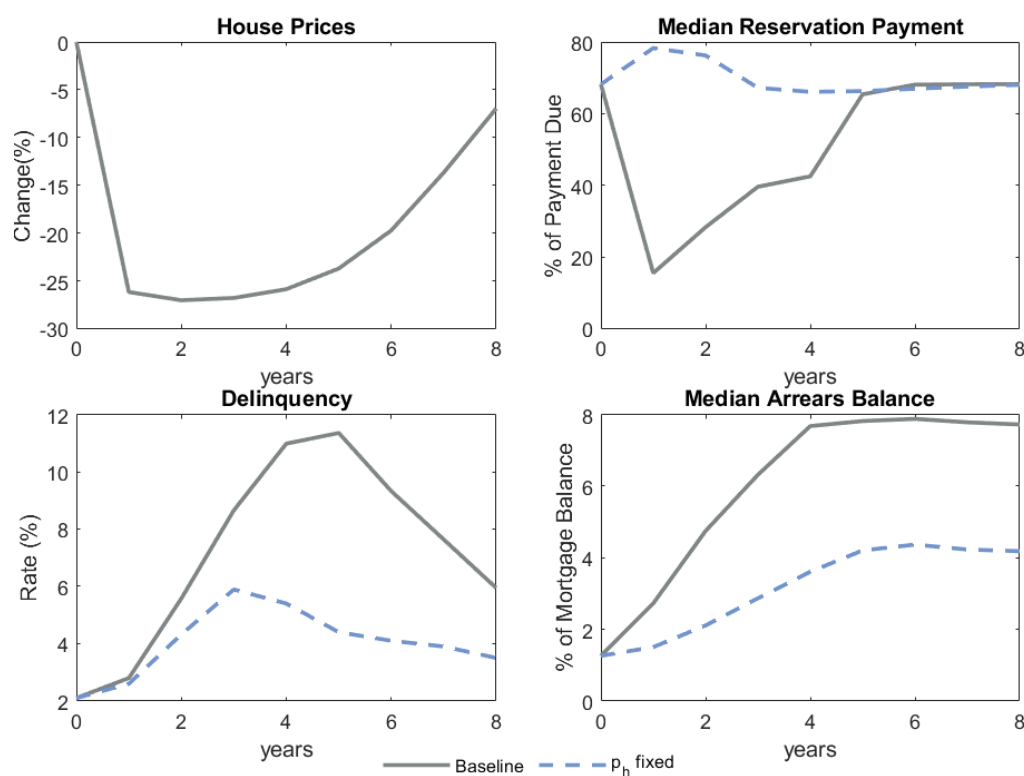


Fig. 2.14: Delinquency and House Prices

The median reservation payment plotted in panel (b) shows dramatically different behaviour in response to fixed house prices. Since the bank is not open to large losses in the case of a foreclosure under the fixed prices case, the reservation payment actually rises slightly as deteriorating incomes (both in realisations and in expectations) lower the continuation value of the loan for the bank. This transmits into lower use of delinquency, both along the extensive margin (lower delinquency rates) and the intensive margin (lower arrears balances among those in delinquency).

The second dimension is what delinquency does to the liquidity-house price spiral. The rush to sell in a crisis leads to a drop in housing market liquidity causing long selling delays. This makes it difficult to convert houses into liquid assets. The first round effect is that owning (or continuing to own) houses with a mortgage is now a riskier proposition and households reduce demand for housing. The second round effect is that banks - recognising this increase in the risk of lending against houses - charge higher risk premia on new mortgages. The contraction in lending further reduces demand for housing. The combined fall in demand leads to less buying and more selling prompting lower liquidity and even worse selling delays. The amplified drop in demand causes significantly larger house price drops.

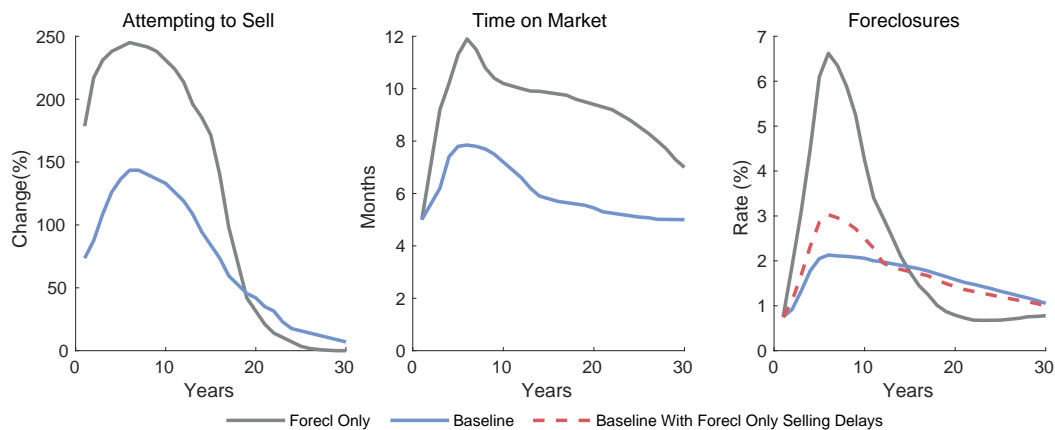


Fig. 2.15: Delinquency and House Prices

The larger house price drops, in turn, push more households towards foreclosure, increasing the number of sales and lengthening the time it takes to sell.

This effect is actually made worse by borrowers who are constrained to sell their house for more than the value of their debt. The matching function should push people to trade off discounting their prices against waiting for a long time to make a sale. Households at risk of foreclosure, however, are not able to make these discounts. The debt overhang keeps their list prices artificially high and leads to long selling delays. The effect is so strong that housing sales actually drop during the crisis. The inability to sell leads borrowers- even borrowers with positive net worth - to be foreclosed on.

Delinquency intervenes in this cycle. It keeps at least some distressed borrowers off the market, attenuates the decline in market illiquidity and makes it easier for distressed borrowers to sell before being forced into foreclosure. So the reduction in foreclosures comes from two sources, the fact that a given borrower can become delinquent rather than default, and the fact that the house doesn't need to be sold makes it easier for other borrowers to sell.

Figure 2.15 shows how the two sources contribute to the difference in foreclosures. It compares the baseline with the evolution of the crisis in the case where delinquency is not allowed. The numbers of agents attempting to sell jumps by much more in the Foreclosure Only case. As a result, market illiquidity - as represented by the amount of time houses spend on the market - also jumps by more. Panel (c) plots the foreclosure rate in the baseline and shows what would have happened if delinquency was not an option. The foreclosure rate peaks three times higher. How much of this gap is due to the difference in market illiquidity? Panel (c) also plots the foreclosures that occur in a counterfactual where delinquency is still an option, but

where liquidity deteriorates by as much as in the Foreclosure Only case. If the time on the market had increased by as much as the Foreclosure case, then even with the ability to enter delinquency foreclosures would have been 49 percent higher.

2.5.2 The Relationship Between Delinquency, House Prices and Consumption

The consumption response to the crisis is moderated by delinquency in two ways. Firstly, through the ability to accrue debt via arrears. Secondly, through the way it changes the marginal propensity to consume from changes in housing wealth. Figure 2.16 plots the consumption response for the crisis compared to the partial equilibrium case of fixed house prices and shows the associated elasticity of consumption with respect to house prices.¹¹ Decomposing consumption in this way, we can see that the partial equilibrium consumption response with fixed prices is smaller under the baseline than in a Foreclosure Only case - where the standard modelling assumption of no delinquency is enforced. The smaller partial equilibrium response is the result of delinquency use absent any amplification from house prices.¹² The trough in consumption is 5.4 percent with delinquency versus 8.9 percent without. On the other hand, with endogenous price drops, the disparity grows to 51 percent (6.5 percent versus 13.1 percent).

For households who can use delinquency, the drop in house prices has two effects on consumption. The first is the response to the deterioration in wealth - present in Foreclosure Only case as well. The second effect is more subtle and changes throughout the crisis episode. It is the fact that the deterioration in house prices has afforded households the opportunity to delay part of their consumption adjustment and spread it out over more years. But as house prices recover, this second effect

¹¹The elasticity of consumption with respect to house prices is defined as the difference in consumption with and without fixed house prices, divided by the change in house prices. That is,

$$E_t = \frac{\% \Delta C}{\% \Delta p^h} \quad (2.45)$$

where the change in consumption in the numerator and the change in the house price in the denominator are:

$$\% \Delta C = \frac{C_t - C_t^{\Delta p^h=0}}{C_t^{\Delta p^h=0}} \quad ; \quad \% \Delta p_t^h = \frac{p_t^h - p_0^h}{p_0^h} \quad (2.46)$$

¹²Figure 2.16 shows the case without recalibration for the Foreclosure Only case. The result of recalibrating is similar and is included in the appendix.

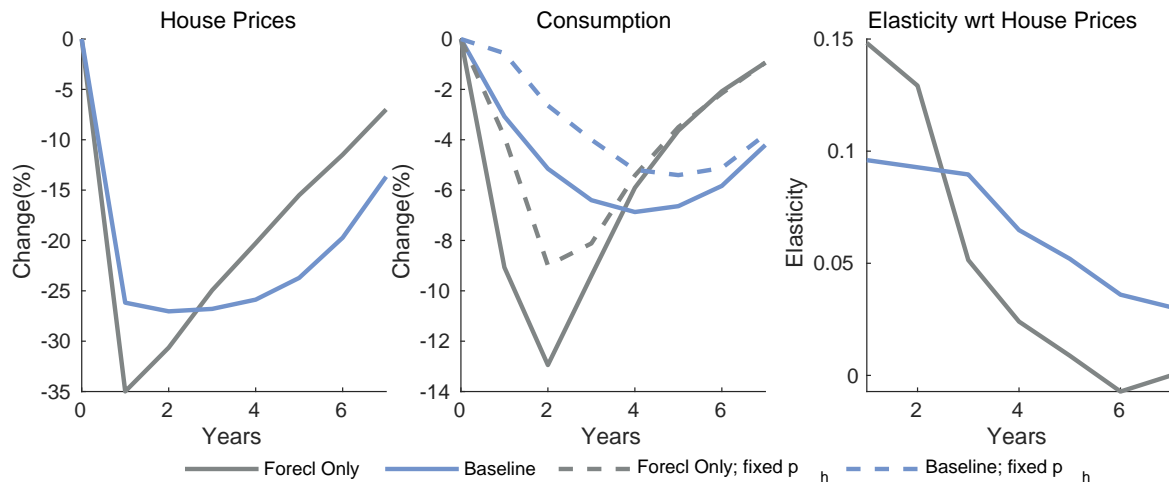


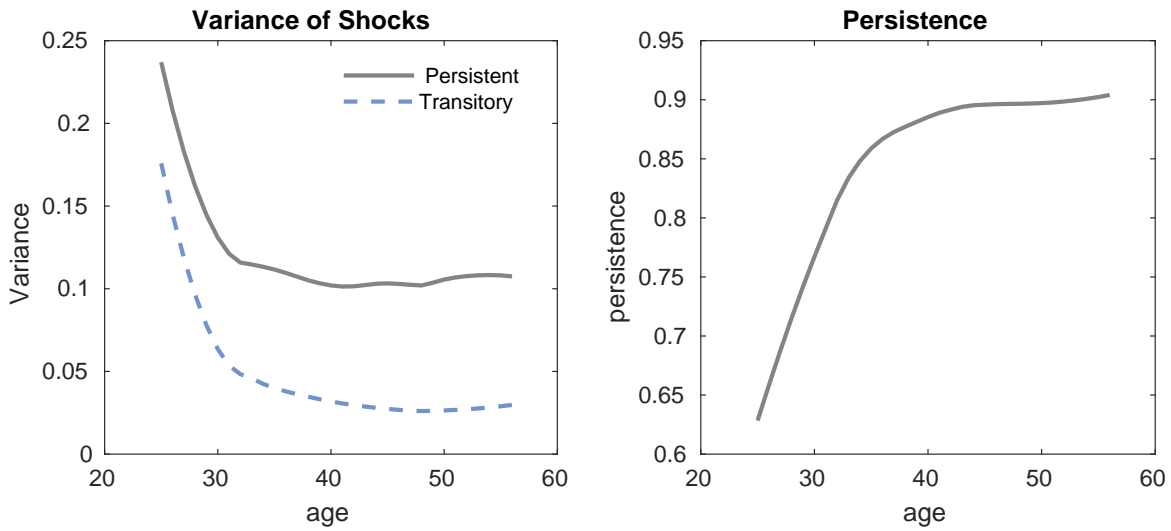
Fig. 2.16: Consumption and House Prices

unwinds and the space for delinquency use shrinks (see Figure 2.14). This results in consumption responses that persist for longer and positive elasticities even after four years. The difference between the elasticity plots can be thought of as the strength of this second effect. The smaller consumption responses to the drop in house prices map onto lower marginal propensities to consume out of drops in housing wealth - at least initially. The backloading of the adjustment and the house-price recovery means that this elasticity stays elevated for longer.

2.5.3 The Importance of the Lifecycle and Income Process

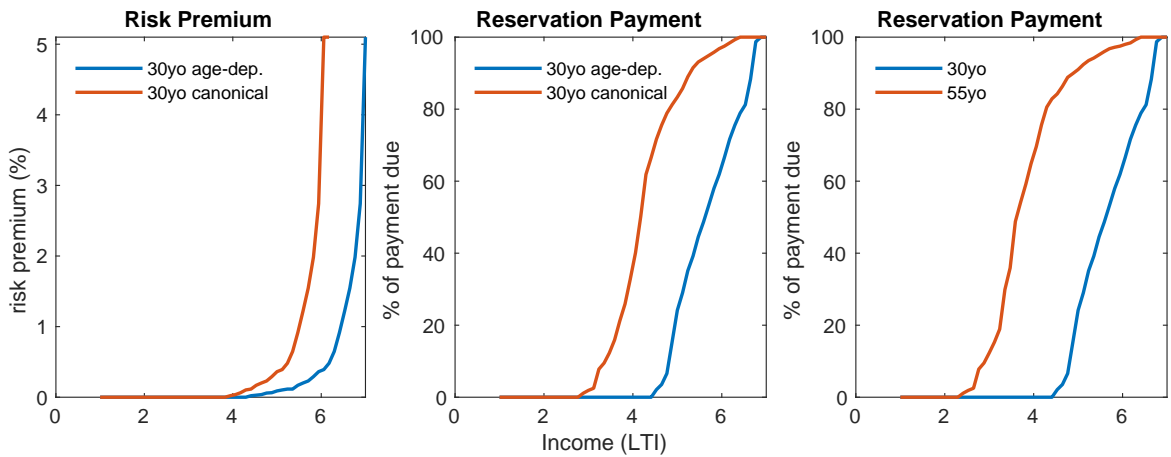
The household's income profile and the age-dependency of the stochastic income process matter. Figure 2.18 plots the age-dependent parameters for the income process specified above. There are two points worth making here. First, is the striking decrease in uncertainty and increase in persistence that occurs as households move from age 25 to age 40. The second is the difference between these numbers and what the literature typically estimates for the variance and persistence of these shocks when a canonical/non-age-dependent process is used. In the case of Spain, for example, Guner et al. (2020) report a persistent variance shock of just 0.0052, with persistence 0.9831 and transitory shock variance of 0.0897.¹³ This demonstrates the general tendency for the canonical process to confuse persistence and variance. For further discussion on the advantages of more flexible income processes, see Guvenen et al. (2021).

¹³The income process in Guner et al. (2020) is also complicated by the possibility of extremely high (superstar) income draws and very low income draws.



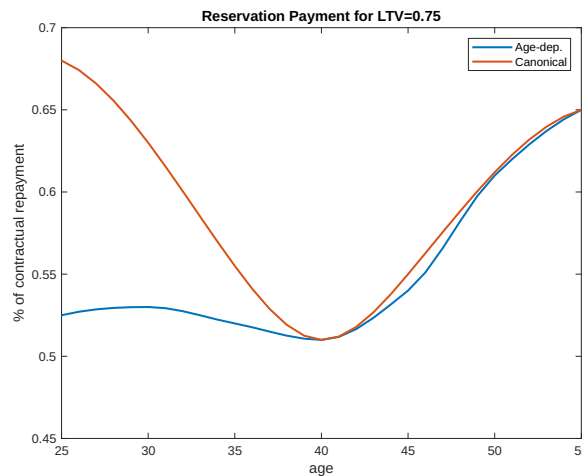
Note: Figure reports result of smoothing by means of locally-weighted regression on raw estimates from Garcia-Cabo and Madera (2019)

Fig. 2.17: Age-Dependent Income Process



Note: Figure shows median reservation payments for households with an LTV of 0.75. Lines compare the results of using the baseline, age-dependent income process with the canonical income process of Guner et al. (2020)

Fig. 2.18: Credit Rationing by Income Process



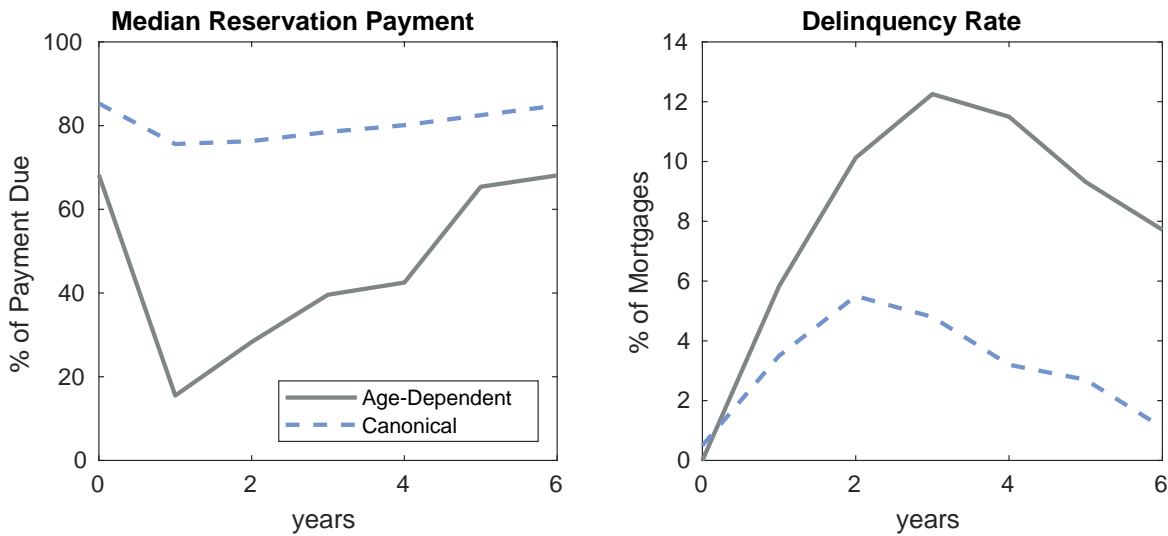
Note: Figure shows median reservation payments for households with an LTV of 0.75. Lines compare the results of using the baseline, age-dependent income process with the canonical income process of Guner et al. (2020)

Fig. 2.19: Median Reservation Payment by Age

For our purposes, this means that households who are of house-buying age are different in an important way to older households. When the shock hits, these households are also the ones who have just bought their houses and so have the highest leverage ratios. This makes them the most likely cohort to use delinquency. The fact that this cohort has much lower persistence of negative income shocks also means the bank's value of a delinquent loan as a going concern is higher. We can show this in Figure 2.17 which compares the age-dependent income process with the canonical income process of Guner et al. (2020). The bank begins to credit-ration a 30 year-old facing a canonical income process earlier than when they face the age-dependent process. In fact, comparing panels (b) and (c) in Figure 2.17 the canonical income process leads the bank to treat the young household more like a middle-aged household.¹⁴

Looking across the lifecycle, we can see from Figure 2.19 that the canonical income process would severely limit young household's access to delinquency relative to the age-dependent process. We can see how this plays out in a crisis in Figure 2.20. The reservation payment barely drops as the effect of lower collateral values are offset by the increased risk faced by young households with much lower chances of

¹⁴We can use the price of the bank's pricing of the debt when the loan is contracted q to back out an effective per period risk premium by calculating the total cost of credit and assuming it is evenly distributed over the lifetime of the loan.



Note: Figure compares crisis experiment for baseline income process with the results of using the canonical income process in Guner et al. (2020).

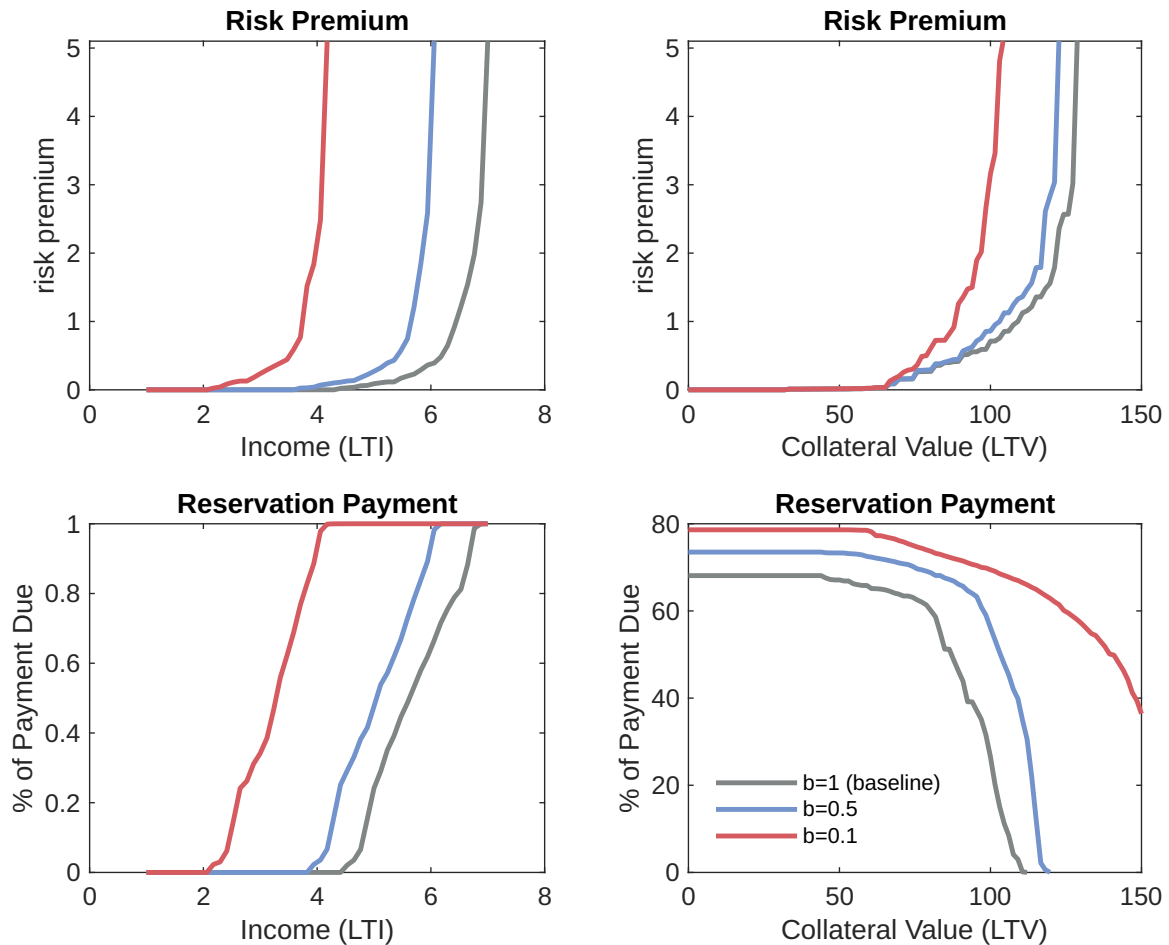
Fig. 2.20: Age-Dependent Income Process

recovery from income shocks. This suppresses the delinquency rate considerably as banks credit ration the young more severely.

2.6 Recourse and Delinquency

With an appreciation for how delinquency emerged as the dominant mode of default in post-GFC Europe, we can now start to think about counterfactuals. One of the most important factors determining whether banks will permit delinquency is whether they expect delinquency to end in foreclosure. If the chances of this are high, then it may be better for the bank to foreclose now and cut its losses. This section shows that an important factor in determining the likelihood of foreclosure is the degree of recourse. That is, how strong are the banks powers to recover losses over and above the value of the house. I do this by varying the fraction of income that is subject to recourse. The higher the fraction, the more painful foreclosure becomes and the harder households will work to avoid it in the future. As a result, banks permit more delinquency today.

One of the notable points about Spanish foreclosure law is the strict rules on recourse after the default. The household's income is essentially subject to an extra tax that becomes extremely punishing at even relatively low levels of income.



Note: Risk premia denote the effective premium at origination. The reservation payment corresponds to the mid-loan minimum repayment needed to make the bank indifferent between foreclosure and continuing with the loan.

Fig. 2.21: Recourse and Risk Pricing

Similarly, in some of the other Eurozone periphery countries, default on a mortgage essentially requires full bankruptcy proceedings and the garnishing of income to repay any remaining debt after the sale of the repossessed house. A hotly contested issue is whether these rules should be relaxed. I take the status quo to be the harshest regime and consider a relaxation.

As mentioned above, Spanish law sets out a sliding scale of income garnishments $\alpha(y_t)$ depending on how far above minimum wage a household's income is. Consider amending this in a very simple way by multiplying these rates by a constant fraction b . I consider two cases in addition to the baseline $b = 1$ case. First, I consider a case that is effectively non-recourse: $b = 0.1$. For comparison, I include

an intermediate case $b = 0.5$. Figure 2.21 plots the risk premium (set at origination), and the bank's reservation payment as a function of income and collateral for an individual household.¹⁵ Note that Figure 2.21 keeps the nominal loan value fixed in all the plots so that only income or collateral are moving while all other factors are kept constant. Panels (a) and (b) show that the risk premium needed to earn the bank zero profits in expectation is increasing in the loan-to-income ratio and loan-to-value ratio, as would be expected, and becomes explosive as we approach the default threshold. Lowering the level of recourse with lower levels of b brings the default threshold forward so that households default at lower LTI and LTV levels.

Panels (c) shows that the bank's reservation payment is also rising in LTI, meaning that as income drops (but the loan and collateral value are kept fixed) the bank allows less leeway for delinquency. This is due to the lower affordability of the loan repayments making a default in the future more likely and depressing the option value of waiting before foreclosing. Similar to the risk premium plotted in panel (a), this threshold moves to the left for lower values of b . Panel (d) shows that the reservation payment behaves in a different way with respect to collateral. As collateral drops (but, again, income is kept constant) the loan repayments are just as affordable but the value of a repossession deteriorates. As the bank stands to make losses if a default is triggered, but the continuation value is high, the bank will tolerate payments (far) below the contractual value. This is the key way that the reservation payment is different from the risk premium and what marks out the mortgage borrower-lender relationship as different from one where a borrower with long-term debt must roll over the debt each period in the face of spiralling interest rates.

Figure 2.21 shows the *ceteris paribus* effects of changing income or collateral values. But a housing crisis typically involves both falling incomes and house prices. The question is, which one predominates? Figure 2.22 repeats the crisis dynamics for the median reservation payment and arrears balance for the three alternative values of b . The crisis dynamics for $b = 1$ shows that the reservation payment drops as seen before, meaning that the effect of the collateral drop is stronger than the effect of the deteriorating affordability of the median mortgage. For the case of $b = 0.5$, the same is true but the scope for arrears is lower. The bank is more worried about the household defaulting because it cannot repay and so it maintains a higher reservation payment, limiting the rise in the median arrears balance to less than half of the baseline case. For $b = 0.1$, however, the effect of the income drop dominates the

¹⁵In this case, a household aged 40 owning a medium sized house

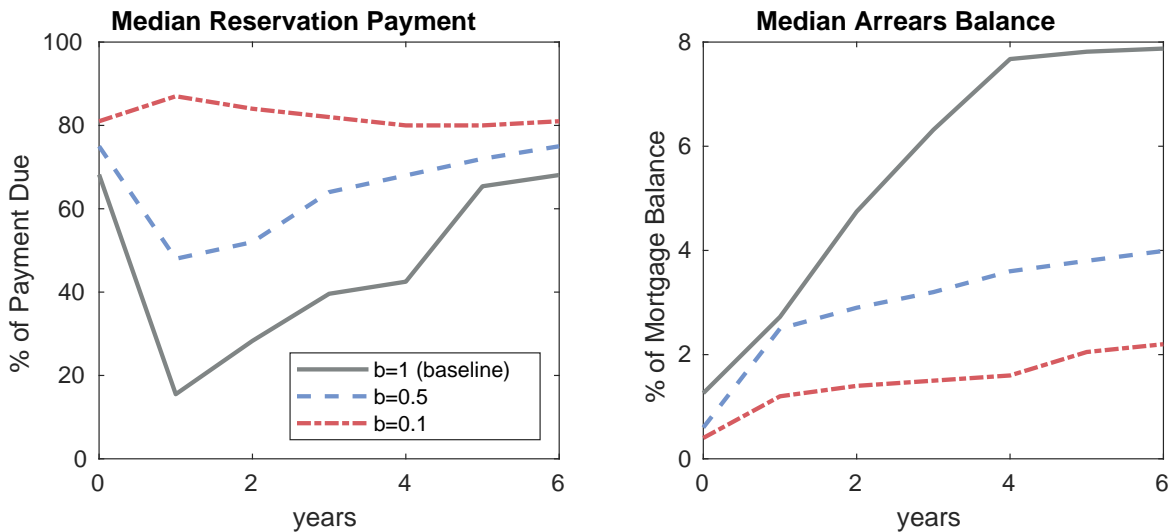


Fig. 2.22: Recourse and Delinquency in a Crisis

effect of the drop in collateral value. The median reservation payment actually rises slightly during the crisis, keeping the arrears balance low by comparison. Together, this shows us that the logic of the model suggests the easier it is for households to default on their mortgages, the less sustainable is nonpayment and the accumulation of mortgage arrears. In the end, this leads to higher use of defaults rather than delinquency. In the end, a regime that would seem to favour borrowers by making foreclosure less painful can be worse because it denies borrowers a far less disruptive solution to their debt problems.

One measure of the disruption caused by this push to foreclosure is the lost wealth as a result of the crisis. Panel (a) of Figure 2.23 plots the wealth gap between an economy with/without a crisis as a function of age at the time of the crisis. Wealth costs are highest for the cohort who experience the crisis in their thirties. This is the cohort who have just bought their houses, have high LTV ratios and enter negative equity. By contrast, younger cohorts of house-buying age enter the market when prices are depressed. They buy low and enjoy the very high returns from home-ownership during the recovery. This effect is large enough to outweigh the wealth effect from lost earnings due to the income skewness shock during the crisis. A similar story holds for the older cohorts. Despite being exposed to the drop in house prices, they have lower LTVs and higher incomes so they are less likely to end up in foreclosure. When the house price recovers, their wealth is restored and they even have the option of trading up to a larger house to increase their exposure to the high housing market returns during the recovery.

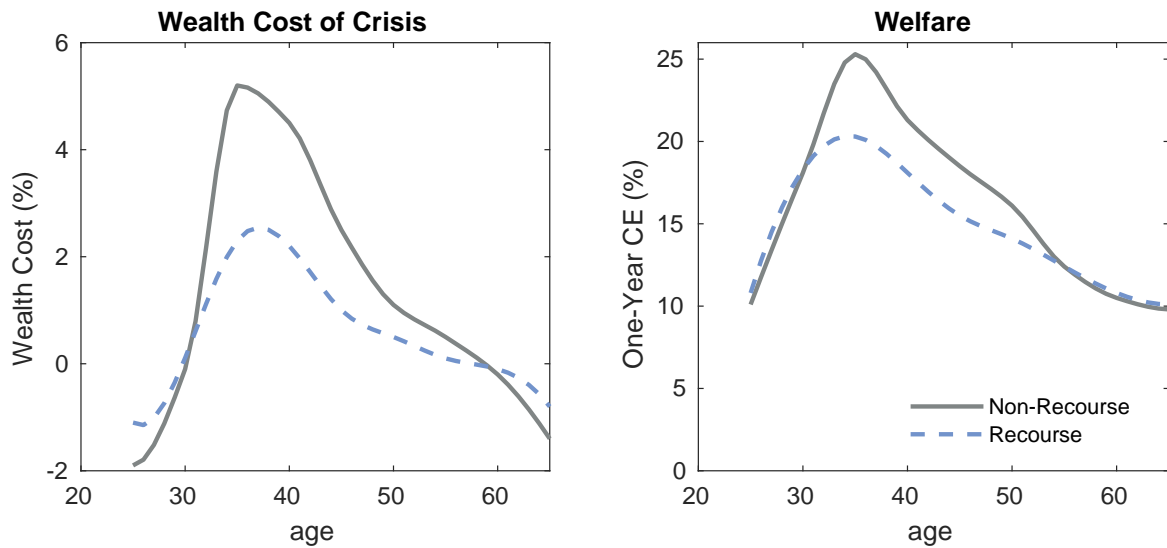


Fig. 2.23: Recourse and Delinquency in a Crisis

The striking result, however, is that recourse lowers the wealth cost from a crisis. This happens despite the lower cost of foreclosure because the household in the recourse regime doesn't use foreclosure - it uses delinquency instead. Holding onto the house means the delinquent households also share in the high returns to home-ownership during the recovery. This is enough to more than outweigh any gains from having negative equity wiped clear.

These effects show up in the welfare costs of the crisis plotted in Panel (b). This graph shows the one-time change in consumption necessary to make the household indifferent between entering a crisis and not entering one.¹⁶ The gap between these curves corresponds to how much more a household needs to be compensated in order to be indifferent between a crisis and steady-state. On average households in a recourse regime need to be given 1.46 percent consumption-equivalent more to endure a crisis. Most ages prefer recourse with the gap peaking at 5.01 percent. The young and the old are close to indifferent between the two regimes.

2.7 The Effects of Loan Repricing

The previous sections have assumed that mortgages are priced at origination and then only repriced at the discretion of the household (by refinancing). This is the

¹⁶This is different from standard lifetime consumption equivalent. Matters are complicated here by the fact that households enter the crisis at different ages and so have different amounts of time left to receive consumption compensation.

most natural case but this section will think about deviating from it. The aim is to understand how strong the assumption is and what the consequences of removing it are. As I will show, allowing for repricing implies a relatively small change to equilibrium outcomes because banks are unwilling to engage in large revisions to debt.

It is becoming increasingly prevalent for households to receive an initial rate for a given period, after which the rate will revert to a substantially higher rate. Both parties expect that after the initial period is over, the rate will be renegotiated or the household will refinance with another lender. In either case, the loan is essentially re-priced to the new creditworthiness of the household. This new interest rate will again expire after a given period and the process will repeat itself. This has long been the norm in the UK, for example, but during our sample 2012-19, it was also quite prevalent in Spain.

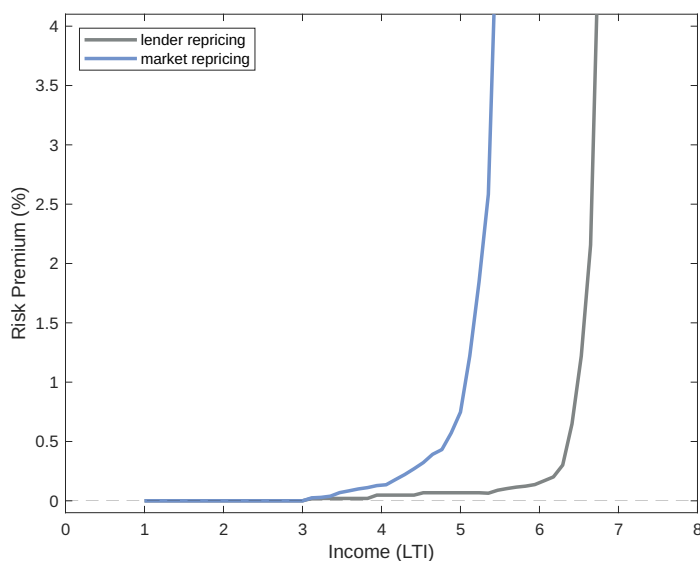
This has the potential to change how banks achieve credit-rationing mid-loan. For debt-distressed, delinquent borrowers banks may seek additional compensation. The requirement to pay more will push households to keep repayments higher to avoid the high costs. This recreates the kind of ‘market discipline’ commonly observed in sovereign/corporate bond markets. To operationalise this in the model, I assume that rate deals expire with probability λ and set this probability so that the expected length of a rate deal is 3 years. Households whose rate expires in period t who carry a_t from the previous period must repay the entire sum $(1 + r_t^m)a_t$. They do this by originating a new loan, with a new price k_t . They receive $k_t(X_t)a_{t+1}$ and carry a_{t+1} forward as their new loan. The bank holding the loan, must offer a new $k(X_t)$. The effect of this is to push the total value of debt up to $a_{t+1} = (1 + r_t^m - m_t)a_t/k_t$.¹⁷

Unlike in the bond market, I assume that the bank internalizes the effect that the repricing has on the household’s future decisions and, so, on the value of the loan going forward:

$$k_t(X_t) = \arg \max_k \left\{ q(k, \cdot) \frac{(1 + r_t^m)a_t}{k} \right\} \quad (2.47)$$

An immediate consequence of this is that the price offered by the bank will be at least as good as the price offered on the marketplace if the household were to seek to refinance elsewhere. If the price were worse than the market price, the household

¹⁷To ensure that interest premiums do not explode in the way they can in bond markets, we can impose that q cannot drop below the exogenous \underline{q} . We can then choose \underline{q} to ensure that a household who always refinances at rate \underline{q} never pays more than the equivalent of a 5 percent interest premium.



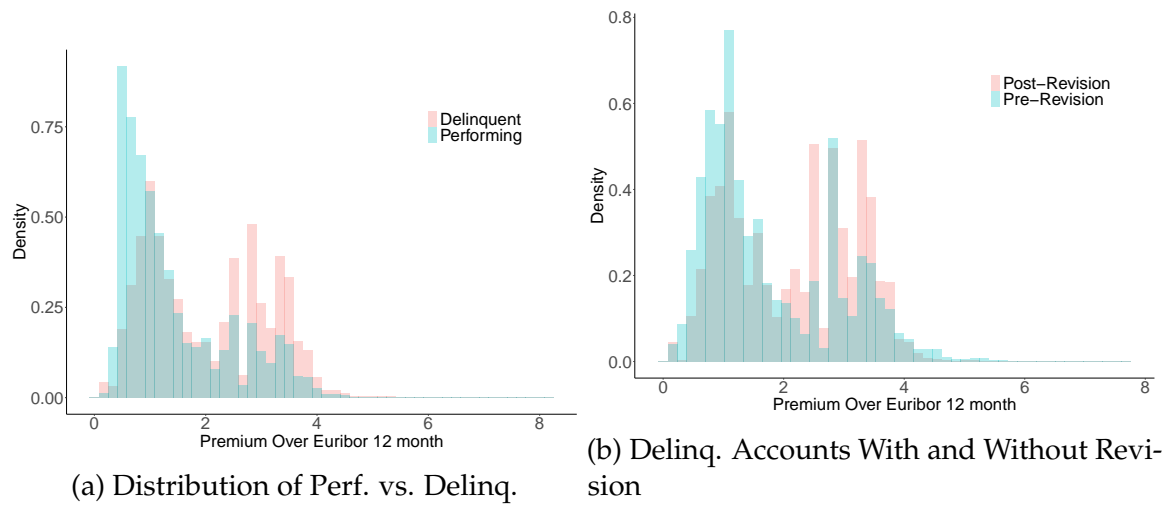
Note: Plotting the implied risk premia for a 40 year old household with an LTV of 80%. The plot compares the pricing the current lender offers with the pricing that a new lender in the market would offer.

Fig. 2.24: Repricing - Lender vs. Market

could just refinance on the market. However, in most cases it will be better because the bank internalises the fact that by increasing the household's debt burden, the bank has diluted the value of that debt.

Figure 2.24 plots the implied risk premium against loan-to-income. It compares the rate the market would charge to refinance the loan q , and the rate the lender offers k . It shows the degree to which the lender is suppressing the implied risk premium to protect the value of the debt going forward. Even after this borrower is shut out of the refinancing market, the lender continues to offer reasonable terms. These rates are applied to delinquent and performing borrowers equally and they help to show why delinquency can represent such an attractive source of cheap credit for households with a mortgage.

Before looking at how price resetting might change the outcome of a crisis, it is useful to get a sense of the dispersion of interest rate premia. Figure 2.25 Panel (a) shows the distribution of interest rate spreads over the 12-month Euribor rate over 2012-19 and splits the sample into performing accounts and delinquent accounts. The delinquent distribution has more mass further to the right indicating higher risk-premia for these accounts. This reflects both the fact that these accounts were assessed as riskier ex-ante and the fact the behaviour of the accounts since origination.



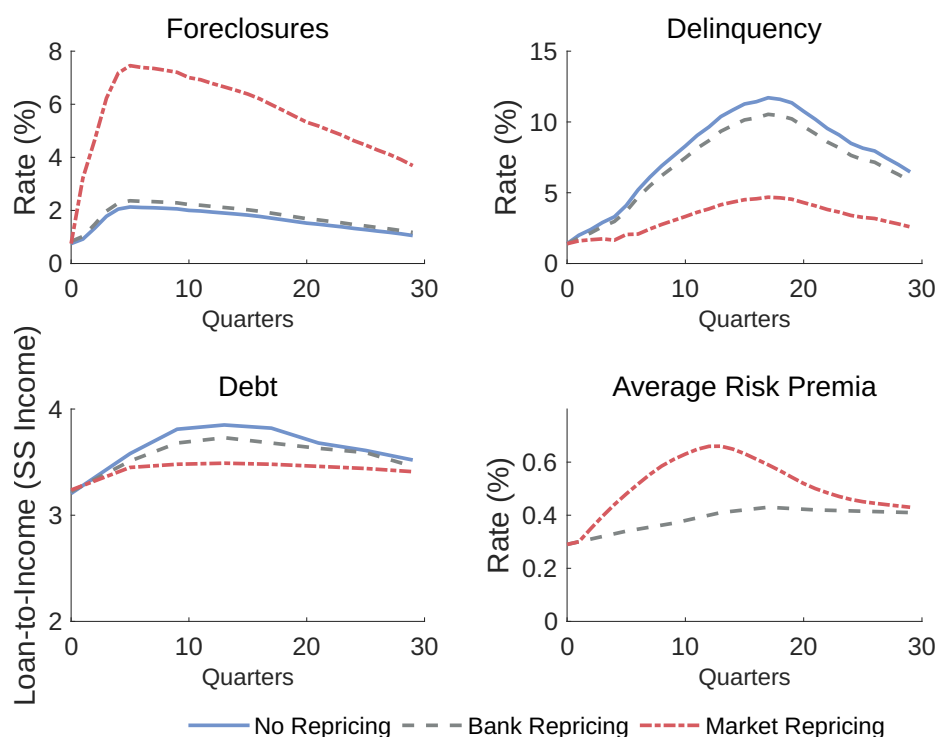
Note: Panel(a): Spread Over Euribor for all mortgages in sample 2012-19. Panel (b): Spread over Euribor for delinquent mortgages that have not been subject to a reset and those who have.

Fig. 2.25: Interest Rate Premia 2012-19

To get a better sense of the ‘punishment’ faced by delinquent borrowers, Panel (b) takes advantage of observed rate resetting. It plots the distribution of accounts that have entered delinquency and splits the sample into those who have had their rate revised during that time, and those who haven’t. We see some movement to the right but considering these accounts are considered in ‘default’, this rightward shift is relatively modest.

A regression analysis of the interest rate consequences of delinquency after a reset is given in the appendix. It shows that after controlling for relevant borrower and loan criteria, the sizes of interest rate hikes for delinquent accounts are modest - of the order of 0.3%.

Figure 2.27 shows the evolution of a crisis comparing no repricing, bank repricing and market repricing. Panel (d) plots the average risk premia among mortgages originated pre-crisis the continue through the crisis (mortgages that are forced into foreclosure from excessively high interest rates are excluded here). Market repricing sees much higher foreclosure rates as households in this case essentially need to refinance but find themselves shut out of credit markets. Since banks internalize the cost of this, their resetting is much less aggressive and the crisis closely mimics the no repricing baseline case.



Note: Compares the baseline case of no repricing repricing under two paradigms (i) where banks internalise the effect of interest rate resets, (ii) market repricing without internalising the effect of interest rates. The axis in Panel (c) is loan-to-income where income is fixed at the pre-crisis level. Panel (d) plots the average risk premia for surviving mortgages. The no repricing case is not shown in Panel (d) because there is no forced repricing.

Fig. 2.27: Repricing in a Crisis

2.8 Delinquency Costs and Benefits in Steady State

The previous section describes how insurance option of delinquency can change the dynamics of housing crisis and seems to point in the direction of delinquency being unambiguously good. However, we should expect that in normal times households will have to compensate banks for the risk that delinquency may be employed in a crisis. This section seeks to address whether and how much households end up having to pay through risk premia and where this extra risk premium comes from. Consider deviating from the above model by replacing the endogenously determined reservation payment with an exogenously pre-specified threshold above which the bank will tolerate delinquency and below which the bank will foreclose even if these choices are not ex-post optimal. Figure 2.28 plots steady-state outcomes as we move this threshold from 0-100 percent of the contractual repayment.

The default rate in Panel (a) of Figure 2.28 show a u-shape as we move from giving the household full freedom to rollover debt (threshold = 0) to the case of no delinquency allowed (threshold=100). This non-monotonic share is the result of two effects. At low thresholds means households with income shocks do not need to lower consumption but can freely run-up debt instead. These higher debt levels, lead to higher default rates *ceteris paribus*. On the hand, at high thresholds, households have less space to absorb income shocks and so they are forced into default more often. Transition rates from delinquency back to the performing state are increasing in the threshold because the composition of those who use arrears has shifted towards those who are most likely to recover. Those with low probability of recover are those who can't cut their consumption enough to take advantage of delinquency and so they default instead. The non-monotonicity of the default rate is reflected in the risk premium and in the welfare of each steady-state. Leverage choice of households are also affected by the risk premia as households trade off the fact that lower thresholds lead to more flexibility in managing higher debt stocks, (meaning higher LTVs at origination and households taking longer to pay down debt) with the fact that risk premia begin to rise at lower thresholds.

This exercise in comparing steady-states is vulnerable to the following complaint. The steady-state assumes no aggregate uncertainty - with the model being shocked by entirely unanticipated MIT shocks. This means that banks are not pricing in the risk of delinquencies during a crisis and households are not fully appreciating the insurance on offer from a so-called 'double-trigger' event where collateral values and incomes fall simultaneously. While solving the full model with aggregate risk

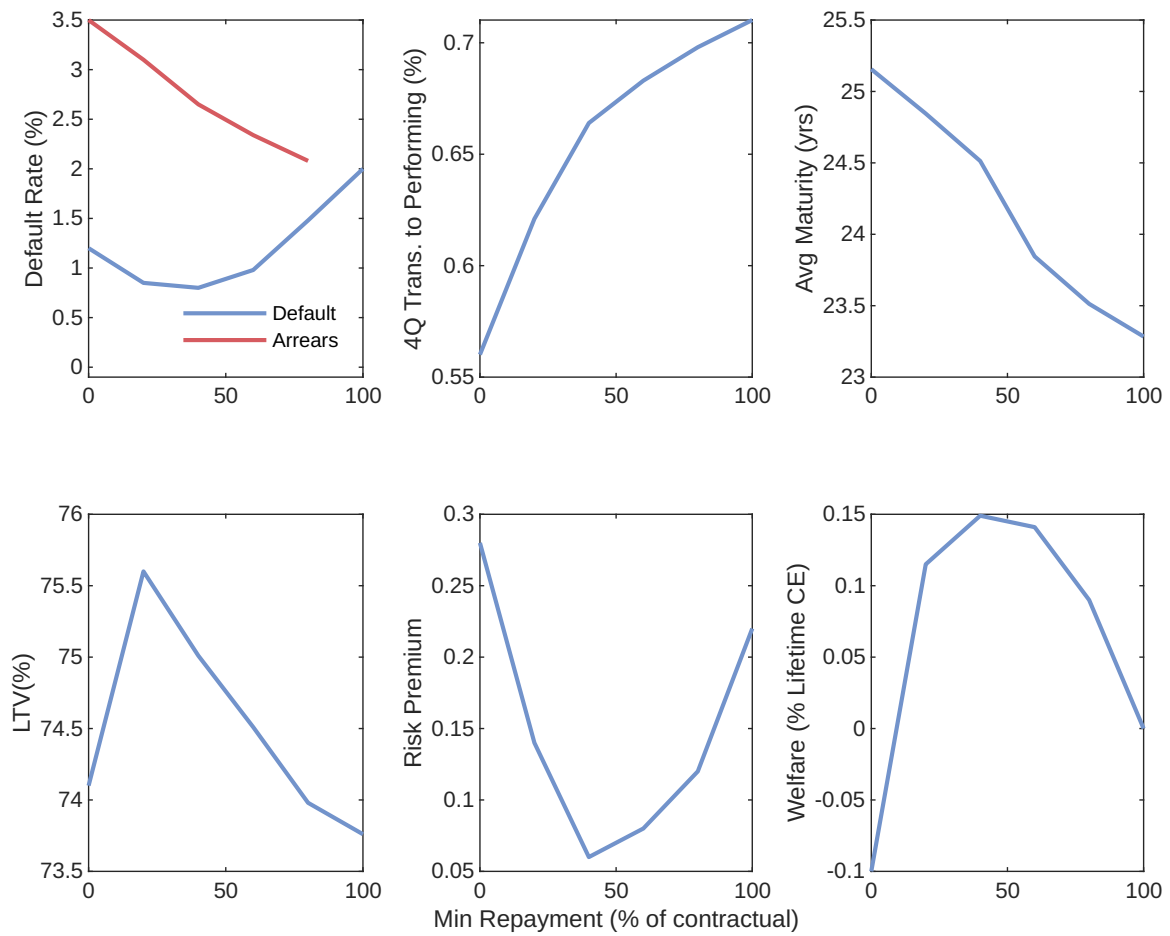


Fig. 2.28: Bank Thresholds and Equilibrium Outcomes

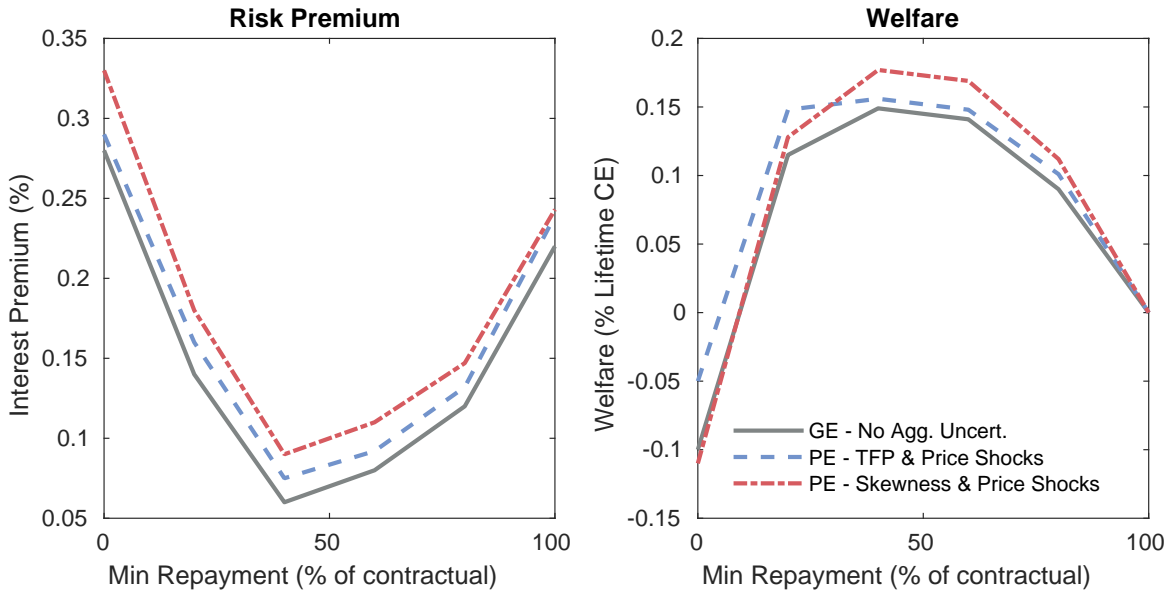


Fig. 2.29: Welfare Facing Different Shocks

would prove intractable due to the richness of the underlying model, Figure 2.29 tries to get at these concerns by comparing the risk premia and welfare gains in the general equilibrium-no aggregate uncertainty case, with two partial equilibrium exercises. Both partial equilibrium cases take prices as exogenous and stochastic. In particular, they assume that house prices follow an AR(1) process:

$$p_t^h = ap_{t-1}^h + (1-a)p_{SS}^h + \sigma^p u_t^p \quad (2.48)$$

where $u_t^p \sim N(0,1)$, σ^p and a are estimated on de-trended house price data from 1990-2019 and p^{SS} is the deterministic steady-state equilibrium price and guides the price back to the neighbourhood of the equilibrium price. The partial equilibrium cases differ based on the income risk they posit. In the case with TFP shocks, households wages are subject to standard productivity shocks from a TFP process estimated on Spanish national accounts data. In the case of the skewness shocks, the aggregate state evolves according to a two-state Markov chain between good times and bad times. In good times, households face idiosyncratic risk calibrated to the steady-state. In bad times, the income risk becomes skewed in the same manner as the crisis experiment above. I assume the probability of this event is one such crisis every 50 years. The results detailed in Figure 2.29 show that the basic pattern holds across these exercises.

2.9 Conclusion

This paper seeks to capture the reality of the process that leads to mortgage default and draw out the implications of this option as a means of consumption smoothing at both a household and aggregate level. It develops a framework for understanding why delinquency spells are so prominent and so lengthy. When included in a model of a housing market crisis, delinquency is shown to significantly attenuate the drop in consumption by affording household's the ability to insure themselves against income shocks.

Delinquency is closely connected to foreclosure as it is one of the alternatives for debt-distressed households and represents the outside option for banks. The paper shows that tougher foreclosure regimes are more likely to give rise to delinquency, while regimes that try to make the foreclosure process less painful for households end up pushing households towards it. Many of these results emerge from the structure of mortgage contracts. Banks have limited ability to adjust interest rates mid-loan so households can draw on a cheap credit line to smooth consumption. Banks try to prevent households from doing this, but in a crisis their threat to foreclose becomes less credible and households can exploit this.

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Appendix B

Appendix to Chapter 2

Appendix A: Data

The data for the stylised facts about delinquencies comes from the ECB RMBS dataset which covers the universe of securitised mortgages in these countries. Table B.1 summarises the data averages across several loan/household characteristics and compares the HFCS with loan-level dataset. The HFCS is a small but representative survey data set that is useful because it is comparable across European countries. Table B.1 compares the aggregate means across the Eurozone periphery and the means for Spain, in particular, since this is the country used for the quantitative exercise.

The comparison is broken out further for the loan-to-value ratios, maturities and interest rates in Figures B.1, B.2, B.3 respectively. The loan-to-value ratios match quite closely. The maturities and interest rates show some bunching at round numbers, particularly in the HFCS data. This is replicated quite closely in the RMBS data for the case of maturities. For interest rates, the RMBS data shows a smoother histogram with fewer and smaller spikes.

Other data used includes the Spanish Household Finances Survey (EFF), the ECB data warehouse for interest rates, the OECD, Bloomberg, the respective statistics offices of the four countries (CSO, INE(Spain), INE(Portugal) and Istat) as well as statistics from the relevant ministries of justice and, in the Spanish case, the Ministry for Transport, Mobility and Urban Agenda. Housing market data is taken from Idealista.

A valid concern is that because the RMBS data is not randomly sampled, it might not be representative. Plotting the histograms below should help to alleviate these concerns. However, we can address this concern in a more formal way by leveraging

the data from the HFCS to poststratify the RMBS data and obtain estimates that are more robust to the concern of non-random sampling. The idea is to partition the data into thousands of cells along demographic and loan characteristics, estimate our variables of interest at the cell-level and then aggregate the cell-level estimates in accordance with the target population's composition which we infer from the HFCS. See Little (1993) for a discussion of this.

The matched variables between the HFCS and the RMBS data are $X = \{\text{income, age, LTV, PTI, house value, maturity and interest}\}$. Breaking each of these into intervals gives us a total cell count of 7500. Within each cell, it's possible to form an estimate of the relevant moment, \hat{y}_j . The poststratification estimate for the population moment is defined by

$$\hat{y}^{PS} = \frac{\sum_{j=1}^J N_j \hat{y}_j}{\sum_{j=1}^J N_j}$$

where N_j is the size of the j th cell in the population.

Fortunately, the RMBS sample size is large enough that, in general, we don't have to worry too much about estimating the mean consistently. With this being the case, it is possible to estimate the population moment for that cell by taking the simple sample average. However, at least in principle, it can sometimes be possible for there to be too few observations in a given cell to form a consistent estimator. With this in mind, I also report the results of estimating the given moments by regressions. In this case, the estimate for y^j is the predicted value from a regression of $y_{i,j}$ on $X_{i,j}$. This resembles the so-called Multilevel Regression and Poststratification (MRP) approach common in non-representative surveys. See Wang et al. (2015) for a prominent example of this.

Table B.2 reports the results of the pure sample moments, the moments derived from poststratification only and the moments derived from poststratification plus estimating the cell level moments through regressions. Specifically, we can run regressions of the form

$$Y_i = f(X_i, \beta_j) + \epsilon_i$$

where Y_i is our outcome of interest. The functional form $f()$ is assumed linear for continuous variables and is assumed to be a logit for discrete variables. The β_j 's are allowed to vary by interval.

Table B.1: Sample Means

	HFCS	ECB RMBS
Eurozone Periphery		
Income	45318 (1570)	45612
Age	36.24 (0.98)	36.56
Loan-to-Value	0.8696 (0.0089)	0.8642
Loan-to-Income	3.28 (0.061)	3.28
Payment-to-Income	0.2128 (0.0055)	0.2125
House Value	110463 (2836)	111561
Maturity (years)	23.38 (0.1536)	23.75
Interest (p.p)	3.300 0.0488	3.284
Credit Score		901
Spain		
Income	52028 (2802)	45612
Age	38.12 (0.86.)	38.41
Loan-to-Value	0.9091 (0.0132)	0.8999
Loan-to-Income	3.42 (0.087)	3.41
Payment-to-Income	0.2229 (0.0075)	0.2231
House Value	135123 (5449)	137411
Maturity (years)	23.39 (0.2133)	23.41
Interest (p.p)	3.340 0.0505	3.307
Credit Score		895

Notes: Standard errors of HFCS sample means in parentheses. Credit score is only available for RMBS data. Scale is from 0-999. Experian define a 'Good' credit score as 881-999 and a 'Fair' credit score as 721-880.

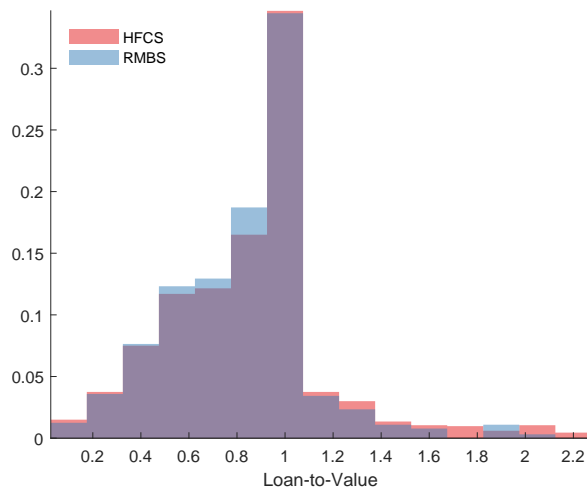
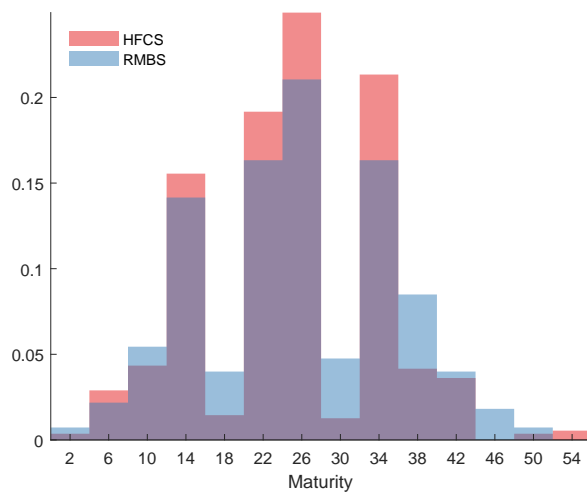
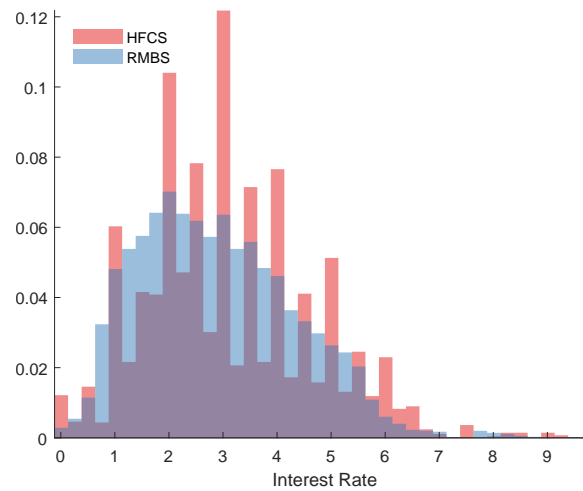


Fig. B.1: Histogram of Loan-to-Value Ratios



Note: Data is for Eurozone periphery. Figure plots the distribution of loan-to-value ratios at origination.

Fig. B.2: Histogram of Maturities



Note: Data is for Eurozone periphery. Figure plots the distribution of interest rates of loans originated in 2010.

Fig. B.3: Histogram of Interest Rates

Table B.2: Moment Estimates

Moment	Sample Moment	PS Only	PS and Regression
Peak Delinquency (%)	12.61 (0.24)	12.41 (0.35)	12.38 (0.38)
Transition Delinq. to Perf. (3 months)	0.341 (0.013)	0.356 (0.021)	0.352 (0.025)
Transition Delinq. to Forecl. (3 months)	0.071 (0.014)	0.073 (0.021)	0.061 (0.022)
Transition Delinq. to Perf. (12 months)	0.412 (0.012)	0.426 (0.020)	0.418 (0.022)
Transition Delinq. to Forecl. (12 months)	0.123 (0.014)	0.138 (0.019)	0.131 (0.021)
Mean Delinq. Spell (months)	10.47 (0.22)	12.10 (0.40)	12.03 (0.46)
Mean Time Delinq. to Forecl. (months)	25.01 (0.28)	23.56 (0.35)	22.43 (0.41)
Mean Arrears Balance After 20 Months	7.62 (0.31)	7.24 (0.42)	7.89 (0.56)

Note: Standard errors in brackets. Standard errors for sample moments assume the sample is representative. Standard errors for post-stratification assume cell-level moments are consistently estimated. Standard errors for PS and regression account for errors at the regression and aggregation steps. The mean arrears balance is reported as a percentage of the monthly repayment.

Appendix B: Algorithm

The model is initially solved in steady-state with no aggregate uncertainty under the assumption of a small open-economy. The price of a unit of housing p^h is a sufficient statistic for equilibrium in the housing and rental markets. The algorithm proceeds as follows:

1. Guess a value for p^h . In steady-state, this implies a value for rents p_t^r .
2. Solve the problem of a bank selling a foreclosed house. Store the value of foreclosure and the price list policy function.
3. Solve the household problem and store policy functions over housing choices and list prices.
4. Solve the construction firm's problem to derive supply of new housing.
5. Use the results from steps 2-4 to calculate \mathbb{D}_t and \mathbb{S}_t from equations 2.39 and 2.42 in the text.
6. If $|\mathbb{D}_t(p_t^h) - \mathbb{S}_t(p_t^h)| < \epsilon$ stop. Otherwise, if $\mathbb{D}_t(p_t^h) > \mathbb{S}_t(p_t^h)$ increase the guess for p^h and begin again. If $\mathbb{D}_t(p_t^h) < \mathbb{S}_t(p_t^h)$ decrease it.

For the transitions path to the shock we can proceed in a similar spirit by guessing a path in response to the shock, solving the problem conditional on that path and deriving the distance from equilibrium in each period. Then update the entire price path in the relevant direction and begin again.

Appendix C: Further Model Equations

C.1: The Minimum Repayment

The repayment equation is the standard annuity formula. It is derived as follows: Start with a level of debt at age τ . Debt at the beginning of the next period is $a_{\tau+1} = (1 + r^m)a_\tau - M_\tau$. Iterating forward:

$$\begin{aligned} a_{\tau+1} &= (1 + r^m)a_\tau - M_\tau \\ a_{\tau+2} &= (1 + r^m)^2 a_\tau - (1 + r^m)M_\tau - M_{\tau+1} \\ &\vdots \\ a_{\tau+N} &= (1 + r^m)^{N-\tau} a_\tau - \sum_{i=0}^{N-1} (1 + r^m)^i M_{\tau+N-1-i} \end{aligned}$$

Now we can impose $a_{\tau+N} = 0$ and $M_{\tau+1} = M_\tau = M$ to ensure that debt is paid off by period N and the per period payment is constant. Using the formula for finite geometric series:

$$a_{\tau+N} = (1 + r^m)^N a_\tau + \frac{1 - (1 + r)^{N-1}}{r} M = 0$$

and solving for M

$$M = \frac{r(1 + r)^{N-1}}{(1 + r)^{N-1} - 1} a_\tau$$

The constraint that debt must be paid off by the end of life amounts to setting $N = T - \tau + 1$. Dividing both sides by a_t gets us the equation in the text.

C.2: Welfare

Estimates of welfare losses along transitions are complicated in lifecycle models by the fact that households are of different ages when they enter a crisis. So it is not obvious how to compensate a household with lifetime consumption equivalents. Rather than attempt to compensate households across lives of varying remaining lengths, I choose the simple approach of Hur (2018) and others in using the one-period consumption equivalent. This is defined as the fraction of consumption $g_{t_0}^\tau$ that I need to give to an agent in period t_0 if they are of age τ given that a crisis hits

at period t . We find this by solving for $g_{t_0}^\tau$ in the following equation:

$$u(c_{t_0}^\tau(p_{t_0}^h)(1 + g_{t_0}^\tau)) + \mathbb{E}_{t_0} \sum_{t=t_0+1}^{T-\tau} \beta^t u(c_t^{\tau+t-t_0}(p_t^h)) = \mathbb{E}_{t_0} \sum_{t=t_0}^{T-\tau} \beta^t u(c_t^{\tau+t-t_0}(p_{ss}^h))$$

where this equation uses the fact that house prices p^h are a sufficient statistic for the aggregate state.

Appendix D: Further Quantitative Results

D.1: TFP Shock

Figure B.4 shows the evolution of a crisis by a TFP shock instead of a skewness shock. The TFP shock is calibrated to achieve the same drop in total incomes as the skewness shock. However, in this case it is evenly distributed across the population rather than concentrated in a select group of unlucky individuals. All of the responses are substantially smaller as households are able to accommodate the shock by running down savings and cutting consumption more moderately. In particular, far fewer houses are forced to sell and the drop in sales is extremely mild.

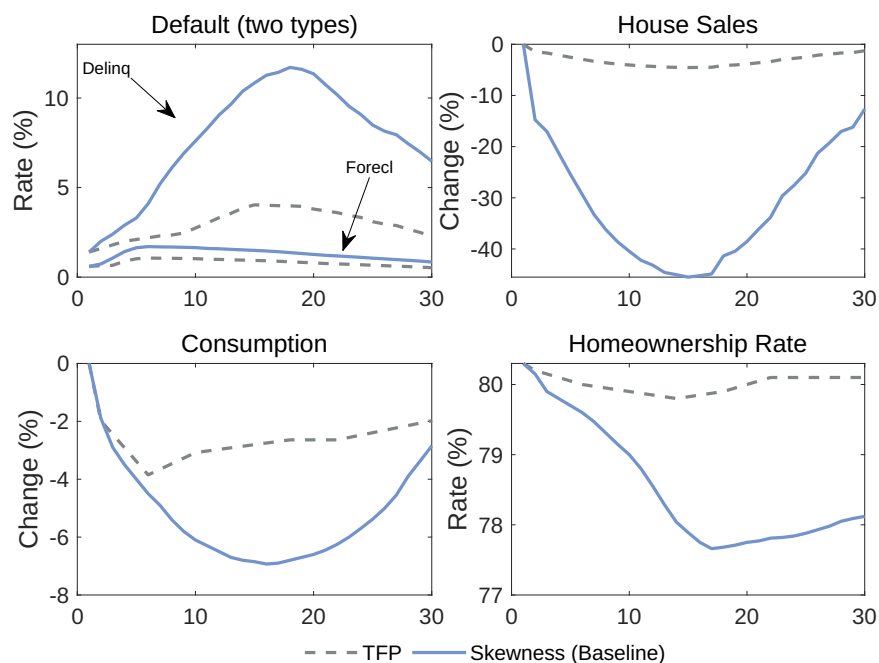


Fig. B.4: Crisis With TFP Shock Instead of Skewness Shock

D.2: Decomposing the Crisis Drivers

The economy is pushed into a crisis with two separate shocks: (i) the skewness shock, (ii) the credit shock in the form of tighter LTV ratio. Figure B.5 compares the combined effect with the case of just hitting the economy with the skewness shock. The result is a crisis that is almost as severe as the case with both shocks simultaneously. This suggests that of the two shocks, it is the credit shock that is doing most of the heavy lifting.

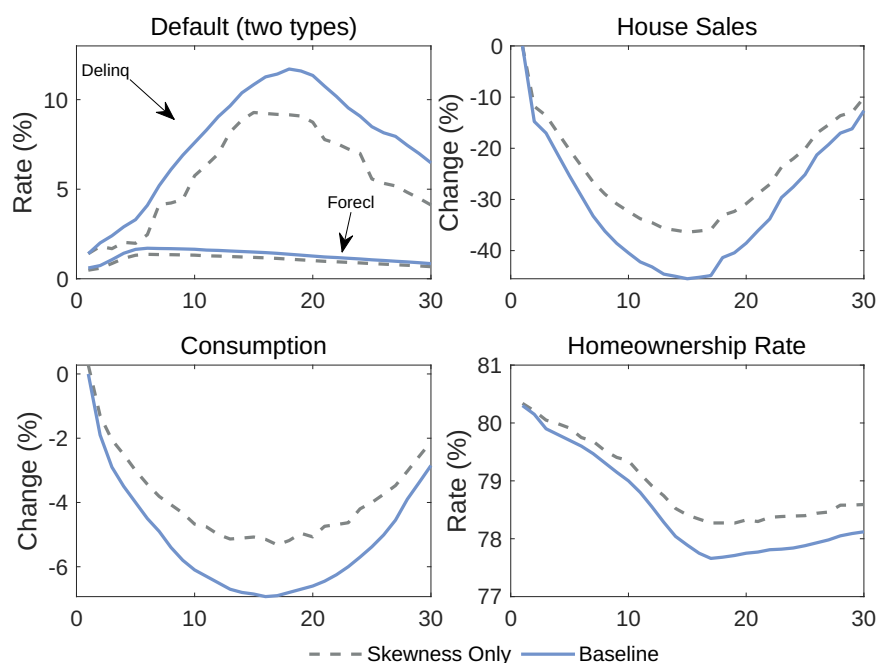


Fig. B.5: Crisis With Only Skewness Shock

D.3: Varying the Length of the Crisis

The length of time for which Spanish employment was falling was exceptionally long at 18 quarters. To get a sense of the significance of the length, I show the case of a shock that lasts for only 12 quarters. The results are plotted in Figure B.6 As expected, the crisis is less severe but it is disproportionately so. This suggests the size of the crisis is non-linear in its length.

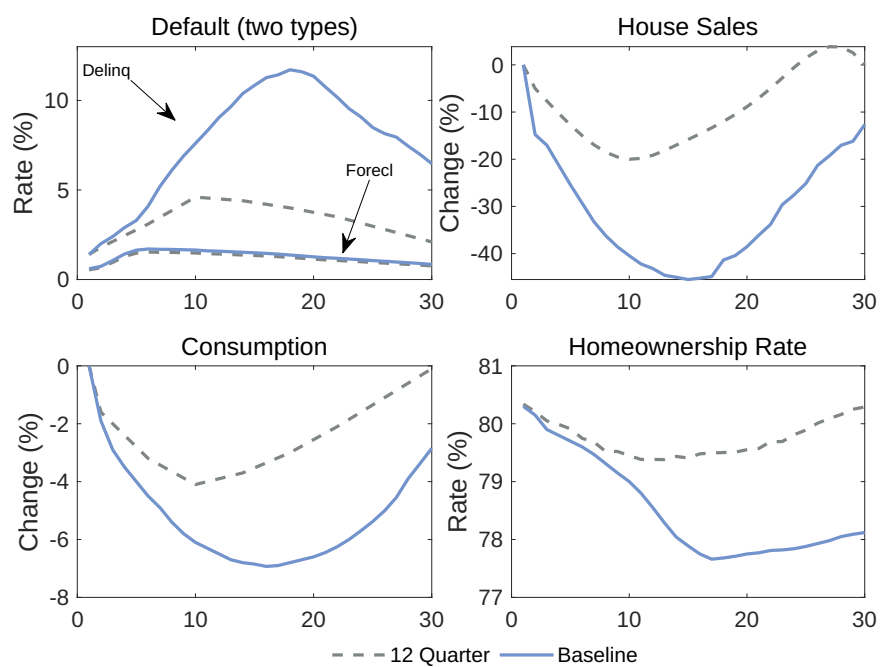


Fig. B.6: Changing the Persistence of the Shock

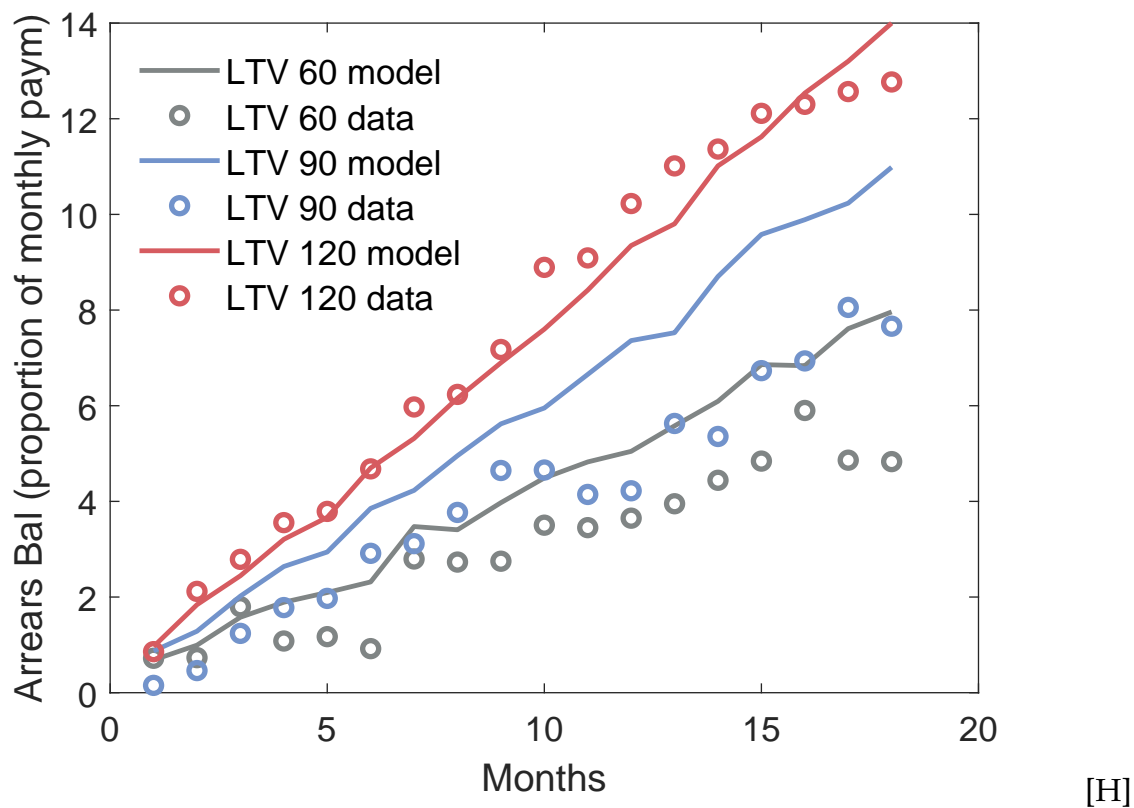


Fig. B.7: Arrears Balances by Months in Arrears

D.5: Some Extra Model Fits

This section shows how average arrears balances change by number of months in arrears (Figure B.7) and by loan-to-value ratio (Figure B.8) and compares the model with the data.

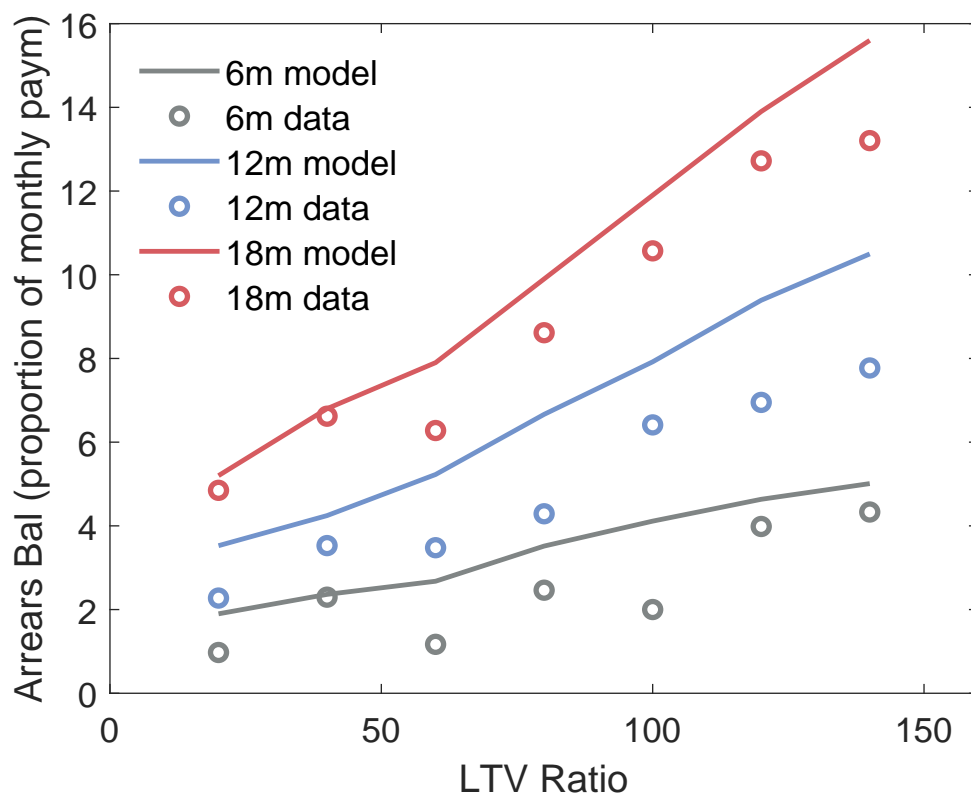


Fig. B.8: Arrears Balances by LTV

[H]

D.5: Recalibrating the Foreclosure Only Case

Table B.3: Recalibrated Parameter Values.

Externally Calibrated			
Parameter	Value	Description	Source/Reason
σ	2	Intertemp. subst.	Standard
δ^h	0.005	Housing maintenance costs	Spanish Ministry of Finance
α	0.6667	Labour share in production	Standard
κ	0.3	Max price list discount	Bloomberg
r	0.485	Deposit rate (annual %)	Real ECB policy rate
r_t^m	1.711	Mortgage rate (annual %)	ECB MIR
χ	0.007	Delinquency penalty	Min. to discourage delinq.
Internally Calibrated			
β	0.9871	Discount factor	Net Wealth (EFF data)
ζ	0.0159	Pref. for ownership	Homeownership Rate (EFF)
A^h	0.2234	Housing production	Price-to-Income Ratio (INE)
ψ	0.6102	Operating cost of rental company	Price-to-Rent Ratio
ϕ	0.0082	Adj. cost for rental company	$Corr(p_t^h, p_t^r)$
γ	0.653	Match function	Time on Market (Idealista)
θ	0.0512	Time in default	Left unchanged
Γ^u	0.9137	Non-pecuniary forecl. cost	Foreclosure Rate
Δ	0.2183	Bank loss on forecl.	Left unchanged

Table B.3 shows the parameters that result from recalibrating the model to not allow delinquency. The goal is to allow the model to do an adequate job at replicating foreclosure rates in steady-state even without delinquency. Since two of the parameters were targeting moments related to delinquency, I leave two moments unchanged and recalibrate on the remaining subset. The resulting fit is shown in Table B.4 with a comparison to the non-recalibrated baseline with delinquencies off. The recalibrated version does slightly better in steady-state but the non-calibrated version is still quite similar to the baseline calibration in the main text.

Figure B.9 shows the results of doing the decomposition of consumption in the Foreclosure Only case after recalibrating. As can be seen, the responses are qualitatively the same as Figure 2.16 in the text and are quantitatively very similar. In many ways this is unsurprising as the calibration is designed to target the low

level of foreclosure in steady state. The recalibration does not require wholesale change of parameter values and so the responses are substantially the same.

Table B.4: Recalibrated Fit on Targeted Moments

Moment	Recalib. Model	Non-Recalib. Model	Empirical
Median Net Wealth-to-Income	4.60	4.71	4.53
Homeownership Rate (%)	80.2	79.5	80.6
Price-to-Income Ratio	5.95	5.95	6.10
Price-to-Rent Ratio	13.11	13.11	13.11
Time on the Market (quarters)	1.67	1.69	1.67
Foreclosures (% , annual)	0.33	0.41	0.31
$Corr(p^h, p^r)$	0.88	0.88	0.88

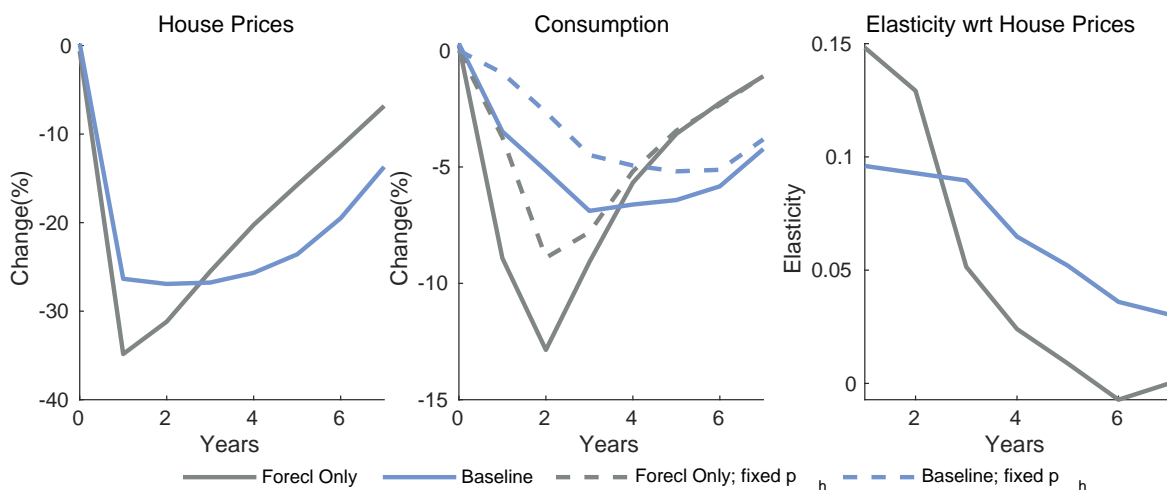


Fig. B.9: Consumption and House Prices With Recalibrated Foreclosure Only

D.6: Recalibrating the Non-Recourse Case

Table B.5: Recalibrated Parameter Values.

Externally Calibrated			
Parameter	Value	Description	Source/Reason
σ	2	Intertemp. subst.	Standard
δ^h	0.005	Housing maintenance costs	Spanish Ministry of Finance
α	0.6667	Labour share in production	Standard
κ	0.3	Max price list discount	Bloomberg
r	0.485	Deposit rate (annual %)	Real ECB policy rate
r_t^m	1.711	Mortgage rate (annual %)	ECB MIR
χ	0.007	Delinquency penalty	Min. to discourage delinq.
Internally Calibrated			
β	0.9879	Discount factor	Net Wealth (EFF data)
ζ	0.0165	Pref. for ownership	Homeownership Rate (EFF)
A^h	0.2234	Housing production	Price-to-Income Ratio (INE)
ψ	0.6102	Operating cost of rental company	Price-to-Rent Ratio
ϕ	0.0082	Adj. cost for rental company	$Corr(p_t^h, p_t^r)$
γ	0.653	Match function	Time on Market (Idealista)
θ	0.0488	Time in default	Left unchanged
Γ^u	0.9864	Non-pecuniary forecl. cost	Foreclosure Rate
Δ	0.2191	Bank loss on forecl.	Left unchanged

Table B.5 shows the parameters that result from recalibrating the model to the case where the level of recourse is adjusted to $b = 0.1$ case. The resulting model fits are shown in Table B.6. Similar to the Foreclosure Only case, the moments when we don't recalibrate are not so different from their empirical counterparts. Only the foreclosure rate shows a concerning departure from the value found in the data. The recalibration is able to bring this back into line.

Figure B.10 shows the impulse responses to the crisis when $b = 0.1$ case is recalibrated vs. when it isn't. As can be seen, the responses are qualitatively the same as the equivalent figure in the main text and are quantitatively very similar. In many ways this is unsurprising as the calibration is designed to target the low level of foreclosure in steady state. The recalibration does not require wholesale change of parameter values and so the responses are substantially the same.

Table B.6: Recalibrated Fit on Targeted Moments

Moment	Recalib. Model	Non-Recalib. Model	Empirical
Median Net Wealth-to-Income	4.63	4.78	4.53
Homeownership Rate (%)	80.6	80.6	80.6
Price-to-Income Ratio	5.95	5.95	6.10
Price-to-Rent Ratio	13.11	13.11	13.11
Time on the Market (quarters)	1.67	1.68	1.67
Foreclosures (% annual)	0.35	0.47	0.31
Delinquency Rate (%)	1.94	1.95	1.94
$Corr(Delinq., Forecl.)$	0.88	0.68	0.84
$Corr(p^h, p^r)$	0.88	0.88	0.88

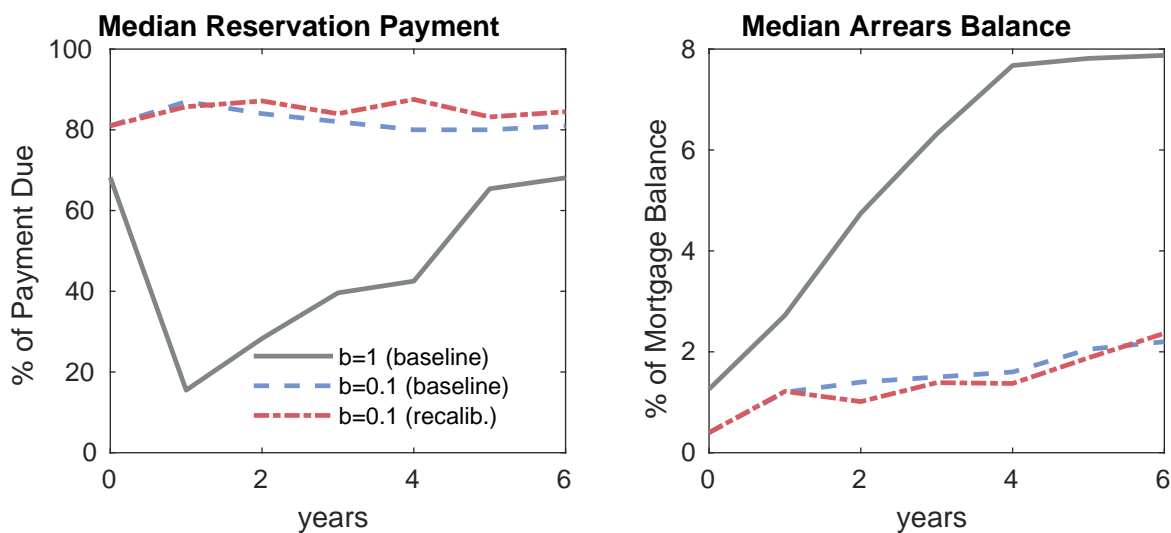


Fig. B.10: Recourse and Non-Recourse With Recalibration

D.4: Recalibrating the Repricing Case

Table B.7: Recalibrated Parameter Values.

Externally Calibrated			
Parameter	Value	Description	Source/Reason
σ	2	Intertemp. subst.	Standard
δ^h	0.005	Housing maintenance costs	Spanish Ministry of Finance
α	0.6667	Labour share in production	Standard
κ	0.3	Max price list discount	Bloomberg
r	0.485	Deposit rate (annual %)	Real ECB policy rate
r_t^m	1.711	Mortgage rate (annual %)	ECB MIR
χ	0.007	Delinquency penalty	Min. to discourage delinq.
Internally Calibrated			
β	0.9896	Discount factor	Net Wealth (EFF data)
ζ	0.0151	Pref. for ownership	Homeownership Rate (EFF)
A^h	0.2234	Housing production	Price-to-Income Ratio (INE)
ψ	0.6102	Operating cost of rental company	Price-to-Rent Ratio
ϕ	0.0082	Adj. cost for rental company	$Corr(p_t^h, p_t^r)$
γ	0.653	Match function	Time on Market (Idealista)
θ	0.0512	Time in default	Left unchanged
Γ^u	0.8411	Non-pecuniary forecl. cost	Foreclosure Rate
Δ	0.2183	Bank loss on forecl.	Left unchanged

Table B.7 shows the parameters that result from recalibrating the model in the case where banks intermittently reprice loans. The resulting fit is shown in Table B.8 with a comparison to the non-recalibrated baseline with repricing. In keeping with the conclusion in the paper that repricing makes very little difference, recalibrating the model for this case makes very little difference.

Figure B.11 shows the results of the impulse responses for the repricing case after recalibrating. Once again, it is reassuring to see that the recalibration makes almost no difference whatsoever.

Table B.8: Recalibrated Fit on Targeted Moments

Moment	Recalib. Model	Non-Recalib. Model	Empirical
Median Net Wealth-to-Income	4.61	4.68	4.53
Homeownership Rate (%)	80.2	80.4	80.6
Price-to-Income Ratio	5.98	5.96	6.10
Price-to-Rent Ratio	13.11	13.11	13.11
Time on the Market (quarters)	1.67	1.68	1.67
Foreclosures (% , annual)	0.34	0.37	0.31
Delinquency Rate (%)	2.01	1.98	1.94
$Corr(Delinq., Forecl.)$	0.86	0.78	0.84
$Corr(p^h, p^r)$	0.88	0.88	0.88

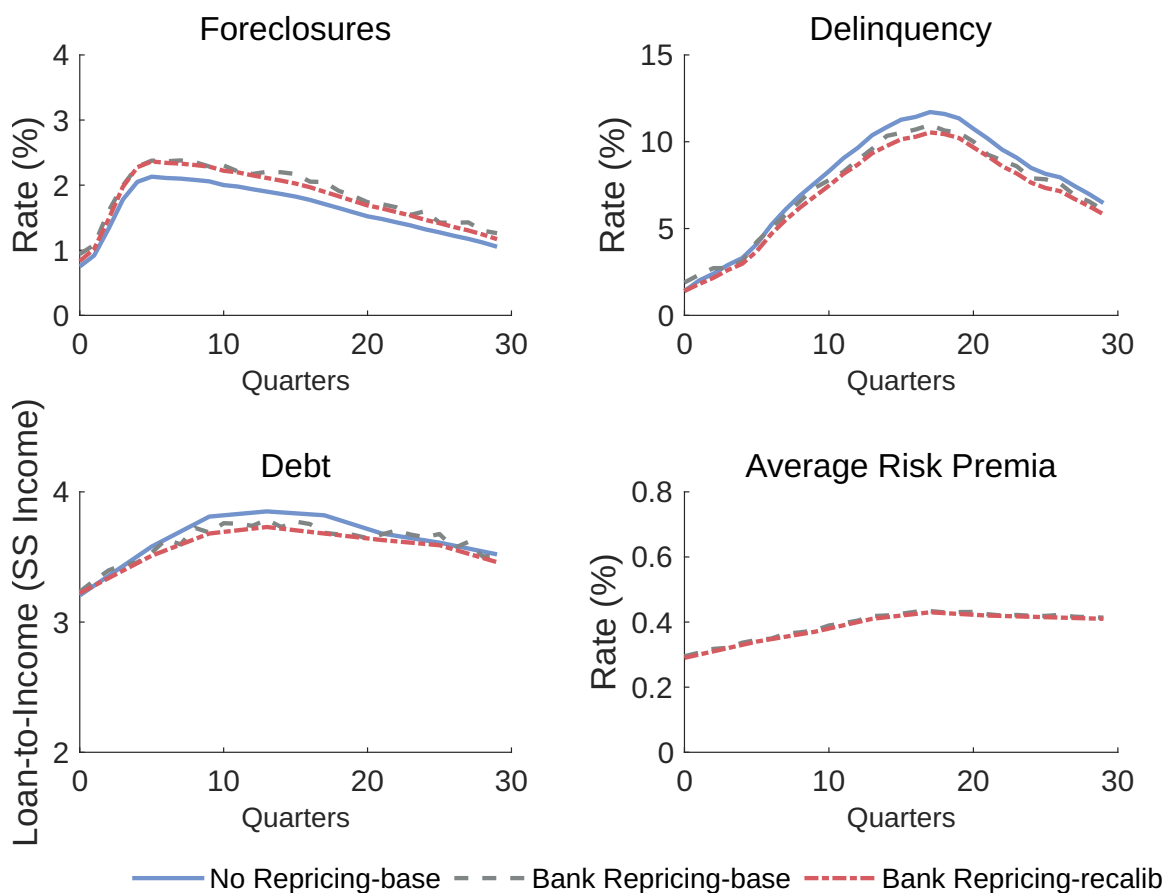


Fig. B.11: Recourse and Non-Recourse With Recalibration

Appendix E: A Simple 2-period model

In the main paper, I show quantitatively how the bank's willingness to credit ration a household through a reservation payment moves with household income, collateral values and the strenght of the bank's recourse rights. Here, I show a very simply two period model that shows the same results analytically.

Consider a household and bank who begin the period $t = 1$ having contracted mortgage debt a_1 secured on a house at interest rate r and minimum repayment schedule m . Let the household's endowments be given by: y_1 and $y_2 = \rho y_1 + (1 - \rho)\bar{y} + \epsilon$, where $\epsilon \sim G(\epsilon)$. Here, $G(\epsilon)$ is the cdf of the i.i.d. process ϵ . The problem for the household is how much of the repayment effort do they undertake in period 1 vs. period 2.

From this, we have that the budget constraint for the household in $t = 1$ and $t = 2$ is:

- BC $t = 1$: $c_1 = y_1 - ma_1$ if repayment and $c_1 = y_1 - \alpha y_1$ if default
- BC $t = 2$: $c_2 = y_2 - (1 + r)(1 - m)a_1$ if repayment and $c_2 = y_2 - \alpha y_2$ if default

In these expressions α is the rate of wage garnishment/default penalty the household is subject to after foreclosure. This household's default rule is then to enter foreclosure at $t = 2$ if

$$u(y_2 - (1 + r)(1 - m)a_1) < u(y_2 - \alpha y_2)$$

From this we can derive the income cutoff threshold,

$$\tilde{y}_2 = \frac{(1 + r)(1 - m)a_1}{\delta}$$

From the standpoint of period 1, the probability that the household forecloses at $t = 2$ is:

$$P(\text{forecl in } t = 2) = P(\epsilon < \tilde{y}_2 - (1 - \rho)\bar{y} - \rho y_1) = G(\tilde{\epsilon})$$

where $\tilde{\epsilon} = \tilde{y}_2 - (1 - \rho)\bar{y} - \rho y_1$.

Some very intuitive results about this probability can now be drawn out. Firstly, the probability of foreclosure at period 2 is decreasing in the amount of effort the household puts into repayment in period 1: $\frac{\partial}{\partial m} G(\tilde{\epsilon}) < 0$. In essence, this is the core tension at the heart of this model, a household with low y_1 will want to pay less at $t = 1$ but by doing so, they become a greater credit risk for the bank.

Another simple result is that the more persistent the income process is, the greater the credit risk a household with low income today is: $\frac{\partial}{\partial \rho} G(\tilde{\epsilon}) = (\bar{y} - y_1)G'(\cdot)$, which is negative for incomes below \bar{y} . If persistence was 0, poor households today would not be perceived as greater credit risks tomorrow. Finally, the greater the level of recourse/garnishment, the lower the likelihood of foreclosure: $\frac{\partial}{\partial \delta} G(\tilde{\epsilon}) < 0$.

Now consider the problem of the bank. If the household chooses $m < \underline{m}$, the bank gains the right to foreclose. The expected profits of the bank in period 1 are given by:

$$Q_1 = \begin{cases} \delta y_1 + \beta \mathbb{E}[\delta y_2] + (1 - \Delta)p_1^h, & \text{if foreclose at } t = 1 \\ ma_1 + \beta \left[G \mathbb{E}[\delta y_2 + (1 - \Delta)p_2^h | \epsilon < \tilde{\epsilon}] + (1 - G)(1 + r)(1 - m)a_1 \right], & \text{if tolerate} \end{cases}$$

The top case represents the profits of foreclosing now, composed of wage garnishments in both periods plus the value of the house, adjusted for foreclosure costs Δ . The bottom line is the profits from tolerating $m < \underline{m}$ and risking a foreclosure next period with probability $G(\tilde{\epsilon})$.

The threshold at which the bank prefers to foreclose at $t = 1$ is thereby given by:

$$m^{res} a_1 + \beta \left[G \mathbb{E}[\delta y_2 + (1 - \Delta)p_2^h | \epsilon < \tilde{\epsilon}] + (1 - G)(1 + r)(1 - m^{res})a_1 \right] = \delta y_1 + \beta \mathbb{E}[\delta y_2] + (1 - \Delta)p_1^h$$

If $m^{res} \geq \underline{m}$, no delinquency will be tolerated. If $m^{res} < \underline{m}$ there will be scope for delinquency. An obvious result coming from this is that this reservation payment is increasing in p_1^h :

$$\frac{\partial m^{res}}{\partial p_1^h} = \frac{(1 - \Delta)}{L} > 0$$

where $L > 0$ is a lengthy expression.¹ This happens because low p_1^h lowers the bank's incentive to foreclose today and so the compensation needed to make them indifferent between toleration and foreclosure is necessarily lower.

¹ $L = \frac{a_1}{\delta} G'(\tilde{\epsilon}) [(1 + r - m)a_1 - \delta \tilde{y}_2 - (1 - \Delta)p_2^h] + a_1(1 - \beta(1 - G(\tilde{\epsilon}))$

How things change with respect to income is perhaps less obvious. The partial derivative is given by:

$$\frac{\partial m^{res}}{\partial y_1} = \frac{1}{L} \left\{ \underbrace{\delta + \beta \delta \rho}_{\substack{\text{Higher} \\ \text{wage} \\ \text{garnish} \\ \text{Forecl.} \\ \text{at } t=1}} - \beta \left[\underbrace{\rho G'(\tilde{\epsilon})}_{\substack{\Delta \text{prob.} \\ \text{Forecl.}}} \underbrace{((1+r)(1-m)a_1)}_{\substack{\text{Debt} \\ \text{repayment}}} - \underbrace{(\delta \tilde{y}_2 + (1-\Delta)p_2^h)}_{\substack{\text{Recovery in} \\ \text{case of forecl.}}} \right] + \underbrace{G(\tilde{\epsilon})\rho\delta}_{\substack{\text{Higher} \\ \text{wage} \\ \text{garnish} \\ \text{Forecl.} \\ \text{at } t=2}} \right] \right\} \geq 0$$

Higher prob. payment
×
Relative Gain of Repayment

The first under-bracketed term is the change in the gain from foreclosure which is increasing in y_1 because the bank can now garnish a higher income. In reality, a bank should expect to recover more from a household that defaults when relatively wealthy. The second term - in square brackets - is the change in the gain from tolerating delinquency. It comes from two sources: (i) the higher probability of repayment times the relative gain from being repaid at $t = 2$ rather than foreclosing at $t = 2$; (ii) the fact that if the household does enter foreclosure at $t = 2$, the bank will still be able to garnish their higher incomes then as well.

So both the gains to foreclosure and the gains to tolerating delinquency are increasing in y_1 . Which one dominates is ambiguous in this stylised model. However, in the quantitative model in the text, it is clear that higher y_1 actually leads to lower m^{res} . Intuitively, this means banks will be more tolerant to households with higher incomes entering delinquency.

Finally, there is a similar story for changing the rate at which recourse/garnishment effect m^{res} :

$$\frac{\partial m^{res}}{\partial \delta} = \frac{1}{L} \left\{ \underbrace{y_1 + \beta \rho \mathbb{E} y_2}_{\substack{\text{Higher} \\ \text{wage} \\ \text{garnish} \\ \text{Forecl.} \\ \text{at } t=1}} - \beta \left[\underbrace{\frac{\partial \tilde{\epsilon}}{\partial \delta} G'(\cdot)}_{\substack{\Delta \text{prob.} \\ \text{Forecl.}}} \underbrace{a_2}_{\substack{\text{Debt} \\ \text{repayment}}} - \underbrace{(\delta \tilde{y}_2 + (1-\Delta)p_2^h)}_{\substack{\text{Recovery in} \\ \text{case of forecl.}}} \right] + \underbrace{G \rho \mathbb{E}[y_2]}_{\substack{\text{Higher} \\ \text{wage} \\ \text{garnish} \\ \text{Forecl.} \\ \text{at } t=2}} \right] \right\} \geq 0$$

Higher prob. payment
×
Relative Gain of Repayment

This equation is almost identical. Again, the net effect is ambiguous. Again, the quantitative model suggests the direction is $\frac{\partial m^{res}}{\partial \delta} < 0$. This results is coming from the fact that the change in the probability of foreclosure in the next period is sufficiently large that it outweighs the relative gains from foreclosing now.

Appendix F: Interest Rate Resetting and Delinquency

The below table shows the case of regressing the interest rate spread on a series of controls and a dummy term for when an interest rate reset has occurred while an account is in delinquency. The estimates suggest that undergoing a reset while the account is delinquent is associated with a 0.3p.p. upward revision in the interest rate. While this is statistically significant is relatively modest and should be contrasted with the explosive interest rate spreads in other debt markets.

Table B.9: Estimate of effect of interest rate resets on spreads

VARIABLES	(1) Interest Spread	(2) Interest Spread	(3) Interest Spread	(4) Interest Spread
Delinquent	0.12367* (0.06311)	0.05491 (0.04312)	0.05132 (0.049822)	0.058464 (0.041235)
Reset	0.0224*** (0.00130)	0.0218*** (0.00129)	0.0235*** (0.00354)	0.0236*** (0.00368)
Reset x Delinquent	-	0.3181*** (0.00327)	-	0.28641*** (0.00386)
Credit Rating	-	-	-7.77e-04*** (5.50e-05)	-8.84e-4*** (6.98e-06)
Maturity	0.00224*** (0.000130)	0.00218*** (0.000129)	0.00221*** (0.000131)	0.00215*** (0.000135)
LTV	0.00307*** (2.11e-04)	0.00507*** (2.03e-04)	0.00477*** (5.50e-04)	0.00479*** (5.53e-04)
Age	-0.000785*** (0.000271)	-0.000742*** (0.000275)	-0.000691*** (0.000326)	-0.000709*** (0.000375)
Constant	1.8612*** (0.51884)	1.8031*** (0.61251)	1.7984*** (0.83237)	1.7951*** (0.83797)
Observations	1,293,317	1,293,317	491,648	491,648
R-squared	0.165	0.168	0.181	0.190
Time FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

It is worth noting that in this context resets refer to changes in the spread - not simply variations due to changes in the base rate. As such, it reflects changing premia, rather than changing macro conditions unrelated to the individual account.

Chapter 3

Consumer Loans, Heterogeneous Interest Rates, and Inequality

This chapter is the product of joint work with Tiago Cavalcanti, Amanda Fantinatti and Cezar Santos

Abstract

Using the Brazilian administrative credit registry data with the universe of all consumer loans originated by banks in the country from 2013 to 2019, the chapter documents high borrowing interest rates, which vary systematically with individual characteristics. In particular, even after controlling for several observable individual attributes - such as income, debt, occupation, and default probabilities, low-income individuals pay higher interest rates than high-income borrowers. We quantitatively analyze a consumer credit market with these characteristics observed in Brazil in a model with endogenous default, and where consumers face idiosyncratic income and expenditure shocks. We perform counterfactual analyses to assess the impact of different financial reforms on borrowing rates, consumption inequality, consumption insurance, and welfare. We find that reforms aiming to reduce intermediation costs and bank market power have sizeable average and distributional welfare implications.

3.1 Introduction

Financial intermediaries such as banks play a critical role in the economy by connecting those seeking to borrow with those seeking to save, improving the allocation

of resources with consequences for efficiency and welfare. Consequently, consumer credit is key to allow individuals to smooth consumption over time when they face uninsurable idiosyncratic income risk. Credit markets in developing countries are characterized by high and dispersed borrowing interest rates (e.g., Banerjee, 2003, Banerjee and Duflo, 2010). Expensive credit may hinder the ability of individuals to smooth their consumption.

Using the *Brazilian Public Credit Register*, which is a confidential loan level data set, covering all unsecured credit operations in Brazil from January 2012 to December 2019 and linked with the *Brazilian matched employer-employee data set (RAIS)*, we document several features of the Brazilian credit market. We focus on two types of loans, which account for more than 80% of all unsecured consumer loans in Brazil. They are the unsecured personal loans, available to all individuals; and payroll loans, consisting of personal loans for which the principal and interest payments are directly deducted from the borrower's payroll check. The later is mainly available for civil servants and retired individuals. Average interest rates are substantially higher for personal loans than for payroll loans (personal loan interest rates are 5 times larger on average) and the former is much more dispersed than the later (the standard deviation for personal loan interest rates is 16 times that of payroll loan interest rates).

For both types of loans, we show that interest rates vary systematically with an individual's characteristics. In particular, even after controlling for loan characteristics (e.g., maturity and loan size), several observable individual attributes (e.g., income, age, gender, race, occupation and financial literacy), and default probabilities, low-income individuals pay higher interest rates than high-income borrowers. Our analysis suggests that a large part of interest rate spreads are not explained by individual characteristics and the risk of the credit operation. We then calculate a risk-cost free rate by subtracting from the realized interest rate the expected cost of default, assuming a conservative zero recovering rate. We report the interest rate wedge which is the realized interest rate minus the risk-cost free rate. For individuals earning 1-2 minimum wages the interest rate wedge is approximately twice (78p.p.) the wedge of individuals earning more than 20 minimum wages for personal loans (40p.p.). For payroll loans the the wedge is about 18.5 percentage points for individuals earning 1-2 minimum wages and 16 percentage points for those earning more than 20 minimum wages. Default rates is about 3 times large for personal loans (6p.p.) than for payroll loans (2p.p.).

The chapter then develops a standard life-cycle incomplete markets economy with unsecured debt and equilibrium default in which individuals are subject to income shocks and can work in the formal, informal or public sectors. After reaching the retirement age they receive a constant pension. Individuals can save and borrow to smooth income shocks. When they borrow, individuals face different interest rates, which correlate negatively with their income. We calibrate and estimate model parameters using our rich micro datasets such that the model replicates debt-income ratio, defaults and interest rate spreads as those observed in Brazil. The chapter performs counterfactual analyses to assess the impact of different financial reforms on borrowing rates, consumption smoothing and welfare. Investigating a financial reform (Resolution n^o 4,292, from December 20, 2013), which facilitated consumers' credit portability in Brazil and exploring local bank concentration at the municipality level, we show that this reform had an important impact on loan interest rate spreads and on welfare.

Related Literature The contribution here is both the empirics and quantitative model. Empirically, we first document new facts about unsecured consumer loans in a developing economy using detailed credit register data. The fact that spreads are large, vary systematically with individual characteristics, and cannot be explained by default probabilities are overlooked in the macro/default literature. We then extend a standard model with unsecured debt and equilibrium default (e.g., Athreya et al., 2012, Chatterjee et al., 2007*b*, Livshits et al., 2007, 2016) in ways consistent with our data and perform several policy evaluations.

Recent papers have focused their attention on heterogeneity in returns to financial and physical capital (see Benhabib et al., 2011, Benhabib and Bisin, 2018, Gabaix et al., 2016). Heterogeneity in returns does not arise merely from differences in wealth allocation between safe and risky assets: returns are heterogeneous even within asset classes and positively correlate to wealth (Fagereng et al., 2020). We also study heterogeneity in interest rates but focusing on borrowing rates instead. We show that there are extremely high levels of heterogeneity on borrowing rates using the Brazilian credit market data and assess its consumption and welfare implications in an otherwise standard model of consumption smoothing with idiosyncratic shocks.

A different strand of the literature focuses on dispersion in borrowing rates from the firm's perspective. Gilchrist et al. (2013) provide evidence on dispersion in borrowing costs among large (Compustat) firms in the United States. Bai et al. (2018) report similar evidence for Chinese firms whereas Banerjee (2003) and Banerjee

and Duflo (2005, 2010) document that this is a pervasive characteristic of credit markets in developing countries. Cavalcanti et al. (2021) report substantial variation in financing costs for firm-level credit in Brazil and show that such variation has important effects on firm dynamics and development. We contribute to this literature on dispersion in borrowing costs by focusing on consumer loans in a credit market for a developing economy (Brazil) and analyze the welfare implications of this dispersion.

3.2 Empirical Analysis

The analysis focuses on Brazil, where we have access to loan-level data. The primary dataset is the Brazilian Central Bank's credit registry (SCR), which provides comprehensive information on unsecured consumer loans including interest rates, loan amounts, credit risk scores, non-performing amounts, and maturity; as well as personal characteristics like income, occupation, gender, among others. Additionally, we supplement our analysis with data from the Brazilian matched employer-employee dataset (RAIS). Further information on our data sources and on the definition of the variables used in our empirical analysis can be found in Appendix C.1. Our research makes use of a representative sample of 1.3 million individuals who are followed monthly from January 2013 to December 2019.

Our investigation is concentrated on two categories of unsecured consumer loans: personal loans and payroll loans, which together represent around 80% of all unsecured consumer loans in Brazil (see Figure C.3 in Appendix C.1.3). Payroll loans are a specific type of loan where the borrower's repayments are automatically deducted from their salary at the source. In Brazil, these loans are primarily available to civil servants and retirees. Some formal employees might have access to them, but informal workers do not.

Table C.1 and C.5 in Appendix C.1 provide summary statistics for personal loans and payroll loans, respectively. Interest rates on personal loans are high - the average for the period is approximately 146% per year, while the average deposit rate when considering the maturity of loans was 9.93%. Therefore, an average interest rate spread of approximately 136%. Personal loan interest rates are also quite dispersed - the standard deviation is approximately 200%. Loans are not necessarily very short maturity - the average maturity is larger than two years. The average default rate is 6% with a standard deviation of 24%. Default rates by income groups are displayed in Figure C.1 in Appendix C.1. Most of the individuals have a credit score

above a B level - about 65% individuals in our sample.¹ For formal employees, the approximate debt-to-monthly-income ratio is 1.48 once we do not consider outliers with a debt-to-monthly-income ratio above 24 - 1% of the sample.

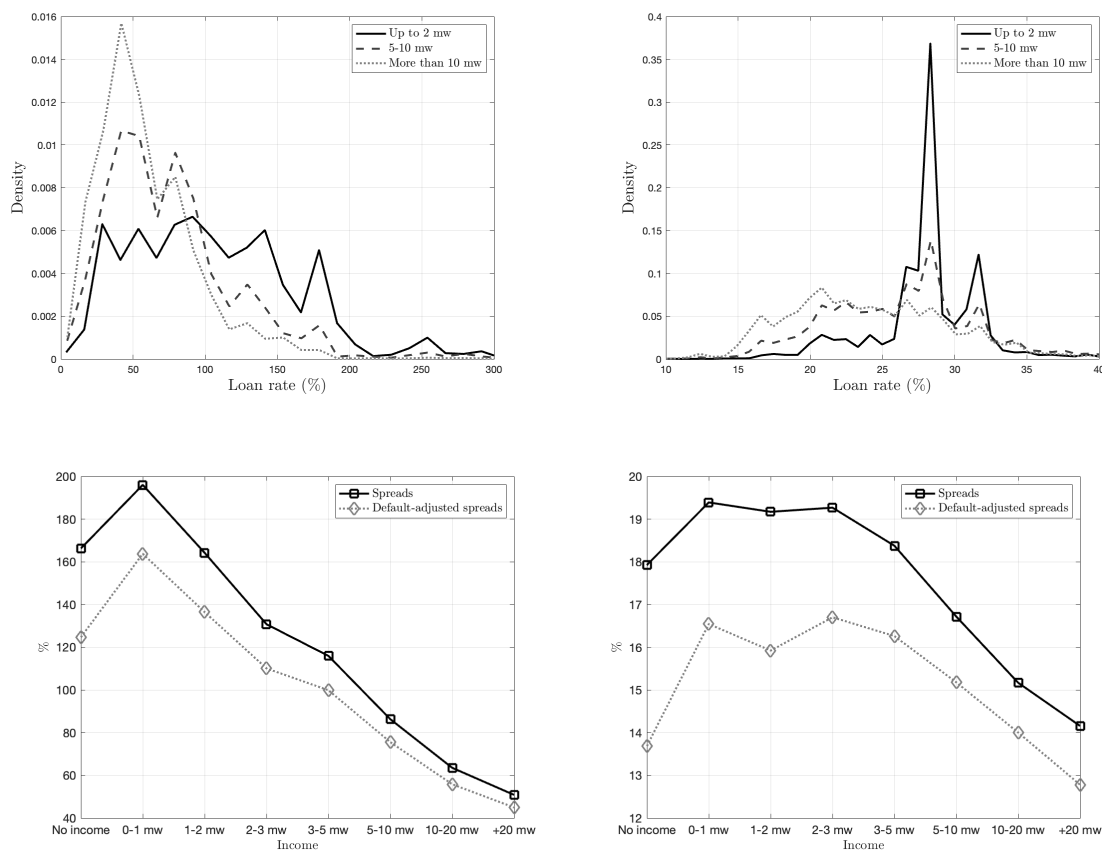
Interest rates on payroll loans are much lower when compared to personal loans, partly reflecting the fact that payroll loans are more secure due to the borrower's employment/income status being verified and payments are made directly from the paycheck - the average annual interest rate is 27.8% per year, approximately 5 times lower than the average interest rate observed for personal loans. The standard deviation of interest rates is approximately 11%. The average maturity of payroll loans is about 5 years. The average deposit rate for payroll loans when taking into account their loan maturity is 9.97%. The average default rate is 2% with a standard deviation of 14%. See also Panel (b) of Figure C.1 in Appendix C.1. Approximately 73% of the individuals taking a payroll loan have a credit score above the B level. Regarding their occupation, 66% of the individuals taking payroll loans are retired, 28% are civil servants,² and 6% are formal employees.

The density of interest rates for personal loans and payroll loans for three different income groups are depicted in Panel (a) and Panel (b) of Figure 3.1, respectively - The density of interest rates for personal (Panel (a)) and payroll (Panel (b)) loans are displayed in Figure C.2 of Appendix C.1, without any division of the sample by income levels. Figure C.2 in Appendix C.1 displays the loan interest rates for personal (Panel (a)) and payroll (Panel (b)) loans without splitting the sample by income levels. There is a significant degree of variability in interest rates for personal and payroll densities, but it is more noticeable for personal loans. Regarding the distribution shape, it shows that kurtosis for personal loans is larger for low-income individuals, earning up to twice the minimum wage, than for high-income individuals, earning more than ten times the minimum wage. Furthermore, the distribution is positively skewed for high-income individuals and relatively symmetric for low-income individuals. This suggests that the interest rate distribution for high-income individuals is more concentrated on lower levels of interest rates, while the distribution for low-income individuals is more spread out.

Contrary to the case for personal loans, the distribution of interest rates for payroll loans exhibits a higher kurtosis among high-income individuals compared to the

¹Credit scores vary from AA to H - there are 9 levels (AA, A, B, ..., H) - and H is the lowest credit score.

²In Brazil, public sector workers are granted lifetime tenure following a three-year probationary period. Due to the absence of performance evaluation mechanisms in the public sector, it is uncommon for a public employee to be denied tenure. But public employee can still face income shocks - being promoted to have some management role or demoted. See Cavalcanti and Santos (2021).



Notes: Panel (a) and Panel (b) display the density of interest rates by income levels (up to 2 minimum wages (mw), 5-10 mw and more than 10 mw) for personal loans and payroll loans, respectively. Panel (c) and Panel (d) display interest rate spreads and default-adjusted spreads versus income levels for personal loans and payroll loans, respectively. Spreads are the contracted interest rates minus the benchmark interest rate. Default-adjusted spreads are calculated by setting the interest rate to -100% for loans in default.

Fig. 3.1: Loan interest rate densities by income groups; spreads and default-adjusted spreads by income groups

one of low-income individuals. Furthermore, the distribution is positively skewed for high-income individuals and relatively symmetric for low-income individuals, similarly to the pattern observed for personal loans.

The higher interest rates paid by low-income individuals may (partially) reflect a higher risk of default among this group of individuals. We show that this is not necessarily the case. Panel (c) and Panel (d) of Figure 3.1 plot *ex-ante* and *ex-post* (default adjusted) spreads against individual monthly income by multiples of the minimum wage. *Ex-ante* spreads are based on contracted interest rates minus the deposit interest rate, which is based on the central bank (Selic) rate but consider that the cost of capital is different from loans of different maturities. *Ex-post* spreads are calculated by setting the interest rate to -100% for loans in default. Such an assumption is clearly conservative since it assumes default occurs immediately, fully and creditor's recovery rate is zero. The difference between *ex-ante* and *ex-post* decrease with income but we still observe that *ex-post* spreads are substantially lower for high-income individuals. For personal loans, for instance, *ex-post* spreads are above 100p.p. for low-income individuals, earning up to 3 times the minimum wage, while for high-income individuals, earning more than 20 times the minimum wage, *ex-post* spreads are about 40p.p..³

³For payroll loans, *ex-post* spreads are about 3p.p. higher for low-income individuals, earning up to 3 times the minimum wage, than for high-income individuals, earning more than 10 times the minimum wage.

Table 3.1: Interest rates and individual characteristics - Personal loans

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate
Maturity	-1.881*** (0.0926)	-1.828*** (0.0941)	-1.828*** (0.0945)	-1.941*** (0.0961)	-1.941*** (0.0965)	-2.126*** (0.0209)	-2.172*** (0.0168)
Maturity ²	0.00748*** (0.00109)	0.00747*** (0.00110)	0.00743*** (0.00110)	0.00774*** (0.00113)	0.00770*** (0.00113)	0.0123*** (0.000250)	0.0128*** (0.000185)
Log of loan	-4.591*** (0.138)	-4.518*** (0.141)	-4.411*** (0.142)	-3.590*** (0.147)	-3.479*** (0.148)	-3.878*** (0.0569)	-3.692*** (0.0568)
No income	87.92*** (0.725)	77.38*** (0.703)	79.54*** (0.722)	84.33*** (0.729)	86.44*** (0.753)	75.70*** (1.193)	77.96*** (1.288)
Up to 1 mw	61.04*** (0.474)	50.09*** (0.498)	50.98*** (0.500)	60.51*** (0.479)	61.45*** (0.481)	47.21*** (0.410)	48.88*** (0.434)
From 1 to 2 mw	43.90*** (0.379)	37.61*** (0.388)	38.27*** (0.390)	43.57*** (0.387)	44.26*** (0.389)	29.01*** (0.295)	29.91*** (0.308)
From 2 to 3 mw	31.54*** (0.315)	26.90*** (0.319)	27.42*** (0.320)	31.91*** (0.326)	32.46*** (0.327)	22.11*** (0.283)	22.67*** (0.296)
From 3 to 5 mw	20.89*** (0.247)	17.32*** (0.243)	17.81*** (0.244)	21.69*** (0.257)	22.22*** (0.258)	14.13*** (0.275)	14.66*** (0.287)
From 5 to 10 mw	9.971*** (0.181)	8.195*** (0.166)	8.564*** (0.167)	10.76*** (0.186)	11.19*** (0.186)	6.815*** (0.259)	7.110*** (0.270)
From 10 to 20 mw	1.644*** (0.122)	1.004*** (0.119)	1.380*** (0.119)	2.075*** (0.123)	2.490*** (0.121)	0.391 (0.253)	0.489* (0.262)
Retired (personal)	0.693*** (0.125)	1.203*** (0.121)	1.478*** (0.121)	0.404*** (0.124)	0.665*** (0.124)	-3.897*** (0.401)	-3.963*** (0.417)
Civil Serv (personal)	-12.21*** (0.179)	-7.839*** (0.171)	-7.445*** (0.171)	-11.68*** (0.181)	-11.27*** (0.181)	-9.758*** (0.162)	-9.384*** (0.162)
Informal (personal)	4.094*** (0.0699)	3.853*** (0.0679)	4.113*** (0.0665)	2.895*** (0.0682)	3.139*** (0.0671)		
Age	1.104*** (0.0116)	1.113*** (0.0113)	1.129*** (0.0113)	1.379*** (0.0127)	1.397*** (0.0127)	0.180*** (0.0263)	0.178*** (0.0273)
Age ²	-0.0114*** (0.000120)	-0.0108*** (0.000114)	-0.0109*** (0.000114)	-0.0135*** (0.000127)	-0.0136*** (0.000127)	0.000107 (0.000330)	0.000300 (0.000343)
Female	7.434*** (0.0628)	8.267*** (0.0609)	8.279*** (0.0613)	8.253*** (0.0648)	8.273*** (0.0652)	3.859*** (0.0943)	3.931*** (0.0974)
Pr. default (personal)				58.19*** (0.595)	58.63*** (0.602)		
Fin. Literacy						-1.335*** (0.0135)	-1.318*** (0.0133)
Constant	122.0*** (0.404)	185.1*** (0.659)	183.4*** (0.666)	104.9*** (0.490)	102.7*** (0.499)	185.2*** (1.063)	184.1*** (1.105)
Observations	20,483,498	20,483,498	20,464,737	20,483,498	20,464,737	2,984,011	2,888,871
R-squared	0.269	0.297	0.309	0.276	0.289	0.292	0.328
Risk control	NO	YES	YES	NO	NO	YES	YES
Time FE	YES	YES	NO	YES	NO	YES	NO
Munic. FE	YES	YES	NO	YES	NO	YES	NO
Munic.xTime FE	NO	NO	YES	NO	YES	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Table 3.1 investigates how personal loan interest rates vary with loan and individual characteristics using a multivariate linear regression model. Columns (1)-(7) consider different control variables. The reported estimated coefficients are, in general, robust to different specifications. The R^2 indicates that the overall fraction explained by observable characteristics vary from 27% - Column (1) - to 33% - Column (7). Personal loan interest rates decrease with maturity and loan amount, which could be explained by a fixed cost for loan provision. Credit risk scores increase the overall explanation of the model, from Column (1) to Column (2), by 2.7 percentage points (p.p.).⁴ Informal employees pay about 2p.p. more in interest rate in a personal loan than formal employees, while civil servants pay roughly 10p.p. less than formal employees. Women pay 3-8p.p. more in interest rates than men. Individuals with financial literacy pay a lower rate but the magnitude of the difference is not substantial.⁵ One standard deviation increase in financial literacy leads to 4p.p. reduction in the personal loan interest rate. We control for fixed effects of time to absorb macro shocks, such as changes in the central bank interest rate, and fixed effects of municipality to control for location characteristics, such as local bank concentration - Columns (1), (2), (4) and (6). Columns (3), (5) and (7) allow also macro shocks to vary by location or local characteristics to vary by time - we add municipality \times time fixed effects.

One noteworthy observation from Table 3.1 is how interest rates decrease monotonically with income, which holds true across all model specifications. Almost all income indicator variables are statistically different from zero at 99% confidence level. Specifically, individuals earning more than 20 times the minimum wage pay an average annual interest rate on personal loans that is approximately 38p.p. lower than those earning 1 to 2 times the minimum wage, as evidenced in Column (3) and 29p.p. in Column (7), which are the two most comprehensive specifications.⁶

⁴Instead of using risk scores provided by the SCR, we also calculated the default probability predicted by observable loan and individual characteristics based on a logit regression. We use the predicted default probabilities as a control variable in the regression of interest rates - Columns (4) and (5) - and coefficients of the other variables are robust to such specifications.

⁵For instance, a person who holds a college degree and possesses strong numeracy skills is typically offered an interest rate that is approximately 5p.p. lower than someone who only has a high school degree and lacks financial literacy.

⁶The coefficient of income dummies are relative to those earning more than 20 times the minimum wage.

Table 3.2: Interest rates and individual characteristics - Payroll loans

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate
Maturity	0.00960*** (0.000313)	0.00740*** (0.000307)	0.00718*** (0.000309)	0.00917*** (0.000311)	0.00893*** (0.000313)	-0.00333 (0.00959)	0.00153 (0.0118)
Maturity ²	-3.31e-05*** (2.17e-06)	-3.12e-05*** (2.15e-06)	-3.09e-05*** (2.17e-06)	-3.26e-05*** (2.16e-06)	-3.23e-05*** (2.17e-06)	-0.000179** (8.54e-05)	-0.000232** (0.000105)
Log of loan	-0.550*** (0.00369)	-0.537*** (0.00366)	-0.535*** (0.00371)	-0.541*** (0.00367)	-0.539*** (0.00372)	-0.388*** (0.00993)	-0.389*** (0.0116)
No income	2.678*** (0.0228)	2.782*** (0.0244)	2.799*** (0.0245)	2.658*** (0.0228)	2.675*** (0.0230)	3.138*** (0.0959)	3.130*** (0.104)
Up to 1 mw	2.569*** (0.0227)	2.626*** (0.0242)	2.631*** (0.0241)	2.566*** (0.0227)	2.571*** (0.0227)	3.161*** (0.0835)	3.175*** (0.0923)
From 1 to 2 mw	2.481*** (0.0228)	2.445*** (0.0240)	2.457*** (0.0240)	2.477*** (0.0228)	2.489*** (0.0228)	2.869*** (0.0788)	2.895*** (0.0857)
From 2 to 3 mw	2.234*** (0.0225)	2.206*** (0.0237)	2.210*** (0.0236)	2.234*** (0.0225)	2.240*** (0.0224)	2.635*** (0.0760)	2.635*** (0.0822)
From 3 to 5 mw	1.921*** (0.0221)	1.882*** (0.0235)	1.893*** (0.0234)	1.924*** (0.0221)	1.936*** (0.0220)	2.325*** (0.0775)	2.315*** (0.0835)
From 5 to 10 mw	1.449*** (0.0215)	1.414*** (0.0232)	1.424*** (0.0231)	1.453*** (0.0215)	1.463*** (0.0215)	1.779*** (0.0735)	1.762*** (0.0783)
From 10 to 20 mw	0.475*** (0.0180)	0.443*** (0.0186)	0.453*** (0.0186)	0.478*** (0.0180)	0.488*** (0.0179)	1.169*** (0.0683)	1.150*** (0.0717)
Retired (payroll)	-0.983*** (0.0150)	-0.954*** (0.0153)	-0.965*** (0.0155)	-0.968*** (0.0149)	-0.980*** (0.0152)	0.0822*** (0.0190)	0.0822*** (0.0203)
Civil Serv (payroll)	-2.535*** (0.0197)	-2.532*** (0.0201)	-2.547*** (0.0205)	-2.529*** (0.0197)	-2.544*** (0.0200)	-2.082*** (0.0205)	-2.141*** (0.0220)
Age	-0.00212** (0.00108)	0.00536*** (0.00111)	0.00511*** (0.00112)	0.00296*** (0.00107)	0.00286*** (0.00108)	-0.0258*** (0.00307)	-0.0217*** (0.00321)
Age ²	9.72e-05*** (8.92e-06)	2.16e-05** (9.27e-06)	2.34e-05** (9.38e-06)	4.82e-05*** (8.92e-06)	4.86e-05*** (9.02e-06)	-8.13e-05** (3.50e-05)	-0.000142*** (3.64e-05)
Female	0.00546* (0.00282)	0.00157 (0.00283)	0.00230 (0.00284)	0.0157*** (0.00276)	0.0168*** (0.00277)	-0.333*** (0.0119)	-0.339*** (0.0126)
Pr. default (payroll)				1.494*** (0.0277)	1.548*** (0.0279)		
Fin. Literacy						-0.0874*** (0.00248)	-0.0871*** (0.00255)
Constant	30.03*** (0.0635)	30.21*** (0.0693)	30.23*** (0.0705)	29.82*** (0.0627)	29.82*** (0.0638)	31.16*** (0.178)	31.05*** (0.199)
Observations	20,524,507	20,524,507	20,506,221	20,524,507	20,506,221	1,864,303	1,777,400
R-squared	0.207	0.211	0.227	0.208	0.223	0.179	0.218
Risk control	NO	YES	YES	NO	NO	YES	YES
Time FE	YES	YES	NO	YES	NO	YES	NO
Munic. FE	YES	YES	NO	YES	NO	YES	NO
Munic.xTime FE	NO	NO	YES	NO	YES	NO	YES

Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Table 3.2 presents regression results for interest rates of payroll loans. Control variables are similar to those used in regressions for personal loans, although payroll loans are not available to informal workers. So the dummy variable for this occupation is dropped in all regressions of Table 3.2. The overall fraction explained by observable characteristics in the case of payroll loans are lower than the case of personal loans, varying from 21% - Column (1) - to 23% - Column (3). Risk controls do not add much in explanation power, increasing the R^2 in less than one percentage point from Column (1) to Column (2). The estimated constant is about 3-5 times lower than the estimated constant for personal loans.

Similarly to the case of personal loans, interest rates are monotonically decreasing with income and all estimated coefficients of the income dummies are statistically different from zero at 99% confidence level. The magnitude of the coefficients are, however, smaller than for the case of personal loans. Controlling for credit scores and occupation, an individual earning 1 to 2 times the minimum wage faces on average approximately 2.5p.p. higher interest rate in a payroll loan than individuals earning more than 20 times the minimum wage. In the case of payroll loans, one standard deviation increase in financial literacy leads to a reduction in interest rate of 0.3p.p.

The key points from this section are as follows: (i) Interest rates for unsecured consumer credit in Brazil are high and vary greatly; (ii) payroll loans, in which lenders can verify employment status and payments are directly deducted from paychecks, still have average interest rates that are approximately 22 percentage points higher than the average benchmark rate; (iii) default probabilities only account for a small fraction of the total variation in loan interest rates, and their role is even smaller in the case of payroll loans; and (iv) loan interest rates vary negatively with individual income, even after controlling for factors like credit scores, loan size, maturity, and other observable individual variables, such as gender, occupation, and financial literacy.

In the next section, we present a model of unsecured consumer credit with heterogeneous agents and two types of loans (personal and payroll) to understand the quantitative implications of such variability in interest rates for consumption insurance and consumer welfare.

3.3 Model

3.3.1 Environment

The economy is populated by a continuum of finitely lived overlapping generations. Each household lives for T periods and their lives are divided into working age - up until T^R - and retirement thereafter. These individuals can either work in the formal, informal or public sectors. The probability of switching from any sector s_i to sector s_j is given by p_{ij} . Workers in the formal or informal sectors are subject to income shocks, whereas the public sector employees income grows at a deterministic rate. The current period's income is denoted by y and next period's income y' fluctuates according to a Markov chain with transition matrix $\Pi(s, s')$, where the element $\pi_{ij}(s, s') = Pr(y' = y_j | y = y_i, s, s')$. Therefore the idiosyncratic income shock is specific to the path for the worker's sector (s, s') . In addition, individuals face independent and identically distributed expenditure (iid) shocks which are designed to capture life events such as health shocks, divorce, etc. These shocks are assumed to be proportional to income and are denoted by $e(y) = e_1 y$. This is designed to capture the fact that life events such as divorce, home repairs, etc. are more expensive for the wealthy. Individuals discount future periods with a factor $\beta \in (0, 1)$ and their intra-period utility is given by $u(c) = c^{1-\sigma} / (1 - \sigma)$ with $\sigma > 0$.

3.3.2 Saving and Borrowing Decisions

Households can save and borrow by buying and selling one-period discount bonds intermediated by banks. Savers buy one-period discount bonds at price $q_B = \frac{1}{1+r}$, where r is the real interest rate determined in international capital markets. When a household is saving, then $a_B \geq 0$. When selling bonds, $a_B < 0$, households can default on their repayment obligations. The price at which banks buy bonds from households will reflect these default probabilities as well as intermediation costs and profit margins. As such, the price banks buy bonds from households at will generally be lower. We refer to these bonds as 'personal loans'. The price of a one-period personal loan given to a household will, of course, depend on her state variables. To save notation, we denote a household's non-debt related state variables by $X = \{y, s, e, \tau\}$.

Households can also borrow by means of so-called 'payroll loans' where the borrower can pledge up to a fraction $\eta \in (0, 1)$ of their per-period income and agree that this payment is deducted 'at source'. That is, the bank can take payment of

the loan before the borrower receives their income from their employer or from state retirement plans. These payroll loans are available to everyone in receipt of state payments (public sector workers and retirees) as well as a measure of formal employees. Whether formal employees have access to payroll loans can change over time according to a Markov chain.

In the period of default, households lose a fraction γ_i of their income and $i \in \{B, P\}$, where B indicates one-period bonds and P indicates payroll loans. This represents the bank's ability to recover losses in the subsequent period. Note that for payroll loans, banks are still - in principle - exposed to the income risk of households because if the household's income drops, they can only collect γ_P of this lower income in the event of default. In general, γ_P is assumed to be the maximum fraction of income that could plausibly be seized by banks in the event of default. As such, we assume (i) the legal maximum seizable income in enforcement of personal loans is lower than this - that is, $\gamma_B < \gamma_P$. (ii) for a borrower with both payroll and personal loans, personal loans are the residual claimant on this maximum seizable fraction of income γ_P . In practice, this means that for a personal loan, the recovery rate depends on whether a household is also defaulting on payroll loans and the quantity of payroll loans held ($-a_P$), since payroll loans are effectively senior. So denoting $\bar{\gamma}_B$ as the official rate and γ_B as the realised rate, the seizable income for bonds is

$$\gamma_B = \begin{cases} \bar{\gamma}_B & \text{if } a_P = 0, \\ \max\{\gamma_P + a_P/y, \bar{\gamma}_B\} & \text{if } 0 < -a_P \leq \gamma_P y, \\ 0 & \text{if } -a_P > \gamma_P y. \end{cases}$$

In the first case, there are no payroll loans so the official seizure rate on personal loans is applied. In the third case, all of the maximum seized income is diverted to servicing payroll loans. In the middle case, some income is being diverted to pay personal loans but they do not account for all of the maximum seizable income. What is left can be diverted to personal loans, up to the limit of $\bar{\gamma}_B$ - enforcement threshold for personal loans.

3.3.3 The Default Decision

Defaulting on either type leads to exclusion from both debt markets in the next period. Households can regain access with constant probability θ every period. While in default households suffer utility loss Γ . Since defaulting on either loan triggers exclusion and utility loss it is easy to see that a household will always

default on both loan types - default on one will trigger mandatory repayment of the other but the household always keeps (weakly) greater resources by defaulting on the second loan as well.

We represent each household's problem in two steps. At the beginning of the period, a household not already in default decides whether to default in this period or not:

$$V(a_B, a_P, P, D, X) = \max_{D' \in \{0,1\}} (1 - D')V^{repay}(a_B, a_P, P, D, X) + D'V^{default}(a_B, a_P, P, D, X),$$

where $P \in \{0,1\}$ is a flag representing whether or not this household has access to payroll loans, $D \in \{0,1\}$ is a default flag indicating whether or not a household is entering the period in the default status ($D = 1$), $-a_B$ is the amount of personal loans (bonds sold), and $-a_P$ is the amount of payroll loans. Recall that when a household is saving, then $a_B > 0$. The household is choosing over which default flag to bring into the next period D' .

If a household has access to a payroll loan, $P = 1$, and decides to repay, the value function representing her problem is:

$$\begin{aligned} V^{repay}(a_B, a_P, P = 1, D = 0, X) &= \max_{c \geq 0, a'_P, a'_B} u(c) + \beta \mathbb{E}V(a'_B, a'_P, P', D' = 0, X'), \\ &\text{subject to } c + e(y) + q_B a'_B + q_P a'_P = y + a_B + a_P, \\ & a'_P \geq -\eta y, \eta \in (0,1). \end{aligned}$$

The price of the one-period bond is given by:

$$q_B = \begin{cases} \frac{1}{1+r} & \text{if } a'_B \geq 0, \\ \frac{\mathbb{E}[1 - D'(1 - \gamma_B \frac{y'}{a'_B})]}{1+r+k_B(a_B, y, s, \tau)} & \text{if } a'_B < 0. \end{cases}$$

The price of the payroll loan is given by:⁷

$$q_P = \frac{\mathbb{E}[1 - D'(1 - \gamma_P \frac{y'}{a'_P})]}{1+r+k_P(a_P, y, s, \tau)}$$

⁷In order to be precise q_B and q_P depend on a household's state variables, such that $q_i(a_B, a_P, P, X)$ with $i \in \{B, P\}$. We are economising on notation and just writing q_i with $i \in \{B, P\}$.

where $k_B(a_B, y, s, \tau)$ and $k_P(a_P, y, s, \tau)$ correspond to the spread over the risk-free rate charged by banks for (risk-free) personal and payroll loans, respectively. That is κ_i accounts for the portion of the spread not explained by default risk.

If a household does not have access to a payroll loan and decides to repay, then the value function representing her problem reads:

$$V^{repay}(a_B, a_P, P = 0, D = 0, X) = \max_{c \geq 0, a'_B} u(c) + \beta \mathbb{E}V(a'_B, 0, P', D' = 0, X')$$

$$\text{subject to } c + e(y) + q_B a'_B = y + a_P + a_B.$$

Note that the household might not have access to payroll loans in this period but may still carry over payroll loans from previous periods - hence presence of a_P in the budget constraint.

Default means assets are reset to zero. The value of default is given by:

$$V_A(a_B, a_P, P = 0, D, X) = \max_{c \geq 0, a'_B \geq 0} u(c) - \Gamma$$

$$+ (1 - \theta) \beta \mathbb{E}V_A(a'_B, 0, P' = 0, D' = 1, X') + \theta \beta \mathbb{E}V(a'_B, 0, P', D' = 0, X'),$$

$$\text{subject to } \begin{cases} c + ey = y - \min \gamma_P y, -a_P - \bar{\gamma}_B y & \text{if } D = 0, \\ c + e(y) + q_y a'_B = y + a_B, a'_B \geq 0, & \text{if } D = 1. \end{cases}$$

If a household begins the period with $D = 0$, then she is entering default for the first time and her income will be garnished and she will not be able to borrow or save. After that period, she receives her full income and she will be able to save.

3.3.4 Welfare

We measure welfare changes according to the annual increase in consumption that would be required to make the household indifferent between two regimes:

$$\begin{aligned} \sum_{i=t}^T \beta^i \mathbb{E} \left[\frac{(\tilde{c}_i(1-\theta))^{1-\sigma}}{1-\sigma} \right] &= \sum_{i=t}^T \beta^i \mathbb{E} \left[\frac{c_i^{1-\sigma}}{1-\sigma} \right] = V_t \\ (1-\theta)^{1-\sigma} \sum_{i=t}^T \beta^i \mathbb{E} \left[\frac{\tilde{c}_i^{1-\sigma}}{1-\sigma} \right] &= V_t \\ (1-\theta)^{1-\sigma} \tilde{V}_t &= V_t \\ \theta &= 1 - \left(\frac{V_t}{\tilde{V}_t} \right)^{\frac{1}{1-\sigma}} \end{aligned}$$

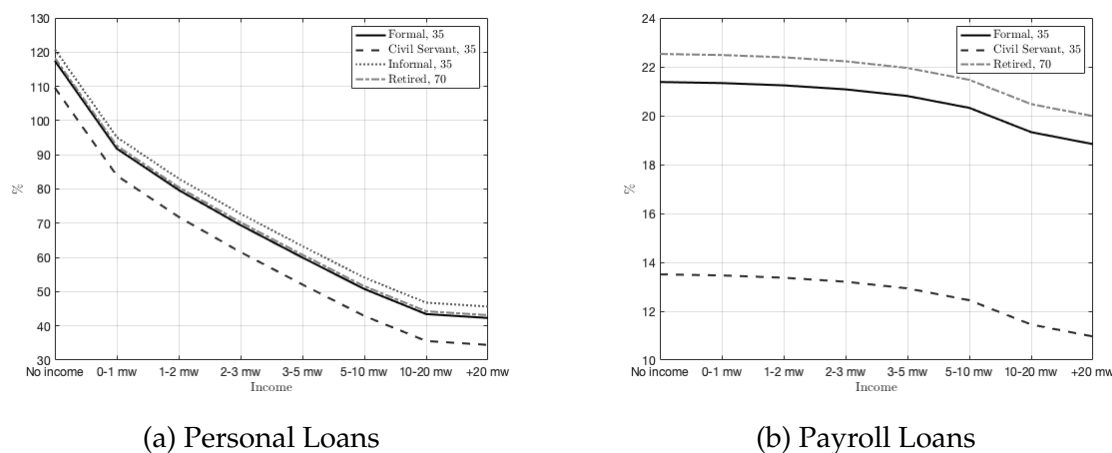
3.4 Fitting the Model to the Data

In order to investigate the effects of spreads on consumption insurance and welfare, we need to calibrate model parameters. The calibration strategy is to assign standard values for some parameters, which are commonly used in the literature; externally set others using our loan-level data and household survey data; and jointly calibrate the remaining parameters of the model to match key micro and macro moments of the Brazilian economy. Below we describe in detail how we define the income process, determine the spread functions $k_B(a_B, y, s, \tau)$ and $k_P(a_P, y, s, \tau)$, and set model parameters.

1. **Model period:** The model period is assumed to be 1 year and households live for $T = 55$ years. Their working-period T^r is 44 years.
2. **Preferences (2 parameters):** Discount factor β and the coefficient of relative risk aversion σ . The coefficient of relative risk aversion is equal to $\sigma = 2$, which is in line with the bulk of the literature on consumption surveyed by Attanasio (1999). This value is also consistent with the literature that estimates σ using Brazilian data. This literature suggests a σ in the range from 1 to 3 (see, for example, Gandelman and Hernández-Murillo, 2014, Fajardo et al., 2012). The subjective discount factor is set internally β and - loosely speaking - the moment identifying this parameter is the ratio of personal credit over income. (One parameter - β - to be estimated)

3. **Deposit interest rate (1 parameter):** The economy is taken to be a small open economy, in which banks have access to funding at real interest rate r . The inflation rate measured by the IPCA (the official consumer price index) for the period (IBGE) is subtracted from the monthly Over/Selic from the Brazilian Central Bank (BCB) to determine the real interest rate $r = 0.0375$.
4. **Stochastic process for labor income (several):** The income process is externally estimated. A non-parametric approach is used to compute the transition matrix for income shocks (De Nardi et al., 2019). We use the PNAD-C household survey that has a rotating panel and divide the individuals into two groups: formal and informal (see Gomes et al., 2020). Within each group, the households are divided into $N = 10$ income groups. For each income group, the average earnings is calculated. These values represent the support of the transition probabilities. Then, for each group, the transition probabilities can be constructed by calculating the fractions of workers who transit between group-sector pairs in one year. These values form the Markov transition matrix.
5. **Credit market variables:** First, we use the share of formal workers with access to payroll loans (which is equal to 6%) to set the probability that a formal worker has access to payroll loans. As in the data, in a payroll loan borrowers can pledge up to 30% of their per-period income. We also externally estimate interest rate wedges, $k_B(a_B, y, s, \tau)$ and $k_P(a_P, y, s, \tau)$, using our credit register data. The procedure for each type of loan, i.e. personal and payroll, is summarised as follows:
 - Run a logit regression of default on loan characteristics (maturity, loan amount, risk) and personal characteristics (income, occupation, gender, age) and get predicted values.
 - With the predicted default values we can calculate the risk-cost-free rate for each households and then the interest wedge (actual rate - risk-cost-free rate),
 - Then run a regression of the wedge on loan amount, income, age polynomial and occupation dummy to construct $k_B(a_B, y, s, \tau)$ and $k_P(a_P, y, s, \tau)$.

The resulting wedges for a samplt of agents are displayed in Figure 3.2



Notes: Panel (a) and Panel (b) display the loan interest rate wedges by income levels for personal loans and payroll loans, respectively. For formal, informal and civil servant workers, they are the wedges for workers who are 45 year old. For retired individuals, they are the wedges of those who are 70 year old.

Fig. 3.2: Loan interest rate densities by income groups; spreads and default-adjusted spreads by income groups

6. **Default parameters:** We set θ equal to 0.2 so that defaulting individuals have a bad credit record for, on average, 5 years. This is consistent with the law in Brazil, see Appendix C.1.2. The wage garnishment for payroll loans is set at the legal limit of 30%. We assume that the income loss under default for personal loans (γ_B) is zero. The non-pecuniary default cost (Γ), the expenditure shock $e(y) = e_1 y$ ($e_1 \in (0, 1)$), and the probability of facing an expenditure shock (π_e), such that the model matches default probabilities by three different levels of income and the percent of households using debt.

(Three parameters - Γ , e_1 , and π_e - to be estimated)

The model parameters are displayed in Table 3.3. The calibration procedure parameterises four parameters using five moments summarised in Table 3.4. The calibration targets both the intensive debt-use margin (average debt-to-income) and the extensive margin (fraction of households using debt). In addition, we target the default rates at 3 different income levels.

Figure 3.3 displays the average interest rate by income group alongside the externally calibrated wedges. The gap between the red and blue lines represents the compensation for default risk. The average model interest rates displayed in 3.3 compare favourable with their data counterparts shown in Figure 3.1 Panels (c) and (d).

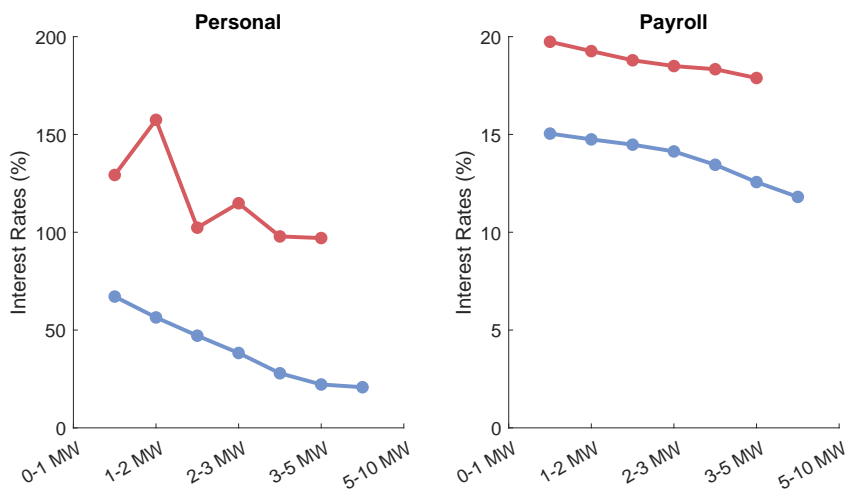
The profile for assets and debt use are shown in Figure 3.4. Unfortunately, we lack data counterparts for these moments at this level of disaggregation. Nonetheless, we the profiles show the general patterns we might expect. Households build up assets over their working life and then run them down in retirement. Younger and poorer households are considerably more likely to be using debt of any kind.

Table 3.3: Calibrated Parameters

Parameter	Description	Value	Source
Panel (a): Externally calibrated			
σ	CRRA	2	Standard
θ	Prob. exit default	0.2	Avg. time in bankr.
γ_P	Loss under default - Payroll	0.3	Legal
r	Real interest rate	0.0375	BCB, IBGE
γ_B	Loss under default - Personal	0	Assumed
Panel (b): Internally calibrated			
β	Disc. factor	0.91	Internal
Γ	Non-pecuniary default cost	2×10^{-4}	Internal
π_e	Prob. of expend. shock	0.11	Internal
e_1	Expend. shock, share of inc.	0.76	Internal

Table 3.4: Model Fit

	Model	Data	Source
Debt-to-Income (ex-housing) (%)	25	24	BCB
Households Using Debt (%)	8.9	9.6	CNC - PEIC
Default Rates (%)			
Up to 2 mw	9.1	7.1	SCR
2-5 mw	2.2	4.7	SCR
+5 mw	1.8	2.9	SCR



Note: Mean wedge by income is shown in blue while mean interest rate is shown in red.

Fig. 3.3: Model Interest Rates and Wedges

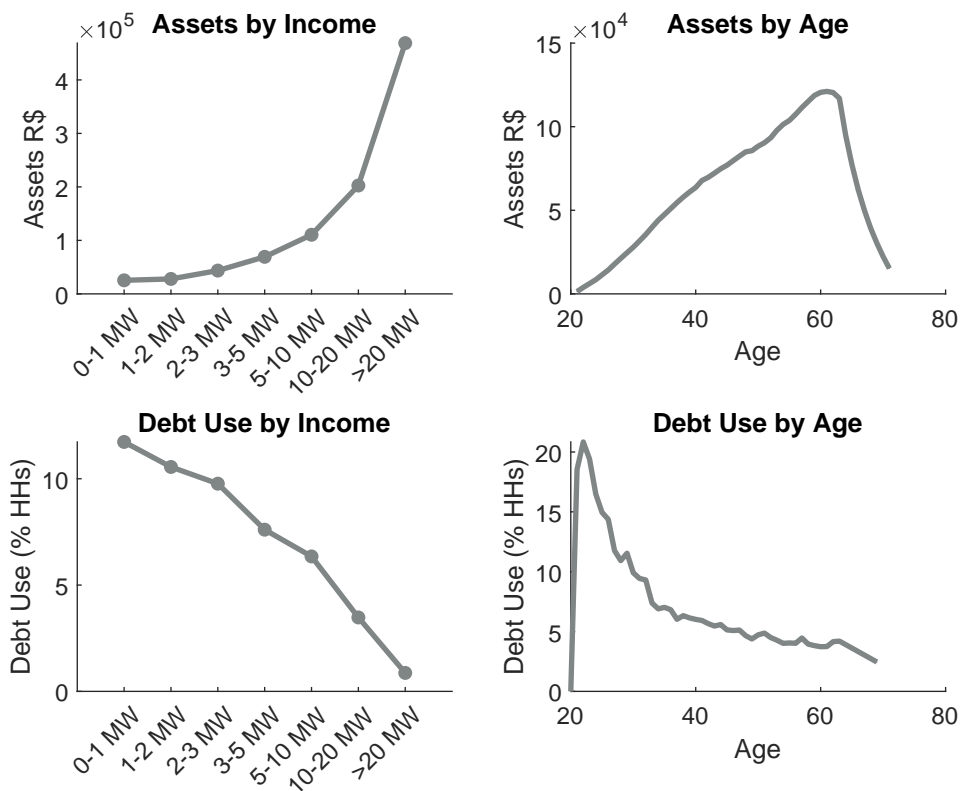


Fig. 3.4: Assets and Debt Use by Age and Income

3.5 Counterfactuals

We consider a number of counterfactuals to assess the changes to welfare, consumption, and debt use under a number of alternative scenarios. The headline results are summarised in Table 3.5. The following sections discuss the counterfactuals in detail.

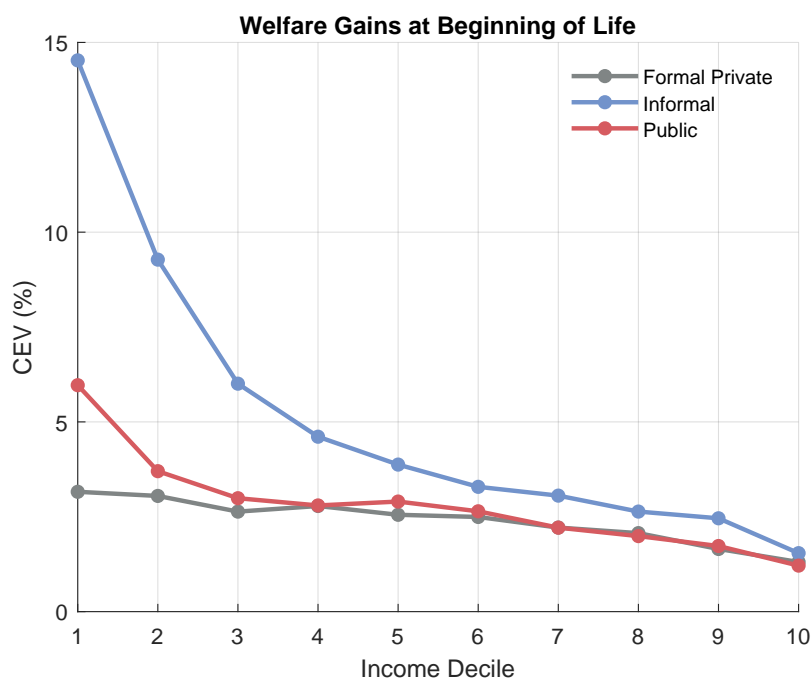
Table 3.5: Baseline vs Counterfactuals Comparison

Moments (%)	Baseline	No Wedge	Portability	Payroll Exp.
Mean Debt	25	39	28	29
Debt Use	8.9	23	13.8	13.2
Default Rates(%)				
$\leq 2MW$	9.1	6.6	8.8	8.4
$2 < MW \leq 5$	2.2	1.8	2.0	1.9
$MW \geq 5$	1.8	1.8	1.7	1.8
Consumer Welfare (% CEV)		3.5	0.7	0.15

3.5.1 Benchmark Counterfactual: No wedges

While unrealistic in the short-term, we consider the case of no wedges to be a good benchmark for assessing the consumer welfare gains that are - in principle - on the table if credit markets in Brazil behaved as they are typically modelled in, for example, the US. It is important to note at the outset that all welfare gains presented here are partial equilibrium gains and, in particular, do not take account of the possibility that the risk free rate might move in response to changed saving and borrowing patterns as a result of changes to the wedges. Neither is the fall to bank profits offsetting the gain for consumers. As such, the aggregate consumer welfare gain from complete removal of all wedges of 3.5% should be thought of as a partial equilibrium result.

Figure 3.5 shows the disaggregation of this welfare gain by sector and income decile. The welfare gain is seen to be largest for the poor and, particularly, the poor working in the informal sector - peaking at almost 15% of annual consumption.



Notes: Consumption equivalent variation (as % of baseline consumption) from fully removing all wedges from both personal and payroll loans.

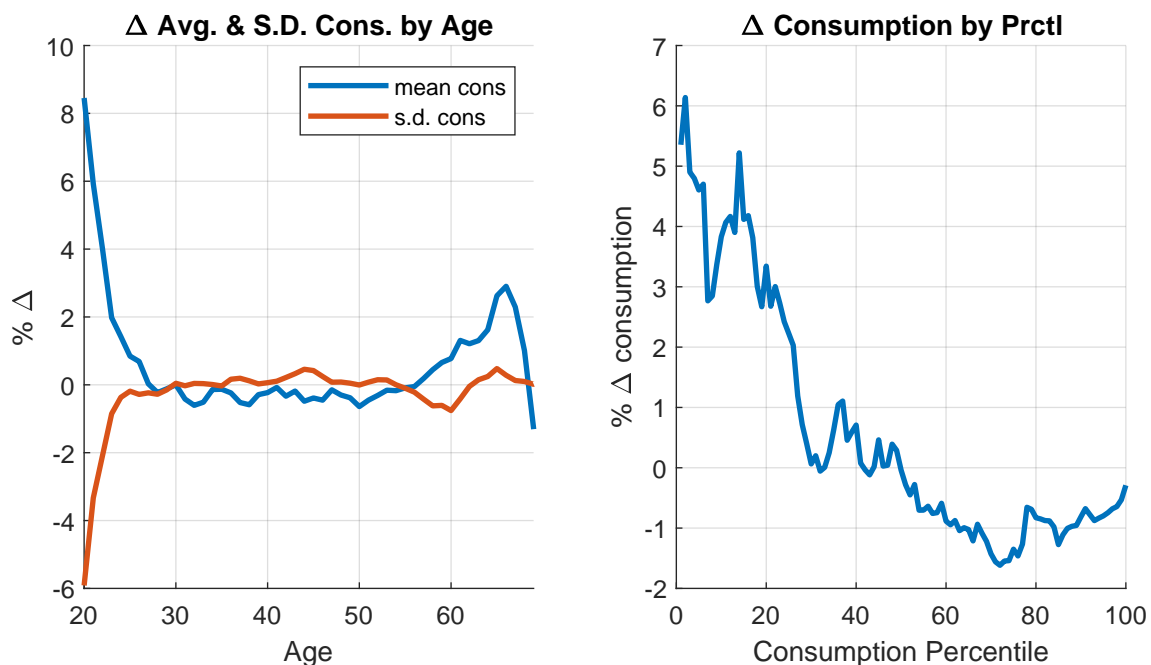
Fig. 3.5: Consumer Welfare Gains From Removing All Wedges - by Sector and Income Decile

Figure 3.6 gives a sense of the change in behaviour induced by the removal of wedges. The blue line in the left panel shows the percentage change in average consumption by age. What we see is quite small changes for most ages but very large increases in consumption for the youngest cohorts. This is consistent with young people borrowing in order to finance higher consumption while young, leading to a slightly negative effect on consumption in middle-age as the debt is repaid.

The orange line shows the change in the cross-sectional standard-deviation of consumption by age. It shows that among the young, the level of consumption inequality drops as the young poor are able to borrow from future income. Again, there is only moderate change to the spread of consumption in later life.

The right-hand panel of Figure 3.6 shows the change in mean consumption ordered by consumption percentile in the baseline. It shows that the median household - in consumption terms - sees almost no change from the removal of wedges. By contrast, the consumption poor see relatively large positive changes to consumption - of the order of 3-5p.p. This is partially offset by smaller declines in consumption for

the top half of the consumption distribution. The finding that the top half actually consume less after the removal of significant market distortions might at first be surprising. It can be rationalised, however, as household's borrowing a lot when they are young and poor and repaying (with interest) when they are older and richer. We can get a better picture of this by looking at the left-hand panel of Figure 3.7 which shows the change in *average* lifetime consumption by a household's place in the overall distribution of average lifetime consumption. By averaging over the household's lifetime, we should be (mostly) removing the effects of consumption shifting from old to young. The consumption gains over a full lifetime are smaller but generally positive.

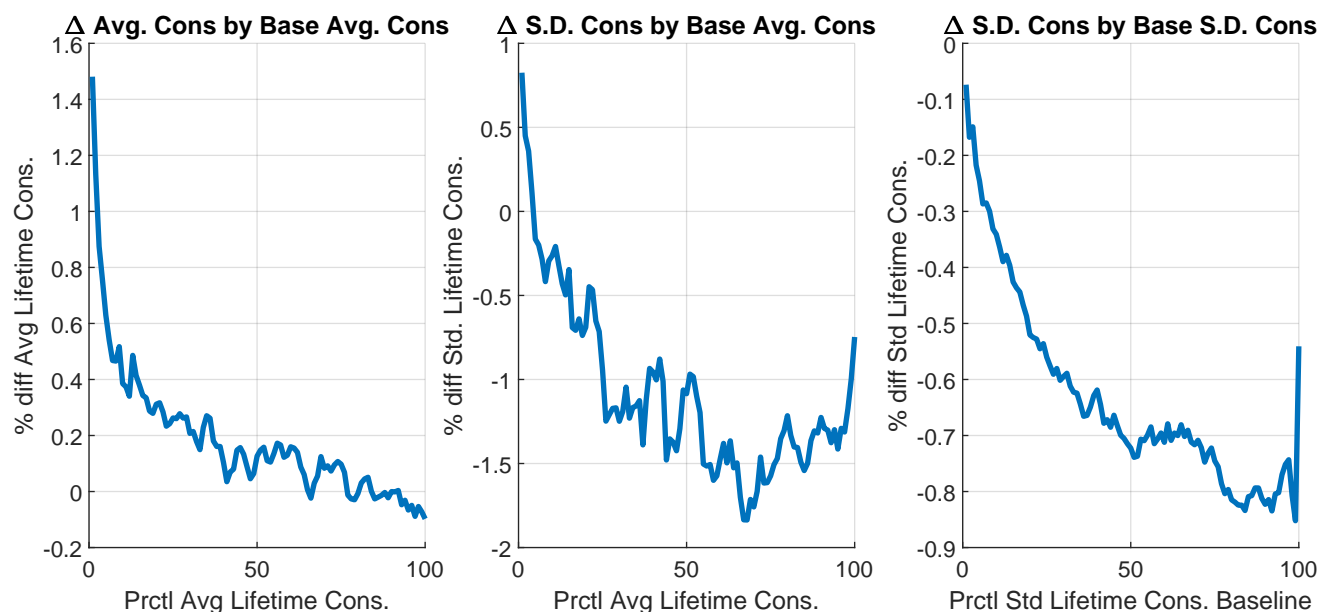


Notes: Left panel: Blue line shows % change in mean consumption by age. Red line shows % change in the cross-sectional standard deviation of consumption by age. Right panel: % change in consumption according to the household's place in the consumption distribution in the baseline.

Fig. 3.6: Change to Consumption Profiles - No-Wedge Benchmark

The other two panels of Figure 3.7 deal with the standard deviation of consumption over a household's life. The middle panel plots the change to this standard deviation over percentiles of the average lifetime consumption. The volatility is lower for most households, with the drop being larger for those with higher lifetime consumption. The right hand panel shows the same statistic but this time plotted

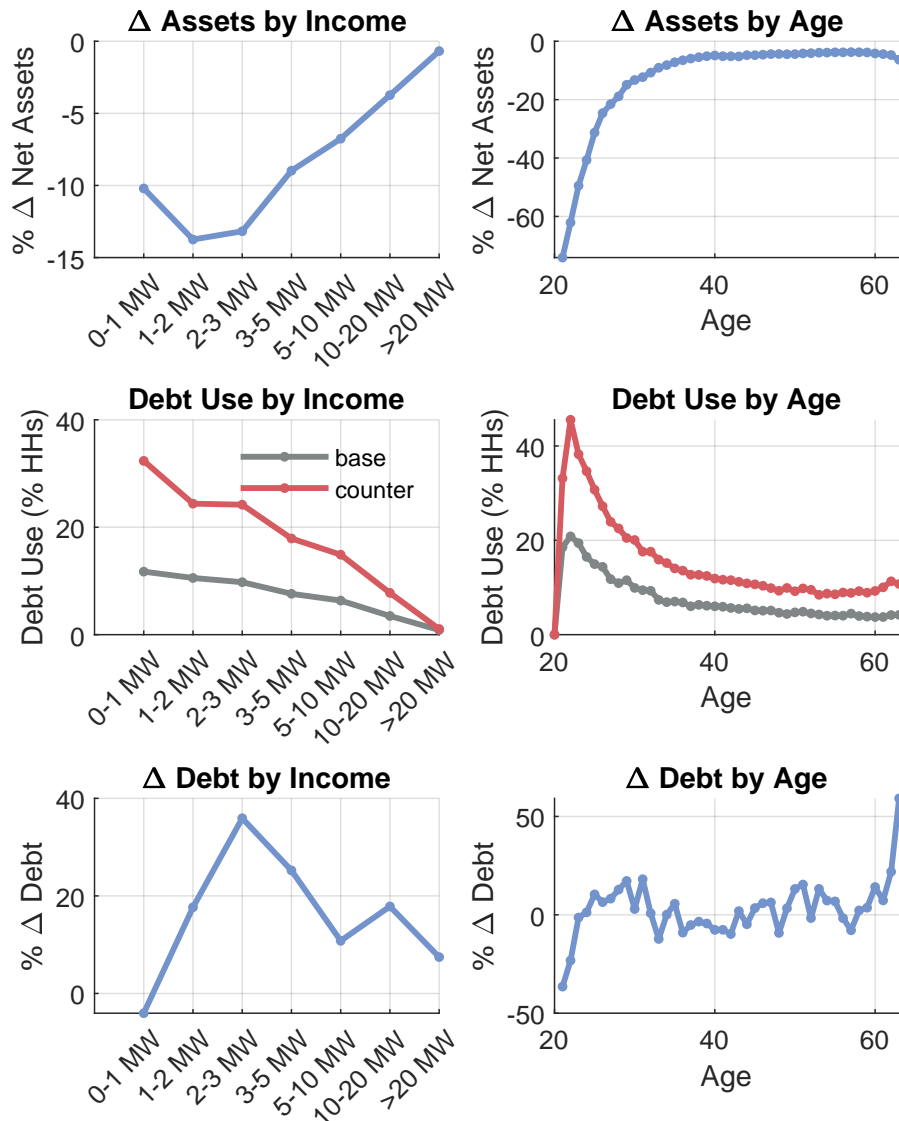
according to the distribution of the standard deviation of lifetime consumption (rather than the average). It shows that the drop in volatility is largest for those with the largest consumption volatility in the baseline.



Notes: Left panel: Plots the % change in household consumption by percentile of average lifetime consumption in the baseline. Middle panel: Plots the % change from the baseline in the standard deviation of consumption over the household's lifetime for each percentile in the average lifetime consumption in the baseline. Right panel: Plots the % change from the baseline in the standard deviation of consumption over the household's lifetime for each percentile in that standard deviation in the baseline.

Fig. 3.7: Effects of Removal of All Wedges on Lifetime Consumption Averages and Standard Deviations

These changes to consumption patterns are reflected in the changes to debt and asset profiles, as shown in Figure 3.8. The consumption shifting of the young and poor is reflected in negative changes to net assets for the poor, in particular, (top-left panel) and young (top-right panel). These changes are also reflected in the increased debt use for the poor and young (middle panels).



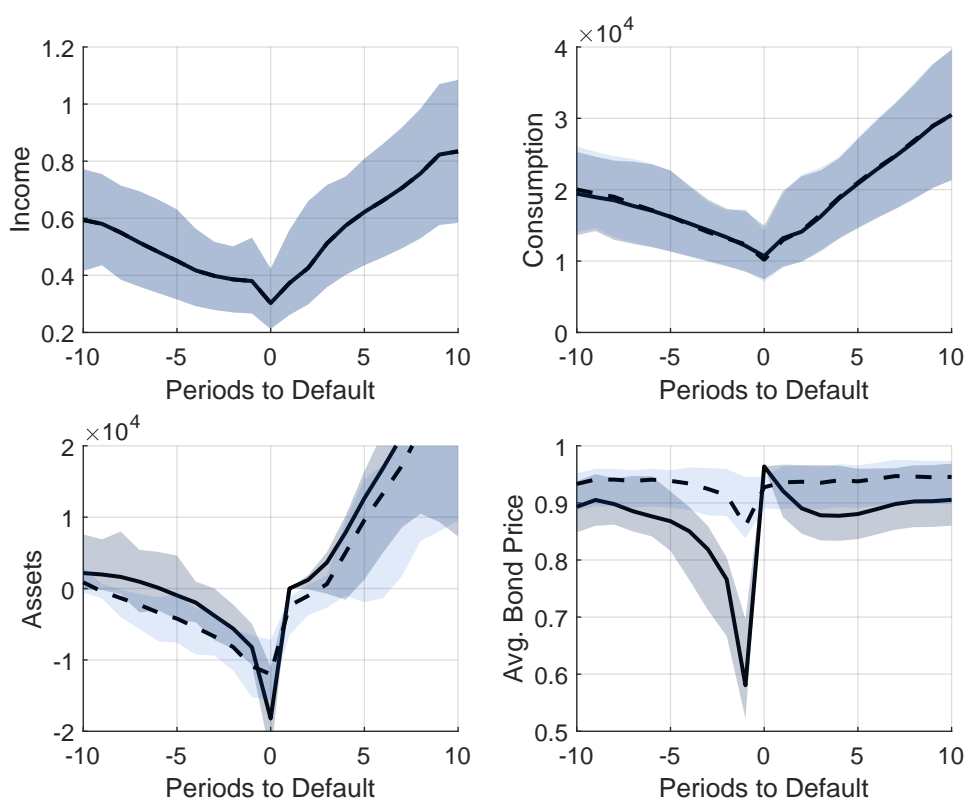
Notes: Blue lines indicate % changes from the baseline to the counterfactual. Grey lines indicate baseline case. Red lines indicate counterfactual case. For the case of debt, an positive % change in debt corresponds to a more negative net asset position.

Fig. 3.8: Change to Debt and Asset Profiles from Removing of All Wedges

What is interesting is that the bottom-left panel shows that the lowest earners are not increasing their debt exposure on the intensive margin. Given the observed

drop in net assets, we can infer that they are actually financing higher consumption by *saving* less.

Before moving on from this benchmark counterfactual to consider more realistic changes to interest-rate wedges, it is worth briefly considering the typical default event, shown in Figure 3.9 and how this reform might change the debt and consumption dynamics of debt-distressed households. These plots are constructed by observing the mean level of debt defaulted on in the baseline and tracking all the households who default on that debt level before and after their default. The plots



Notes: Solid line in the baseline while the dotted lines are the counterfactual. Plots show the path around a (baseline) default event for household income (normalised by average income), consumption, assets, and the (weighted) average bond price over bonds and personal loans. The paths are constructed by taking the mean debt defaulted on in simulations and plotting the path of the baseline variables before and after the default event. Since several households may share the mean debt at default, an average is taken. These exact same households are tracked over the same periods in the counterfactual (whether or not a default occurs in the counterfactual) and the resulting paths are the dotted line. Shaded areas show observations between 20th and 60th percentiles.

Fig. 3.9: Path for Typical Default Event - Baseline vs. No-Wedge Benchmark

are the average among these households. The shaded areas around the plots show observations between 20th and 60th percentiles.

There are a few interesting points to note in Figure 3.9. The first is that the typical household that defaults in the baseline does not default in the counterfactual - despite the same history of income and expenditure shocks. This can be observed from the bottom-right panel which plots the average bond price which plummets at time $t - 1$ in the baseline but stays high in the counterfactual. Secondly, the households in the counterfactual are carrying less wealth into $t - 10$ than under the baseline. They also enter debt from $t - 5$ and are able to sustain this negative net asset position until they exit it - without defaulting - in period $t + 3$. By contrast, in the baseline, households maintain a higher level of wealth in the run-up to their default - only becoming indebted immediately beforehand.

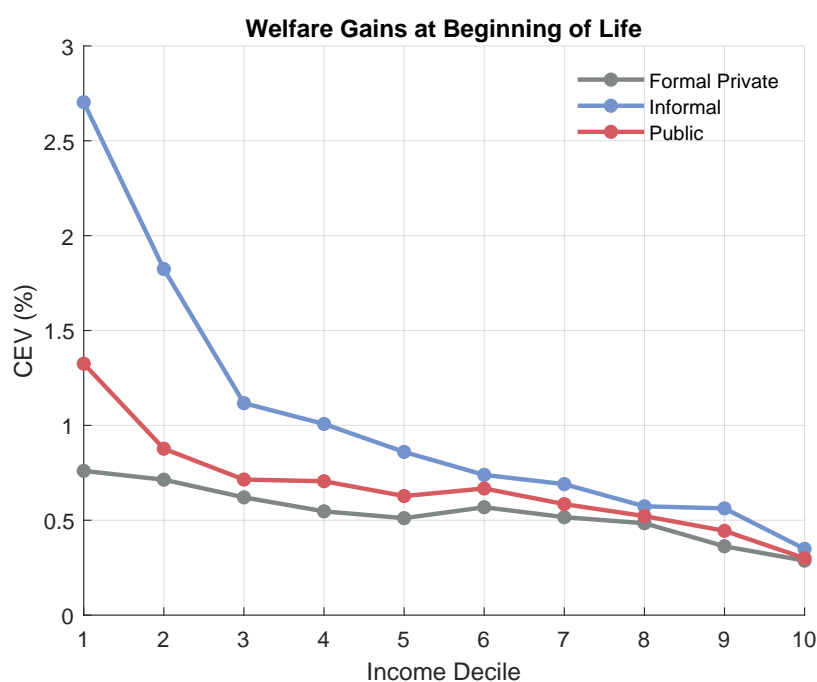
Finally, despite the divergent paths for debt, default and bond prices, it is striking that the consumption paths are similar. It would seem that the lower wedges allow the household avoid default but market discipline still prevents an excessive run-up in debt and forces deep consumption cuts.

3.5.2 Portability

To construct this scenario, we draw on the results of Cavalcanti and Fantinatti (2023) who analyse the results of increased competition due to the 2014 Loan Portability Law which increased competition in the market for consumer loans by making it easy to move your loan from the bank that initially gave you the loan to a competitor bank with a lower interest rate. That paper uses regional variation in the competitiveness of local markets for consumer loans. The empirical strategy rests on the idea that banks who enjoy a local monopoly will be unaffected by the portability reform as consumers have no practical alternative but to keep their loan with them. Using the Herfindahl-Hirschman Index (HHI) of market concentration and competitiveness, the average region in Brazil has a HHI score of 4000 (a monopoly has a score of 10,000 and 2,000 is considered very competitive). Using the results from Cavalcanti and Fantinatti (2023) the estimated reduction in interest rates for the Brazilian region of average competitiveness as a result of the portability reform is 1.269p.p. for payroll loans and 18.834p.p. for personal loans. For the results in this section, we assume the interest rate wedges drop by these amounts.

The aggregate welfare gains of 0.7% from this portability reform are approximately one fifth of the gains from completely removing the interest rate wedges. This holds roughly true for the disaggregated results shown in Figure 3.10 where the

graph is similar to the welfare results in Figure 3.5 but scaled down by 20%. As an aside, it is an interesting feature that despite the micro-level kinks and non-linearities inherent in the household problem, the resulting macro picture from portability is almost a linear transformation of the more extreme no-wedge benchmark.



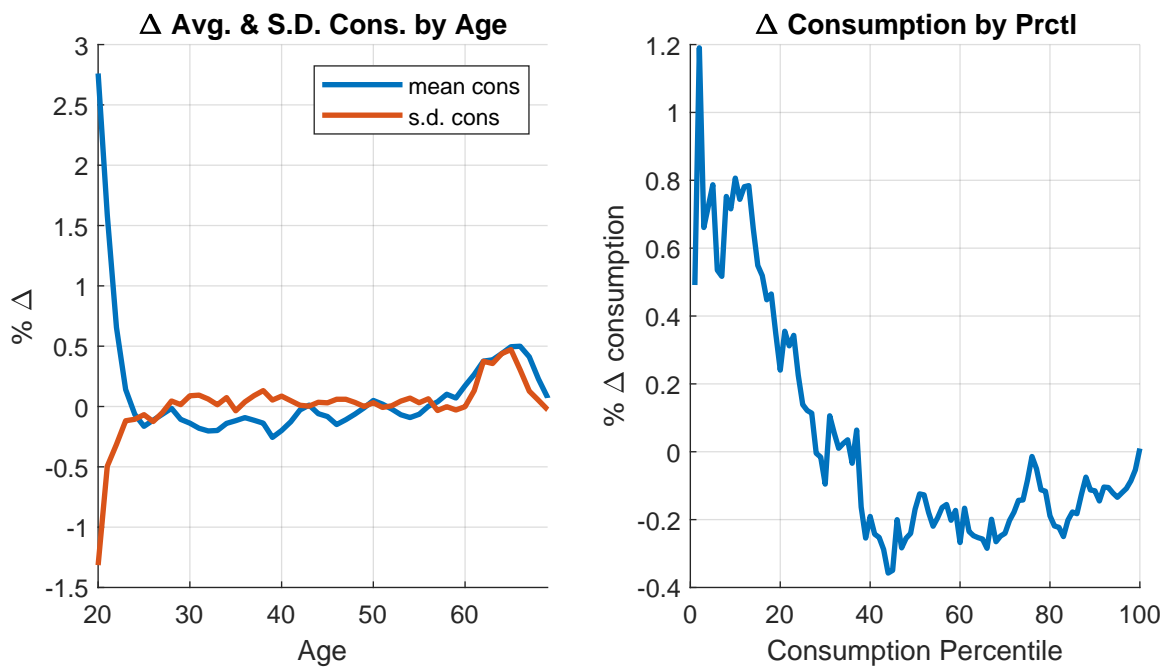
Notes: Consumption equivalent variation (as % of baseline consumption) from fully removing all wedges from both personal and payroll loans.

Fig. 3.10: Consumer Welfare Gains From Portability Reform - by Sector and Income Decile

Similar patterns hold true for Figures 3.11 and 3.12 which are correspondingly scaled down versions of Figures 3.6 and 3.7 respectively. One notable difference in Figure 3.11 is that consumption gains appear somewhat more limited to the young and poor - presumably because for those who do shift consumption using debt, the cost of doing so is much higher.

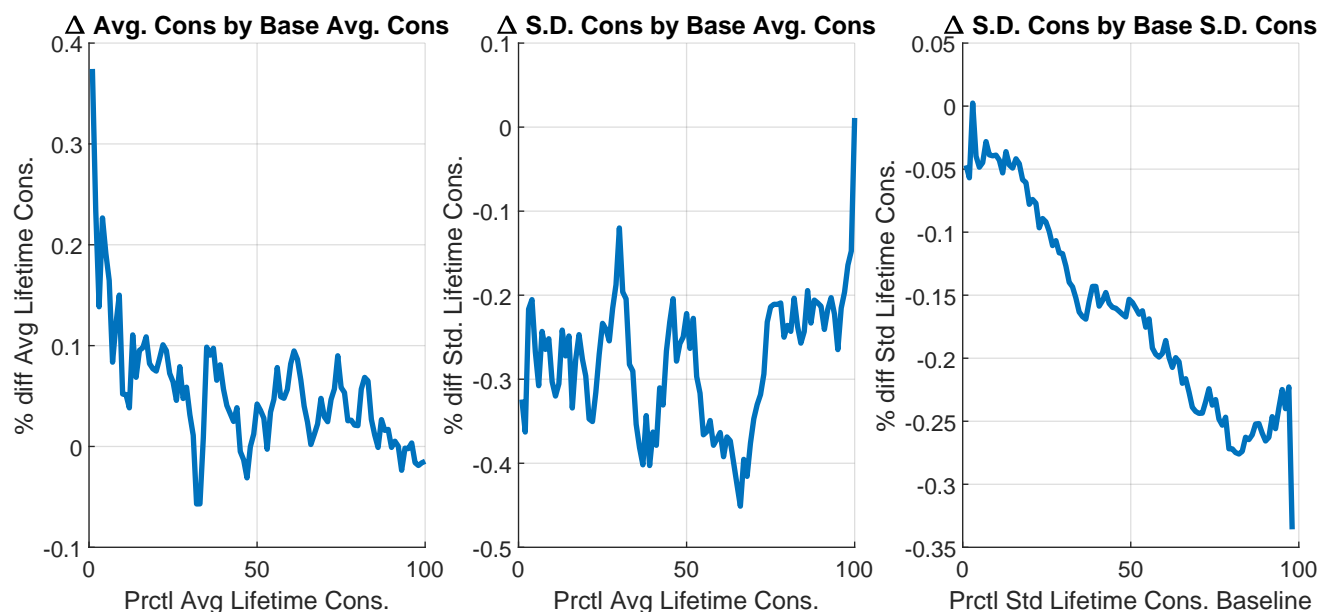
When we look at the profiles for assets and debt use in Figure 3.13 we again see similar patterns to the benchmark counterfactual of no wedges. Assets are lower, particularly for the young and poor and debt use has expanded on the extensive margin. One difference is that the average debt for households earning between 0 – 1 minimum wages has gone down by more. This is a feature of two things.

Firstly, debt among the very poorest is already low so small absolute changes show up as large % changes. Secondly, it is because of the expansion of debt use along the extensive margin is primarily by households who contract lower levels of debt. The average debt-to-income is thereby diluted.



Notes: Left panel: Blue line shows % change in mean consumption by age. Red line shows % change in the cross-sectional standard deviation of consumption by age. Right panel: % change in consumption according to the household's place in the consumption distribution in the baseline.

Fig. 3.11: Change to Consumption Profiles - Portability Reform



Notes: Left panel: Plots the % change in household consumption by percentile of average lifetime consumption in the baseline. Middle panel: Plots the % change from the baseline in the standard deviation of consumption over the household's lifetime for each percentile in the average lifetime consumption in the baseline. Right panel: Plots the % change from the baseline in the standard deviation of consumption over the household's lifetime for each percentile in that standard deviation in the baseline.

Fig. 3.12: Effects of Portability Reform on Lifetime Consumption Averages and Standard Deviations

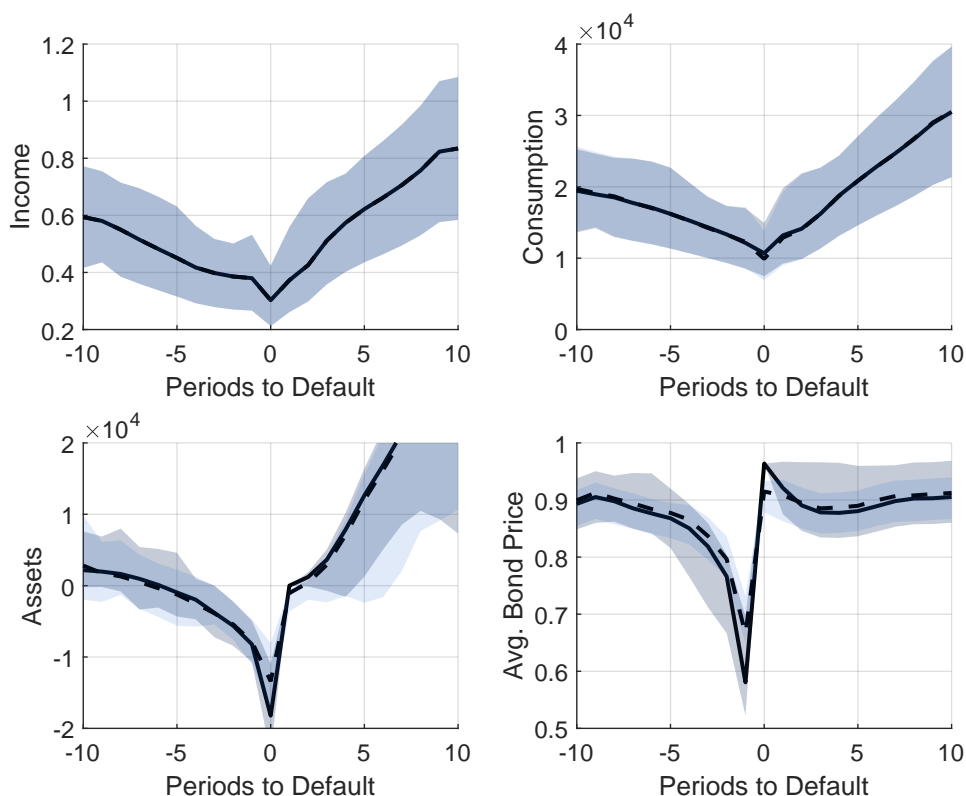
Coming to the typical default event - constructed in the same way as discussed above - we can see that the counterfactual and the baseline are now much more similar. In particular, default still occurs in the counterfactual scenario. Bond prices in the counterfactual also drop significantly in the counterfactual (bottom-right panel) while debt (negative assets) are reset to zero in period 1.

In common with the no-wedge counterfactual, the lower interest rates from increased portability aid consumption through lower levels of precautionary saving - particularly for the young and poor - and allow for an expansion of debt use. However, when it comes to households who default in the baseline, these changes to the interest rate regime appear not to be of much help.



Notes: Blue lines indicate % changes from the baseline to the counterfactual. Grey lines indicate baseline case. Red lines indicate counterfactual case. For the case of debt, an positive % change in debt corresponds to a more negative net asset position.

Fig. 3.13: Change to Debt and Asset Profiles from Portability Reform



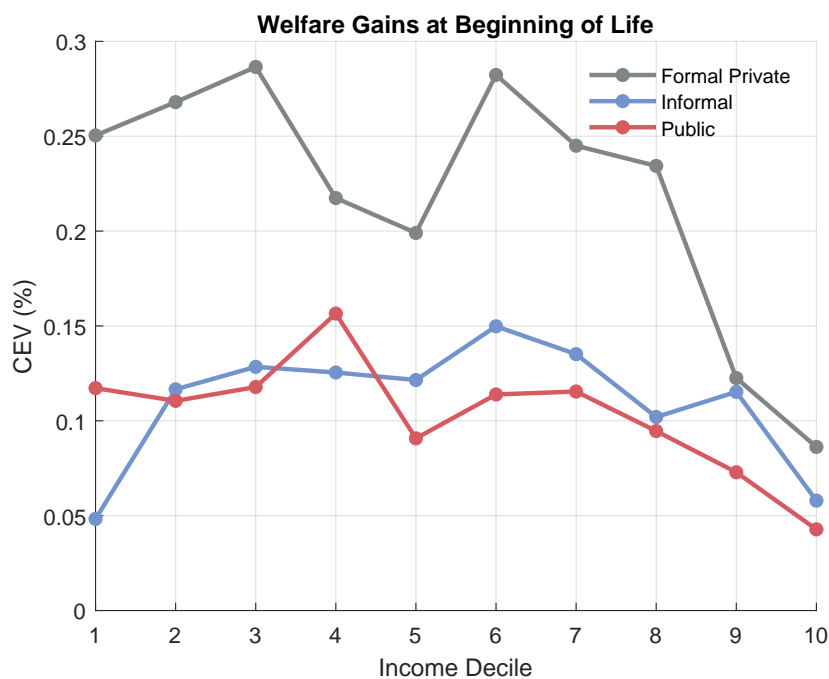
Notes: Solid line in the baseline while the dotted lines are the counterfactual. Plots show the path around a (baseline) default event for household income (normalised by average income), consumption, assets, and the (weighted) average bond price over bonds and personal loans. The paths are constructed by taking the mean debt defaulted on in simulations and plotting the path of the baseline variables before and after the default event. Since several households may share the mean debt at default, an average is taken. These exact same households are tracked over the same periods in the counterfactual (whether or not a default occurs in the counterfactual) and the resulting paths are the dotted line. Shaded areas show observations between 20th and 60th percentiles.

Fig. 3.14: Path for Typical Default Event - Baseline vs. Portability Reform

3.5.3 Payroll Expansion

In this section, we turn to considering a reform of a different type. What if payroll loans were more broadly available? This is a proposal often mooted in public debate in Brazil. As discussed above, these loans are a form of debt available only to public sector workers, the retired, and a small measure of formal workers. This is generally because the loans require agreement between banks and lenders to

essentially garnish the worker's wages to ensure repayment. This requires trust between the bank and employer - something which is naturally easier to achieve when the employer is the state or certain large private employers but seems infeasible for firms hiring workers in the informal economy. Here we imagine a government scheme that facilitates the expansion of payroll loans to all formal workers. This gives a large segment of the population access to a debt instrument with two important features. Firstly, the interest rate wedge is much smaller so even absent of default considerations, the cost of borrowing will be lower. Secondly, the fact that wages can be garnished after a default allows the household to choose to expose itself to greater recourse and - consequently - greater costs of default. These should, in turn, lead to lower interest rates.

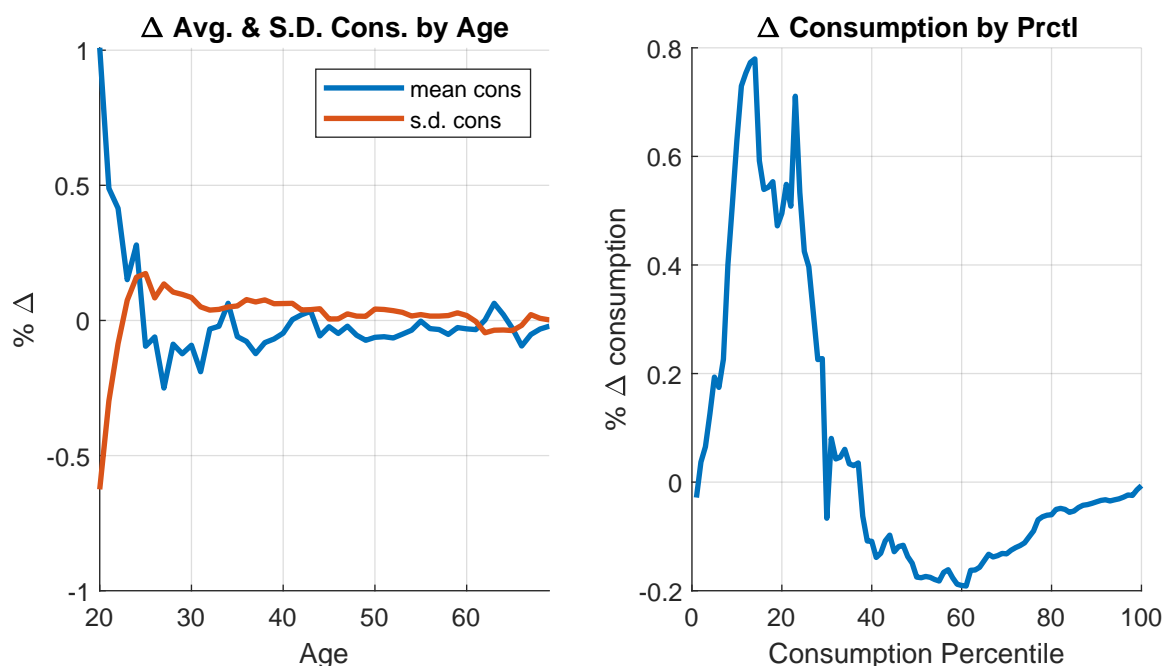


Notes: Consumption equivalent variation (as % of baseline consumption) from fully removing all wedges from both personal and payroll loans.

Fig. 3.15: Consumer Welfare Gains From Payroll Expansion - by Sector and Income Decile

The aggregate consumer welfare gain of 0.15% is small. This is, perhaps, unsurprising, given that the reform applies only to a segment of the population. The disaggregated consumer welfare gains are shown in Figure 3.15 and show that

among formal workers the gains are somewhat higher - although still moderate at 0.21% on average. We see from Figure 3.16 that the increase in consumption for the young is smaller and more limited. This reflects the fact that the young are more likely to be informal workers than the old and so the primary beneficiaries of lower interest rates are less able to take advantage of them in this case.

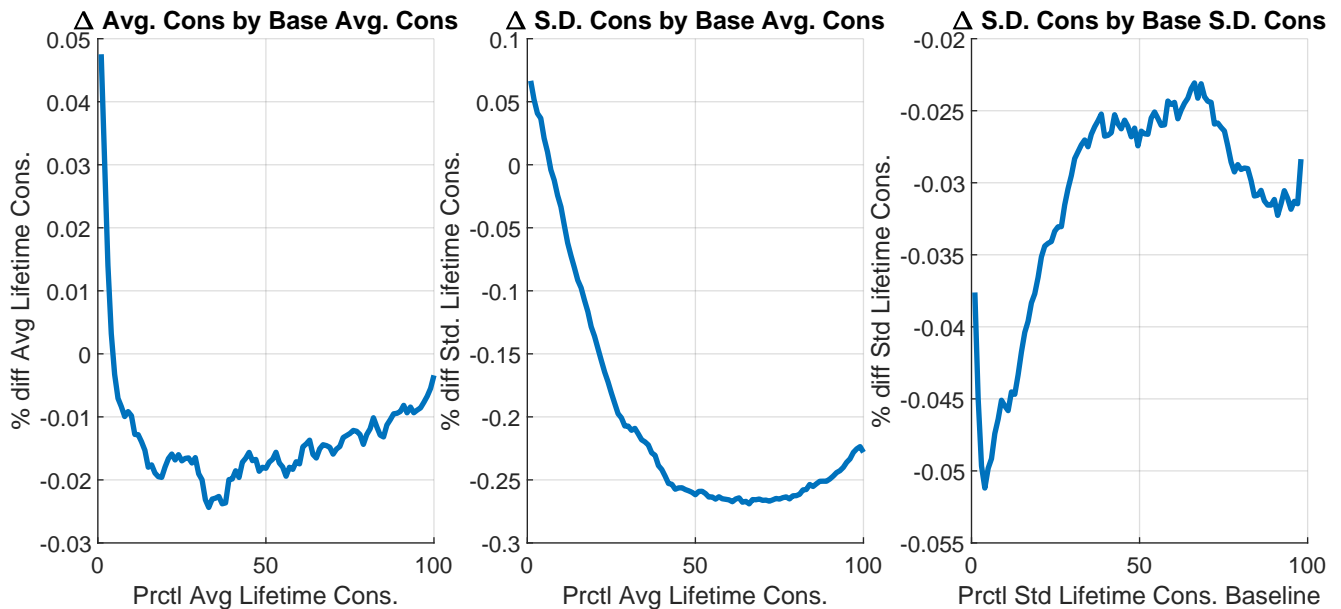


Notes: Left panel: Blue line shows % change in mean consumption by age. Red line shows % change in the cross-sectional standard deviation of consumption by age. Right panel: % change in consumption according to the household's place in the consumption distribution in the baseline. Finally, consistent with the small effects on consumption and welfare, the change to debt and asset management are quite small and the change to debt use, in particular, is negligible. The overall takeaway from this is that an expansion of payroll loans in this omits the segment of the population who would stand to gain the most from the reform - informal workers who are younger and poorer.

Fig. 3.16: Change to Consumption Profiles - Payroll Expansion

Aside from the youngest age groups, the cross-sectional standard-deviation of consumption is also slightly higher in the counterfactual, possibly reflecting the fact that the benefits of the policy accrue to the sector with relatively higher income and so the reform increases consumption inequality. When we look at the lifetime effects on the mean and standard deviation of consumption, we find the effects to be much smaller than previously. Figure 3.18 shows that the corresponding changes to the

paths for debt and asset management show very limited changes relative to those observed in the other experiments.



Notes: Left panel: Plots the % change in household consumption by percentile of average lifetime consumption in the baseline. Middle panel: Plots the % change from the baseline in the standard deviation of consumption over the household's lifetime for each percentile in the average lifetime consumption in the baseline. Right panel: Plots the % change from the baseline in the standard deviation of consumption over the household's lifetime for each percentile in that standard deviation in the baseline.

Fig. 3.17: Effects of Payroll Expansion on Lifetime Consumption Averages and Standard Deviations

Despite the only small changes to consumption and debt patters, we do see some moderate improvements in default rates among formal workers. The overall default rate for formal workers drops from 2.1% to 1.5%. Among the formal workers earning less than twice the minimum wage the model default rate drops from 2.6% to 1.6%. Figure 3.19 helps to show why. It shows the path for personal and payroll debt around a default by the average formal worker in the baseline and the corresponding counterfactual path. The figure is constructed in the same way as previous typical default paths but this time we break out personal (bond) and payroll separately.

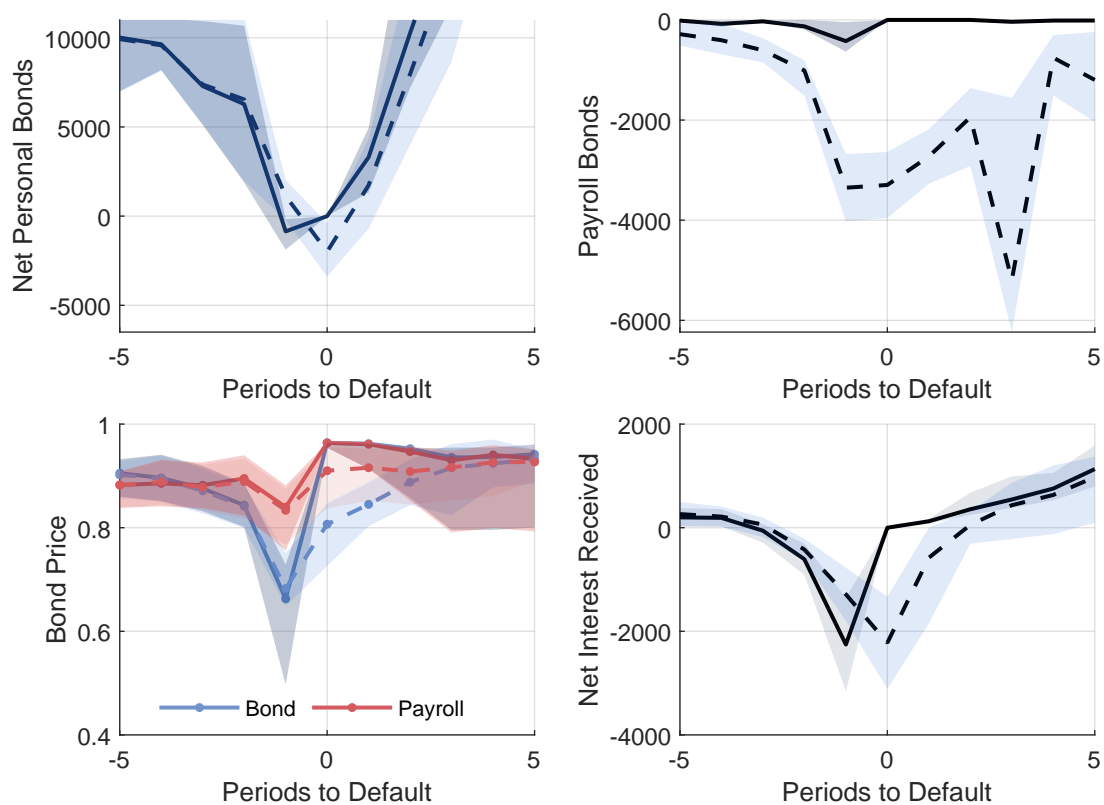
The key difference is that despite similar paths for personal loans, default is avoided because the formal workers in the counterfactual can access extra credit



Notes: Blue lines indicate % changes from the baseline to the counterfactual. Grey lines indicate baseline case. Red lines indicate counterfactual case.

Fig. 3.18: Change to Debt and Asset Profiles from Payroll Expansion

in the form of payroll loans which have lower interest rates. The net interest rate received (negative for the case of net debt) is shown in the lower right panel where despite the higher debt level, interests costs over the period are less burdensome in the counterfactual.

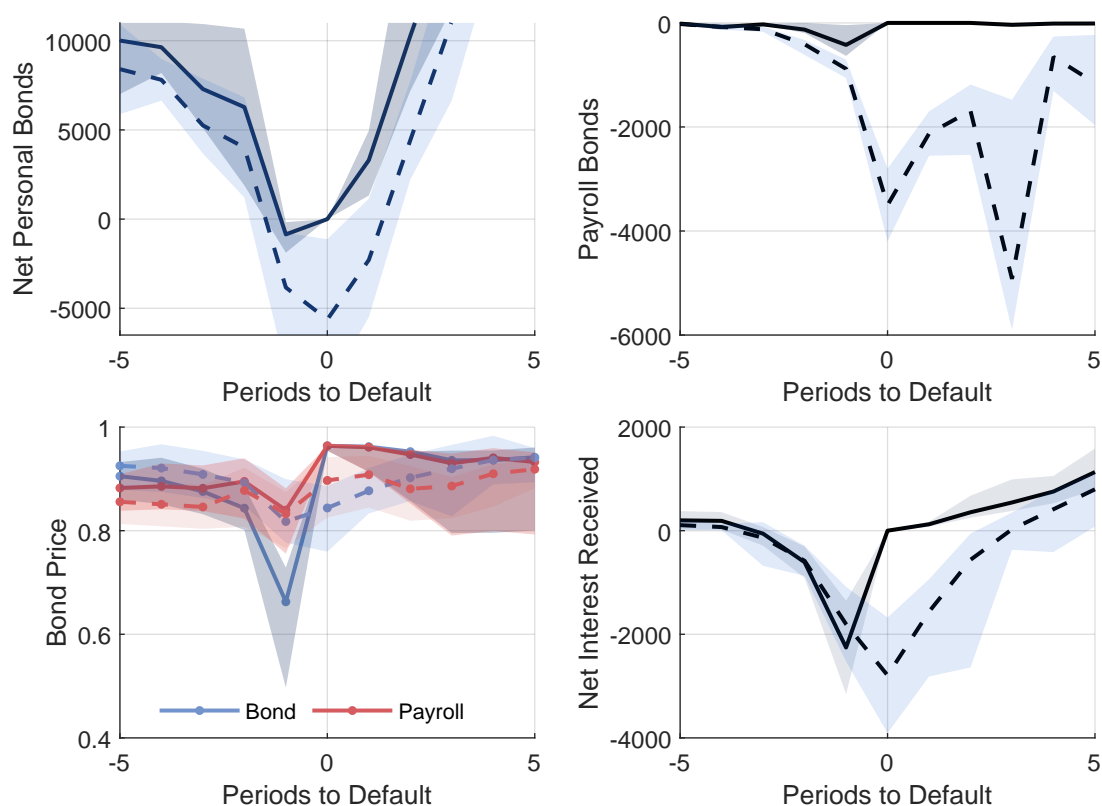


Notes: Plots show the path around default for bonds, payroll loans, bond prices of personal loans and payroll loans and the net interest received/paid around a (baseline) default event. The paths are constructed by taking the mean debt defaulted on in simulations and plotting the path of the baseline variables before and after the default event. Since several households may share the mean debt at default, an average is taken. These exact same households are tracked over the same periods in the counterfactual (whether or not a default occurs in the counterfactual) and the resulting paths are the dotted line. The shaded areas show observations between the 20th and 80th percentiles.

Fig. 3.19: Path for Typical Default Event - Baseline vs. Expanded Payroll (baseline wedges)

Figure 3.19 shows that payroll loans become a useful tool for households trying to avoid default. Lower interest-rate wedges and higher recovery rates for banks in the event of default combine to make payroll loans attractive for formal workers.

It is worth asking, however, whether payroll loans are generally preferred in the counterfactual only because personal loans have a much larger wedge, or would households still prefer payroll loans even if personal loans were just as cheap. Figure 3.20 considers this by plotting a counterfactual where personal loans have the same low wedge as payroll loans. The only remaining difference is now the higher rate of garnishing for payroll loans in the event of default. In the absence of this, the loans would be identical and the portfolio choice between personal and payroll loans would be indeterminate.



Notes: Plots show the path around default for bonds, payroll loans, bond prices of personal loans and payroll loans and the net interest received/paid around a (baseline) default event. The paths are constructed by taking the mean debt defaulted on in simulations and plotting the path of the baseline variables before and after the default event. Since several households may share the mean debt at default, an average is taken. These exact same households are tracked over the same periods in the counterfactual (whether or not a default occurs in the counterfactual) and the resulting paths are the dotted line. The shaded areas show observations between the 20th and 80th percentiles.

Fig. 3.20: Path for Typical Default Event - Baseline vs. Expanded Payroll (equal wedges)

Figure 3.20 shows that when making the wedge on personal loans just as cheap, payroll loans are household's first choice for entering into debt. Having said that, payroll loans are not so preferred that households rely only on them. As the interest burden and probability of default increase, households choose to use both personal and payroll loans to increase their debt burden. The mixed strategy is interesting as it suggests households are *ex-ante* trading off higher default costs with lower interest rates.

3.6 Conclusion

Using the Brazilian administrative credit registry data, this paper reports high and dispersed interest rate spreads for consumer loans in Brazil. Default rates explain a relatively small fraction of such spreads and loan interest rate wedges are negatively correlated with income. Informal workers pay relative higher interest rates.

We then build a life cycle model economy with formal and informal workers, and retired individuals and endogenous default. The model displays credit market features similar to those observed in the Brazilian economy. We set model parameters such that the model matches interest rate spreads, default rates and debt levels by income of the Brazilian economy and we run counterfactual exercises to show that welfare effects are large. For poor and informal workers, welfare effects of loan interest rate wedges are equivalent to about 15% of consumption per year.

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Appendix C

Appendix to Chapter 3

C.1 Data Appendix

C.1.1 Description of Data Sets and Summary Statistics

Data on loans in Brazil are from the Brazilian Public Credit Registry (SCR - *Sistema de Informações de Crédito*).¹ This is a confidential loan-level database managed by the Central Bank of Brazil. For any loan, we identify the lender, borrower, size of the loan, the interest rate on loan, the loan maturity, default rates, and credit scores. We also have some information on borrowers' characteristics such as age, gender, income, location, and occupation. An individual can have multiple loans in a period. We have a representative sample of 1,362 million individuals, and they are followed from January 2013 to December 2019.²

We also use RAIS (*Relação Anual de Informações Sociais*), a matched employer-employee administrative dataset covering all formal employment in Brazil. This is a mandatory annual survey maintained by the Ministry of Economy. RAIS provides information on the borrower's income and detailed occupation. We use this dataset to construct a measure of financial literacy. We follow 403,530 individuals and build an individual financial literacy index using two-individual-level characteristics that are observable in RAIS dataset: years of education and occupation. To measure financial literacy, we rely on the occupation descriptions provided by the Brazilian Ministry of Labor. Specifically, we identify occupations that require a strong

¹SCR detailed records on credit relationships between individuals, firms and Brazilian banks (covers all credit relationships above a threshold). The reporting threshold has changed over time: R\$ 5,000 from January 2003 to December 2011, R\$ 1,000 from January 2012 and May 2016, and R\$ 200 starting in June 2016.

²In the SCR database, we use code 0202 for payroll loans and code 0203 for personal loans.

foundation in numeracy, such as economics, finance, math, statistics, accounting, engineering, and banking services. We consider individuals in these occupations to have a higher likelihood of being familiar with financial concepts. Our financial literacy index is computed by multiplying the number of years of education by a dummy variable that indicates whether the individual works in a finance-related occupation. Unfortunately, the RAIS database only contains data on formal employees, which prevent us to measure financial literacy for informal employees.

Table C.1 provides descriptive statistics for the main variables used in our empirical analysis for personal loans. For the deposit rate we consider the maturity of the loan and the term structure of interest rates in order to take into account the cost of capital for longer maturity. As we can observe, there are more than 25 million observations, and statistics for the following variables are provided: annual interest rate, maturity, default rate, loan amount and credit risk score (from AA - lowest risk score or lowest default probability to H - highest risk score), occupation (formal, retired, civil servant and informal)³, as well as borrower's age, gender, race, monthly income⁴ and loan amount as a share of the formal monthly income. We also have the municipality of the loan origination, which is not reported in Table C.1.

³Formal employees are well identified since they must appear at RAIS. For informal employees, we cannot assess whether they are informal workers or self-employed. For robustness, we also do our empirical analysis restricting informal employees as those who earn up to 10 minimum wages in monthly income.

⁴Those reported as multiple of minimum wages are borrower's reported income by the bank to the SCR. The wage from RAIS is also reported but only for formal employees.

Table C.1: Summary Statistics - Personal Loans

	N	mean	sd	p10	p50	p90
Deposit rate (personal)	2.54e+07	9.93	3.11	6.36	10.17	14.10
Rate (personal)	2.16e+07	146.39	200.29	31.07	89.26	254.41
Maturity	2.16e+07	26.89	21.11	5.97	24.07	58.13
Default (personal)	2.16e+07	0.06	0.24	0.00	0.00	0.00
Loan (personal)	2.16e+07	4393.85	54132.88	267.63	1460.56	8012.17
Risk: AA	2.16e+07	0.04	0.20	0.00	0.00	0.00
Risk: A	2.16e+07	0.50	0.50	0.00	1.00	1.00
Risk: B	2.16e+07	0.11	0.31	0.00	0.00	1.00
Risk: C	2.16e+07	0.16	0.36	0.00	0.00	1.00
Risk: D	2.16e+07	0.10	0.30	0.00	0.00	1.00
Risk: E	2.16e+07	0.05	0.22	0.00	0.00	0.00
Risk: F	2.16e+07	0.01	0.12	0.00	0.00	0.00
Risk: G	2.16e+07	0.01	0.09	0.00	0.00	0.00
Risk: H	2.16e+07	0.02	0.13	0.00	0.00	0.00
Retired (personal)	2.16e+07	0.20	0.40	0.00	0.00	1.00
Civil Serv (personal)	2.16e+07	0.12	0.33	0.00	0.00	1.00
Informal (personal)	2.16e+07	0.56	0.50	0.00	1.00	1.00
Formal (personal)	2.16e+07	0.12	0.33	0.00	0.00	1.00
Age	2.16e+07	47.34	15.65	27.00	46.00	69.00
Female	2.16e+07	0.49	0.50	0.00	0.00	1.00
White	2.16e+07	0.06	0.24	0.00	0.00	0.00
No income	2.16e+07	0.01	0.11	0.00	0.00	0.00
Up to 1 mw	2.16e+07	0.16	0.37	0.00	0.00	1.00
From 1 to 2 mw	2.16e+07	0.27	0.45	0.00	0.00	1.00
From 2 to 3 mw	2.16e+07	0.17	0.38	0.00	0.00	1.00
From 3 to 5 mw	2.16e+07	0.16	0.37	0.00	0.00	1.00
From 5 to 10 mw	2.16e+07	0.14	0.35	0.00	0.00	1.00
From 10 to 20 mw	2.16e+07	0.06	0.23	0.00	0.00	0.00
+20 mw	2.16e+07	0.03	0.16	0.00	0.00	0.00
Wage (RAIS)	3035985	2564.57	3334.20	888.50	1644.44	4904.19
Loan/wage (personal) (RAIS)	3035985	1.48	2.43	0.13	0.79	3.23
Fin. Literacy	3035985	0.74	3.25	0.00	0.00	0.00
Yield curve (personal)	2.16e+07	9.97	3.19	6.36	10.63	14.11
Observations	21565721					

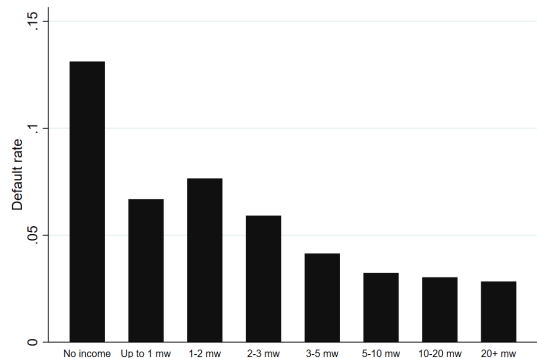
Table C.5 contains similar statistics for the variables of Table C.1 but for payroll loans. The deposit interest rates are different because loan maturity for payroll and

personal loans are different and we consider the term structure of interest rates to define the deposit rate. There are more than 34 million observations. Some individuals can appear at RAIS, i.e. be a formal worker, but be also a civil servant. Since a job in the public sector is safer and, in general, there is a wage premium to work in the public sector, we denote those individuals as civil servants. Similarly, a worker can have a formal job and be retired. We denote such individuals as retired. One of the reasons to follow this approach is that civil servants and retired individuals have easier access to payroll loans than formal workers and our model would not allow individuals to have more than one occupation.

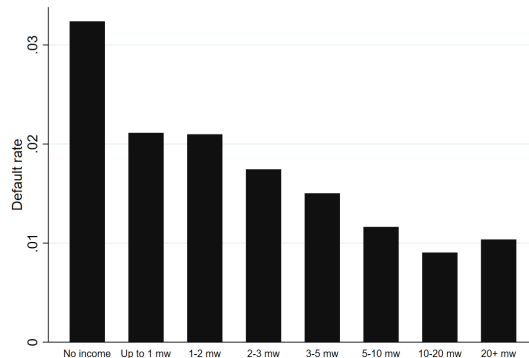
Figure C.1 reports default rates by income groups for personal (Panel (a)) and payroll (Panel (b)) loans. Although the average default rate is high for individuals without any income, their share in our sample is quite low (1% and 3% for personal and payroll loans, respectively). Default rates are negatively correlated with income. Figure C.2 displays the density of interest rates for personal (Panel (a)) and payroll (Panel (b)) loans. As can be seen, the variability in interest rates is larger for personal loans than for payroll loans.

Table C.2: Summary Statistics - Payroll Loans

	N	mean	sd	p10	p50	p90
Deposit rate (payroll)	2.12e+07	9.97	3.31	6.32	10.81	14.15
Rate (payroll)	2.11e+07	27.80	10.87	20.98	28.18	31.99
Maturity	2.11e+07	62.44	21.24	33.07	61.67	86.07
Default (payroll)	2.11e+07	0.02	0.14	0.00	0.00	0.00
Loan (payroll)	2.11e+07	8100.90	15915.24	643.72	3616.71	18358.28
Risk: AA	2.11e+07	0.05	0.21	0.00	0.00	0.00
Risk: A	2.11e+07	0.47	0.50	0.00	0.00	1.00
Risk: B	2.11e+07	0.21	0.41	0.00	0.00	1.00
Risk: C	2.11e+07	0.16	0.37	0.00	0.00	1.00
Risk: D	2.11e+07	0.05	0.21	0.00	0.00	0.00
Risk: E	2.11e+07	0.02	0.14	0.00	0.00	0.00
Risk: F	2.11e+07	0.02	0.14	0.00	0.00	0.00
Risk: G	2.11e+07	0.01	0.11	0.00	0.00	0.00
Risk: H	2.11e+07	0.01	0.12	0.00	0.00	0.00
Retired (payroll)	2.11e+07	0.65	0.48	0.00	1.00	1.00
Civil Serv (payroll)	2.11e+07	0.27	0.44	0.00	0.00	1.00
Formal (payroll)	2.11e+07	0.08	0.27	0.00	0.00	0.00
Age	2.11e+07	60.94	15.35	36.00	66.00	77.00
Female	2.11e+07	0.59	0.49	0.00	1.00	1.00
White	2.11e+07	0.04	0.20	0.00	0.00	0.00
No income	2.11e+07	0.03	0.17	0.00	0.00	0.00
Up to 1 mw	2.11e+07	0.25	0.43	0.00	0.00	1.00
From 1 to 2 mw	2.11e+07	0.26	0.44	0.00	0.00	1.00
From 2 to 3 mw	2.11e+07	0.12	0.33	0.00	0.00	1.00
From 3 to 5 mw	2.11e+07	0.15	0.36	0.00	0.00	1.00
From 5 to 10 mw	2.11e+07	0.12	0.32	0.00	0.00	1.00
From 10 to 20 mw	2.11e+07	0.04	0.20	0.00	0.00	0.00
+20 mw	2.11e+07	0.01	0.12	0.00	0.00	0.00
Wage (RAIS)	2266268	2952.29	3309.93	942.45	1919.41	5921.05
Loan/wage (payroll) (RAIS)	2266268	3.41	3.96	0.42	2.14	7.65
Fin. Literacy	2266268	0.59	2.95	0.00	0.00	0.00
Yield curve (payroll)	2.11e+07	9.98	3.30	6.32	10.81	14.15
Observations	21137420					



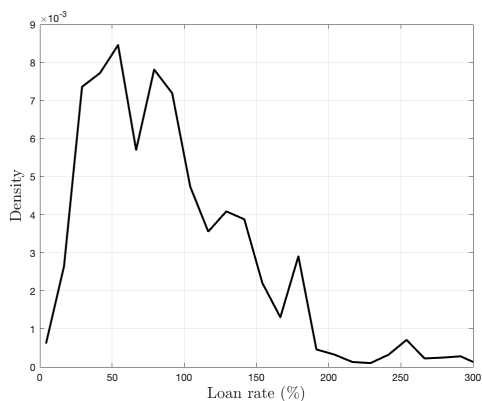
(a) Personal Loans



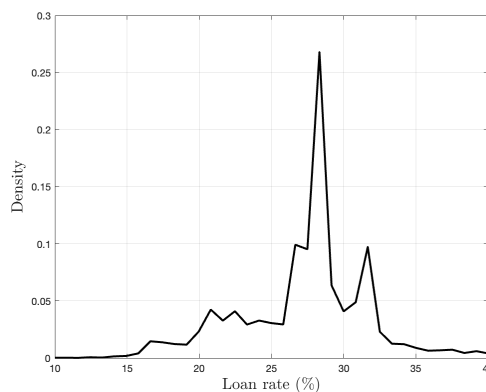
(b) Payroll Loans

Notes: Panel (a) and Panel (b) display default rates by income levels for personal loans and payroll loans, respectively.

Fig. C.1: Default rates by income groups



(a) Personal Loans



(b) Payroll Loans

Notes: Panel (a) and Panel (b) display the density of interest rates for personal loans and payroll loans, respectively.

Fig. C.2: Default rates by income groups

C.1.2 Bankruptcy

We use the standard international definition of non-performing loans (NPLs), that is, a 90-day past-due threshold. In Brazil, after some days of delinquency (usually 45 days, depending on each bank's rules), the default credit record of an individual is sent to Serasa (a credit bureau that keeps a record of all delinquent individuals), and this credit record is accessible to other banks. Therefore, if a client becomes delinquent in one bank, all the others will know this information. In general, after a client becomes delinquent in a type of credit, all the other types of credit are shut down for this individual. According to the Consumer Protection Code (**Law No. 8078/90**), after five years, this negative credit record is canceled, and the consumer will be able to acquire new bank credit.

C.1.3 Description of Data Moments

- Debt-to-Income (ex-housing): This data has been reported monthly since March 2005 by the Brazilian Central Bank. The debt-to-income ratio is the value corresponding to the expected payments for debt service with the Banking System and the monthly income of families in a quarterly moving average, seasonally adjusted.
- Households Using Debt: This is a survey⁵, and it has been reported monthly by Confederação Nacional da Indústria (CNC) since January 2010. This survey aims to draw a profile of indebtedness in Brazil, following the level of commitment of consumers with debts and their perception of their ability to pay.
- Real interest rate: The real interest rate is calculated using the effective nominal interest rate (Selic) per annum and the 12-month rolling average of the inflation rate (IPCA). The nominal interest rate is available at the Brazilian Central Bank, and the inflation rate is released by IBGE.

⁵This survey is called Pesquisa Endividamento e Inadimplência do Consumidor (PEIC).

C.1.4 Wedges

Here we present the regression results for the interest loan interest rate wedge using our credit register data. For each type of loans, i.e., personal and payroll, we proceed in the following steps:

- First, we run a logit regression of default on loan characteristics (maturity, maturity squared, log of loan, risk), personal characteristics (income, occupation, gender, age) and fixed effects of time and municipality. Then we get predicted the predicted probability of default.
- With the predicted probability of default we calculate the risk-cost-free rate for each individual and then the calculate the interest wedge (actual rate-risk-cost-free rate).
- We then run a regression of the wedge on observable characteristics, such as those presented in Tables C.3 and C.4.

For the wedges used in the calibration, we consider the regression presented in column (2) of Tables C.3 (personal) and C.4 (payroll). Since the wedge corresponds to all costs not related to default, we set the risk dummy at the highest risk score (i.e., *AA*) to construct the wedge. For personal loans, this decreases the constant by 79.78pp, while for payroll loans there is a negligible change in the constant. Since our model period is one year, we let maturity to be equal to 12 months. The wedge still vary by income, age, occupation and loan size, as described by the regression coefficients of Column (2) of Tables C.3 and C.4.

Table C.3: Wedges and individual characteristics - Personal loans

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate
Maturity	-1.907*** (0.0945)	-1.827*** (0.0944)	-1.827*** (0.0948)	-2.132*** (0.0209)	-2.177*** (0.0168)
Maturity ²	0.00763*** (0.00111)	0.00749*** (0.00111)	0.00745*** (0.00111)	0.0124*** (0.000250)	0.0128*** (0.000185)
Log of loan	-4.065*** (0.141)	-4.254*** (0.142)	-4.147*** (0.143)	-3.586*** (0.0574)	-3.401*** (0.0574)
No income	85.83*** (0.737)	75.15*** (0.708)	77.31*** (0.727)	73.42*** (1.191)	75.72*** (1.285)
Up to 1 mw	60.94*** (0.479)	49.50*** (0.500)	50.40*** (0.502)	46.68*** (0.409)	48.34*** (0.433)
From 1 to 2 mw	43.94*** (0.385)	37.40*** (0.389)	38.07*** (0.391)	29.00*** (0.295)	29.90*** (0.308)
From 2 to 3 mw	32.04*** (0.320)	27.13*** (0.319)	27.65*** (0.321)	22.53*** (0.283)	23.09*** (0.296)
From 3 to 5 mw	21.52*** (0.250)	17.66*** (0.243)	18.15*** (0.244)	14.62*** (0.274)	15.17*** (0.287)
From 5 to 10 mw	10.51*** (0.182)	8.469*** (0.166)	8.839*** (0.167)	7.216*** (0.259)	7.523*** (0.270)
From 10 to 20 mw	1.926*** (0.122)	1.135*** (0.119)	1.513*** (0.119)	0.591** (0.251)	0.693*** (0.260)
Retired	0.395*** (0.125)	0.910*** (0.121)	1.189*** (0.121)	-3.682*** (0.401)	-3.747*** (0.417)
Civil Serv	-12.12*** (0.182)	-7.871*** (0.172)	-7.471*** (0.171)	-9.582*** (0.162)	-9.196*** (0.162)
Informal	3.373*** (0.0693)	3.336*** (0.0678)	3.598*** (0.0664)		
Age	1.271*** (0.0113)	1.253*** (0.0111)	1.269*** (0.0112)	0.339*** (0.0262)	0.338*** (0.0273)
Age ²	-0.0127*** (0.000118)	-0.0120*** (0.000113)	-0.0121*** (0.000113)	-0.00148*** (0.000329)	-0.00128*** (0.000342)
Female	7.879*** (0.0623)	8.636*** (0.0607)	8.647*** (0.0611)	4.273*** (0.0946)	4.342*** (0.0977)
Fin. Literacy				-1.345*** (0.0135)	-1.328*** (0.0133)
Constant	102.8*** (0.394)	143.1*** (0.683)	141.4*** (0.691)	141.8*** (1.071)	140.7*** (1.115)
Observations	20,483,498	20,483,498	20,464,737	2,984,011	2,888,871
R-squared	0.273	0.295	0.307	0.287	0.323
Risk control	NO	YES	YES	YES	YES
Time FE	YES	YES	NO	YES	NO
Munic. FE	YES	YES	NO	YES	NO
Munic.xTime FE	NO	NO	YES	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Table C.4: Wedges and individual characteristics - Payroll loans

VARIABLES	(1) wedge	(2) wedge	(3) wedge	(4) wedge	(5) wedge
Maturity	0.00824*** (0.000300)	0.00978*** (0.000300)	0.00965*** (0.000301)	-0.00483 (0.00920)	-0.000357 (0.0113)
Maturity ²	-3.25e-05*** (2.04e-06)	-3.43e-05*** (2.09e-06)	-3.41e-05*** (2.10e-06)	-0.000173** (8.19e-05)	-0.000223** (0.000101)
Log of loan	-0.460*** (0.00381)	-0.497*** (0.00370)	-0.496*** (0.00375)	-0.336*** (0.00977)	-0.336*** (0.0114)
No income	2.509*** (0.0232)	2.543*** (0.0247)	2.561*** (0.0249)	2.819*** (0.0975)	2.816*** (0.106)
Up to 1 mw	2.534*** (0.0229)	2.499*** (0.0243)	2.509*** (0.0243)	3.010*** (0.0831)	3.021*** (0.0916)
From 1 to 2 mw	2.427*** (0.0231)	2.406*** (0.0241)	2.415*** (0.0241)	2.854*** (0.0787)	2.880*** (0.0853)
From 2 to 3 mw	2.242*** (0.0227)	2.242*** (0.0238)	2.247*** (0.0238)	2.706*** (0.0758)	2.708*** (0.0818)
From 3 to 5 mw	1.953*** (0.0224)	1.970*** (0.0235)	1.983*** (0.0235)	2.439*** (0.0772)	2.432*** (0.0830)
From 5 to 10 mw	1.481*** (0.0219)	1.485*** (0.0233)	1.494*** (0.0232)	1.878*** (0.0733)	1.863*** (0.0780)
From 10 to 20 mw	0.502*** (0.0183)	0.491*** (0.0188)	0.501*** (0.0187)	1.231*** (0.0684)	1.213*** (0.0717)
Retired (payroll)	-0.852*** (0.0151)	-0.886*** (0.0154)	-0.893*** (0.0157)	0.161*** (0.0190)	0.161*** (0.0203)
Civil Serv (payroll)	-2.511*** (0.0201)	-2.563*** (0.0203)	-2.574*** (0.0208)	-2.073*** (0.0205)	-2.131*** (0.0219)
Age	0.0511*** (0.00107)	0.0516*** (0.00111)	0.0514*** (0.00112)	0.0359*** (0.00313)	0.0403*** (0.00327)
Age ²	-0.000422*** (9.15e-06)	-0.000427*** (9.53e-06)	-0.000425*** (9.64e-06)	-0.000672*** (3.57e-05)	-0.000736*** (3.72e-05)
Female	0.102*** (0.00276)	0.0874*** (0.00276)	0.0879*** (0.00277)	-0.232*** (0.0118)	-0.237*** (0.0125)
Fin. Literacy				-0.0868*** (0.00248)	-0.0863*** (0.00255)
Constant	17.82*** (0.0645)	16.06*** (0.0712)	16.08*** (0.0725)	14.97*** (0.173)	14.79*** (0.194)
Observations	20,524,507	20,524,507	20,506,221	1,864,303	1,777,400
R-squared	0.486	0.498	0.507	0.335	0.360
Risk control	NO	YES	YES	YES	YES
Time FE	YES	YES	NO	YES	NO
Munic. FE	YES	YES	NO	YES	NO
Munic.xTime FE	NO	NO	YES	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

C.1.5 Summary of All Different Loan Types

Figure C.3 shows the percentage of different loan types based on their values, excluding housing and earmarked credit. This data is collected monthly by the BCB starting from March 2007 (source: BCB-DSTAT). For our analysis, we focus on data from 2013 to 2019. As observed in Figure A3, the majority of loans fall into three categories: payroll (59%), auto (27%), and personal (23%).

In this study, we specifically consider payroll and personal loans as the most significant examples of non-collateralized loans. Table C.5 provides descriptive statistics for these loan types. Notably, auto (23.06%, on average) and payroll (26.10%) have the lowest interest rates among all loan categories due to their collateralized nature.

Conversely, "revolving" credit lines carry the highest interest rates for consumers, with revolving credit cards at 347%, overdraft at 224%, and installment credit cards at 141%. As for personal loans, the other category analyzed in this paper has an average interest rate of 112% during the specified period.

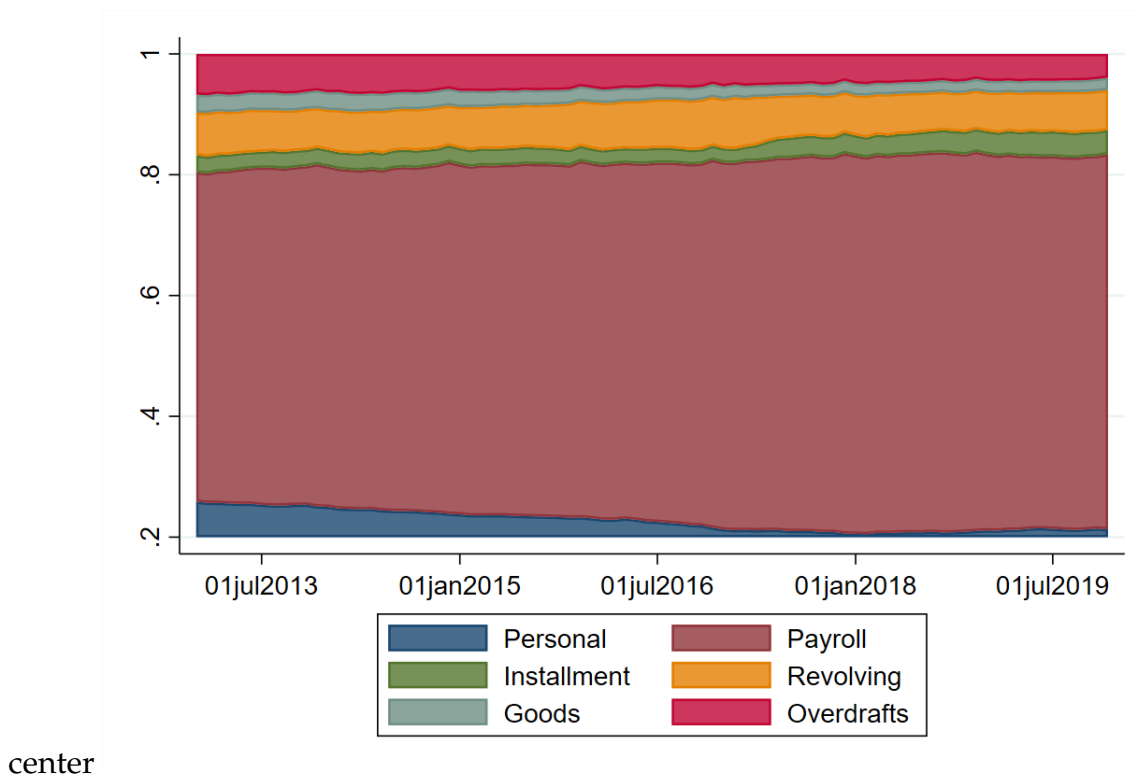


Fig. C.3: Percentage of different loan types

Table C.5: Summary Statistics - Consumer Loan (ex-housing and earmarked credit)

	N	mean	sd	min	max
Loan (Cars)	84	0.27	0.04	0.23	0.36
Loan (Personal)	84	0.23	0.02	0.20	0.26
Loan (Payroll)	84	0.59	0.03	0.55	0.63
Loan (CC Installment)	84	0.03	0.01	0.02	0.04
Loan (CC Revolving)	84	0.07	0.01	0.06	0.09
Loan (Goods)	84	0.02	0.00	0.02	0.03
Loan (Overdraft)	84	0.04	0.00	0.03	0.05
Rate (Cars), % p.a.	84	23.06	2.19	19.15	27.56
Rate (Personal), % p.a.	84	112.32	19.28	67.84	141.86
Rate (Payroll), % p.a.	84	26.10	2.30	20.54	29.97
Rate (CC Installment), % p.a.	84	140.99	28.06	100.13	178.46
Rate (CC Revolving), % p.a.	84	346.77	76.42	250.18	497.73
Rate (Goods), % p.a.	84	81.50	9.14	66.20	96.66
Rate (Overdraft), % p.a.	84	224.22	60.02	121.13	285.17
Maturity (Cars), mos	84	42.34	0.94	40.83	44.90
Maturity (Personal), mos	84	38.37	2.39	31.31	46.46
Maturity (Payroll), mos	84	69.15	5.21	59.55	80.03
Maturity (CC Installment), mos	84	9.00	0.86	7.97	10.83
Maturity (Goods), mos	84	16.04	2.28	12.35	21.21
Observations	84				

C.1.6 Wedges

Table C.6: Wedges and individual characteristics - Personal loans

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate	Loan rate
Maturity	-1.907*** (0.0945)	-1.827*** (0.0944)	-1.827*** (0.0948)	-1.933*** (0.0962)	-1.934*** (0.0967)	-2.132*** (0.0209)	-2.177*** (0.0168)
Maturity ²	0.00763*** (0.00111)	0.00749*** (0.00111)	0.00745*** (0.00111)	0.00774*** (0.00113)	0.00771*** (0.00113)	0.0124*** (0.000250)	0.0128*** (0.000185)
Log of loan	-4.065*** (0.141)	-4.254*** (0.142)	-4.147*** (0.143)	-3.618*** (0.147)	-3.506*** (0.148)	-3.586*** (0.0574)	-3.401*** (0.0574)
No income	85.83*** (0.737)	75.15*** (0.708)	77.31*** (0.727)	84.23*** (0.738)	86.34*** (0.761)	73.42*** (1.191)	75.72*** (1.285)
Up to 1 mw	60.94*** (0.479)	49.50*** (0.500)	50.40*** (0.502)	60.70*** (0.479)	61.65*** (0.481)	46.68*** (0.409)	48.34*** (0.433)
From 1 to 2 mw	43.94*** (0.385)	37.40*** (0.389)	38.07*** (0.391)	43.79*** (0.388)	44.48*** (0.389)	29.00*** (0.295)	29.90*** (0.308)
From 2 to 3 mw	32.04*** (0.320)	27.13*** (0.319)	27.65*** (0.321)	32.20*** (0.326)	32.76*** (0.328)	22.53*** (0.283)	23.09*** (0.296)
From 3 to 5 mw	21.52*** (0.250)	17.66*** (0.243)	18.15*** (0.244)	21.88*** (0.257)	22.41*** (0.258)	14.62*** (0.274)	15.17*** (0.287)
From 5 to 10 mw	10.51*** (0.182)	8.469*** (0.166)	8.839*** (0.167)	10.87*** (0.186)	11.29*** (0.186)	7.216*** (0.259)	7.523*** (0.270)
From 10 to 20 mw	1.926*** (0.122)	1.135*** (0.119)	1.513*** (0.119)	2.119*** (0.123)	2.535*** (0.121)	0.591** (0.251)	0.693*** (0.260)
Retired (personal)	0.395*** (0.125)	0.910*** (0.121)	1.189*** (0.121)	0.267** (0.124)	0.528*** (0.124)	-3.682*** (0.401)	-3.747*** (0.417)
Civil Serv (personal)	-12.12*** (0.182)	-7.871*** (0.172)	-7.471*** (0.171)	-11.89*** (0.181)	-11.47*** (0.181)	-9.582*** (0.162)	-9.196*** (0.162)
Informal (personal)	3.373*** (0.0693)	3.336*** (0.0678)	3.598*** (0.0664)	2.837*** (0.0682)	3.079*** (0.0671)		
Age	1.271*** (0.0113)	1.253*** (0.0111)	1.269*** (0.0112)	1.393*** (0.0128)	1.412*** (0.0128)	0.339*** (0.0262)	0.338*** (0.0273)
Age ²	-0.0127*** (0.000118)	-0.0120*** (0.000113)	-0.0121*** (0.000113)	-0.0136*** (0.000128)	-0.0137*** (0.000128)	-0.00148*** (0.000329)	-0.00128*** (0.000342)
Female	7.879*** (0.0623)	8.636*** (0.0607)	8.647*** (0.0611)	8.245*** (0.0647)	8.264*** (0.0652)	4.273*** (0.0946)	4.342*** (0.0977)
Pr. default (personal)				26.01*** (0.627)	26.43*** (0.635)		
Fin. Literacy						-1.345*** (0.0135)	-1.328*** (0.0133)
Constant	102.8*** (0.394)	143.1*** (0.683)	141.4*** (0.691)	95.12*** (0.495)	92.94*** (0.503)	141.8*** (1.071)	140.7*** (1.115)
Observations	20,483,498	20,483,498	20,464,737	20,483,498	20,464,737	2,984,011	2,888,871
R-squared	0.273	0.295	0.307	0.274	0.287	0.287	0.323
Risk control	NO	YES	YES	NO	NO	YES	YES
Time FE	YES	YES	NO	YES	NO	YES	NO
Munic. FE	YES	YES	NO	YES	NO	YES	NO
Munic.xTime FE	NO	NO	YES	NO	YES	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Table C.7: Wedges and individual characteristics - Payroll loans

VARIABLES	(1) wedge	(2) wedge	(3) wedge	(4) wedge	(5) wedge	(6) wedge	(7) wedge
Maturity	0.00824*** (0.000300)	0.00978*** (0.000300)	0.00965*** (0.000301)	0.0124*** (0.000307)	0.0122*** (0.000309)	-0.00483 (0.00920)	-0.000357 (0.0113)
Maturity ²	-3.25e-05*** (2.04e-06)	-3.43e-05*** (2.09e-06)	-3.41e-05*** (2.10e-06)	-3.70e-05*** (2.14e-06)	-3.68e-05*** (2.15e-06)	-0.000173** (8.19e-05)	-0.000223** (0.000101)
Log of loan	-0.460*** (0.00381)	-0.497*** (0.00370)	-0.496*** (0.00375)	-0.551*** (0.00368)	-0.549*** (0.00373)	-0.336*** (0.00977)	-0.336*** (0.0114)
No income	2.509*** (0.0232)	2.543*** (0.0247)	2.561*** (0.0249)	2.705*** (0.0229)	2.724*** (0.0231)	2.819*** (0.0975)	2.816*** (0.106)
Up to 1 mw	2.534*** (0.0229)	2.499*** (0.0243)	2.509*** (0.0243)	2.564*** (0.0229)	2.574*** (0.0229)	3.010*** (0.0831)	3.021*** (0.0916)
From 1 to 2 mw	2.427*** (0.0231)	2.406*** (0.0241)	2.415*** (0.0241)	2.462*** (0.0230)	2.473*** (0.0230)	2.854*** (0.0787)	2.880*** (0.0853)
From 2 to 3 mw	2.242*** (0.0227)	2.242*** (0.0238)	2.247*** (0.0238)	2.233*** (0.0226)	2.239*** (0.0227)	2.706*** (0.0758)	2.708*** (0.0818)
From 3 to 5 mw	1.953*** (0.0224)	1.970*** (0.0235)	1.983*** (0.0235)	1.928*** (0.0223)	1.942*** (0.0223)	2.439*** (0.0772)	2.432*** (0.0830)
From 5 to 10 mw	1.481*** (0.0219)	1.485*** (0.0233)	1.494*** (0.0232)	1.447*** (0.0217)	1.457*** (0.0217)	1.878*** (0.0733)	1.863*** (0.0780)
From 10 to 20 mw	0.502*** (0.0183)	0.491*** (0.0188)	0.501*** (0.0187)	0.471*** (0.0182)	0.481*** (0.0181)	1.231*** (0.0684)	1.213*** (0.0717)
Retired (payroll)	-0.852*** (0.0151)	-0.886*** (0.0154)	-0.893*** (0.0157)	-0.990*** (0.0149)	-0.998*** (0.0152)	0.161*** (0.0190)	0.161*** (0.0203)
Civil Serv (payroll)	-2.511*** (0.0201)	-2.563*** (0.0203)	-2.574*** (0.0208)	-2.568*** (0.0199)	-2.580*** (0.0203)	-2.073*** (0.0205)	-2.131*** (0.0219)
Age	0.0511*** (0.00107)	0.0516*** (0.00111)	0.0514*** (0.00112)	0.00225** (0.00105)	0.00226** (0.00105)	0.0359*** (0.00313)	0.0403*** (0.00327)
Age ²	-0.000422*** (9.15e-06)	-0.000427*** (9.53e-06)	-0.000425*** (9.64e-06)	4.86e-05*** (8.66e-06)	4.81e-05*** (8.76e-06)	-0.000672*** (3.57e-05)	-0.000736*** (3.72e-05)
Female	0.102*** (0.00276)	0.0874*** (0.00276)	0.0879*** (0.00277)	0.00351 (0.00277)	0.00443 (0.00277)	-0.232*** (0.0118)	-0.237*** (0.0125)
Pr. default (payroll)				-14.37*** (0.0503)	-14.31*** (0.0508)		
Fin. Literacy						-0.0868*** (0.00248)	-0.0863*** (0.00255)
Constant	17.82*** (0.0645)	16.06*** (0.0712)	16.08*** (0.0725)	19.88*** (0.0640)	19.87*** (0.0651)	14.97*** (0.173)	14.79*** (0.194)
Observations	20,524,507	20,524,507	20,506,221	20,524,507	20,506,221	1,864,303	1,777,400
R-squared	0.486	0.498	0.507	0.504	0.512	0.335	0.360
Risk control	NO	YES	YES	NO	NO	YES	YES
Time FE	YES	YES	NO	YES	NO	YES	NO
Munic. FE	YES	YES	NO	YES	NO	YES	NO
Munic.xTime FE	NO	NO	YES	NO	YES	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

C.1.7 Interest Rates and Individual Characteristics by Risk

The Central Bank of Brazil Resolution 2682, issued on December 21, 1999, mandates that financial institutions categorize credit operations based on ascending risk levels, ranging from AA to H. The institution responsible for the credit must carry out this risk classification using consistent and verifiable criteria. Furthermore, the institution is required to review this classification at least on a monthly basis, taking into account any delays in paying the principal installment. Here is the risk classification based on the delay period:

- Delays between 15 and 30 days: risk level B, at least.
- Delays between 31 and 60 days: risk level C, at least.
- Delays between 61 and 90 days: risk level D, at least.
- Delays between 91 and 120 days: risk level E, at least.
- Delays between 121 and 150 days: risk level F, at least.
- Delays between 151 and 180 days: risk level G, at least.
- Delays greater than 180 days: risk level H.

In summary, Resolution 2682 outlines the process and criteria for credit risk classification, with specific risk levels assigned based on the duration of delays in paying the principal installment.

Risk AA and A

Table C.8: Interest Rates and Individual Characteristics by Risk (AA and A) - Personal loans

VARIABLES	Loan rate	Loan rate
Maturity	-2.293*** (0.0681)	-2.289*** (0.0681)
Maturity ²	0.00511*** (0.000921)	0.00506*** (0.000918)
Log of loan	-2.643*** (0.119)	-2.486*** (0.120)
No income	108.4*** (0.903)	111.5*** (0.948)
Up to 1 mw	65.53*** (0.451)	66.81*** (0.456)
From 1 to 2 mw	52.37*** (0.381)	53.62*** (0.384)
From 2 to 3 mw	41.28*** (0.349)	42.50*** (0.352)
From 3 to 5 mw	28.33*** (0.329)	29.50*** (0.331)
From 5 to 10 mw	14.31*** (0.284)	15.40*** (0.284)
From 10 to 20 mw	3.772*** (0.195)	4.838*** (0.194)
Retired (personal)	0.958*** (0.168)	1.201*** (0.171)
Civil Serv (personal)	-12.93*** (0.234)	-11.96*** (0.237)
Informal (personal)	5.293*** (0.0931)	5.556*** (0.0916)
Age	1.215*** (0.0157)	1.223*** (0.0158)
Age ²	-0.0110*** (0.000165)	-0.0110*** (0.000165)
Female	9.971*** (0.0834)	10.05*** (0.0844)
Constant	108.1*** (0.651)	105.0*** (0.651)
Observations	11,043,508	11,000,832
R-squared	0.311	0.333
Risk control	NO	NO
Time FE	YES	NO
Munic. FE	YES	NO
Munic.xTime FE	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those

earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Table C.9: Interest Rates and Individual Characteristics by Risk (AA and A) - Payroll loans

VARIABLES	Loan rate	Loan rate
Maturity	0.0243*** (0.00103)	0.0253*** (0.00106)
Maturity ²	-7.81e-05*** (8.70e-06)	-8.04e-05*** (8.99e-06)
Log of loan	-0.587*** (0.00441)	-0.637*** (0.00528)
No income	2.208*** (0.0318)	2.602*** (0.0302)
Up to 1 mw	2.226*** (0.0312)	2.415*** (0.0300)
From 1 to 2 mw	1.884*** (0.0309)	1.935*** (0.0309)
From 2 to 3 mw	1.677*** (0.0307)	1.673*** (0.0311)
From 3 to 5 mw	1.353*** (0.0309)	1.330*** (0.0316)
From 5 to 10 mw	1.051*** (0.0313)	1.031*** (0.0318)
From 10 to 20 mw	0.130*** (0.0259)	0.116*** (0.0263)
Retired (payroll)	-0.817*** (0.0150)	-0.939*** (0.0151)
Civil Serv (payroll)	-2.534*** (0.0190)	-2.569*** (0.0192)
Age	0.00460*** (0.00110)	-0.0460*** (0.00189)
Age ²	0.000108*** (8.99e-06)	0.000590*** (1.74e-05)
Female	-0.00648** (0.00328)	-0.118*** (0.00460)
Constant	29.34*** (0.0690)	31.24*** (0.101)
Observations	10,590,749	10,554,285
R-squared	0.243	0.270
Risk control	NO	NO
Time FE	YES	NO
Munic. FE	YES	NO
Munic.xTime FE	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those

earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Risk B, C and D

Table C.10: Interest Rates and Individual Characteristics by Risk (B, C and D) - Personal loans

VARIABLES	(1) Loan rate	(2) Loan rate
Maturity	-0.876*** (0.00854)	-0.891*** (0.00885)
Maturity ²	0.00334*** (6.17e-05)	0.00340*** (6.39e-05)
Log of loan	-3.207*** (0.0371)	-3.111*** (0.0383)
No income	48.06*** (0.711)	49.13*** (0.736)
Up to 1 mw	43.82*** (0.355)	45.25*** (0.368)
From 1 to 2 mw	35.20*** (0.214)	35.78*** (0.222)
From 2 to 3 mw	22.81*** (0.201)	23.04*** (0.212)
From 3 to 5 mw	15.02*** (0.186)	15.19*** (0.196)
From 5 to 10 mw	8.403*** (0.160)	8.525*** (0.167)
From 10 to 20 mw	1.665*** (0.124)	1.818*** (0.127)
Retired (personal)	0.462*** (0.131)	0.623*** (0.134)
Civil Serv (personal)	-9.093*** (0.136)	-9.046*** (0.138)
Informal (personal)	1.514*** (0.0859)	1.635*** (0.0873)
Age	0.647*** (0.0113)	0.669*** (0.0115)
Age ²	-0.00799*** (0.000119)	-0.00821*** (0.000122)
Female	3.500*** (0.0511)	3.489*** (0.0520)
Constant	99.61*** (0.374)	98.38*** (0.399)
Observations	7,745,936	7,679,462
R-squared	0.186	0.212
Risk control	NO	NO
Time FE	YES	NO
Munic. FE	YES	NO
Munic.xTime FE	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those

earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Table C.11: Interest Rates and Individual Characteristics by Risk (B, C and D) - Payroll loans

VARIABLES	(1) Loan rate	(2) Loan rate
Maturity	-0.00495*** (0.000246)	-0.00505*** (0.000249)
Maturity ²	-1.25e-05*** (1.45e-06)	-1.21e-05*** (1.46e-06)
Log of loan	-0.471*** (0.00382)	-0.476*** (0.00391)
No income	4.358*** (0.0318)	4.366*** (0.0325)
Up to 1 mw	3.197*** (0.0227)	3.242*** (0.0226)
From 1 to 2 mw	3.293*** (0.0220)	3.341*** (0.0223)
From 2 to 3 mw	3.048*** (0.0224)	3.064*** (0.0226)
From 3 to 5 mw	2.714*** (0.0221)	2.719*** (0.0224)
From 5 to 10 mw	1.956*** (0.0217)	1.957*** (0.0219)
From 10 to 20 mw	0.911*** (0.0196)	0.908*** (0.0197)
Retired (payroll)	-1.622*** (0.0203)	-1.610*** (0.0222)
Civil Serv (payroll)	-3.011*** (0.0263)	-2.997*** (0.0284)
Informal (payroll) = 0,	-	-
Age	-0.0147*** (0.00144)	-0.0198*** (0.00156)
Age ²	0.000134*** (1.20e-05)	0.000178*** (1.30e-05)
Female	0.00219 (0.00383)	-0.0176*** (0.00401)
Constant	30.86*** (0.0797)	31.07*** (0.0877)
Observations	8,629,766	8,575,777
R-squared	0.222	0.249
Risk control	NO	NO
Time FE	YES	NO
Munic. FE	YES	NO
Munic.xTime FE	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Risk E, F and G

Table C.12: Interest Rates and Individual Characteristics by Risk (E, F and G) - Personal loans

VARIABLES	(1) Loan rate	(2) Loan rate
Maturity	-2.632*** (0.0445)	-2.865*** (0.0451)
Maturity ²	0.0125*** (0.000433)	0.0146*** (0.000426)
Log of loan	-1.862*** (0.0750)	-1.590*** (0.0814)
No income	22.60*** (0.707)	24.01*** (0.777)
Up to 1 mw	65.33*** (0.752)	70.48*** (0.826)
From 1 to 2 mw	36.91*** (0.519)	38.58*** (0.557)
From 2 to 3 mw	28.68*** (0.493)	30.00*** (0.533)
From 3 to 5 mw	23.50*** (0.478)	24.57*** (0.517)
From 5 to 10 mw	15.82*** (0.429)	16.65*** (0.464)
From 10 to 20 mw	6.036*** (0.405)	6.904*** (0.437)
Retired (personal)	0.741* (0.439)	1.103** (0.473)
Civil Serv (personal)	-7.204*** (0.299)	-6.925*** (0.318)
Informal (personal)	1.741*** (0.191)	2.272*** (0.205)
Age	1.557*** (0.0326)	1.622*** (0.0355)
Age ²	-0.0148*** (0.000369)	-0.0151*** (0.000404)
Female	6.936*** (0.155)	6.850*** (0.165)
Constant	116.9*** (0.985)	116.1*** (1.073)
Observations	1,424,938	1,326,288
R-squared	0.290	0.351
Risk control	NO	NO
Time FE	YES	NO
Munic. FE	YES	NO
Munic.xTime FE	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.

Table C.13: Interest Rates and Individual Characteristics by Risk (E, F and G) - Payroll loans

VARIABLES	(1) Loan rate	(2) Loan rate
Maturity	-0.0112*** (0.000550)	-0.0103*** (0.000595)
Maturity ²	-2.93e-06** (1.44e-06)	-3.88e-06** (1.59e-06)
Log of loan	-0.442*** (0.00457)	-0.508*** (0.00533)
No income	2.297*** (0.0723)	2.763*** (0.0759)
Up to 1 mw	2.068*** (0.0629)	2.333*** (0.0641)
From 1 to 2 mw	2.357*** (0.0606)	2.373*** (0.0622)
From 2 to 3 mw	2.168*** (0.0615)	2.104*** (0.0636)
From 3 to 5 mw	1.936*** (0.0611)	1.834*** (0.0633)
From 5 to 10 mw	1.385*** (0.0601)	1.330*** (0.0620)
From 10 to 20 mw	0.529*** (0.0627)	0.487*** (0.0646)
Retired (payroll)	-1.915*** (0.0326)	-2.066*** (0.0348)
Civil Serv (payroll)	-3.261*** (0.0406)	-3.447*** (0.0419)
Age	-0.0648*** (0.00264)	-0.119*** (0.00309)
Age ²	0.000481*** (2.28e-05)	0.000991*** (2.67e-05)
Female	0.0123 (0.00916)	-0.139*** (0.0108)
Pr. default (payroll)		-2.225*** (0.0587)
Constant	34.24*** (0.116)	36.60*** (0.142)
Observations	1,007,668	921,572
R-squared	0.195	0.257
Risk control	NO	NO
Time FE	YES	NO
Munic. FE	YES	NO
Munic.xTime FE	NO	YES

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Estimated coefficients for income dummies are relative to those

earning more than 20 mw. Estimated coefficient for occupations are relative to formal workers.