Income Inequality, Mortgage Debt and House Prices*

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Abstract

The last few decades in the US have been characterized by two secular trends: rising income inequality and declining real interest rates. This paper studies macroeconomic and financial stability implications of increasing income inequality and discusses how a low interest rate environment can alter its consequences. I develop an analytical model of mortgage and housing markets. The framework departs from standard lending models with exogenous lending constraints by incorporating collateral into a rational default model. The model predicts that following an increase in income inequality house prices decline and aggregate default risk rises in equilibrium. I then show that low real rates mitigate the depressing effect of inequality on house prices at the cost of amplifying aggregate default risk in the mortgage market. Using a panel data of US states between the years 1992-2015 for house prices and 2003-2015 for mortgage variables, I verify the model's predictions. I find that a rise in income inequality is associated with (i) a decline in house prices, (ii) an increase in mortgage delinquencies and (iii) a decline in mortgage debt.

Keywords: income inequality, mortgage lending, mortgage default, house prices, real interest rates, risk taking

JEL codes: D31, E44, E58, G21, R21

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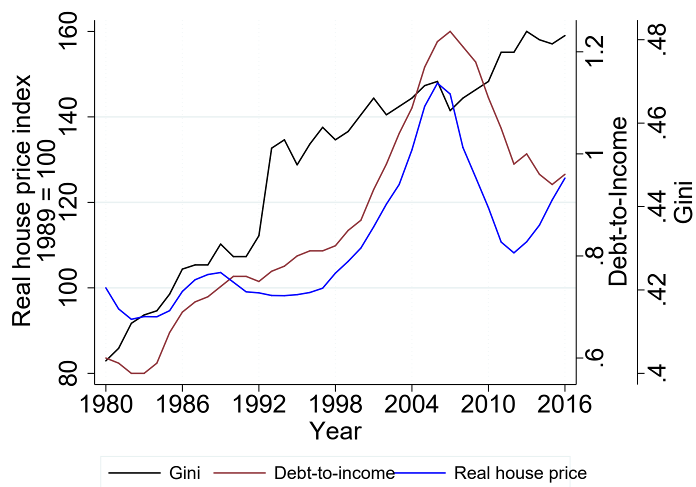
1 Introduction

In recent decades the US has experienced a steady increase in income inequality. In the period preceding the Great Recession of 2008-09, this was accompanied by rapid growth in real house prices and household debt. These patterns can be seen in Figure 1, which plots the Gini coefficient, debt-to-income ratio and real house price between 1980 and 2016. Credit growth has been documented to be one of the main determinants of financial crises (Schularick and Taylor, 2012). In the case of the US, it has been argued that increasing income inequality led household debt to rise.[1] This paper contributes to this debate by investigating how income inequality influences mortgage debt, house prices and the risk of mortgage default.[2]

Figure 1: Income inequality, real house prices and household debt-to-income ratio in the US



Data source: US Census Bureau, US Flow of Funds, Federal Housing and Finance Agency, Bureau of Labor Statistics

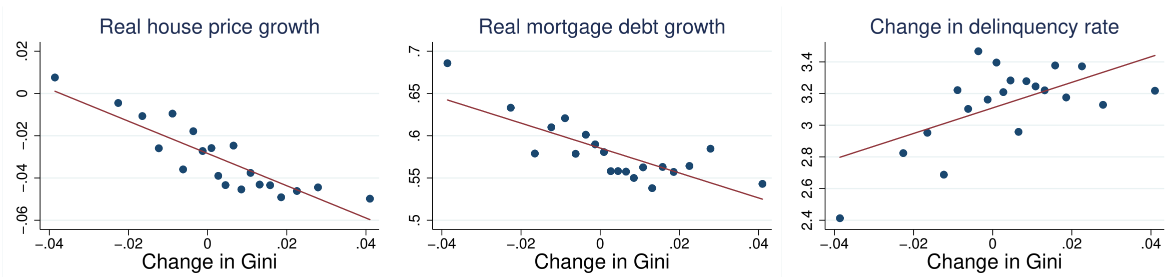
The first contribution of this paper is to document new cross-sectional facts regarding growth in income inequality, house prices, and mortgage credit. Figure 2 plots the partial correlation with the change in Gini coefficient between 1999 and 2011 for three variables using data from US counties. The first panel shows the relationship between the change in Gini coefficient and real house price growth, the second the relationship with real mortgage debt growth, and the third the relationship with the change in the delinquency rate. In constructing this figure I control for a variety of county characteristics. The figure shows that counties which experienced a greater increase in income inequality between 1999 and 2011 had lower house price growth, lower mortgage debt growth and a greater increase in

[1] Among others Krueger (2012), Rajan (2010), Stiglitz (2012) and Kumhof, Rancière and Winant (2015) suggest that rising inequality may have contributed to the recent financial crisis by causing an increase in household credit.

[2] Using historical cross-country data, Jorda, Schularick and Taylor (2016) compare the influence over business cycles of different components of credit, and find that the main determinant of contemporary cycles is mortgage booms. Such episodes are followed with deep recessions and slow recoveries.

the delinquency rate over the same period.[3] For both house prices and mortgage debt, the cross-sectional relationships are at odds with the aggregate trends in Figure 1, although the positive correlation between income inequality and delinquency suggests a channel through which higher inequality may have reduced financial stability.

Figure 2: Changes in income inequality, real house price growth, mortgage debt growth and change in mortgage delinquency rate over US counties between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics.

Note: To construct this figure I use the binscatter command in Stata. This regresses the three title variables on the change in Gini coefficient, state fixed effects, mean income growth, population growth, the share of subprime borrowers in 2000, median income in 1999, and the number of households in 1999. The slope of the line of fit is the coefficient for the change in Gini coefficient in this regression. For the data points, it first obtains the residuals from regressions of the title variable and the change in Gini coefficient on the other control variables. These are then grouped in twenty equally sized bins for the Gini coefficient residual. The position of each point is the mean value of the title variable residual and Gini coefficient residual for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011.

The second contribution of this paper is to construct a structural model which can be used to study the inequality-house price-mortgage debt nexus. The model is parsimonious, but allows for feedback effects between housing and mortgage markets. Households with heterogeneous incomes borrow to finance housing purchases. Housing serves as collateral for these loans. Borrowers may later default if doing so offers higher utility than repayment. In this case they forfeit their housing assets. There is no information asymmetry in the model. Perfectly competitive lenders offer a menu of mortgage contracts to each borrower. Mortgage interest rates vary with the value of the collateral and mortgage debt, both of which are chosen by borrowers.[4] The mortgage interest rate increases with debt and decreases with the value of collateral. Borrowers internalize these effects when choosing their mortgage. Borrowers at different points in the income distribution make different contract choices. A rise in income inequality increases the number of households that opt for low housing consumption and make low down-payments, and these loans have a high default risk. In equilibrium this has two effects. First, aggregate demand for housing, and thus house prices, declines. Second, aggregate default risk increases. This is consistent with the cross-sectional evidence presented

[3]These correlations are robust to the inclusion of control variables such as county mean income and population growth. In Figure 12 I construct the partial correlations using US state level data between the years 2003 and 2015, and find similar relationships. Figure C.2.2 provides additional evidence on house price-inequality relationship for a longer time period.

[4]Geanakoplos (2014) calls this menu of contracts a credit surface, wherein the mortgage interest rate depends on the value of collateral and the borrower's credit score. In my model, lenders use default risk instead of a credit score when pricing mortgage loans.

in Figure 2.

This raises the question of why house prices and mortgage debt have been increasing with income inequality in the aggregate data. Another secular trend for the US in the same time period is declining real interest rates. In the model, a decline in the real interest rate leads the mortgage interest rate and down-payment to decline for all mortgage contracts. Borrowers then demand larger houses, which increases house prices. Declining real interest rates can thus overturn the negative effect of increasing inequality on house prices, and allow the model to match the aggregate trend in real house prices. However, this further undermines mortgage market stability. Holding default risk fixed, a fall in the real interest implies that the associated contract has a lower down payment and a higher level of housing consumption. The reduction in down payment and increase in housing consumption are particularly high for mortgage contracts where there is a high risk of default. This leads to more borrowers opting for these high risk mortgages. Aggregate default risk further increases, amplifying the effect of rising income inequality. This paper therefore also contributes to the literature on the risk-taking implications of low interest rate environments by providing a mechanism which operates through the housing market.[5]

To verify the model's predictions, I turn to a panel of US states. I use data from 1992 to 2015 for house prices, and from 2003 to 2015 for mortgage credit and delinquency. I estimate specifications which include time fixed effects to control for macroeconomic developments, and state fixed effects to control for any time invariant state characteristics. I find that a 10 percentage point *increase* in Gini coefficient is associated with a 16% *decline* in real house prices, a 1.2 percentage point *increase* in the share of delinquent mortgages, and a 10% *decline* in real mortgage debt per capita.[6] I then examine how changes in the long-term real interest rate alters the responses of these variables to changes in income inequality. I find that a 100 basis point decline in the real rate mitigates the effect of inequality on house prices by about 2.3 percentage points, and adds 0.85 percentage points to the effect of income inequality on mortgage delinquencies.

Relation to the Literature. This paper is related to the literatures on income inequality, house prices and mortgages, and financial stability. In particular, it theoretically and empirically links the literature on the relationship between inequality, debt and financial crises relationship to the literature on the house price-credit nexus.[7]

Similar to this paper, Kumhof, Rancière and Winant (2015) study income inequality as a long-run determinant of financial risk and household debt. They employ a two-agent model in which aggregate output is shared by two income groups. Top earners are the top 5% of the income distribution and act as lenders with the bottom 95% being borrowers. They show that increasing the income share of the top 5% leads them to save more, which in turn reduces interest rates and increases borrowing by the bottom 95%. This increases

[5] DellAriccia, Laeven and Marquez (2014) present a theoretical model of bank-risk taking. They show that, when bank capital cannot adjust, a decrease in the real interest rate can increase risk-taking. However, this results depends on the shape of an exogenous loan demand. Similar to my paper, Sheedy (2018) studies the financial stability implications of low interest rates through housing and mortgage markets.

[6] Between the years 1992 and 2015, US real house prices increased by 22% and its Gini coefficient increased by about 5 percentage points.

[7] Blinder (1975), Auclert and Rognlie (2018) and Straub (2018) study the effect of income inequality on consumption behavior. The focus of this paper is the interaction between borrowing behaviour and house prices. Over the business cycle house price developments are strongly correlated with consumption and credit.

the risk of a financial crisis. My paper complements their analysis by allowing for greater income heterogeneity among borrowers, and studying the effects of income inequality on house prices. I find that, for a cross-section of US counties, growth in the income of the top 5% is negatively correlated with mortgage debt growth.[8] It can then be argued that the model of Kumhof, Rancière and Winant (2015) describes a case where the effect of declining interest rates dominates the effect of increasing income inequality.[9]

Nakajima (2005) studies the implications of higher earnings risk for house prices and debt by employing a quantitative overlapping generations model. He compares steady states for environments with low and high income variance. The low variance environment is calibrated using data for 1967, and the high variance environment with data for 1996. He finds that debt is lower and house prices are higher in the steady state with higher income variance.[10]

Several empirical studies have examined the question of whether rising income inequality is related to household debt, and is thus a source of financial instability as suggested by Rajan (2010). Most studies in this literature use country level data, and their findings have been conflicting.[11] For instance, Bordo and Meissner (2012) finds no evidence of a rise in the top income share leading to credit booms, whereas Perugini, Hölscher and Collie (2016) finds a positive relationship between income concentration and private sector debt. Schularick and Taylor (2012) and Mian, Sufi and Verner (2017) document the role of credit growth in the occurrence of financial crises.[12] More recently, Paul (2017) has suggested that a rising top income share is a better predictor of financial distress than credit growth, while Kiley (2018) suggests run-ups in house prices. My paper shows that financial risk, debt and inequality form a nexus with feedback effects between the variables, so should be studied in a general equilibrium framework. In addition, mortgages comprise the largest part of household debt and are closely correlated with house prices. The dynamics of house prices are thus both endogenous to this nexus and essential to understand it. In contrast to these studies, I use a micro measure of financial risk, mortgage delinquency, in my analysis of a panel of US states.

Another literature focuses on the cyclical relationship between house prices and credit. These studies do not address the role of changing inequality. It is generally accepted that housing and mortgages markets were at the heart of the Great Recession of 2008-9. Since the onset of the crisis, an extensive amount of research has examined the causes of this particular cycle. The research on the house price and mortgage boom has attributed these developments to either changes in lending standards or house price expectations.[13] Justiniano, Primiceri

[8] See Appendix C.2 for details and Figure C.2.3.

[9] Cairo and Sim (2018) introduce monetary policy into the framework of Kumhof et al. (2015)

[10] Iacoviello (2008) and Krueger and Perri (2006) also investigate the effects of higher income risk on household debt. Both find that consumption smoothing leads household debt to increase with income risk. These studies do not incorporate housing or default.

[11] An exception is Coibion et al. (2014). They employ borrower level data and find that borrowing by low income households does not increase with local income inequality. They construct a model in which lenders use income inequality in the local area together with the borrower's income level to infer exogenous default risk. This model produces a decline in lending to low income borrowers when local income inequality increases.

[12] Jorda, Schularick and Taylor (2016) find that the growth of mortgage credit in particular has been an increasingly important determinant of financial stability.

[13] For example, Justiniano, Primiceri and Tambalotti (2015), Favilukis, Ludvigson and Nieuwerburgh (2017) and Kiyotaki, Michaelides and Nikolov (2011). See Mian and Sufi (2018) for a review of quantitative models which incorporate the explanations related to credit supply. Piazzesi and Schneider (2009) and Glaeser, Gottlieb and Gyourko (2012) support the view that house price expectations played an important role in the boom episode. Using a quantitative model, Kaplan, Mitman and Violante (2017) suggest that both an

and Tambalotti (2016) is closely related to this paper. In a two-agent analytical framework, they show that following an expansion in the credit supply house prices and mortgage debt increase more in areas with a higher share of subprime borrowers. Their model abstracts from default: subprime borrowers are defined as agents for whom a minimum consumption constraint binds. In my model, expected default risk is an equilibrium choice, and is endogenous with respect to house prices. This leads to feedback effects between house prices and aggregate risk in the economy.[14, 15]

On the empirical side, my paper is related to the literate that employs identification strategies based on geographical variation. This line of research was initiated by Mian and Sufi (2009), and many papers have used similar techniques.[16] Most recently, in a similar manner to this paper, Gertler and Gilchrist (2018) use a panel of US states to study the effects of a local development and an aggregate development separately. In particular, they use this strategy to disentangle the effects of house prices and lending disruption on employment during the recession.

This paper abstracts from heterogeneity in housing quality: real house prices are measured by an aggregate house price index. Määttänen and Terviö (2014) allow for matches between different income households and different house qualities. They reach a similar conclusion to this paper. For a given distribution of housing qualities, a mean-preserving spread of the income distribution leads to a decline in the prices of lower quality houses, which can spillover to the higher end of the quality distribution.[17]

Layout. The rest of this paper is organized as follows. Section 2 presents an equilibrium model of housing and mortgage markets. Section 3 verifies the model's predictions through panel data analysis. Section 4 concludes. Appendix C.2 provides additional analyses of the cross-sectional facts presented in Figure 2.

exogenous change in lending terms and expectations of increasing house prices are necessary needs to match the dynamics of leverage and house prices.

[14] Adelino, Schoar and Severino (2016) show that the default share of prime borrowers increased during the financial crisis. Therefore, an ex-ante measure of risk may not represent the rational risk choice of these borrowers.

[15] Corbae and Quintin (2015), Chatterjee and Eyigungor (2015), Hedlund (2016) and Campbell and Cocco (2015) among others find a relationship between house price changes and foreclosures in a quantitative model. Mian, Sufi and Trebbi (2015) document that mortgage foreclosures had significant effects on house prices and employment.

[16] For example, Midrigan and Philippon (2016) and Mian, Rao and Sufi (2013). See Nakamura and Steinsson (2017) for a discussion of the use of regional variation for identification in macroeconomics, and its applications in areas other than household credit and house prices.

[17] They consider a mean and order-preserving change in the income distribution. Incomes below a certain quintile decrease while those above it increase. Reduced incomes at the lower end of the distribution push the price of lower quality houses down. This spills over to the higher housing qualities as each borrower is a marginal buyer for a given quality. If the difference between high and low quality houses is not large, prices decline across the income distribution as no buyer wants to pay for extra housing quality. Landvoigt, Piazzesi and Schneider (2015) also employ a quantitative assignment model of housing. They differ from Määttänen and Terviö (2014) in that in their model housing purchases are financed with mortgages. They show that capital gains between 2000 and 2005 for low quality houses in San Diego can be explained by a combination of an increase in the income of buyers of these houses, a relaxation in lending terms and high house price expectations.

2 An analytical model of housing and mortgage markets

To the best of my knowledge, this paper is the first to use a general equilibrium structural model to study the response of house prices and the mortgage market to changes in income inequality. The key ingredients of the model are endogenous lending terms and rational default decisions. This leads lenders to offer borrowers a menu of different mortgage contracts to choose from. The menu offered depends on the borrower's income, so borrowers with different income levels will choose different levels of housing and mortgage debt. This allows the probability of default to vary with with income level. Changes in the income distribution then lead to concurrent changes in housing and mortgage demand. In general equilibrium, housing and mortgage markets both clear. This means that house prices and the aggregate default risk are determined endogenously.

Environment. The model has two periods $t = 1, 2$. There is a continuum of borrowers who differ in their first period endowment income. A measure $\psi(y_{1i})$ of borrowers receive endowment income y_{1i}, and the income distribution is denoted by Ψ. Endowment income in the second period is

$$y_{2i} = \omega y_{1i}$$

where ω is an aggregate income growth shock which renders this income uncertain. The distribution of income growth shocks is denoted by Ω.[18] In addition to their endowment income, each household receives a housing endowment of h. The housing endowment is symmetric across the income distribution.[19] Households borrow in the first period. In the second period, they observe their income and decide whether to repay their loan. Borrowers derive utility from non-durable consumption in both periods, but housing consumption is valued only in the first period.[20] The consumption good is the numeraire and p_t is the house price in period $t = 1, 2$.

Borrowers. Borrowers maximize their lifetime utility, which is derived from non-durable and housing consumption. In the second period, the total resources available for consumption depend on the default of the borrower. For each income growth realization the borrower faces the following trade-off. If she defaults she loses her house, incurs a default cost proportional to her income, and receives debt relief without recourse. On the other hand, if she repays, she can consume her entire endowment and the value of her house net of the repayment. Let c_{2i}^d and c_{2i}^r denote consumption under default and repayment, respectively. The rational default rule may then be defined as:

$$\mathbb{1}_i(\omega, y_{1i}, d_i, h_{1i}) = \begin{cases} 1 & \text{if } c_{2i}^d(\omega, y_{1i}) > c_{2i}^r(\omega, y_{1i}, h_{1i}, d_i) \\ 0 & \text{otherwise} \end{cases}$$

The default rule takes a value of one for income y_{1i}, mortgage debt d_i and housing h_{1i} if

[18] The distribution of initial endowment incomes can be interpreted as a skill distribution, and ω as an aggregate labor productivity shock. For simplicity, this set-up here abstracts from idiosyncratic risk and income mobility. It is consistent with the finding of (Guvenen et al., 2017) that income inequality is persistent over the life cycle in the US.

[19] Income is the sole source of inequality in the model.

[20] The borrowers are assumed not to derive utility from housing in the second period to simplify the algebra.

the borrower chooses to default at this point in the state space. There is no information asymmetry, so lenders use the same default rule when they price loans. To simplify notation, I henceforth to use $\mathbb{1}_i$ in place of $\mathbb{1}_i(\omega, y_{1i}, d_i, h_{1i})$. In the first period, the borrowers' optimization problem is:

$$\max_{h_{1i},d_i,c_{1i}} U_1(c_{1i}, h_{1i}) + \beta E_\Omega \left\{ \max_{\mathbb{1}_i} \mathbb{1}_i U_2(c^d_{2i}(\omega, y_{1i})) + (1 - \mathbb{1}_i) U_2(c^r_{2i}(\omega, y_{1i}, h_{1i}, d_i) \right\} \tag{1}$$

subject to the constraint

$$c_{1i} + p_1 h_{1i} = y_{1i} + q(y_{1i}, d_i, h_{1i}) d_i + p_1 h$$

This constraint states that first period consumption, c_{1i}, and housing expenditure, $p_1 h_{1i}$ are financed by endowment income, the value of the initial housing endowment, $p_1 h$, and a mortgage loan priced at q. For each unit of debt d_i to be repaid in the second period, the lender gives the borrower $q d_i$ units of consumption good in the first period. The interest rate of the loan is given by the inverse of the loan price. Borrowers internalize the effect of their choices of housing consumption and debt on the loan price, and their effects on the default decision in the second period for each realization of the aggregate income shock.

Lenders. Lenders are perfectly competitive, risk neutral and have deep pockets. Housing serves as collateral. If a borrower defaults, the lender seizes their house and receives $\theta p_2(\omega)$ per unit of housing, where θ is the loan recovery rate and $p_2(\omega)$ is the relative house price when the income growth realization is ω.

Lenders solve the optimization problem:

$$\max_{d_i} d_i \left\{ -q_i + \frac{1}{R^f} E_\Omega \left(1 - \mathbb{1}_i + \mathbb{1}_i \frac{\theta p_2(\omega) h_{1i}}{d_i} \right) \right\}$$

d_i and q_i correspond to the volume and price of the loan for the borrower with income y_{1i}. Lenders discount future consumption at the risk-free rate R^f. Perfect competition between lenders and risk neutrality lead to the following loan price schedule:

$$q(y_{1i}, d_i, h_{1i}) = \frac{1}{R^f} E_\Omega \left(1 - \mathbb{1}_i + \mathbb{1}_i \frac{\theta p_2(\omega) h_{1i}}{d_i} \right)$$

If the borrower repays the loan irrespective of the realization of the income growth shock, that is $E_\Omega \mathbb{1}_i = 0$, then the loan price is equal to the lenders' discount rate. I refer to any contract with a combination of debt and housing collateral such that the borrower will always repay the mortgage as risk-free.

When the borrower strategically defaults under certain income growth realizations, $E_\Omega \mathbb{1}_i > 0$, the lenders price this risk. If there was no collateral, as is the case with models of sovereign default a la Eaton and Gersovitz (1981), the price would be the lenders' discount factor adjusted by the default probability $\frac{E_\Omega \mathbb{1}_i}{R^f}$. The presence of collateral gives rise to a loan spread that is lower that the default risk, and is endogenous to the amount of collateral and debt. Unsurprisingly, a high loan-to-value ratio, $\frac{d_i}{p_1 h_{1i}}$, leads to a low loan price.

Functional forms. In order to derive closed-form solutions, I make two assumptions regarding functional forms. In order to simplify aggregation in the housing market, preferences are assumed to be quasi-linear in consumption.[21] Second, I assume that lenders do not derive utility from housing consumption. This assumption is relaxed in Justiniano, Primiceri and Tambalotti (2015). However, they assume that lender's demand for housing is a fixed exogenous quantity. The stock of housing available to borrowers is the aggregate housing stock net of lenders' fixed housing consumption.[22] The assumption in this paper corresponds to lenders having a fixed housing demand of zero. Trades in the housing market are then always between borrowers.

Finally, I assume that income growth risk can take two values

$$\omega = \begin{cases} \omega^H & \text{, with probability } \nu \\ \omega^L & \text{, with probability } 1-\nu \end{cases}$$

ν is the probability of high income growth. This assumption simplifies the loan price schedule $q(y_{1i}, d_i, h_{1i})$ and the default rule $\mathbb{1}_i$, which will be described in detail in the next section. Moreover, house prices in the second period are exogenous and depend on the income growth realization. That is, house prices in the second period under high income growth realization is $p_2(\omega^H)$ and it is $p_2(\omega^L)$ under high income growth realization. I assume house prices are pro-cyclical: $p_2(\omega^H) \geq p_2(\omega^L)$.

General equilibrium. The general equilibrium of the model is defined as market clearing in both housing and mortgage markets. In the mortgage market, borrowers and lenders take house prices as given, and across the income distribution borrowers make different housing consumption and mortgage debt choices. The mortgage market clears loan-by-loan in a manner that is consistent with the loan pricing schedule. In the housing market, contract choices are taken as given and the aggregate demand for housing varies with mortgage market conditions. Housing demand is the aggregate of housing consumption choices across the income distribution, p_1 is then implicitly defined by market clearing as:

$$\int h_{1i}(p_1, y_{1i})\psi(y_{1i})di = h$$

I first describe the mortgage market equilibrium, and then formalize the general equilibrium. Having characterized the general equilibrium, I study the effects of income inequality and its interaction with low interest rates.

2.1 Partial equilibrium in the mortgage market

I solve for mortgage market equilibrium through backward induction. I begin with the rational default decision of borrowers in the second period. I then move to the first period decisions of both lenders and borrowers. Here lenders price mortgage loans, and borrowers choose mortgage and housing portfolios. Both lenders and borrowers take into account the optimal second period default policy for borrowers.

[21] Justiniano, Primiceri and Tambalotti (2015) also assume quasilinear preferences in order to derive analytical results.

[22] This assumption is a simple way of introducing housing market segmentation. Changes in lending terms then only affect the price of houses that borrowers buy.

2.1.1 Default/Repayment decision

In the second period the borrower makes a rational default decision. Borrowers do not derive utility from housing in the second period. If a borrowers chooses to repay her loan, she sells her house. In order to sell her house, she must pay a fixed cost κ.[23] Utility under repayment is:

$$U_2(c_{2i}^r) = \omega y_{1i} - d_i + p_2(\omega)h_{1i} - \kappa$$

If the borrower defaults, she receives a share ξ of her second period endowment income and consumes it.[24] Therefore, utility under default is:

$$U_2(c_{2i}^d) = \xi\omega y_{1i}$$

Under these assumptions, the borrower's default rule can be written as:

$$\mathbb{1}(\omega, y_{1i}, d_i, h_{1i}) = \begin{cases} 1 & \text{if } d_i \geq (1-\xi)y_{1i}\omega + p_2(\omega)h_{1i} - \kappa \\ 0 & \text{otherwise} \end{cases}$$

A borrower defaults on her loan if the price of housing is sufficiently low, if her income is sufficiently low, or under some combination of the two. The final case corresponds to the double-trigger explanation of default, under which negative home equity is a necessary but not sufficient condition for default. Borrowers may find it optimal to repay even if they are underwater due to the costs associated with default. This is consistent with the finding of Gerardi et al. (2017) that borrowers remain current on their mortgage debt even when they are underwater.[25]

2.1.2 Loan pricing by the lenders

For lenders to price loans in the first period, it is necessary to specify their expectation of house prices in the second period $E_\Omega p_2(\omega)$. I assume that expectations are uniform across lenders, and that the house price is positively correlated with the aggregate income shock.

The default rule implies the existence of two debt thresholds $\bar{d}_i^L$ and $\bar{d}_i^H$. These are the minimum levels of debt where a borrower with first period income y_{1i} and housing h_{1i} would default when the aggregate shock takes values ω^L and ω^H.

$$\bar{d}_i^L = (1-\xi)y_{1i}\omega^L + E_\Omega p_2(\omega^L)h_{1i} - \kappa$$
$$\bar{d}_i^H = (1-\xi)y_{1i}\omega^H + E_\Omega p_2(\omega^H)h_{1i} - \kappa$$

Note that $\bar{d}_i^L \leq \bar{d}_i^H$. The loan pricing schedule for a borrower with income y_{1i} who

[23] These fixed costs can also include any fixed costs and fees associated with the mortgage loan.

[24] Eaton and Gersovitz (1981), Arellano (2008) and Kumhof, Rancière and Winant (2015) also assume income losses in the case of default. This captures the effect of default penalties outside of asset forfeiture, such as a negative effect on the borrowers credit history.

[25] See Gete and Reher (2016) and Jeske, Krueger and Mitman (2013) for models with one period mortgage loans with rational default decision. Both papers assume that borrowers default when they are underwater and there is no utility or economic cost of default. Among others, Foote, Gerardi and Willen (2008) provide empirical evidence of double-trigger defaults. See Foote and Willen (2017) for a review of mortgage default research.

purchases housing h_{1i} is given by:

$$q(y_{1i}, d_i, h_{1i}) = \begin{cases} \frac{1}{R^f} & \text{if } d_i \le \bar{d}_i^L \\ \frac{1}{R^f}\{\nu + (1-\nu)\theta E_\Omega p_2(\omega^L)\frac{h_{1i}}{d_i}\} & \text{if } \bar{d}_i^L < d_i \le \bar{d}_i^H \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

If $d_i \le \bar{d}_i^L$, then the borrower repays for all realizations of the aggregate shock and the loan is risk-free. The loan is thus priced at the lender's discount rate. If $d_i > \bar{d}_i^L$, then the borrower will always default on the loan. I assume that lenders will not issue loans in these circumstances, so the price is zero. For debt levels between these thresholds, the borrower defaults only when aggregate income growth is low. The loan is repaid in full with probability ν. With probability $1-\nu$, the borrower defaults and the lender seizes the collateral. Since the borrower only defaults when aggregate income growth is low, the expected price of the housing collateral is the price conditional on low income growth $E_\Omega p_2(\omega^L)$.

For a risk-free loan with $d_i \le \bar{d}_i^L$, an increase in housing collateral raises $\bar{d}_i^L$, but has no effect on the loan price, or equivalently on the interest rate. For risky loans with $\bar{d}_i^L < d_i \le \bar{d}_i^H$, an increase in housing collateral will increase $\bar{d}_i^H$ and the price of the loan. This heterogeneity across loan types affects the optimal choice of housing consumption. Moreover, I will show later that it leads a change in the risk-free rate to have heterogeneous effects for different types of borrowers.

Relation to the exogenous lending constraint models. How does the framework here relate to the existing models of borrowing constraints with fixed loan-to-value(LTV) or loan-to-income(LTI) constraints?

This framework includes LTV constraints as a special case. Let $\lambda_{LTV} = \frac{d}{h_1 p_1}$ and $\lambda_{LTI} = \frac{d}{y_1}$ denote LTV and LTI ratio. The debt threshold for a given income growth realization can be expressed as

$$\lambda_{LTV}(\omega) = (1-\xi)\omega\frac{\lambda_{LTV}}{\lambda_{LTI}} + \frac{E_\Omega p_2(\omega)}{p_1} - \frac{\kappa}{h_1 p_1}$$

Assume that there is no proportional income loss from default, $\xi = 1$, and no fixed cost in the housing market, $\kappa = 0$. This can then be simplified to a LTV constraint which depends on the expected house price:

$$\lambda_{LTV}(\omega) = \frac{E_\Omega p_2(\omega)}{p_1}$$

While not the focus of this paper, the framework here provides a micro foundation for the relaxation of lending constraints following an increase in lenders' house price expectations.[26]

Next I characterize optimal debt and housing choices, and show the implications of the optimal portfolio choice for default risk across the income distribution.

[26] Kaplan, Mitman and Violante (2017) show that an increase in the exogenous LTV limit has limited effect on house prices unless it is accompanied by an increase in house price expectations. Within the framework of my model LTV limits themselves are endogenous to house price expectation. This may amplify the effect of lenders' beliefs on house prices and leverage.

2.1.3 Mortgage debt and housing consumption choice across the income distribution

In the first period borrowers choose mortgage debt and housing consumption. When doing so, they internalize the effect of their decisions on the loan price and their second period default decision. Lenders offer a continuum of loan contracts with loan prices determined by default risk and the value of housing collateral. As I have shown, loans can be categorized as risk-free, in which case the borrower always repays, and risky, in which case the borrower defaults when aggregate income growth is low. The borrower's problem can be solved in two steps. The first to step is to find the optimal housing and debt choices conditional on the loan being risk-free and risky. The second is comparing the borrower's utility in the two cases to find the overall optimal choice. Appendix A presents the borrower's problem conditional on choosing a risk-free and risky loan. I discuss only the results within the main text.

As preferences are quasilinear, housing consumption under each loan type is a fixed amount. Let h^{NR} and h^R represent housing consumption under risk-free and risky loans. In addition, due to quasilinear preferences and borrower impatience, when the loan is risk-free debt is $\bar{d}_i^L$, and when the loan is risky debt is $\bar{d}_i^H$.

Proposition 1 *Let*

$$\gamma = (1 - \xi) \left\{ \frac{\omega^L - \nu\omega^H}{R^f} + \beta\nu(\omega^H - \omega^L) \right\}$$

There exists a unique income cut-off $\bar{y}$

$$\bar{y} = \frac{1}{\gamma} \left\{ \frac{1 - \nu}{R^f}\kappa - \phi \ln\left(\frac{h^{NR}}{h^R}\right) \right\}$$

such that borrowers with income less than $\bar{y}$ *take risky loans as long as risk-free rate is sufficiently high*

$$R^f \geq \frac{1}{\beta} \frac{\nu\omega^H - \omega^L}{\omega^H - \omega^L}$$

Proposition 1 implies that the borrower's contract choice can be represented by the function Γ^R which takes value 1 when the borrower opts for a risky contract

$$\Gamma^R = \begin{cases} 1 & \text{if } y_1 \leq \bar{y} \\ 0 & \text{if } y_1 > \bar{y} \end{cases}$$

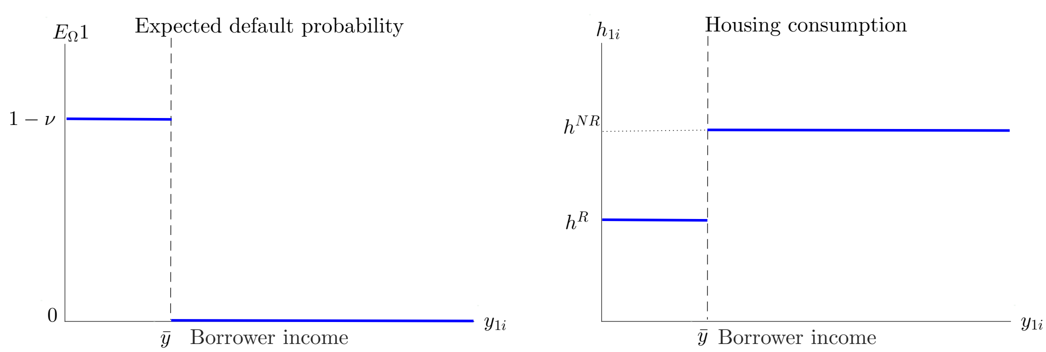
The two panels of Figure 3 display expected default and housing consumption policy functions for borrowers of different income levels. Across the income distribution, different contract choices arise due to a trade-off faced by borrowers which has three components. Conditional on choosing a risky loan, a borrower

1. makes a lower down-payment (Lemma 1)
2. has lower housing consumption (Lemma 2)
3. has lower expected second period consumption (Lemma 3).

compared to a risk-free loan. As the borrower makes a lower down-payment, her consumption in the first period is higher. Utility derived from first period consumption is thus higher than under a risk-free loan. Expected consumption in the second period is lower for two reasons. When aggregate income growth is low, the borrower defaults and loses part of her endowment. In addition, her expected income from selling her house is lower as it is lost when she defaults.

For low income borrowers, the utility gain from a low down-payment exceeds the cost from the risk of default, so they sort into risky loans. Borrowers with incomes above a certain level will not wish to sacrifice expected second period consumption to increase first period consumption. When interest rates are high, the gain in first period consumption when switching from a risk-free loan to a risky loan is low. Therefore, only low income borrowers opt for risky loans. When interest rates are low, loan prices are high and down-payments low. This makes switching from risk-free to risky loans more attractive. The model thus implies that in very low interest rate environments all borrowers will find it optimal to take out risky loans.

Figure 3: Policy functions for default probability and housing consumption



Note: As described in Proposition 1, borrowers with income below $\bar{y}$ choose mortgage contracts with a default probability of $1-\nu$. Housing consumption for these borrowers is h^R units. Borrowers with income above $\bar{y}$ always repay and have housing consumption h^{NR}.

Lemma 1 *The down-payment of a risky loan is lower than a risk-free loan at all points in the income distribution.*

A sufficient condition is:

$$\frac{\nu\omega^H}{\omega^L} \geq 1$$

As borrowers set debt equal to the threshold under both loan types, the down-payment for both depends on the second period fixed housing transaction cost. With a risky loan, the borrower repays infrequently and the effect of the fixed cost is small. This means that the part of the down-payment which is invariant with respect to borrower income is smaller under a risky loan compared to a risk-free loan.[27] If the sufficient condition holds, the down-payment for a risky loan is small across the income distribution.

[27]This is the source of the down-payment gain from a risky loan for a borrower with low income.

Lemma 2 *Housing consumption is higher under a risk free contract compared to a risky contract:*

$$h^{NR} \geq h^R$$

as long as loan recovery rate is sufficiently low:

$$\theta \leq \theta^{max} \quad where \quad \theta^{max} = 1 - (1 - \beta R^f) \left(\frac{E_\Omega p_2(\omega^H)}{E_\Omega p_2(\omega^L)} - 1 \right) \frac{\nu}{1-\nu}$$

Housing consumption affects utility both directly and indirectly. Since the direct marginal utility effect is symmetric, the indirect marginal utility effects determine whether borrowers want to consume more housing under one loan type compared to the other. Under a risky loan, an increase in housing consumption raises the loan price as houses serve as collateral. This relaxes the first period budget constraint. The higher the loan recovery rate, the higher is the impact of this channel. As described earlier, this effect is absent in a risk-free loan.

On the other hand, the effect of selling the house in the second period and consuming is weaker under a risky loan as the borrower defaults when aggregate income growth is low.

Moreover, as housing acts as collateral, an increase in housing consumption increases both debt thresholds. The impact of this relaxation is unclear as there are two forces at play: $\frac{\partial \bar{d}_i}{\partial h_{1i}}$ and the shadow value of debt, λ^R. In comparison to a risk-free loan, the former is high and the latter is low under a risky loan.[28]

For a borrower to buy a larger house under a risky loan, it must be the case that the loan price effect dominates all other indirect utility effects. This requires a high loan recovery rate. Put differently, when the recovery rate is sufficiently low, there is a positive loan spread for risky loans. This means that loan prices for risky loans are low, so borrowers consume smaller housing. This is formalized in Lemma 2.

When borrowers' and lenders' discount rates are sufficiently close, housing consumption under a risk-free loan is high for any feasible value of the loan recovery rate. Similarly, when the house price risk is low, i.e. $\frac{E_\Omega p_2(\omega^H)}{E_\Omega p_2(\omega^L)}$ is close to 1, housing consumption is high under a risk-free loan.

The third component of the contract choice is the expected utility derived from second period consumption. Since preferences are linear in consumption in the second period, a difference in consumption levels directly translates to a difference in utility. Expected second period consumption is higher under a risk-free loan than a risky loan. Under a risky loan, a borrower expects to consume $\xi \omega y_{1i}$ for each realization of the aggregate shock. When income growth is ω^L, the borrower defaults, loses their house and a fraction $(1-\xi)$ of her endowment and consumes what remains. When income growth is ω^H, the amount the borrower repays is equal to the value of her house plus a fraction $(1-\xi)$ of her endowment, so she makes no financial income through selling her house. With a risk-free loan, the borrower's second

[28] $\lambda^R = \nu \lambda^{NR} = \nu(\frac{1}{R^f} - \beta)$ in equilibrium. For $x \in \{H, L\}$

$$\frac{\partial \bar{d}_i^x}{\partial h_{1i}} = E_\Omega p_2(\omega^x)$$

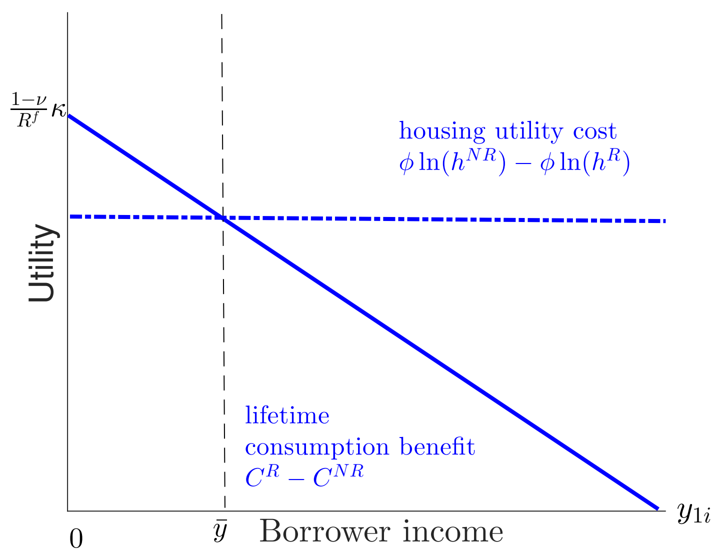
period consumption is a fraction ξ of her endowment when the second period shock is ω^L. When the shock is ω^H, the borrower's financial income is positive, so her consumption is higher.

Lemma 3 *Expected second period consumption is higher under a risk-free loan than a risky loan across the income distribution.*

Taking stock: Borrowers of all income levels derive higher expected utility from second period consumption when their loan is risk-free. Under a risky contract, they make a smaller down payment and consume more in the first period. Since preferences are linear in consumption, lifetime utility derived from non-durable consumption is linear in income. The relative consumption (utility) gain from a risky loan can be expressed as:[29]

$$C^R - C^{NR} = \frac{1-\nu}{R^f}\kappa - y_1(1-\xi)\left\{\frac{\omega^L - \nu\omega^H}{R^f} + \beta\nu(\omega^H - \omega^L)\right\}$$

Figure 4: Utility trade-off: costs and benefits of a risky loan



Note: The diagram plots the utility costs and benefits from switching to a risky loan for different levels of borrower income. For borrowers with income below $\bar{y}$, the utility benefits exceed the utility costs.

The intercept of the relative non-durable consumption utility gain is due to the down-payment being lower under a risky loan then a risk-free loan for a borrower with zero income.

29

$$C^R = hp_1 - \frac{\nu}{R^f}\kappa - \phi + y_1\{1 + \beta\xi(\nu\omega^H + (1-\nu)\omega^L) + \frac{(1-\xi)\nu\omega^H}{R^f}\}$$

$$C^{NR} = hp_1 - \frac{1}{R^f}\kappa - \phi + y_1\{1 + \beta(\nu\omega^H + (\nu+\xi)\omega^L) + \frac{(1-\xi)\omega^L}{R^f}\}$$

The higher the transaction cost in the housing market, the larger is the gain under a risky loan.

Figure 4 represents Proposition 1 graphically. It plots the total consumption gain from a risky loan against the housing utility cost. Low income borrowers opt for risky loans as long as the gain from a low down-payment exceeds the costs of lower housing and expected second period consumption. This is true when the fixed cost κ is sufficiently high, so that the intercept of the consumption gain is above that of the housing utility loss. This is the benchmark specification that I use to study the consequences of income distribution changes. [30]

2.2 General Equilibrium

The equilibrium of the model is characterized by quantities $\{h^R, h^{NR}, d_i^R, d_i^{NR}\}$, prices $\{q_i, p_1\}$ and contract type choice Γ_i^R such that

1. Borrowers optimize by solving problem 1 with associated decision rules $\{h^R, h^{NR}, d_i^R, d_i^{NR}, \Gamma_i^R\}$
2. The mortgage market clears loan-by-loan with loan prices defined by equation 2 and decision rules $\{h^R, h^{NR}, d_i^R, d_i^{NR}, \Gamma_i^R\}$
3. The housing market clears at price p_1

$$\int (\Gamma_i^R h^R(p_1) + (1 - \Gamma_i^R) h^{NR}(p_1)) \psi(y_{1i}) di = h$$

Total housing demand is obtained by aggregating individual housing consumption choices over the income distribution. Since the population is normalized to 1 and and all borrowers begin with an initial endowment of hosing h, the aggregate housing supply is h.

Remark 1 *The general equilibrium of the model can be represented in (p_1, S) space as follows:*

The locus of (p_1, S) consistent with housing market clearing is HH:

$$S h^R(p_1) + (1 - S) h^{NR}(p_1) = h \quad (HH)$$

The locus of (p_1, S) consistent with mortgage market clearing is MM:

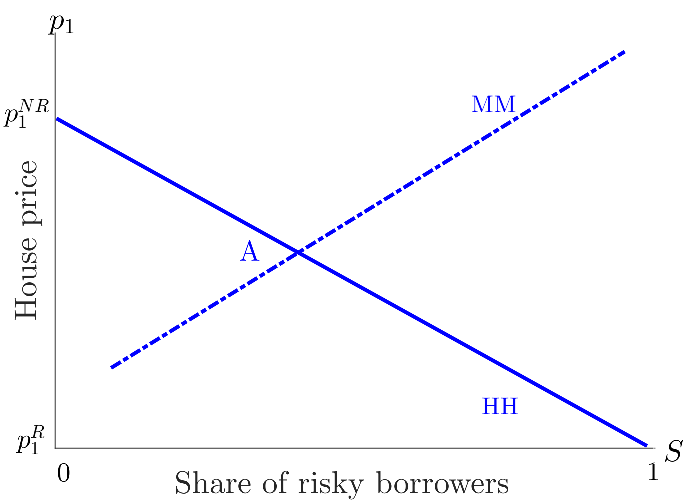
$$S = \Psi(\bar{y}(p_1)) \quad (MM)$$

where $\Psi(\bar{y}(p_1))$ is the share of borrowers with income less than $\bar{y}$, and thus S is the share of risky borrowers.

[30] Three other cases are possible. First, if the real interest rate is low, then the consumption gain schedule is upward sloping and it is optimal to choose a risky loan irrespective of income. Second, if κ is small and the risk-free rate is low, then only the risk-free contract exists in equilibrium. Finally, if κ is small and the risk-free rate is high, then low income borrowers will opt for risk-free loans and high income borrowers risky loans. The last case may arise at business cycle frequency. Adelino, Schoar and Severino (2016) show that middle-income, high-income, and prime borrowers all sharply increased their share of delinquencies in the recent crisis. Since the focus of the current paper is the long-run determinants of house price and credit developments, I leave this interesting case for future research.

- *The HH curve is downward sloping in S*
- *The MM curve is upward sloping in S*

Figure 5: General equilibrium of the model



Note: The HH curve represents equilibrium in the housing market. The MM curve represents equilibrium in the mortgage market.

Figure 5 represents the general equilibrium of the model with house prices p_1 on the y-axis and the share of risky borrowers S on the x-axis. The HH curve has intercept p^{NR}. This corresponds to the case where all borrowers choose risk-free loan, housing demand is high and thus the equilibrium house price is at its highest level. As the share of risky borrowers increases, the total demand for housing declines. Thus, the house price declines along the HH curve.

The MM curve depicts how the share of risky borrowers changes with the house price, which is taken as given in the mortgage market. Figure 13 displays the effect of a change in the house price on the income cut-off, and thus on the share of risky borrowers. As the house price increases, the housing consumption cost of a risky loan decreases. This implies that it is optimal for a higher share of borrowers to choose a risky loan. That is, $\bar{y}$ increases. This is because h^{NR} has a higher price elasticity than h^R. Thus a risky loan is less costly in terms of housing consumption at high price levels.

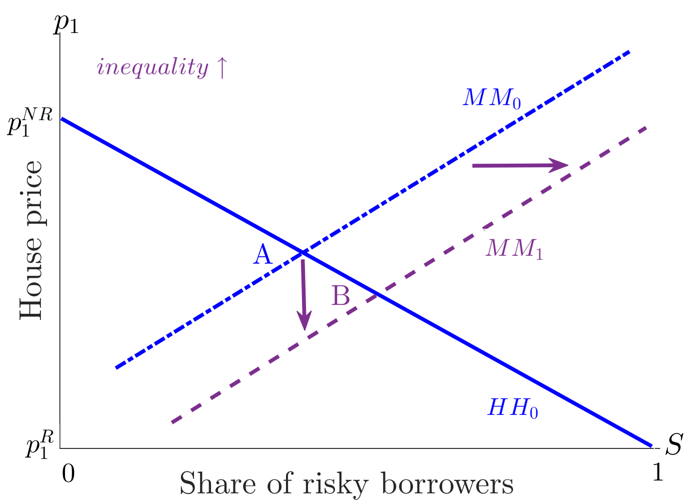
A change in the risk-free rate shifts both the HH and MM schedules. However, a change in the income distribution from Ψ to $\tilde{\Psi}$ lead only MM to shift, which then implies a movement along HH. These experiments are the topic of subsequent sections.

2.3 The general equilibrium effect of an increase in income inequality: matching the cross-sectional facts

I now study the general equilibrium effect of a mean-preserving increase in income inequality. I hold mean income constant in order to isolate the effect of an increase in inequality.[31]

[31] See, for instance, Blinder (1975) and Auclert and Rognlie (2018) for applications to consumption demand.

Figure 6: The general equilibrium impact of a mean-preserving increase in income inequality



Note: The HH curve represents equilibrium in the housing market. The MM curve represents equilibrium in the mortgage market for a given house price. A mean-preserving change in income inequality shifts MM_0 to MM_1. The equilibrium of the model moves from point A to point B.

I show that a mean-preserving increase in income inequality leads to a decline in equilibrium house prices and an increase in the share of risky borrowers. This result is depicted in Figure 6.

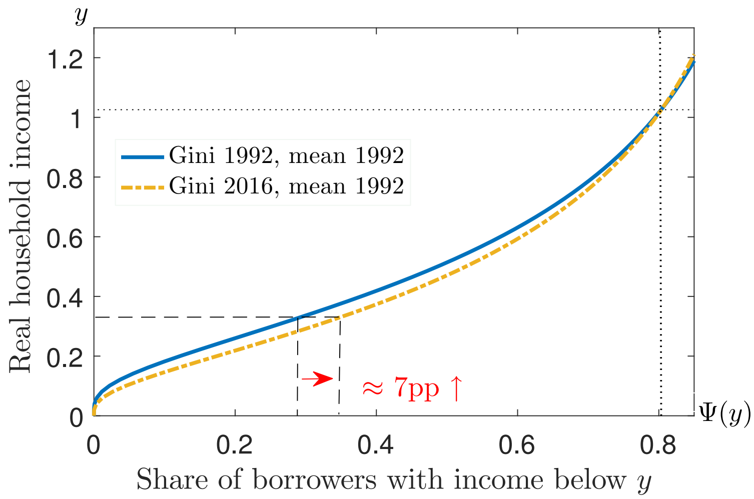
The intuition for this result is as follows. A mean-preserving increase in income inequality means that incomes decline for the lower percentiles of the distribution. The share of borrowers with incomes below $\bar{y}$ thus rises. I consider Pareto and log-normal income distributions, two empirically plausible parametric income distributions for which it is possible to derive an analytical result for the change in the share of risky borrowers.

Figure 7 shows an example of a mean preserving increase in inequality. The y-axis shows real household income in hundred thousand dollars, the x-axis the cumulative share of borrowers below each income level. The blue solid line is calibrated such that it matches the Gini coefficient and median income for the year 1992.[32] The yellow dashed line is calibrated to match the Gini coefficient for 2016, while holding mean income at its 1992 level. A mean-preserving increase in inequality corresponds to an increase in the higher income percentiles. For instance, the median earner in the 2016 distribution has lower real income then to the median earner in the 1992 distribution. In terms of the model, when the income cut-off is sufficiently low, this change in income inequality increases the share of borrowers below it. If the income cut-off is forty thousand dollars, then the change depicted would lead to seven percentage point increase in the number of risky borrowers.

A mean preserving increase in income inequality is consistent with the data. Figure 8 plots the cross-sectional correlation between the change in the Gini coefficient and upper limits of different income quintiles, median income and the lower limit of top 5 percentile between the years 1999 and 2011. The figure shows that an increase in income inequality

[32]For 1992, the US Gini coefficient is 0.433 and real median income is 51390 US dollars. The Gini increased to 0.481 in 2016.

Figure 7: Effect of a mean-preserving increase in income inequality on income percentiles



Note: This is a parametric representation of a change in income inequality calibrated using US data and assuming a log-linear income distribution. The y-axis shows income levels, and the x-axis the cumulative density with incomes below this level. The blue solid line matches the Gini coefficient and real mean income for the year 1992. The yellow dashed line matches the Gini coefficient for the year 2016, holding mean income at its 1992 level.

is associated with an increase in the lower limit of the top 5 percentile only. That is, areas that experienced large increases in income inequality tended to experience large declines in income limits in the lowest three quintiles and the median county income. A rise in income inequality is associated with a lower decline in the 80^{th} income percentile. This implies that a rise income inequality at the cross-section corresponds to a more than half of the population that has incomes below the median income of 1999.

2.3.1 Income Distribution: Pareto

The Pareto distribution is characterized by two parameters: a scale parameter y_{min} and a shape parameter α. The mean Gini coefficient and mean a Pareto distribution are:

$$Gini = \frac{1}{2\alpha - 1}, \quad Mean = \frac{\alpha}{\alpha - 1} y_{min}$$

The scale parameter affects only the mean of the distribution, whereas the shape parameter affects both the mean and the Gini coefficient.

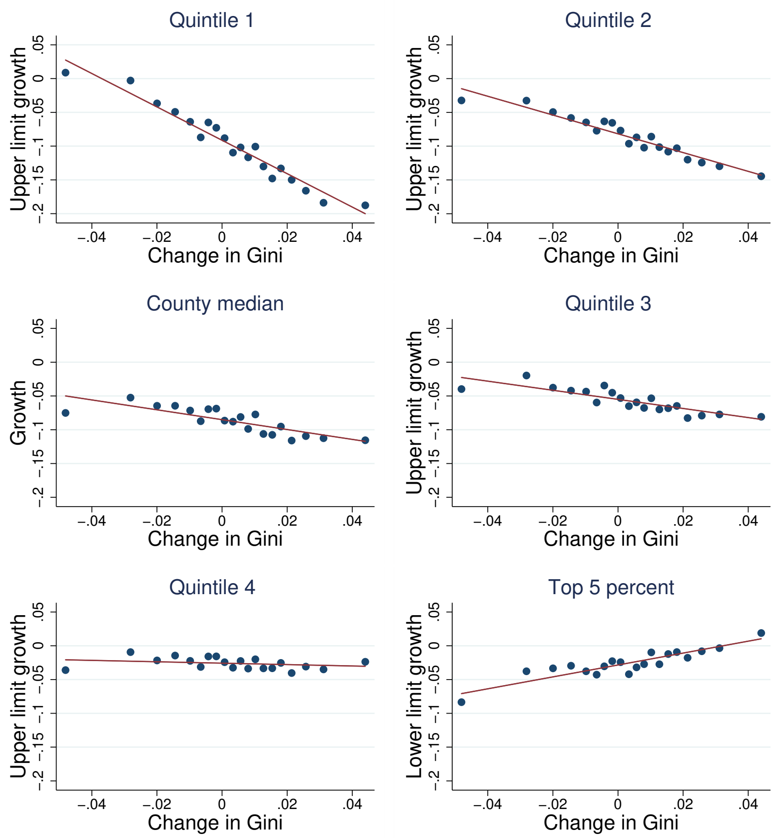
For this distribution, the fraction of borrowers with income lower than $\bar{y}$ is:

$$\Psi(\bar{y}) = 1 - \left(\frac{y_{min}}{\bar{y}}\right)^{\alpha}$$

A increase in income inequality corresponds to a decline in α. As $\frac{y_{min}}{\bar{y}} < 1$, $\Psi(\bar{y})$ must then decline. The formula for mean income implies that this change will also increase mean income.

In order to understand the impact of income inequality alone, I consider changes in income inequality with mean income held constant. To achieve this, I vary y_{min} with α. Let mean

Figure 8: The relationship between an increase in income inequality and the upper income limit in different income quintiles



Data source: US Census Bureau.

Note: The y-axis of each subplot is the real growth rate of the upper limit of a particular income quintile, median or lower limit of top 5 percent. The binscatter command of Stata is used to produce this figure. Change in the Gini coefficient is grouped into 20 equally sized bins. The position of each point in the graph is the mean value of the change in the Gini coefficient and mean value of y-axis variable for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011.

income be fixed at $\bar{M}$, then

$$y_{min} = \bar{M}\frac{\alpha - 1}{\alpha}$$

For a given mean income level, the share of borrowers with income below $\bar{y}$ can be written as:

$$\Psi(\bar{y}) = 1 - \left(\frac{\bar{M}}{\bar{y}}\frac{\alpha - 1}{\alpha}\right)^{\alpha}$$

Proposition 2 *A mean-preserving increase in income inequality under a Pareto income distribution increases the share of risky borrowers in the economy*

$$\frac{\partial\Psi(\bar{y})}{\partial Gini} > 0$$

as long as

$$\Psi(\bar{y}) \leq 1 - exp(-1) = 0.63$$

For the income inequality levels of the early 1990s, the sufficient condition is much weaker than Proposition 2. The share of risky borrowers in the economy before the mean-preserving change is required to be less than around 95%. Equivalently, in the new income distribution, incomes of the top 5% must have increased, and incomes of the bottom 95% declined. That is, income must have been redistributed towards the top of the income distribution.

The Pareto distribution is widely used to study incomes in the upper tail, rather than the whole distribution. For robustness, I also consider the log-normal income distribution.

2.3.2 Income Distribution: Log-normal

The log-normal distribution is characterized by parameters μ and σ^2. The Gini coefficient, mean and median of a log-normal distribution are given by[33]

$$Gini = erf\left(\frac{\sigma}{2}\right), \quad Mean = exp\left(\mu + \frac{\sigma^2}{2}\right), \quad Median = exp\left(\mu\right)$$

Similar to the Pareto distribution, one parameter, μ, affects only the mean income, while another, σ^2, affects both mean income and the Gini coefficient.

For this distribution, the fraction of borrowers with income below $\bar{y}$ is

$$\Psi(\bar{y}) = \frac{1}{2} + \frac{1}{2}erf\left(\frac{\ln(\bar{y}) - \mu}{\sqrt{2}\sigma}\right)$$

From these formulas, it is straightforward to show that an increase in inequality increases the share of the population with income below the median. The share of risky borrowers will

[33] where erf is the error function defined as:

$$erf(x) = \frac{1}{\pi}\int_{-x}^{x} e^{-t^2}dt$$

$erf(x)$ is an increasing function of x.

then also increase as long as less than half of the population opt for a risky loan.

Proposition 3 *An increase in income inequality under a log-normal income distribution increases the share of risky borrowers in the economy*

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} > 0$$

as long as

$$\bar{y} \leq median$$

An increase in inequality will also increase mean income. Let $\bar{M}$ be the target level of mean income. The cumulative density function can be expressed as:

$$\Psi(\bar{y}) = \frac{1}{2} + \frac{1}{2} erf\left(\frac{\ln(\bar{y}) - \ln(\bar{M})}{\sqrt{2}\sigma} + \frac{\sigma}{2\sqrt{2}}\right)$$

To hold mean income constant, it is necesarry to vary μ in line with σ. This is equivalent to varying it with the Gini coefficient. The following proposition provides a sufficient condition for the share of risky borrowers to increase following a mean-preserving increase in the Gini coefficient. Notice that the condition is less restrictive compared to that of Proposition 3.

Proposition 4 *A mean-preserving increase in income inequality under a log-normal income distribution increases the share of risky borrowers in the economy*

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} > 0$$

as long as

$$\bar{y} \leq e^{\sigma^2} median$$

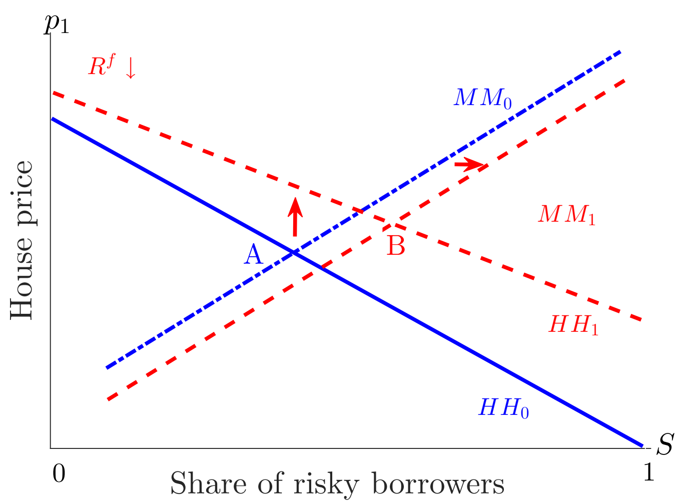
For the log-normal distribution, an increase in inequality with mean income held constant leads even some incomes above the median to decline. Given the rates of defaults in the data, the sufficient condition is likely to hold. In the calibrations of Figure 7, $e^{\sigma^2} median$ is around the 80^{th} income percentile. Data from the US counties in Figure 8 shows that incomes in the bottom 60^{th} percentiles tended to fall when income inequality increased.

In the next section I study the effect of a change in the risk-free rate on the equilibrium of the model. I then study the interaction of these effects with those of a rise in income inequality.

2.4 The general equilibrium effect of a decline in the risk-free rate

This section analyses the impact of a decrease in the risk-free rate on the equilibrium house price and aggregate default risk. Unlike an increase in income inequality, a change in the risk-free rate affects partial equilibrium in both the housing and mortgage markets. That is, both the HH and MM loci shift.

Figure 9: The general equilibrium impact of a decline in the risk-free rate



Note: The HH curve represents the partial equilibrium in the housing market. The MM curve represents the equilibrium in the mortgage market for a given house price. A decline in the real rate shifts the MM curve from MM_0 to MM_1, and the HH curve from HH_0 to HH_1. The equilibrium of the model moves from point A to point B.

A decline in the risk-free rate increases loan prices. Therefore, down-payments fall. This enables borrowers to increase housing consumption under any contract type, so the HH curve shifts outwards. For a given share of risky borrowers, equilibrium house price increases. The differential response of h^R and h^{NR} to a change in R^f determines the slope of the new housing market clearing condition. If the relative increase in housing consumption is higher under a risky loan, then the HH curve flattens. Lemma 5 shows that this is the case as long as loan recovery rate is sufficiently high. The response of the housing market equilibrium is shown by the red dashed HH line in Figure 9.

A lower interest rate affects the mortgage market as the changes in down-payments and housing consumption affect mortgage choice. Under a risky contract, the down-payment declines more (Lemma 4) and the relative increase in housing consumption is higher (Lemma 5). Changes in the real rate do not affect expected future consumption. Therefore, a decline in the real rate leads to a rise in the consumption benefit of a the risky loan increases, and a fall in the utility cost from lower housing consumption. For a given price of housing, the income cut-off rises. Figure 14 shows the effect of declining real rates on the mortgage market, holding the price of house constant. It corresponds to a visual representation of Proposition 5. An increase in the share of risky borrowers in the mortgage market leads the MM to shift to the right in Figure 9.

Lemma 4 *A decline in the risk-free rate decreases the down-payment more for a risky loan than a risk-free loan.*

A sufficient condition is

$$\frac{\nu\omega^H}{\omega^L} \geq 1$$

Lemma 5 *There exists a loan recovery rate $\underline{\theta}$ such that, for any loan recovery rate above $\underline{\theta}$*

1. *The semi-elasticity of housing demand is higher under a risky loan compared to a risk-free loan:*

$$\left|\frac{\partial \ln(h^R)}{\partial R^f}\right| \geq \left|\frac{\partial \ln(h^{NR})}{\partial R^f}\right|$$

2. *The HH curve flattens following a decline in the risk-free rate.*

The following proposition describes the impact of a change in the risk-free rate on the mortgage market equilibrium. It combines the findings of Lemma 5 and Lemma 4.

Proposition 5 *Holding the price of housing constant, a decline in the risk-free rate increases the share of borrowers with a risky loan*

$$\frac{\partial \Psi(\bar{y}(p_1))}{\partial R^f} < 0$$

The general equilibrium effect of a decline in the risk-free rate is an increase in aggregate mortgage default risk. The effect on the house price depends on the relative shifts of the MM and the HH curves.

2.5 Reconciling cross-sectional facts with aggregate trends

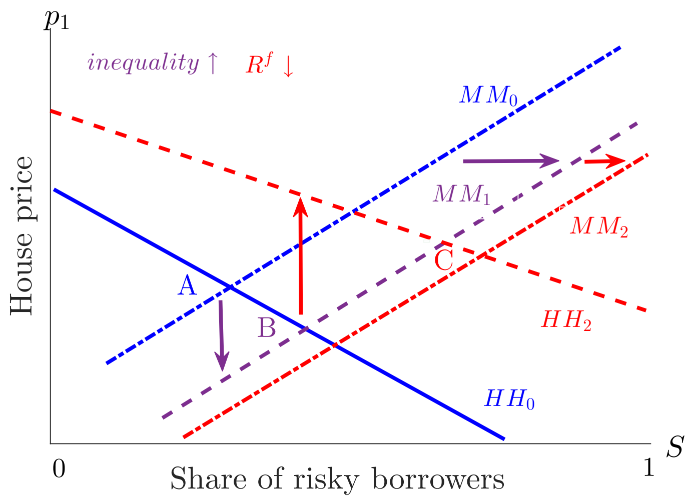
This section studies together the effects of rising income inequality and a decline in the real interest rate. I show a decline in the real interest rate is necessary to match the observed aggregate trends in income inequality and house prices. Figure 10 adds the effects of a real interest rate decline to those of an increase in inequality which were depicted in Figure 6. An increase in income inequality moves the economy from A to B, which is consistent with the stylized facts provided earlier. A decline in the risk-free rate then moves equilibrium from point B to C. The decline in the risk-free rate overturns the negative effect of income inequality on house prices. This is accompanied with an increase in the share of risky borrowers in the economy. A lower risk-free rate stimulates housing consumption across the income distribution. However, the effect is stronger for the borrowers with risky loans. This mitigates the effect on house prices.

3 Verifying the model's predictions: a panel data analysis

The model presented in the previous section implies the following testable predictions

1. Income inequality and house prices are negatively correlated
2. Income inequality and aggregate default risk are positively correlated
3. Declining real rates mitigate the effect of rising inequality on house prices
4. Declining real rates amplify the effect of rising inequality on aggregate default risk

Figure 10: Reconciling cross sectional facts and aggregate trends: the equilibrium impact of rising inequality and a declining real interest rate



Note: The HH curve represents equilibrium in the housing market. The MM curve represents equilibrium in the mortgage market for a given house price. A mean-preserving change in income inequality shifts the MM curve from MM_0 to MM_1. A decline in the real rate shifts the MM curve from MM_1 to MM_2, and the HH curve from HH_0 to HH_2. The equilibrium of the model moves from point A to point C.

3.1 Data description and summary statistics

In my empirical analysis I use a panel of US States. My data includes measures of house prices, mortgage debt, mortgage delinquency, mean income and population. I use the Federal Housing and Financing Agency (FHFA) all transactions index to measure house prices. The FHFA constructs this index by reviewing repeat mortgage transactions, both purchase and refinancing, on properties whose mortgages were securitized or bought by Fannie Mae or Freddie Mac.

My measure of household debt data uses Consumer Credit Panel/Equifax (CCP) data available at the state level from the New York Federal Reserve website.[34] I use the per capita balance of mortgage debt excluding home equity lines of credit as my measure of mortgage debt. My measure of delinquency is the percent of the mortgage debt balance that has been delinquent for more than ninety days.

Data on resident populations, the 10-year treasury constant maturity rate, the number if new private housing permits authorized, and mean adjusted gross income are available from the St Louis Federal Reserve Bank.[35] I use the CPI-UR-S series from Bureau of Labor Statistics to deflate the house price index, mortgage debt and mean adjusted gross income.[36] I construct long-term real rates by subtracting 10-year inflation forecasts from Survey of

[34] `https://www.newyorkfed.org/microeconomics/databank.html` For a detailed description of this data see Lee and der Klaauw (2010).

[35] 10-year treasury constant maturity rate is from Board of Governors of the Federal Reserve System (US). New private housing permits authorized is from US Bureau of the Census and U.S. Department of Housing and Urban Development. Mean adjusted gross income series are from US Bureau of the Census.

[36] This series is considered to be the most detailed and systematic consistent CPI series available. This is important as my data starts before 2000 where the series had a methodological change.

Professional Forecasters from the 10-year treasury constant maturity rate. I find the annual forecast by taking the average of quarterly forecasts.

The Gini coefficient is taken from Mark Frank's website. It is constructed from individual tax filing data available through the Internal Revenue Service website.[37]

The data set covers spans the years between 1992-2015 for house prices and 2003-2015 for mortgage variables. It covers all US states excluding Alaska and the District of Columbia.

3.2 Empirical Strategy and Results

This section described my estimation strategy and presents estimation results. To isolate the effect of income inequality on outcome variables, I use specifications that include both state and year fixed effects. Year fixed effects capture changes in aggregate variables that might confound the effect of income inequality. For example, declining real interest rates, business cycles, or an increase in the aggregate supply of credit. State fixed effects control for any time-invariant heterogeneity across states. This includes any cultural, social, historical, geographic and other conditions that remained constant within the study period. This identification strategy is similar to a difference-in-differences approach with continuous treatment as the remaining variation in the data is that of state and time.

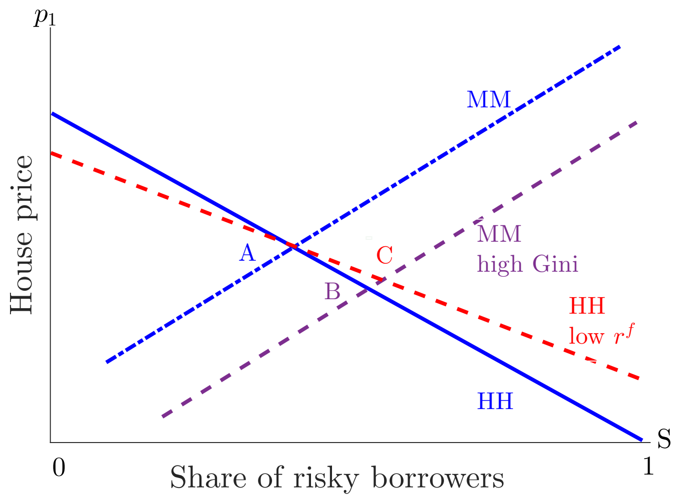
I include variables that vary by state over time in order to control for confounding effects in the state-by-time dimension. Changes in inequality might be correlated with changes in other variables that directly affect housing demand. For example, real mean income and population. A rise in income inequality can result from changes in the different quintiles of the income distribution which might give rise to an increase or a decrease in the mean income. Therefore, to analyze whether income inequality is an independent vector explaining the developments in the outcome variable, I control for mean income. Including population controls directly for aggregate housing demand and also indirectly for changes in the demographics of a state, which could affect preferences for home-ownership and thus housing demand. Demographics can also affect the borrower pool. While state fixed effects can control for the time invariant component of borrower quality, including population can be considered as an indirect control for this type of change. Moreover, changes in demographics can affect the income distribution in a state. Depending on the relative incomes of movers and residents, mean income and income inequality might increase or decrease. I include the home-ownership rate in the model to control for cyclical changes in housing demand that can arise from various sources such as an increase in house price expectations or easier access to mortgage lending. If the access to lending is not increasing homogeneously across the income distribution, its effect might confound that of income inequality. Finally, I introduce a measure of a change in housing supply that cannot be captured by the state fixed effects. Developers may wish to build more houses when incomes are increasing. This might confound the effect of income inequality especially if potential buyers from some points of the income distribution fare better than others.

I use the following regression specification:

$$Y_{s,t} = \alpha_s + \alpha_t + \beta Gini_{s,t} + \Gamma X_{s,t} + \epsilon_{s,t}$$

[37] http://www.shsu.edu/eco_mwf/inequality.html

Figure 11: Equilibrium impact of rising inequality in high and low interest rate environments



Note: The HH curve represents equilibrium in the housing market. The MM curve represents equilibrium in the mortgage market for a given house price. A mean-preserving change in income inequality shifts MM to MMhigh Gini. The slope of the HH curve increases with the real rate.

where $Y_{s,t}$ is the outcome variable, α_s and α_t are state and time fixed effects, and $X_{s,t}$ is a vector of time-varying state level covariates.

In order to test the joint effect of low interest rates and increasing income inequality, I also estimate a specification which includes the interaction of the Gini coefficient with the real interest rate. Note that the year fixed effects absorb all variation in the real rate itself.

$$Y_{s,t} = \alpha_s + \alpha_t + \beta Gini_{s,t} + \mu Gini_{s,t} \times Rate_t + \Gamma X_{s,t} + \epsilon_{s,t}$$

Figure 11 provides model based guidance regarding the interaction between inequality and the interest rate environment. The figure is a variant of Figure 9 with the direct effects of the decline in the risk-free rate eliminated or, within the context of the regression specification, are averaged out. A negative μ coefficient implies that in high interest rate environments, one percentage point increase in income inequality increases the outcome variable at a lower rate.

Finding 1: House prices decline with income inequality

Table 1 presents estimation results when house prices are the dependent variable. The first column shows that, consistent with the model's predictions, income inequality and real house prices are negatively correlated. A 10 percentage point increase in income inequality is associated with a 20% decline in house prices. Equivalently, a one standard deviation increase in income inequality corresponds to a 7.7% decline in real house prices.[38] The second column shows that income inequality remains significant when controlling for mean income and population, two variables that are most likely to confound income inequality. In column (3) I add two additional controls: the home-ownership rate and the number of new

[38]This corresponds to roughly 27% of the overall variation in real house prices for the period analyzed.

private housing permits authorized. Column (3) shows that a 10 percentage point increase in income inequality is associated with a 16% decline in real house prices. For robustness, I repeat the regressions in columns (4) – (6) using population weights and find similar results.

Table 1: Income inequality and real house prices
Dependent variable: Log real FHFA house price index

	(1)	(2)	(3)	(4)	(5)	(6)
Gini	-2.138***	-1.745***	-1.605***	-2.093***	-1.793***	-1.701***
	(0.338)	(0.261)	(0.242)	(0.601)	(0.551)	(0.536)
Log real mean income		1.107***	1.059***		1.293***	1.251***
		(0.159)	(0.143)		(0.186)	(0.182)
Log population		0.250*	0.272*		0.191	0.188
		(0.136)	(0.146)		(0.216)	(0.224)
Homeownership rate			0.010***			0.007
			(0.003)			(0.005)
Log new permits			0.001			-0.000
			(0.002)			(0.002)
year fe	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes
population weight	no	no	no	yes	yes	yes
R-squared within	0.699	0.802	0.812	0.716	0.810	0.813
R-squared overall	0.163	0.235	0.162	0.166	0.318	0.274
Observations	1200	1200	1200	1200	1200	1200
Years	1992-2015	1992-2015	1992-2015	1992-2015	1992-2015	1992-2015

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Heteroscedasticity and auto-correlation robust standard errors in parenthesis clustered at the state level. House price index and income variables are deflated by CPI-UR-S series. Columns (4) – (6) present population weighted estimates.

Next I examine the effect of a low interest environment on the income inequality-house price nexus. Figure 11 shows that a given increase in income inequality leads to a smaller decline in house prices when the real rate is low. The model therefore predicts that the interaction term will have a negative coefficient.

The first column of the Table 2 presents estimation results when the model is estimated without controls. The results imply that a one percentage point increase in the real interest rate increases the response of house prices to income inequality by about half a percentage point. That is, when the 10-year real rate is one percent, a 10 percentage points increase in income inequality implies a decline in house prices of about 19%. Columns (2) and (3) show that the effect of real rates remains significant when controls are included and columns (4)-(6) show that the effect is not driven by states with small populations.

An alternative interpretation of these findings is that, in an environment with rising income inequality, real rates must remain low to mitigate the depressing effect of inequality on house prices. The results in column (3) imply that, to compensate for the effect of income inequality on house prices, the 10-year real interest rate has to decline by 6 percent. From 1992 to 2015, income inequality increased by about 5 basis points and the 10-year real rate declined by roughly 3 percent. This fall would mitigate only half of the effect of the increase in income inequality. However, this is only the interaction effect of the real interest rate on real house prices. Glaeser, Gottlieb and Gyourko (2012) find that the direct effect of a one percent decline in 10-year real rates is a roughly 7% increase in real house prices. A back of

Table 2: Income inequality and real house prices: the effect of the interest rate environment
Dependent variable: Log real FHFA house price index

	(1)	(2)	(3)	(4)	(5)	(6)
Gini	-1.479***	-1.438***	-1.339***	-1.429***	-1.362***	-1.316***
	(0.498)	(0.341)	(0.308)	(0.400)	(0.377)	(0.366)
Gini x Real 10-year rate	-0.547**	-0.259*	-0.228*	-0.768***	-0.516***	-0.493***
	(0.214)	(0.144)	(0.135)	(0.207)	(0.179)	(0.183)
Log real mean income		1.066***	1.025***		1.174***	1.149***
		(0.147)	(0.133)		(0.175)	(0.166)
Log population		0.202	0.229		0.103	0.105
		(0.134)	(0.144)		(0.205)	(0.215)
Homeownership rate			0.010***			0.005
			(0.003)			(0.005)
Log new permits			0.001			-0.000
			(0.002)			(0.002)
year fe	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes
population weight	no	no	no	yes	yes	yes
R-squared within	0.716	0.806	0.815	0.756	0.826	0.828
R-squared overall	0.160	0.280	0.190	0.148	0.424	0.378
Observations	1200	1200	1200	1200	1200	1200
Years	1992-2015	1992-2015	1992-2015	1992-2015	1992-2015	1992-2015

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Heteroscedasticity and auto-correlation robust standard errors in parenthesis clustered at the state level. House price index and income variables are deflated by CPI-UR-S series. Real 10 year-rate is 10-year constant maturity treasury rate minus 10-year ahead inflation forecasts from Survey of Professional Forecasters. Columns (4) − (6) present population weighted estimates.

envelope calculation suggests that the income inequality and real interest rate developments between 1992 and 2015 together imply a 17% increase in house prices. This is roughly three quarters of the observed increase for this period.

Finding 2: The mortgage delinquency rate increases with income inequality

Next, I analyze how income inequality affects mortgage market stability. Table 3 presents estimation results with the percent of delinquent mortgages as the dependent variable. The results in column (1) imply that a 10 percentage point increase in inequality is associated with a roughly 21 percentage point increase in the delinquency rate. Equivalently, a one standard deviation increase in inequality corresponds to a 0.76 percentage points increase in the delinquency rate. Column (2) shows that the estimated coefficient is smaller when controlling for mean income, and column (3) that it is smaller when controlling for other variables. Finally, population weighted estimates lead to quantitatively similar results.

Figure 11 shows that a given increase in income inequality leads to a larger increase in equilibrium default risk when the real rate is low. Therefore, the model predicts that the interaction term has a positive coefficient.

Table 4 shows that, in high interest rate environments. a one percentage point increase in income inequality implies a smaller increase in mortgage delinquencies. Column (1) shows that a one percentage point increase in the real interest rate implies that mortgage delinquencies rise by 0.7 percentage points less when there is a 10 percentage point increase in income inequality. Controlling for income and other variables reduces the estimated effect of

Table 3: Income inequality and mortgage delinquency
Dependent variable: Percent of Mortgage Debt Balance 90+ Days Delinquent

	(1)	(2)	(3)	(4)	(5)	(6)
Gini	20.958***	12.309**	12.641**	28.751**	15.382	15.995
	(5.946)	(4.917)	(4.963)	(10.729)	(11.153)	(9.782)
Log real mean income		-13.645***	-14.387***		-28.249**	-31.280**
		(4.737)	(5.172)		(11.926)	(13.448)
Log population			-0.945			-6.238
			(4.753)			(7.829)
Homeownership rate			0.091			0.270
			(0.059)			(0.194)
year fe	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes
population weight	no	no	no	yes	yes	yes
R-squared within	0.625	0.674	0.677	0.625	0.704	0.714
R-squared overall	0.507	0.163	0.061	0.501	0.064	0.003
Observations	650	650	650	650	650	650
Years	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Heteroscedasticity and auto-correlation robust standard errors in parenthesis clustered at the state level. House price index and income variables are deflated by CPI-UR-S series. Columns (4) − (6) present population weighted estimates.

Table 4: Income Inequality and mortgage delinquency: the effect of the interest rate environment
Dependent variable: Percent of Mortgage Debt Balance 90+ Days Delinquent

	(1)	(2)	(3)	(4)	(5)	(6)
Gini	26.822***	18.623***	19.925***	34.011**	20.608*	21.919**
	(8.038)	(6.114)	(6.143)	(12.963)	(12.289)	(10.678)
Gini x Real 10-year rate	-7.050	-7.763*	-8.580*	-12.943	-12.771**	-14.402**
	(4.857)	(4.149)	(4.377)	(8.678)	(5.619)	(5.522)
Log real mean income		-13.870***	-14.743***		-28.171***	-31.302**
		(4.535)	(5.136)		(10.340)	(11.905)
Log population			-3.024			-9.963
			(4.723)			(6.232)
Homeownership rate			0.101			0.274
			(0.065)			(0.206)
year fe	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes
population weight	no	no	no	yes	yes	yes
R-squared within	0.632	0.683	0.687	0.642	0.720	0.734
R-squared overall	0.524	0.175	0.006	0.511	0.065	0.013
Observations	650	650	650	650	650	650
Years	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Heteroscedasticity and auto-correlation robust standard errors in parenthesis clustered at the state level. House price index and income variables are deflated by CPI-UR-S series. Columns (4) − (6) present population weighted estimates.

inequality on mortgage delinquency is reduced. Population weighted estimates are presented in columns (4) − (6). They imply a stronger effect of interest rates in mitigating the default risk arising from income inequality.

Finding 3: Mortgage debt declines with income inequality

I next investigate whether the estimates using state data are consistent with those using county data. Recall that, in county data, an increase in income inequality was correlated with a decrease in lending. The estimates presented in table 5 imply that, for state data, an increase in inequality is associated with a decline in mortgage lending. The estimate in column (1) implies that a 10 percentage points increase in the Gini coefficient leads to a 13.7% decline in real mortgage debt per capita. The negative relationship between mortgage debt and income inequality is robust to controlling for other variables and estimating population weighted specifications. I next examine whether the debt-inequality relationship varies with the interest rate. Results are reported in Table 6. I find no significant effect of the real rate across all the different specifications.

Table 5: Income inequality and real mortgage debt
Dependent variable: Real Mortgage Debt Balance per Capita (excluding HELOC)

	(1)	(2)	(3)	(4)	(5)	(6)
Gini	-1.374***	-0.949***	-1.016***	-1.332***	-1.029**	-1.004**
	(0.316)	(0.237)	(0.237)	(0.417)	(0.422)	(0.404)
Log real mean income		0.675***	0.616***		0.642***	0.512**
		(0.104)	(0.098)		(0.153)	(0.205)
Log population			0.634**			0.404
			(0.252)			(0.322)
Homeownership rate			0.009*			0.013
			(0.004)			(0.008)
year fe	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes
population weight	no	no	no	yes	yes	yes
R-squared within	0.725	0.773	0.791	0.770	0.795	0.809
R-squared overall	0.060	0.484	0.051	0.061	0.450	0.053
Observations	649	649	649	649	649	649
Years	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Heteroscedasticity and auto-correlation robust standard errors in parenthesis clustered at the state level. House price index and income variables are deflated by CPI-UR-S series. Columns (4) − (6) present population weighted estimates.

A further reality check: a cross-section of US states

Figure 12 displays the results of between regressions of real house price growth, real mortgage debt growth and the change in mortgage delinquency on the change in income inequality. This provides a visual representation of the state level variation in the panel. All variables are normalised average annual changes between 2003-2015. That is, each value is computed by subtracting the mean value for a state from the average annual change of the variable, and then dividing by the standard deviation. For example, Nevada and New York experienced increases in income inequality about two standard deviations greater than the mean increase across states, while the District of Columbia saw an average annual real

Table 6: Income Inequality and mortgage debt: the effect of the interest rate environment
Dependent variable: Real Mortgage Debt Balance per Capita (excluding HELOC)

	(1)	(2)	(3)	(4)	(5)	(6)
Gini	-1.384***	-0.987***	-1.120***	-1.334***	-1.029**	-1.024**
	(0.440)	(0.321)	(0.332)	(0.472)	(0.478)	(0.460)
Gini x Real 10-year rate	0.013	0.046	0.122	0.004	0.000	0.048
	(0.241)	(0.183)	(0.185)	(0.323)	(0.247)	(0.236)
Log real mean income		0.676***	0.621***		0.642***	0.512**
		(0.102)	(0.095)		(0.154)	(0.209)
Log population			0.664**			0.416
			(0.264)			(0.334)
Homeownership rate			0.008*			0.013
			(0.004)			(0.008)
year fe	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes
population weight	no	no	no	yes	yes	yes
R-squared within	0.725	0.773	0.792	0.770	0.795	0.809
R-squared overall	0.060	0.482	0.049	0.061	0.450	0.052
Observations	649	649	649	649	649	649
Years	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015	2003-2015

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Heteroscedasticity and auto-correlation robust standard errors in parenthesis clustered at the state level. House price index and income variables are deflated by CPI-UR-S series. Columns $(4) - (6)$ present population weighted estimates.

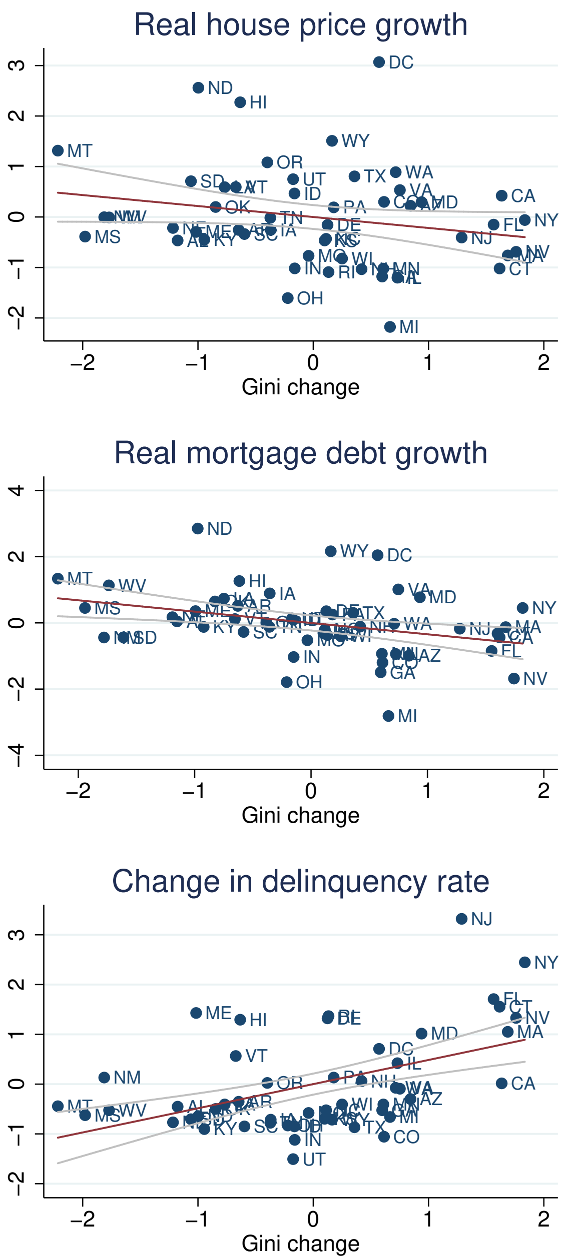
house price growth that is about three standard deviations above the mean over states for this time period. Qualitatively, Figure 12 displays results in line with those for US counties depicted in Figure 2, despite the source of the Gini coefficient being different and averages being calculated over a larger number of time periods.[39]

4 Conclusions

Income inequality, real house prices and household debt have increased enormously in the US in the last few decades. During the same period, real interest rates declined to historically low levels. This paper adopts empirical and theoretical strategies that disentangle the effect of income inequality from macroeconomic developments, particularly the direct effect of declining real rates. I find that, in isolation, rising income inequality leads to declines in real house prices and mortgage debt, but a rise in mortgage delinquencies. While house price and debt dynamics are positively correlated with income inequality in aggregate data, I show that the model's predictions hold for a panel of US states. That is, the cross sectional and aggregate trends are at odds. I show that declining real rates are central to reconciling the cross-sectional and aggregate correlations as they can overturn the negative effect of income inequality on house prices. However, this leads to a rise in mortgage delinquencies and amplifies the effect of income inequality on financial stability. While it might be desirable to keep interest rates low for macroeconomic stability, this paper argues that such a policy might be sowing the seeds of a new mortgage foreclosure crisis.

[39] County level data gives the growth between the years 1999 and 2011, whereas state level data is an average of 13 annual changes. County level inequality data is calculated from Census Surveys, whereas state level inequality data is calculated from IRS tax returns.

Figure 12: Income inequality, real house prices, mortgage debt and mortgage delinquency rate in US States between 2003 and 2015



Data source: New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics.

This figure uses the normalized average annual change of each variable. For the Gini coefficient, for instance, it is calculated as follows. I first compute the annual change in the Gini coefficient for each year between 2003 to 2015. I then calculate the average change for each state and the across state mean and standard deviation of average changes. The value for each state is its average change in Gini coefficient net of the across state mean and divided by the across state standard deviation. A state that takes value 2 in the x-axis of each panel experienced an increase in income inequality 2 standard deviations above that of the across state mean. The slope of the regression line is the estimated coefficient of a between regression estimated of each variable on the change in the Gini coefficient. Both the dependent variable and the Gini coefficient are normalized annual changes.

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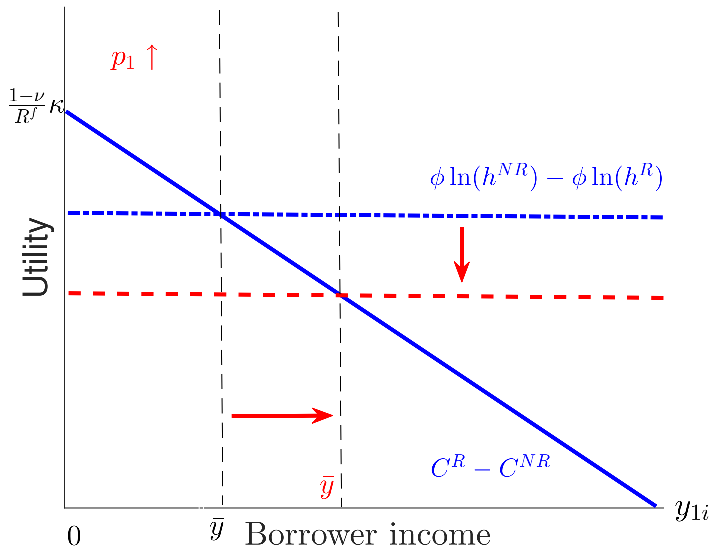
Table 7: Panel data summary statistics: US states

Variable		Mean	Std. Dev.	Min	Max	Observations
Log real FHFA house price	overall	-0.059	0.288	-0.743	0.906	N = 1200
	between		0.244	-0.523	0.564	n = 50
	within		0.158	-0.561	0.490	T = 24
Gini	overall	0.589	0.036	0.521	0.711	N = 1200
	between		0.026	0.550	0.651	n = 50
	within		0.026	0.533	0.698	T = 24
Log real mean income	overall	5.188	0.170	4.770	5.755	N = 1200
	between		0.147	4.899	5.602	n = 50
	within		0.088	4.904	5.505	T = 24
Log population	overall	8.174	1.016	6.139	10.572	N = 1200
	between		1.022	6.248	10.460	n = 50
	within		0.085	7.698	8.471	T = 24
Home ownership rate	overall	68.104	6.429	35.000	81.300	N = 1200
	between		6.059	42.417	76.433	n = 50
	within		2.305	60.467	73.484	T = 24
Log new housing permits	overall	9.343	1.136	6.358	12.279	N = 1200
	between		0.244	8.581	10.163	n = 50
	within		1.110	6.261	12.334	T = 24
Log real mortgage debt per capita	overall	4.497	0.368	3.510	5.438	N = 649
	between		0.354	3.751	5.178	n = 50
	within		0.112	4.093	4.883	T-bar = 12.98
Share of delinquent mortgages	overall	3.050	2.649	0.300	20.740	N = 650
	between		1.447	0.945	9.225	n = 50
	within		2.227	-5.485	14.565	T = 13
Real 10-year rate		1.900	1.273	-0.629	3.658	T = 24
Population in 2015 (thousands)		6406	7150	586	39032	n = 50

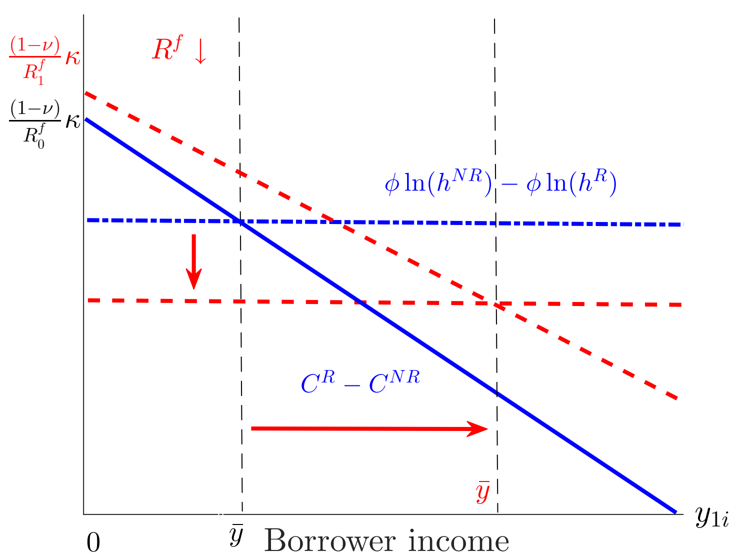
Note: Share of delinquent mortgages and real mortgage debt per capita variables are for the period 2003-2015. All other variables cover the years between 1992-2015.

Figure 13: The effect of an increase in house price on the utility trade-off: costs and benefits of a risky loan



Note: An increase in house price, p_1, shifts the housing utility cost curve down and increases the income cut-off $\bar{y}$. Borrowers with incomes below $\bar{y}$ choose a risky loan.

Figure 14: The effect of a decline in the real interest rate on the utility trade-off: costs and benefits of a risky loan



Note: An decrease in the real-rate, R^f, shifts the housing utility cost curve down and shifts the consumption utility gain curve up. This increases the income cut-off $\bar{y}$. Borrowers with incomes below $\bar{y}$ choose a risky loan.

Appendix for Income Inequality, Mortgage Debt and House Prices

A Borrower optimization

In this section I define the optimal decisions consistent with a risk-free contract and with a risky contract.

A.1 Risk-free Loan

Borrower solves the following optimization problem if she were to take on a risk-free loan:

$$\max_{h_{1i},d_i} c_{1i} + \phi \ln(h_{1i}) + \beta\nu E_\Omega c^r_{2i}(\omega^H) + \beta(1-\nu)E_\Omega c^r_{2i}(\omega^L)$$

subject to

$$d_i \leq \bar{d}^L_i = h_{1i}E_\Omega p_2(\omega^L) + (1-\xi)y_{1i}\omega^L - \kappa$$

$$d_i \geq 0$$

$$q(y_{1i}, d_i, h_{1i}) = \frac{1}{R^f}$$

where

$$c_{1i} = y_{1i} + q(y_{1i}, d_i, h_{1i})d_i - h_{1i}p_1 + hp_1$$

$$c^r_{2i}(\omega^H) = y_{1i}\omega^H - d_i + p_2(\omega^H)h_{1i} - \kappa$$

$$c^r_{2i}(\omega^L) = y_{1i}\omega^L - d_i + p_2(\omega^L)h_{1i} - \kappa$$

Since the borrower repays the debt under each income growth realization, the price she pays is the lenders' discount rate $q(y_{1i}, d_i, h_{1i}) = 1/R^f$. The second constraint ensures that the borrowing is low enough to be paid under low income growth realization. The first order conditions are as follows:

$$D_i: \quad -\beta + \frac{1}{R^f} - \lambda_1 + \lambda_2 = 0$$

$$h_i: \quad -p_1 + \lambda_1 E_\Omega p_2(\omega^L) + \frac{\phi}{h_1} + \beta\{\nu E_\Omega p_2(\omega^H) + (1-\nu)E_\Omega p_2(\omega^L)\} = 0$$

Since borrowers are assumed to be impatient, i.e. $\beta \leq \frac{1}{R^f}$, first order condition with respect to mortgage debt implies that the debt constraint binds in equilibrium. Borrowers' optimal choices under the risk-free contract is then

$$d_i = \bar{d}^L_i, \lambda^{NR}_1 = \frac{1}{R^f} - \beta, \lambda^{NR}_2 = 0$$

$$h^{NR} = \frac{\phi}{p_1 - \frac{1}{R^f}E_\Omega p_2(\omega^L) - \beta\nu(E_\Omega p_2(\omega^H) - E_\Omega p_2(\omega^L))}$$

Note that each borrower that takes out a risk-free loan consumes the same amount of housing. This results from log-linear preferences assumed in order to simplify the aggregation in the housing market.

$$c_{1i}^{NR} = p_1 h + y_{1i} - \underbrace{(h^{NR} p_1 - \frac{1}{R^f}((1-\xi)\omega^L y_{1i} - \kappa + h^{NR} E_\Omega p_2(\omega^L))}_{down-payment}$$

Thus down-payment under a risk-free loan is:

$$down-payment = \phi \underbrace{\frac{p_1 - \frac{1}{R^f} E_\Omega p_2(\omega^L)}{p_1 - \frac{1}{R^f} E_\Omega p_2(\omega^L) - \beta\nu(E_\Omega p_2(\omega^H) - E_\Omega p_2(\omega^L))}}_{\geq 1} - \frac{1}{R^f}((1-\xi)\omega^L y_{1i} - \nu)$$

and the expected second period consumption is:

$$Ec_{2i}^{NR} = (\nu\omega^H + (\nu + \xi)\omega^L) y_{1i} + h^{NR}\nu(E_\Omega p_2(\omega^H) - E_\Omega p_2(\omega^L))$$

Discounted lifetime utility derived from non-durable consumption is then:

$$C^{NR} = c_{1i}^{NR} + \beta E c_{2i}^{NR} = p_1 h - \frac{1}{R^f}\kappa - \phi + y_{1i}\left\{1 + \beta(\nu\omega^H + (\nu+\xi)\omega^L) + \frac{(1-\xi)\omega^L}{R^f}\right\}$$

A.2 Risky Loan

Risky loan in the model is defined as a promise to repay only under high income growth realization. Since the lenders make zero expected profit due to competition, the loan price for a risky loan is given by:

$$q(y_{1i}, d_i, h_{1i}) = \frac{1}{R^f}\left\{\nu + (1-\nu)\frac{\theta E_\Omega p_2(\omega^L) h_{1i}}{d_i}\right\}$$

Borrower solves the following optimization problem if she takes a risky loan:

$$\max_{h_{1i}, d_i} c_{1i} + \phi \ln(h_{1i}) + \beta\nu E_\Omega c_{2i}^r(\omega^H) + \beta(1-\nu) E_\Omega c_{2i}^d(\omega^L)$$

subject to

$$d_i \leq \bar{d}_i^H = h_{1i} E_\Omega p_2(\omega^H) + (1-\xi) y_{1i}\omega^H - \tau$$
$$d_i \geq \bar{d}_i^L = h_{1i} p_2(\omega^L) + (1-\xi) y_{1i}\omega^L - \tau$$

$$q(y_{1i}, d_i, h_{1i}) = \frac{1}{R^f}\left\{\nu + (1-\nu)\frac{\theta E_\Omega p_2(\omega^L) h_{1i}}{d_i}\right\}$$

where

$$c_{1i} = y_{1i} + q(y_{1i}, d_i, h_{1i}) d_i - h_{1i} p_1 + h p_1$$
$$c_{2i}^r(\omega^H) = y_{1i}\omega^H - d_i + p_2(\omega^H) - \kappa$$
$$c_{2i}^d(\omega^L) = \xi y_1 \omega$$

$$d_i: \qquad \nu(-\beta + \frac{1}{R^f}) - \lambda_1 + \lambda_2 = 0$$

$$h_{1i}: \quad -p_1 + \frac{1}{R^f}(1-\nu)\theta E_\Omega p_2(\omega^L) + \lambda_1 E_\Omega p_2(\omega^H) - \lambda_2 E_\Omega p_2(\omega^L) + \frac{\phi}{h_{1i}} + \beta\nu E_\Omega p_2(\omega^H) = 0$$

The first constraint is to ensure that borrower can repay the loan under high income growth realization. The second constraint is imposed so that loan pricing is consistent with borrower choice. That is, if borrower takes an amount less than the low debt level constraint, she can repay it under low income growth realization as well and the correct loan price is then lenders' discount rate.

Borrower impatience again implies that it is optimal to take on the largest loan that she can repay, i.e. $\lambda_1 = \nu(\frac{1}{R^f} - \beta) > 0$. Therefore under a risky contract it is optimal to have

$$d_i = \bar{D}_i(\omega^H), \lambda_1^R = \nu(\frac{1}{R^f} - \beta), \lambda_2^R = 0$$

$$h_1^R = \frac{\phi}{p_1 - \frac{1}{R^f}(\nu E_\Omega p_2(\omega^H) + \theta(1-\nu)E_\Omega p_2(\omega^L))}$$

$$c_{1i}^R = p_1 h + y_{1i} - \underbrace{(h^R p_1 - \frac{1}{R^f}((1-\xi)\nu\omega^H y_{1i} - \kappa\nu + h^R(\theta(1-\nu)E_\Omega p_2(\omega^L) + \nu E_\Omega p_2(\omega^H)))}_{down-payment}$$

Using the equilibrium value of h^R, down-payment under a risky loan is:

$$down - payment = \phi - \frac{1}{R^f}((1-\xi)\nu\omega^H y_{1i} - \kappa\nu)$$

and the expected second period consumption is:

$$Ec_{2i}^R = \xi((1-\nu)\omega^L + \nu\omega^H)y_{1i}$$

lifetime utility derived from non-durable consumption is

$$C^R = c_{1i}^{NR} + \beta Ec_{2i}^{NR} = p_1 h - \frac{\nu}{R^f}\kappa - \phi + y_1 \left\{ 1 + \beta\xi(\nu\omega^H + (1-\nu)\omega^L) + \frac{(1-\xi)\nu\omega^H}{R^f} \right\}$$

B Proofs

B.1 Partial equilibrium of the mortgage market

Proposition 1 *Let*

$$\gamma = (1-\xi)\left\{\frac{\omega^L - \nu\omega^H}{R^f} + \beta\nu(\omega^H - \omega^L)\right\}$$

There exists a unique income cut-off $\bar{y}$

$$\bar{y} = \frac{1}{\gamma}\left\{\frac{1-\nu}{R^f}\kappa - \phi \ln\left(\frac{h^{NR}}{h^R}\right)\right\}$$

such that borrowers with income less than $\bar{y}$ *take risky loans as long as risk-free rate is sufficiently high*

$$R^f \geq \frac{1}{\beta}\frac{\nu\omega^H - \omega^L}{\omega^H - \omega^L}$$

Proof. It is optimal to take a risky loan if:

$$U^R - U^{NR} = -\phi \ln\left(\frac{h^{NR}}{h^R}\right) + \frac{1-\nu}{R^f}\kappa - y_1(1-\xi)\left\{\frac{\omega^L - \nu\omega^H}{R^f} + \beta\nu(\omega^H - \omega^L)\right\} \geq 0$$

$$\frac{1-\nu}{R^f}\kappa - \phi \ln\left(\frac{h^{NR}}{h^R}\right) - y_1\gamma \geq 0$$

Thus, if $\gamma > 0$ borrowers with income less than $\bar{y}$ choose a risky loan. This is satisfied when

$$R^f \geq \frac{1}{\beta}\frac{\nu\omega^H - \omega^L}{\omega^H - \omega^L}$$

■

Lemma 1 *The down-payment of a risky loan is lower than a risk-free loan at all points in the income distribution.*

A sufficient condition is:

$$\frac{\nu\omega^H}{\omega^L} \geq 1$$

Proof. Under a risk-free loan

$$down\text{−}payment^{NR} = \phi \underbrace{\frac{p_1 - \frac{1}{R^f}E_\Omega p_2(\omega^L)}{p_1 - \frac{1}{R^f}E_\Omega p_2(\omega^L) - \beta\nu(E_\Omega p_2(\omega^H) - E_\Omega p_2(\omega^L))}}_{\geq 1} - \frac{1}{R^f}((1-\xi)\omega^L y_{1i} - \nu)$$

Under a risky loan

$$down - payment^R = \phi - \frac{1}{R^f}((1-\xi)\nu\omega^H y_{1i} - \kappa\nu)$$

Therefore, a sufficient condition for low down-payment across the income distribution is $\frac{\pi\omega^H}{\omega^L} \geq 1$. Note that, for low income borrowers, this condition does not need to hold, i.e. when $y_{1i} = 0$ for instance. ■

Lemma 2 *Housing consumption is higher under a risk free contract compared to a risky contract:*

$$h^{NR} \geq h^R$$

as long as loan recovery rate is sufficiently low:

$$\theta \leq \theta^{max} \quad where \quad \theta^{max} = 1 - (1 - \beta R^f)\left(\frac{E_\Omega p_2(\omega^H)}{E_\Omega p_2(\omega^L)} - 1\right)\frac{\nu}{1-\nu}$$

Proof. Optimality condition under a risky loan is:

$$\frac{\phi}{h_{1i}} = \underbrace{p_1}_{\frac{-\partial c_{1i}}{\partial h_{1i}}} - \underbrace{\frac{1}{R^f}(1-\nu)\theta E_\Omega p_2(\omega^L)}_{\frac{\partial q(y_{1i},d_i,h_{1i})D}{\partial D}} - \lambda^R \underbrace{E_\Omega p_2(\omega^H)}_{\frac{\partial \bar{d}_i^H}{\partial h_{1i}}} + \beta \underbrace{\nu E_\Omega p_2(\omega^H)}_{\frac{\partial E_\Omega c_{2i}^r(\omega^H)}{\partial h_{1i}}}$$

Optimality condition under a risk-free loan is:

$$\frac{\phi}{h_{1i}} = \underbrace{p_1}_{\frac{-\partial c_{1i}}{\partial h_{1i}}} - \lambda^{NR} \underbrace{E_\Omega p_2(\omega^L)}_{\frac{\partial \bar{d}_i^L}{\partial h_{1i}}} - \beta \underbrace{\{\pi E_\Omega p_2(\omega^H) + (1-\pi)E_\Omega p_2(\omega^L)\}}_{\frac{\partial c_{2i}^r}{\partial h_{1i}}}$$

Then $h^{NR} - h^R \geq 0$ if $\frac{\phi}{h^{NR}} - \frac{\phi}{h^R} \leq 0$

$$\frac{\phi}{h^{NR}} - \frac{\phi}{h^R} = \nu(\frac{1}{R^f} - \beta)E_\Omega p_2(\omega^H) - (\frac{1}{R^f} - \beta)E_\Omega p_2(\omega^L) - (1-\nu)(\beta - \frac{\theta}{R^f})E_\Omega p_2(\omega^L)$$

Thus housing consumption under a risk-free contract is higher than that of a risky contract as long as:

$$\theta \leq 1 - (1 - \beta R^f)\left(\frac{E_\Omega p_2(\omega^H)}{E_\Omega p_2(\omega^L)} - 1\right)\frac{\nu}{1-\nu}$$

■

Lemma 3 *Expected second period consumption is higher under a risk-free loan than a risky loan across the income distribution.*

Proof.

$$Ec_{2i}^R = \xi((1-\nu)\omega^L + \nu\omega^H)y_{1i}$$
$$Ec_{2i}^{NR} = (\nu\omega^H + (\nu+\xi)\omega^L)y_{1i} + h^{NR}\nu(E_\Omega p_2(\omega^H) - E_\Omega p_2(\omega^L))$$

■

B.2 General equilibrium representation

Remark 1 *The general equilibrium of the model can be represented in (p_1, S) space as follows:*

The locus of (p_1, S) consistent with housing market clearing is HH:

$$Sh^R(p_1) + (1 - S)h^{NR}(p_1) = h \quad (HH)$$

The locus of (p_1, S) consistent with mortgage market clearing is MM:

$$S = \Psi(\bar{y}(p_1)) \quad (MM)$$

where $\Psi(\bar{y}(p_1))$ is the share of borrowers with income less than $\bar{y}$, and thus S is the share of risky borrowers.

- *The HH curve is downward sloping in S*
- *The MM curve is upward sloping in S*

Proof.

- The HH curve: Since $h^{NR} > h^R$, then as S increases, total housing demand declines and thus house prices needs to decline for housing market to clear at quantity h.

$$\frac{\partial p_1}{\partial S} < 0$$

- The MM curve:

$$\frac{\partial S}{\partial p_1} = \frac{\partial S}{\partial \ln(h^{NR}/h^R)} \frac{\partial \ln(h^{NR}/h^R)}{\partial p_1}$$

First partial derivative is negative as relative increase in housing consumption under a risk free contract discourages taking a risky contract and thus share of risky borrowers decline. Second partial derivative is also negative as price elasticity of housing consumption is higher under a risk-free contract.

$$\frac{\partial \ln(h^{NR})}{\partial p_1} - \frac{\partial \ln(h^R)}{\partial p_1} = -\frac{h^{NR}}{\phi} + \frac{h^R}{\phi} < 0$$

as $h^{NR} \geq h^R$.

■

B.3 Share of risky borrowers and change in income inequality

B.3.1 Pareto income distribution

Proposition 2 *A mean-preserving increase in income inequality under a Pareto income distribution increases the share of risky borrowers in the economy*

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} > 0$$

as long as

$$\Psi(\bar{y}) \leq 1 - exp(-1) = 0.63$$

Proof.

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} = \underbrace{\frac{\partial \Psi(\bar{y})}{\partial \alpha}}_{\leq 0} \underbrace{\frac{\partial \alpha}{\partial Gini}}_{<0} > 0$$

First,

$$\frac{\partial \Psi(\bar{y})}{\partial \alpha} = -\frac{1 - \Psi(\bar{y})}{\alpha - 1} \left(\frac{\alpha - 1}{\alpha} \ln(1 - \Psi(\bar{y})) + 1 \right)$$

$$\frac{\partial \Psi(\bar{y})}{\partial \alpha} \leq 0 \quad if \quad \Psi(\bar{y}) \leq 1 - exp\left(-\frac{1}{\alpha - 1}\right)^{\alpha}$$

Note that as α increases, feasible values for $\Psi(\bar{y})$ declines and thus the lowest upper bound is given by:

$$\lim_{\alpha \to \infty} 1 - exp\left(-\frac{1}{\alpha - 1}\right)^{\alpha} = 1 - exp(-1) = 0.63$$

Second, using the definition of Gini coefficient for Pareto distribution

$$\alpha = \frac{1}{2}\left(\frac{1}{Gini} + 1\right)$$

$$\frac{\partial \alpha}{\partial Gini} < 0$$

For $\alpha = 6$, the Gini coefficient is as low as 0.1, and the condition that needs to be satisfied is that $\Psi(\bar{y}) \leq 0.6988$. For 1990s levels of income inequality the condition is $\Psi(\bar{y}) \leq 0.95$. ∎

B.3.2 Log-normal income distribution

Proposition 3 *An increase in income inequality under a log-normal income distribution increases the share of risky borrowers in the economy*

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} > 0$$

as long as

$$\bar{y} \leq median$$

Proof.

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} = \frac{\partial \Psi(\bar{y})}{\partial \sigma} \frac{\partial \sigma}{\partial Gini}$$

$$\frac{\partial Gini}{\partial \sigma} = \frac{e^{-\frac{\sigma^2}{4}}}{\sqrt{\pi}} > 0$$

Since erf is increasing in its argument, then it is straightforward to see that

$$\frac{\partial \left(\frac{\ln(\bar{y}) - \mu}{\sqrt{2}\sigma} \right)}{\partial \sigma} = - \left(\frac{\ln(\bar{y}) - \mu}{\sqrt{2}\sigma^2} \right)$$

This is positive if $\bar{y} < e^{\mu}$ =median, or equivalently if $\Psi(\bar{y}) < 0.5$. ∎

Proposition 4 *A mean-preserving increase in income inequality under a log-normal income distribution increases the share of risky borrowers in the economy*

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} > 0$$

as long as

$$\bar{y} \leq e^{\sigma^2} median$$

Proof.

$$\frac{\partial \Psi(\bar{y})}{\partial Gini} = \frac{\partial \Psi(\bar{y})}{\partial \sigma} \frac{\partial \sigma}{\partial Gini}$$

$$\frac{\partial Gini}{\partial \sigma} = \frac{e^{-\frac{\sigma^2}{4}}}{\sqrt{\pi}} > 0$$

Let $x = \frac{\ln(\bar{y}) - \ln(\bar{M})}{\sqrt{2}\sigma} + \frac{\sigma}{2\sqrt{2}}$

$$\frac{\partial \Psi(\bar{y})}{\partial \sigma} = \frac{1}{2} erf'(x) \frac{\partial x}{\partial \sigma}$$

$$\frac{\partial x}{\partial \sigma} = - \left(\frac{\ln(\bar{y}) - \ln(\bar{M})}{\sqrt{2}\sigma^2} \right) + \frac{1}{2\sqrt{2}}$$

Since $erf(x)$ is increasing in x, then $\frac{\partial x}{\partial \sigma}$ positive if $\bar{y} \leq \bar{M} e^{\frac{\sigma^2}{2}} = e^{\mu + \sigma^2}$, since median is e^{μ}, then the sufficiency condition can be written as

$$\frac{\partial \Psi(\bar{y})}{\partial \sigma} \geq 0 \quad \text{if} \quad \bar{y} \leq e^{\sigma^2} median$$

∎

Lemma 4 *A decline in the risk-free rate decreases the down-payment more for a risky loan than a risk-free loan.*

A sufficient condition is

$$\frac{\nu \omega^H}{\omega^L} \geq 1$$

Proof.

$$\frac{\partial down - payment^R}{\partial R^f} = \frac{1}{(R^f)^2}((1-\xi)\nu\omega^H y_{1i} - \kappa\nu) > 0$$

$$\frac{\partial down - payment^{NR}}{\partial R^f} = \frac{1}{(R^f)^2}((1-\xi)\omega^L y_{1i} - \nu) > 0$$

Similar to the case in Lemma 1 $\frac{\pi\omega^H}{\omega^L} \geq 1$ is a sufficient condition. ■

Lemma 5 *There exists a loan recovery rate $\underline{\theta}$ such that, for any loan recovery rate above $\underline{\theta}$*

1. *The semi-elasticity of housing demand is higher under a risky loan compared to a risk-free loan:*

$$\left|\frac{\partial \ln(h^R)}{\partial R^f}\right| \geq \left|\frac{\partial \ln(h^{NR})}{\partial R^f}\right|$$

2. *The HH curve flattens following a decline in the risk-free rate.*

Proof.

1.

$$\epsilon^{NR} = \frac{\partial \ln(h^{NR})}{\partial R^f} = -E_\Omega p_2(\omega^L)\frac{h^{NR}}{\phi(R^f)^2} < 0$$

$$\epsilon^R = \frac{\partial \ln(h^R)}{\partial R^f} = -(\theta(1-\nu)E_\Omega p_2(\omega^L) + \nu E_\Omega p_2(\omega^H))\frac{h^R}{\phi(R^f)^2} < 0$$

Note that as θ increases ϵ^R increases monotonically. Let $\underline{\theta}$ denote the value at which $\epsilon^R(\underline{\theta}) = \epsilon^{NR}$. That is

$$\left(\underline{\theta}(1-\nu) + \nu\frac{E_\Omega p_2(\omega^H)}{E_\Omega p_2(\omega^L)}\right)\frac{h^R}{h^{NR}} = 1$$

It needs to be proven that the set $[\bar{\theta}, \theta^{max}]$ is nonempty. I prove by contradiction. Suppose $\underline{\theta} = \varepsilon + \theta^{max}$ with $\varepsilon > 0$ and thus from Lemma 2 $h^R > h^{NR}$. Then

$$\underline{\theta}(1-\nu) + \nu\frac{E_\Omega p_2(\omega^H)}{E_\Omega p_2(\omega^L)} = \frac{h^{NR}}{h^R} < 1$$

Since $\underline{\theta} = \theta^{max} + \varepsilon$, left hand-side becomes

$$(1-\nu)\varepsilon + 1 + \beta R^f\left(\frac{E_\Omega p_2(\omega^H)}{E_\Omega p_2(\omega^L)} - 1\right) > 1$$

contradiction. Thus $\underline{\theta} < \theta^{max}$.

2. The HH curve flattens if

$$\frac{\partial p^R}{\partial R^f} / \frac{\partial p^{NR}}{\partial R^f} \geq 1$$

where p^R is market clearing price when $\Psi(\bar{y}) = 1$ and p^{NR} is market clearing price when $\Psi(\bar{y}) = 0$. Optimality conditions imply the following prices:

$$p^R = \frac{\phi}{h} + \frac{1}{R^f}(\theta(1-\nu)E_\Omega p_2(\omega^L) + \nu E_\Omega p_2(\omega^H))$$

$$p^{NR} = \frac{\phi}{h} + \frac{1}{R^f}E_\Omega p_2(\omega^L)$$

Then

$$\frac{\partial p^R}{\partial R^f} = -\frac{1}{(R^f)^2}(\theta(1-\nu)E_\Omega p_2(\omega^L) + \nu E_\Omega p_2(\omega^H)) = \epsilon^R \frac{\phi}{h^R}$$

$$\frac{\partial p^{NR}}{\partial R^f} = -\frac{1}{(R^f)^2}E_\Omega p_2(\omega^L) = \epsilon^{NR}\frac{\phi}{h^{NR}}$$

Thus

$$\frac{\partial p^R}{\partial R^f} / \frac{\partial p^{NR}}{\partial R^f} = \frac{\epsilon^R}{\epsilon^{NR}}\frac{h^{NR}}{h^R} \geq 1$$

Therefore, following a decline in the risk-free rate the HH curve flattens.

■

Proposition 5 *Holding the price of housing constant, a decline in the risk-free rate increases the share of borrowers with a risky loan*

$$\frac{\partial \Psi(\bar{y}(p_1))}{\partial R^f} < 0$$

Proof. Remember from Proposition 1 that the income cut-off for the risky loan is given by:

$$\bar{y} = \frac{1}{\gamma}\left\{\frac{1-\nu}{R^f}\kappa - \phi \ln\left(\frac{h^{NR}}{h^R}\right)\right\}$$

where

$$\gamma = (1-\xi)\left\{\frac{\omega^L - \nu\omega^H}{R^f} + \beta\nu(\omega^H - \omega^L)\right\}$$

Thus

$$\frac{\partial \gamma}{\partial R^f} = -\frac{\omega^L - \nu\omega^H}{(R^f)^2} > 0$$

Therefore, as R^f increases using the results from Lemma 5 and Lemma 4, $\bar{y}$ declines. Thus, share of risky borrowers decline with the risk-free rate. ■

C Additional cross-sectional analysis on the relationship between income inequality, house prices and mortgage debt

In this section I first describe the data used to derive Figure 2 and then provide more evidence on the relationship between income inequality and house prices. Finally, I provide a deeper investigation on the relation of income house prices and mortgage market variables to income inequality using different quintiles of the income distribution.

C.1 County level data

This paper primarily uses data from the U.S. Census and the American Community Survey (ACS) 5-year averages.[40] The Gini coefficient, population, mean household income, number of households are obtained from these source. I use the 1990, 2000, 2011 and 2016 releases. County level data gives rise to a larger number of cross-sections than state level data.

House price data is from the Federal Housing Finance Agency. This is a repeat-sales index, that measures average price changes in repeat sales or refinancing on the same properties since 1975. I deflate nominal quantities using the CPI-U-RS price index provided by the Bureau of Labor Statistics.[41]

County level debt data is from the Federal Reserve Bank of New York Consumer Credit Panel (FRBNY CCP). This is publicly available for the period 1999 to 2011.[42] I use the per capita balance of mortgage debt excluding home equity lines of credit as my measure of mortgage debt. My measure of delinquency is the percent of the mortgage debt balance that has been delinquent for more than ninety days. The share of subprime borrowers is also from this source. The data used for Figure 2 includes 2093 US counties that have data for both house prices and mortgage variables.

C.2 Additional cross-sectional analysis

In this section I provide nonparametric evidence regarding the correlation between real house prices and income inequality growth. This complements the evidence in Figure 2. Inequality is measured by the Gini coefficient. A higher value of the Gini coefficient corresponds to greater income inequality. Each panel of Figure C.2.2 displays the real house price trends for the US counties that had the highest and the lowest increase in income inequality over a given time period.[43] The red dashed line shows house price growth for counties in the top quintile for income inequality growth. The blue solid line shows income growth for

[40]For the ACS, sampling error from the survey decreases with the size of the county and the number of yearly surveys used, and some counties are not reported in 1 year surveys. In the decennial Census, income data is for the previous calender year. That is, the 1990 Census reports income data for the year 1989. In the ACS, income is for the year prior to the interview date, and the survey is conducted monthly. To avoid sampling error, income inequality data for 2016 thus includes incomes reported as early as year 2012 for some respondents. However, income levels are adjusted to 2016 current dollars. The Census Bureau advises the use of ACS 5 years estimates for areas with a population below 65000.

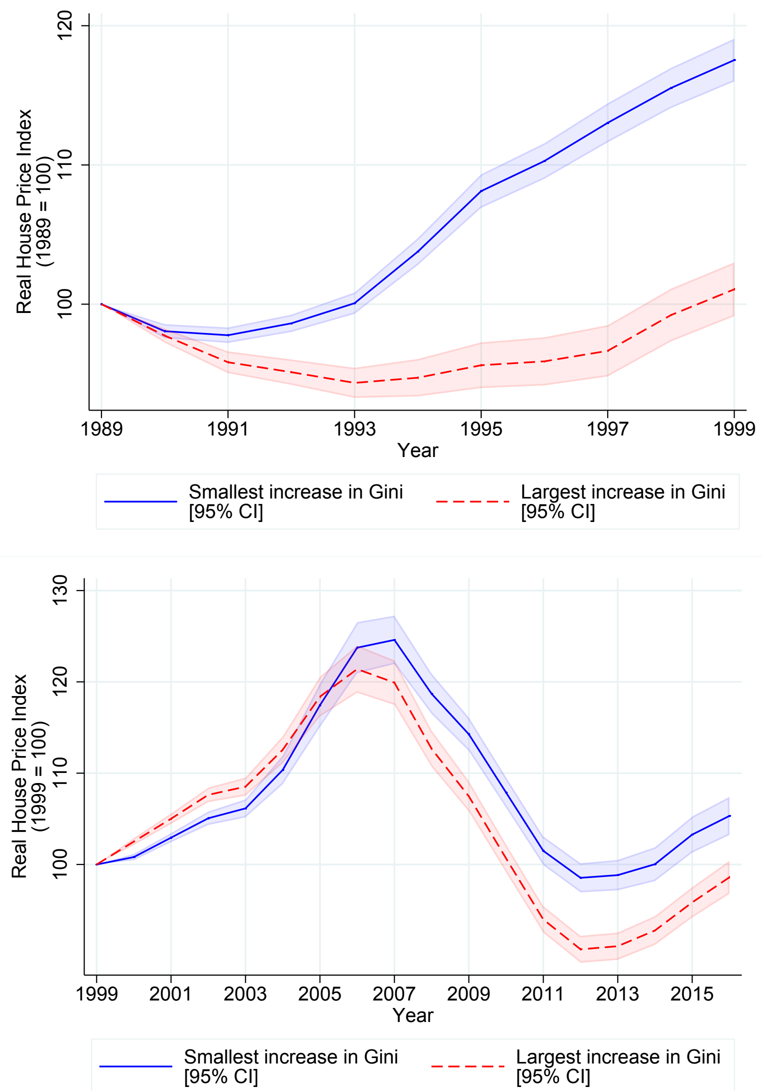
[41]This series is considered to be the most detailed and systematic estimate available of a consistent CPI series. This matters as there was an important methodological in the construction of CPI series before 2000.

[42]The data has not been updated since 2011.

[43]House price data is available for 1390 counties from 1989 onwards. These counties comprise 89.5% of the total population in 1999.

counties in the bottom quintile. In both subperiods, being in the bottom quintile corresponds to experiencing a decline in income inequality. Both subplots have the same message: house price growth is higher for counties in the bottom quintile for income inequality growth. The difference is as high as 15.3% in 1999 and 8.8% in 2012.

Figure C.2.1: House price growth and income inequality change for US counties



Source: US Census Bureau, Federal Housing and Finance Agency, own calculations.

Note: The red dashed line is real house prices for US counties in the top quintile for income inequality growth. The blue line is real house prices for counties in the bottom quintile. Growth in income inequality is measured by the change in Gini coefficient between the first and the last year of the subperiod. The counties in each group remain the same over time within a subperiod. To ensure comparability, only counties where data for the Gini coefficient and house prices is available for both subperiods are used. This corresponds to 1390 counties, which comprise about 90% of the total population in 1999.

High income inequality growth is associated with low house price growth in comparison not only to other counties but also to the initial time period. That is, for both subsamples, high growth in income inequality is associated with a real terms decline in house prices.

The second panel of Figure C.2.2 shows that, between 1999-2005, counties in the highest inequality growth quintile experienced slightly higher house price growth than other counties. House price growth in these counties is around 2% higher that of the lowest inequality growth quintile. Limiting my analysis to this specific time span would lead to the opposite conclusion to the rest of this paper. In fact, counties where income inequality growth was lowest experienced a larger boom and a smaller bust than counties with high income inequality growth that experienced high house price growth at the beginning of the cycle. Over the entire span of the data, the boom episode preceding the Great Recession is the exception, rather than the rule, in terms of the relationship between house prices and inequality.

Digging deeper: the relevance of the different quintiles of the income distribution

In this section I decompose the change in income distribution into changes in income at different quintiles. This enables me to further evaluate the potential explanations for the relationship between house prices, mortgage debt and income inequality.

Figure C.2.2 plots the change in income inequality against the relative income gains for each of the five income quintiles and the top 5%. The relative income gain for quintile j in county i is the growth of mean income in that quintile X_i^j relative to the mean income growth for a given county $\bar{X}_i$.

$$x_i^j = \Delta_t \ln \left(\frac{X_i^j}{\bar{X}_i} \right)$$

The figure suggests that a change rise in income inequality is associated with both low relative income growth at the bottom 80 percent population and high relative income growth at the top of the income distribution. Therefore, at the cross-section, counties that experienced high increase in income inequality saw declines for the lowest 4 income quintiles and increases for the top income quintile relative to the mean. The message is similar to the one from Figure 8.

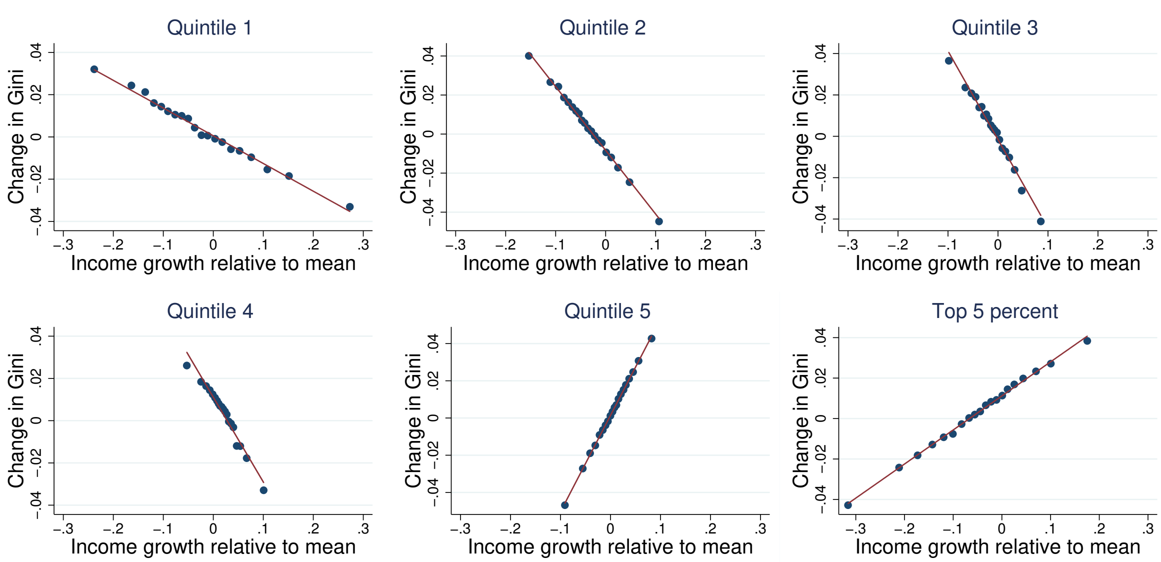
Figure C.2.3 shows the relationship between relative income gains for different income quintiles and debt growth. Consistent with the mechanism proposed in this paper, as long as incomes for the low quintiles fare well, mortgage debt increases. That is, relative income gains for the bottom 60% of the population are positively associated with mortgage debt growth. On the other hand, the cross-sectional data suggests that large income gains at the higher end of the income distribution, i.e. of the top income quintile or the top 5 percent, are negatively correlated with mortgage debt growth. Figure C.2.4 implies similar dynamics by displaying the relationship between mortgage debt growth and change in income share of different income quintiles. At the cross-section an increase in income shares of the top earners, i.e. top 20 % or top 5%, are negatively correlated with debt growth. This finding contradicts explanations based around higher income gains at the top of the distribution leading to an increase in debt.

Figure C.2.5 shows the relationship between house price growth and relative income gains for different quintiles. Income gains at the lower end of the income distribution are positively related to house price growth. This finding is consistent with the mechanism proposed in this paper, and inconsistent with explanations that predict an increase in house prices together with large relative gains in top incomes. Figure C.2.6 confirms this prediction by showing the relationship between house price growth and change in income share of different income quintiles. An increase in the income shares of top 5% and the top 20% of the income distribution is negatively associated with house price growth.

Taking stock

The fact that higher income inequality leads to lower debt, higher delinquencies and lower house prices is consistent with the following explanation. An increase in income inequality worsens the pool of borrowers, in the sense that they are more likely to default. Mortgage debt falls as lenders price in the increased risk from the change in the pool of borrowers. This leads to lower housing demand and prices. The theoretical model described in this paper formalizes this intuition.

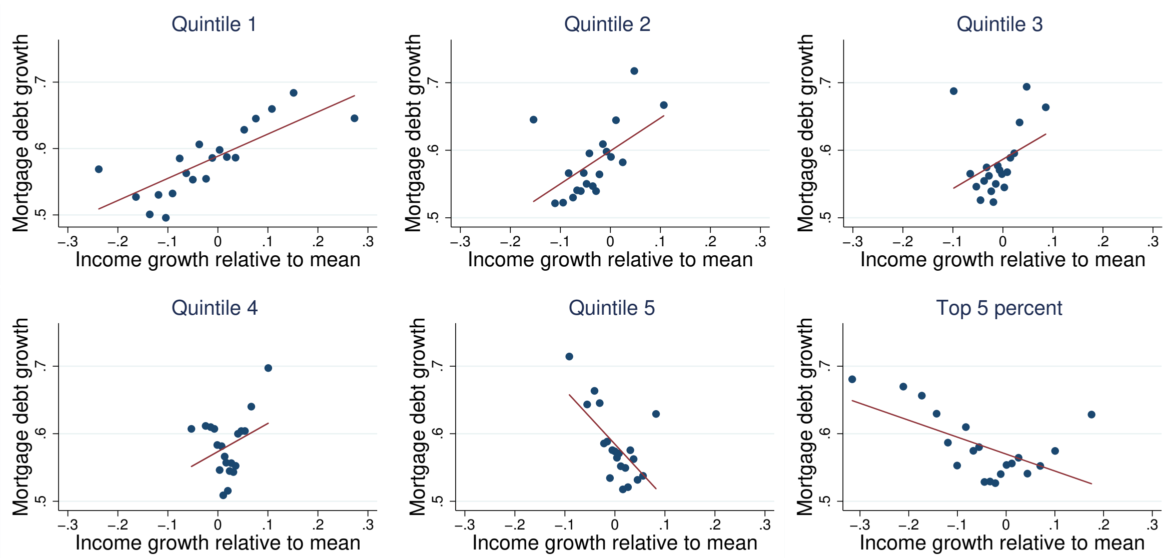
Figure C.2.2: Income inequality change and quintile relative income growth between the years 1999 and 2011



Data source: US Census Bureau.

Note: The binscatter command of Stata is used to produce this figure. The x-axis in each subplot is the income growth in each income quintile relative to the mean income of the county. Relative income gain is grouped into 20 equally sized bins. The position of each point in the graph is the mean value of the change in the Gini coefficient and mean value of relative income growth for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011.

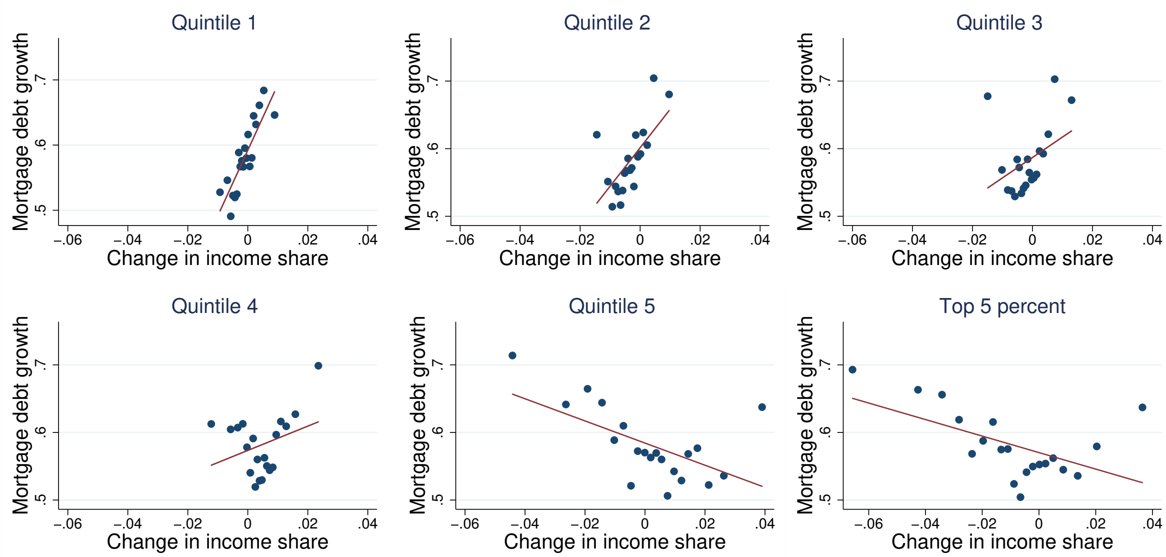
Figure C.2.3: Real mortgage debt growth and quintile relative income growth between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel.

Note: The x-axis in each subplot is the real income growth in each income quintile relative to the mean income of the county. The binscatter command of Stata is used to produce this figure. Relative income gain is grouped into 20 equal bins. The locations of each point is the mean in income gain and mortgage debt growth for the points in that bin.

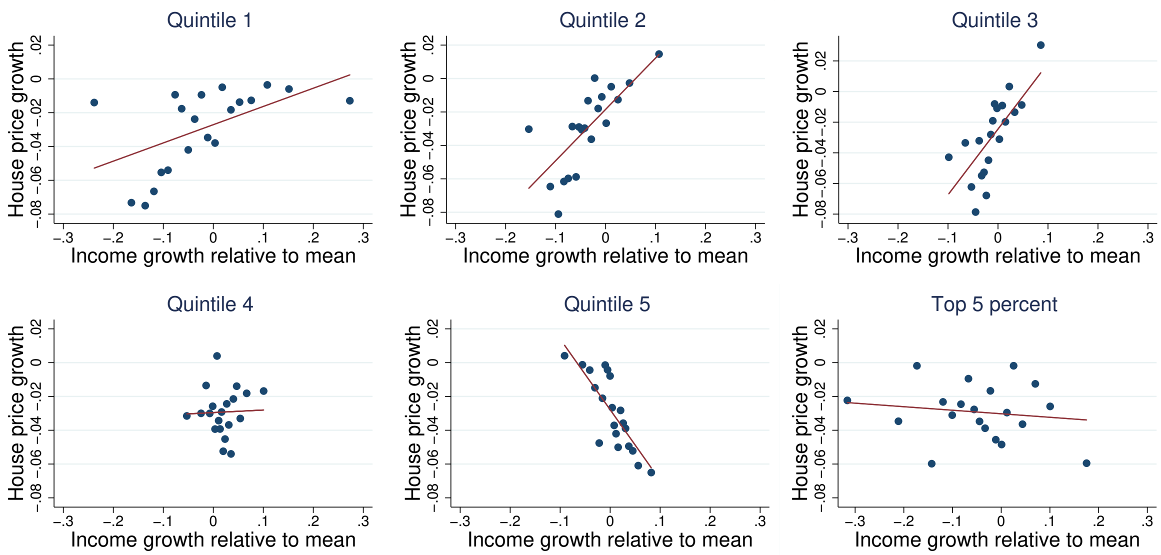
Figure C.2.4: Real mortgage debt growth and change in quintile income share between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel.

Note: The binscatter command of Stata is used to produce this figure. The x-axis in each subplot is the income growth in each income quintile relative to the mean income of the county. Relative income gain is grouped into 20 equally sized bins. The position of each point in the graph is the mean value of the mortgage debt growth and mean value of relative income growth for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011.

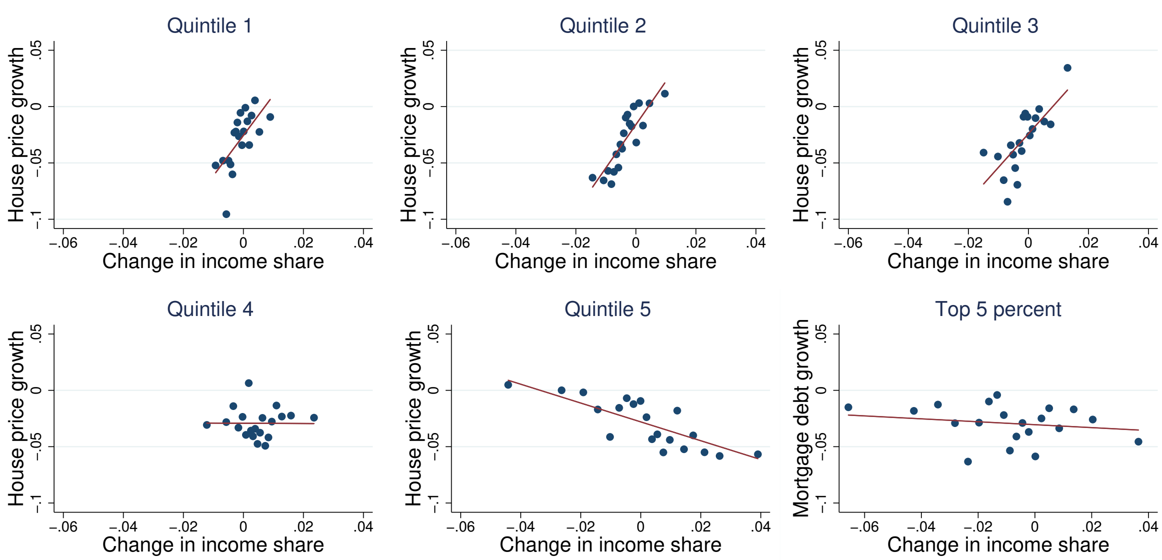
Figure C.2.5: Real house price growth and quintile relative income growth between the years 1999 and 2011



Data source: US Census Bureau, Federal Housing and Finance Agency.

Note: The binscatter command of Stata is used to produce this figure. The x-axis in each subplot is the income growth in each income quintile relative to the mean income of the county. Relative income gain is grouped into 20 equally sized bins. The position of each point in the graph is the mean value of the house price growth and mean value of relative income growth for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011.

Figure C.2.6: Real house price growth and change in quintile income share 1999 - 2011



Data source: US Census Bureau, Federal Housing and Finance Agency.

Note: The binscatter command of Stata is used to produce this figure. The x-axis in each subplot is the change in the income share of each income quintile. Change in income share is grouped into 20 equally sized bins. The position of each point in the graph is the mean value of the house price growth and mean value of change in income share for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011.

D Robustness Checks: County level data

D.1 Controlling for housing supply elasticity

In this section, I first show that the empirical findings of this paper are robust to inclusion of housing supply elasticity as a control variable. If housing supply elasticity is a common driver of house prices and income inequality, then it is essential to control for it to study whether income inequality is an independent vector affecting house prices.

Figure D.2.7 plots the partial correlation with the change in Gini coefficient between 1999 and 2011 for three variables using data from US counties. The first panel shows the relationship between the change in Gini coefficient and real house price growth, the second the relationship with real mortgage debt growth, and the third the relationship with the change in the delinquency rate. In constructing this figure I control for a variety of county characteristics including the housing supply elasticity measured by Saiz (2010). This measure is available for a subset of counties and reduces the sample size from 2093 to 746.[44] Therefore, even when controlled for housing supply elasticity, cross-sectional correlations qualitatively remain the same. This is not suprising since counties with low housing supply elasticity are on average densely populated and I control for household size in Figure 2.

Next, I consider whether the relationship between income inequality and house price growth is qualitatively different across high and low housing supply elasticity areas. Figure D.2.8 displays the correlation between house price growth and change in income inequality without controlling for county characteristics. I group counties into three categories depending on their Saiz (2010) elasticity measure. First panel in Figure D.2.8 corresponds to the counties at the lowest tercile of supply elasticity. The figure shows that house price growth and change in income inequality is negatively correlated at the cross-section, independent of the level of supply elasticity. Figure D.2.9 displays the partial correlations having controlled for county characteristics and points into the same conclusion as Figure D.2.8. Therefore, the results in Figure 2 is not reflecting the dynamics of low housing supply elasticity areas that would on average be expected to have the largest house price changes.

Finally, Figures D.2.10 and D.2.11 depict that real mortgage debt growth and change in income inequality are negatively associated in each housing supply elasticity group both with and without controlling for county characteristics.

D.2 Controlling for the share of subprime borrowers

In this section I show that the negative association of income inequality with both house prices and mortgage debt holds for subsamples of counties with different share of subprime credit population share as of 2000.[45]

I first consider whether the relationship between income inequality and mortgage debt growth differs across high and low subprime credit population areas. Figure D.2.12 displays the simple correlations. I group counties into three categories depending on their subprime population share. First panel in Figure D.2.12 corresponds to the counties at the lowest tercile of subprime borrower share. The figure shows that house price growth and change

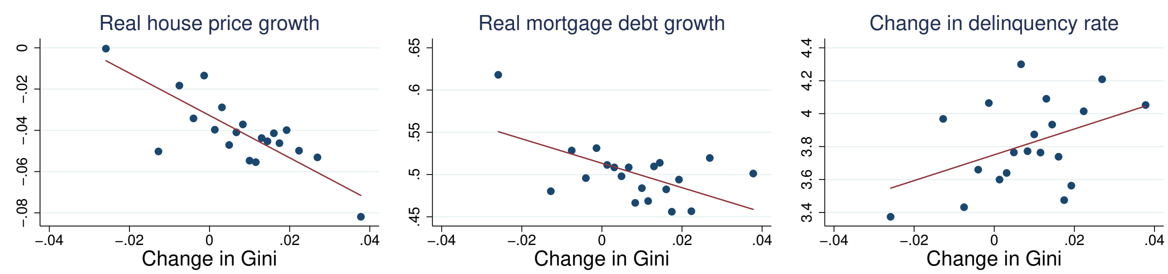
[44] Saiz (2010) housing supply elasticity measure is available at the metropolitan statistical area (MSA) level, I assume that the counties in the same MSA have the same elasticity.

[45] The data includes a larger fraction of counties if I consider the share of subprime credit population in year 2000 instead of year 1999.

in income inequality is negatively correlated at the cross-section, independent of the subprime population share. Figure D.2.13 displays the partial correlations having controlled for county characteristics. Similar to Figure D.2.12, Figure D.2.13 shows that the association between mortgage debt and income inequality is negative independent of the share of subprime population.

Next, I analyse whether the relationship between income inequality and house price growth varies with the share of subprime credit population. Figure D.2.14 shows that house price growth and change in income inequality is negatively correlated at the cross-section, independent of the subprime population share. In this figure I display the correlations without controlling for covariates like mean income and population growth. Figure D.2.15 displays the partial correlations having controlled for county characteristics and confirms the empirical findings of this paper for different subsamples of US counties.

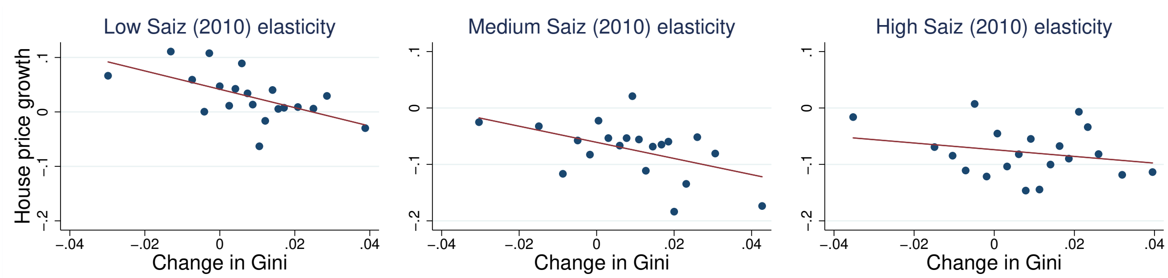
Figure D.2.7: Changes in income inequality, real house price growth, mortgage debt growth and change in mortgage delinquency rate over US counties between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics, Saiz (2010).

Note: To construct this figure I use the binscatter command in Stata. This regresses the three title variables on the change in Gini coefficient, Saiz (2010) housing supply elasticity, state fixed effects, mean income growth, population growth, the share of subprime borrowers in 2000, median income in 1999, and the number of households in 1999. The slope of the line of fit is the coefficient for the change in Gini coefficient in this regression. For the data points, it first obtains the residuals from regressions of the title variable and the change in Gini coefficient on the other control variables. These are then grouped in twenty equally sized bins for the Gini coefficient residual. The position of each point is the mean value of the title variable residual and Gini coefficient residual for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011.

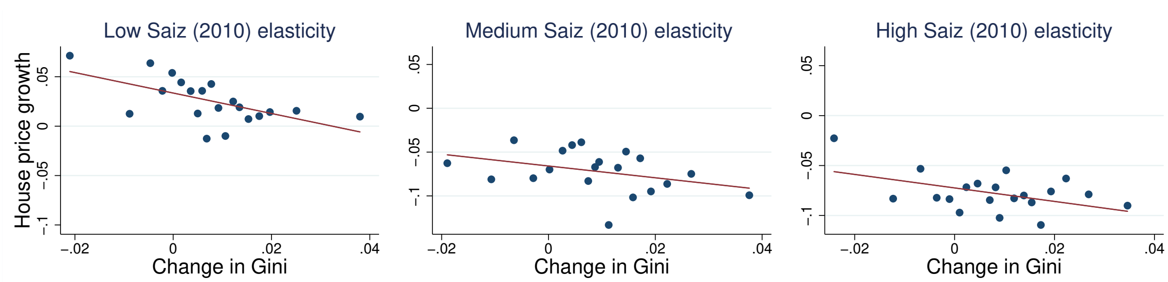
Figure D.2.8: Changes in income inequality and real house price growth between the years 1999 and 2011 over US counties with different housing supply elasticity



Data source: US Census Bureau, Federal Housing and Finance Agency, Bureau of Labor Statistics, Saiz (2010).

Note: To construct this figure I use the binscatter command in Stata. Change in the Gini coefficient is grouped into 20 equally sized bins. The position of each point is the mean value of the real house price growth and the change in Gini for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to housing supply elasticity. Low and high correspond to the lowest and the highest Saiz (2010) housing supply elasticity terciles, respectively.

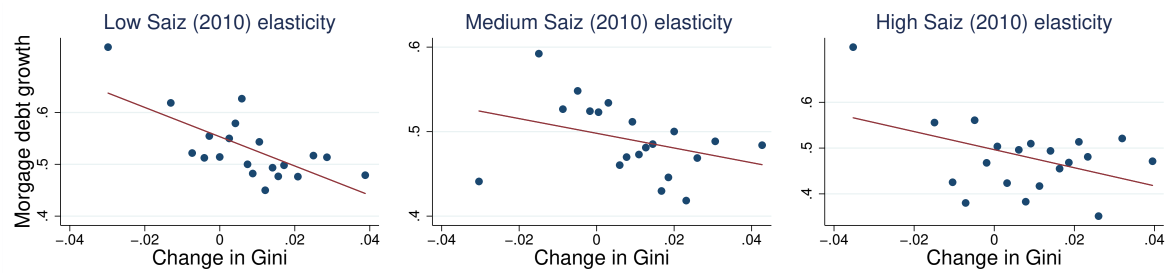
Figure D.2.9: Changes in income inequality and real house price growth in US counties with different housing supply elasticity between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics, Saiz (2010).

Note: To construct this figure I use the binscatter command in Stata. This regresses the house price growth on the change in Gini coefficient, state fixed effects, mean income growth, population growth, the share of subprime borrowers in 2000, median income in 1999, and the number of households in 1999 for each elasticity group. The slope of the line of fit is the coefficient for the change in Gini coefficient in this regression. For the data points, it first obtains the residuals from regressions of real house price growth and the change in Gini coefficient on the other control variables. These are then grouped in 20 equally sized bins for the Gini coefficient residual. The position of each point is the mean value of house price growth residual and Gini coefficient residual for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to housing supply elasticity. Low and high correspond to the lowest and the highest Saiz (2010) housing supply elasticity terciles, respectively.

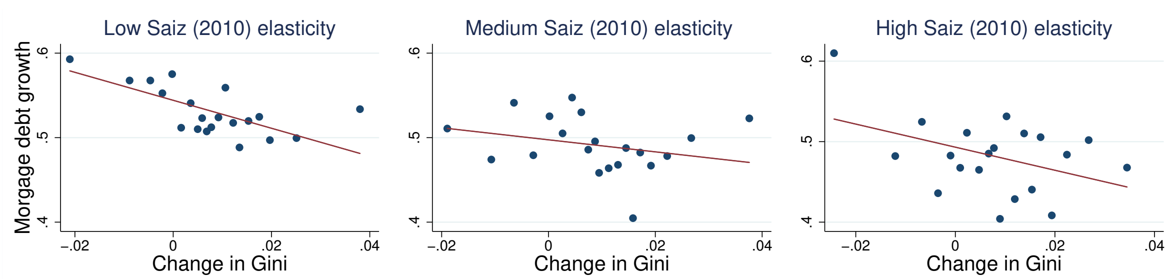
Figure D.2.10: Changes in income inequality and real mortgage debt growth between the years 1999 and 2011 over US counties with different housing supply elasticity



Data source: US Census Bureau, Federal Housing and Finance Agency, Bureau of Labor Statistics, Saiz (2010).

Note: To construct this figure I use the binscatter command in Stata. Change in the Gini coefficient is grouped into 20 equally sized bins. The position of each point is the mean value of the real mortgage debt growth and the change in Gini for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to housing supply elasticity. Low and high correspond to the lowest and the highest Saiz (2010) housing supply elasticity terciles, respectively.

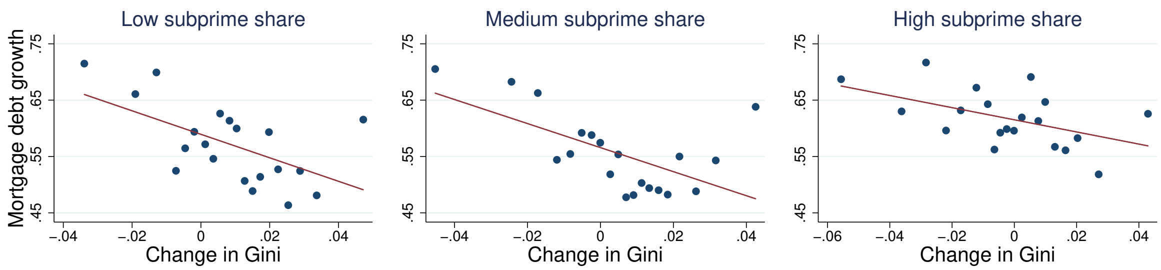
Figure D.2.11: Changes in income inequality and real mortgage debt growth in US counties with different housing supply elasticity between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics, Saiz (2010).

Note: To construct this figure I use the binscatter command in Stata. This regresses the real mortgage debt growth on the change in Gini coefficient, state fixed effects, mean income growth, population growth, the share of subprime borrowers in 2000, median income in 1999, and the number of households in 1999 for each elasticity group. The slope of the line of fit is the coefficient for the change in Gini coefficient in this regression. For the data points, it first obtains the residuals from regressions of real mortgage debt growth and the change in Gini coefficient on the other control variables. These are then grouped in 20 equally sized bins for the Gini coefficient residual. The position of each point is the mean value of real mortgage debt growth residual and Gini coefficient residual for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to housing supply elasticity. Low and high correspond to the lowest and the highest Saiz (2010) housing supply elasticity terciles, respectively.

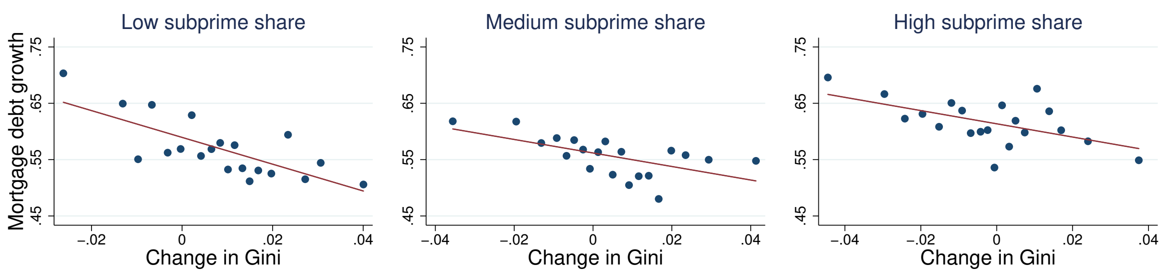
Figure D.2.12: Changes in income inequality and real mortgage debt growth in US counties with different initial subprime credit population share between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics.

Note: To construct this figure I use the binscatter command in Stata. Change in the Gini coefficient is grouped into 20 equally sized bins. The position of each point is the mean value of the real mortgage debt growth and the change in Gini for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to share of subprime credit population share as of 2000. Low and high correspond to the lowest and the highest share of subprime credit population, respectively.

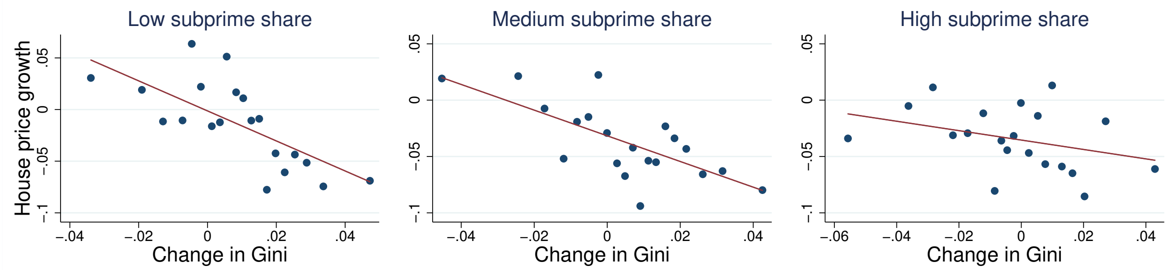
Figure D.2.13: Changes in income inequality and real mortgage debt growth in US counties with different initial subprime credit population share between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics.

Note: To construct this figure I use the binscatter command in Stata. This regresses the house price growth on the change in Gini coefficient, state fixed effects, mean income growth, population growth, the share of subprime borrowers in 2000, median income in 1999, and the number of households in 1999 for each elasticity group. The slope of the line of fit is the coefficient for the change in Gini coefficient in this regression. For the data points, it first obtains the residuals from regressions of the title variable and the change in Gini coefficient on the other control variables. These are then grouped in 20 equally sized bins for the Gini coefficient residual. The position of each point is the mean value of the mortgage debt growth residual and Gini coefficient residual for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to share of subprime credit population share as of 2000. Low and high correspond to the lowest and the highest share of subprime credit population, respectively.

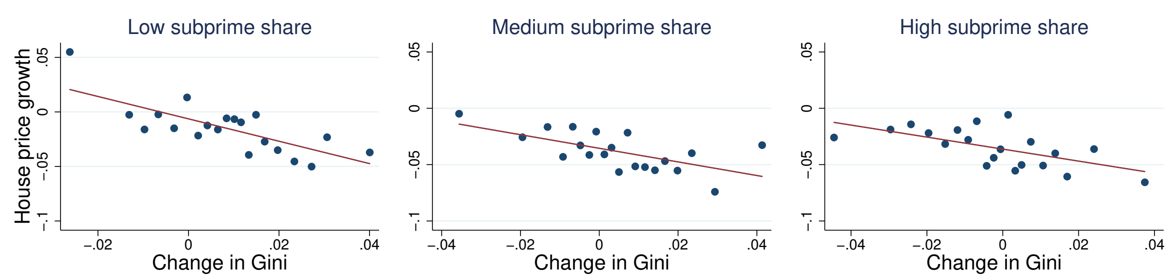
Figure D.2.14: Changes in income inequality and real house price growth in US counties with different initial subprime credit population share between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics.

Note: To construct this figure I use the binscatter command in Stata. Change in the Gini coefficient is grouped into 20 equally sized bins. The position of each point is the mean value of the real house price growth and the change in Gini for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to share of subprime credit population share as of 2000. Low and high correspond to the lowest and the highest share of subprime credit population, respectively.

Figure D.2.15: Changes in income inequality and real house price growth in US counties with different initial subprime credit population share between the years 1999 and 2011



Data source: US Census Bureau, New York Fed Consumer Credit Panel, Federal Housing and Finance Agency, Bureau of Labor Statistics.

Note: To construct this figure I use the binscatter command in Stata. This regresses the house price growth on the change in Gini coefficient, state fixed effects, mean income growth, population growth, the share of subprime borrowers in 2000, median income in 1999, and the number of households in 1999 for each elasticity group. The slope of the line of fit is the coefficient for the change in Gini coefficient in this regression. For the data points, it first obtains the residuals from regressions of the title variable and the change in Gini coefficient on the other control variables. These are then grouped in 20 equally sized bins for the Gini coefficient residual. The position of each point is the mean value of the house price growth residual and Gini coefficient residual for one of these bins. All growth rates and changes are calculated between the years 1999 and 2011. Counties are grouped into three according to share of subprime credit population share as of 2000. Low and high correspond to the lowest and the highest share of subprime credit population, respectively.