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Essays on Macro and International Finance

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Declaration

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Bu doktora tezi annem, babam, Hakan, Sinem ve Doğa'ya adanmıştır.

Abstract

This thesis consists of three chapters. The first two chapters study the macroeconomic and financial stability implications of income inequality and discuss how a low interest rate environment can alter its consequences. The third chapter studies how macroeconomic and financial instability can arise from foreign shocks in the presence of global banks.

Chapter 1 presents 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.

Chapter 2 studies how income inequality is associated with house prices, mortgage debt and mortgage delinquency using panel data of US states. In order to isolate the effect of income inequality from that of the declining real rates, I use year fixed effects in the specifications, in addition to state fixed effects and covariates that vary both by year and state. I find that the data verifies the predictions of the theoretical framework presented in Chapter 1 of this thesis.

Chapter 3 analyses the role of global banks in international transmission of shocks when countries have different domestic financial market structures. In particular, (i) bank capital requirements and (ii) firm borrowing constraints are different across countries. I show that a financial shock might give rise to a global decline in real output if the shock originates in the country with loose firm borrowing constraints. Moreover, tight borrowing constraints and high bank capital requirements are associated with limited economic contraction and fast recovery following a financial shock, independent of its origin.

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Chapter 1

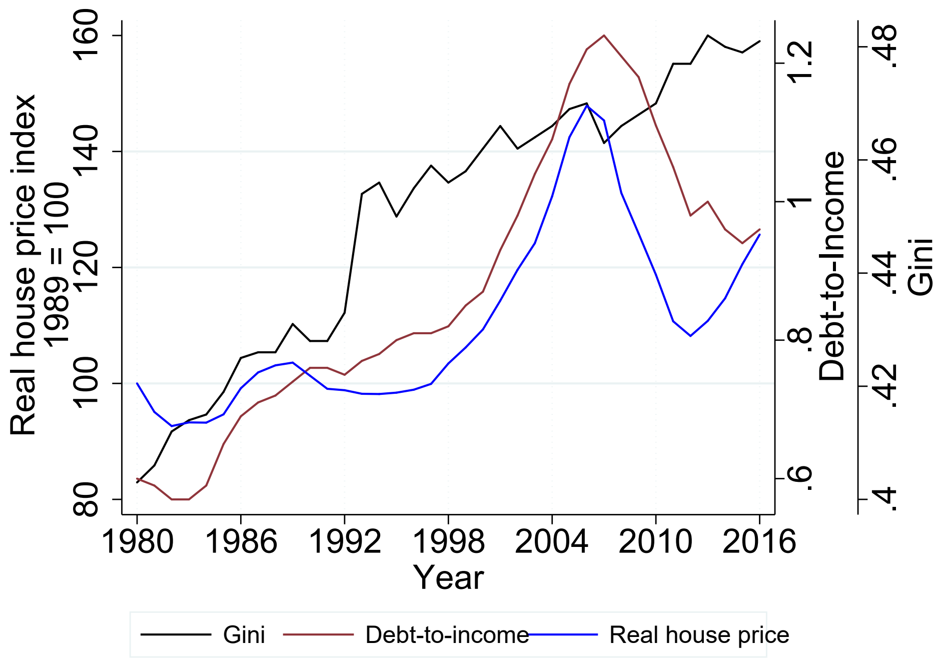
Income Inequality, Mortgage Debt and House Prices: An Analytical Model

The last few decades in the US have been characterized by two secular trends: rising income inequality and declining real interest rates. This chapter 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.

1.1 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 1.1, 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 1.1. 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

[1]Among others Krueger (2012), Rajan (2010), Stiglitz (2012) and Kumhof et al. (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 et al. (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.

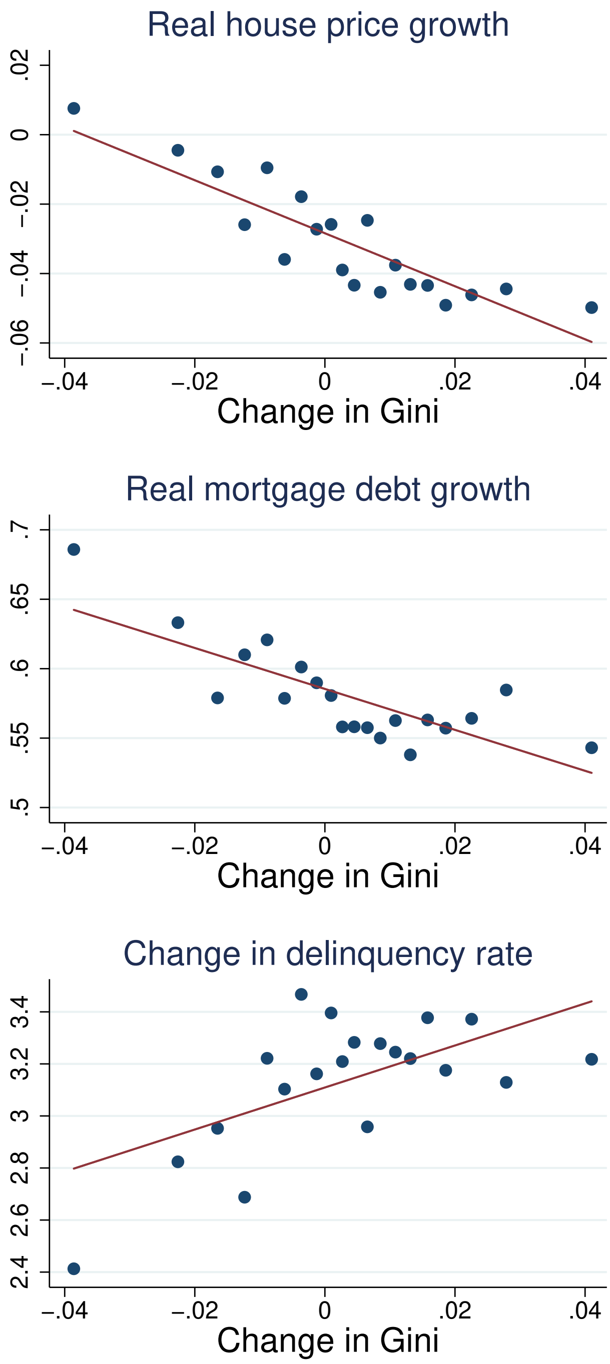
The first contribution of this chapter is to document new cross-sectional facts regarding growth in income inequality, house prices, and mortgage credit. Figure 1.2 plots the partial correlation with the change in Gini coefficient between 1999 and 2011 for three variables using data from US counties. 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 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 1.1, although the positive correlation between income inequality and delinquency suggests a channel through which higher inequality may have reduced financial stability.

The second contribution of this chapter 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 size 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.

[3]These correlations are robust to the inclusion of control variables such as county mean income and population growth. In Figures 2.2 to 2.4 I construct the partial correlations using US state level data between the years 2003 and 2015, and find similar relationships. Figure 1.D.2.1 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.

FIGURE 1.2. Changes in income inequality, real house price growth, mortgage debt growth and change in mortgage delinquency rate



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

Note: All growth rates and changes are calculated between the years 1999 and 2011 for US counties. 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.

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 in Figure 1.2.

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]

In my model, a rise in income inequality in absence of a change in lending conditions, i.e. change in the real rates, corresponds to a worsening of the borrower pool in terms of mortgage risk-type selection. Appendix 1.C.2 provides additional analyses of the cross-sectional facts presented in Figure 1.2 in order to inspect the underlying mechanism. I find that in the cross-section of US counties, a rise in mortgage debt and house prices are associated with relative income gains in the lowest 3 quintiles of the income distribution. On the other hand, income gains in the top of the income distribution is *negatively* associated with both income and house price growth. Finally, Appendix 1.D shows that Figure 1.2 is robust under subsamples with different share of subprime mortgages and housing supply elasticity measured by Saiz (2010). Therefore, the negative correlation is not driven by the US counties with high share of subprime

[5] DellAriccia et al. (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.

borrowers that have been argued to have the largest boom and bust episode in mortgage debt and house prices due to expansion in the supply of credit. Neither, large counties with limited housing construction display dynamics different than those where it is easy to build.

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.[6]

Similar to this paper, Kumhof et al. (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 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.[7] It can then be argued that the model of Kumhof et al. (2015) describes a case where the effect of declining interest rates dominates the effect of increasing income inequality.[8]

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.[9]

[6] 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.

[7] See Appendix 1.C.2 for details and Figure 1.D.2.2.

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

[9] 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.

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.[10] For instance, Bordo and Meissner (2012) finds no evidence of a rise in the top income share leading to credit booms, whereas Perugini et al. (2016) finds a positive relationship between income concentration and private sector debt. Schularick and Taylor (2012) and Mian et al. (2017) document the role of credit growth in the occurrence of financial crises.[11] 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.[12] Justiniano et al. (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

[10] 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.

[11] Jorda et al. (2016) find that the growth of mortgage credit in particular has been an increasingly important determinant of financial stability.

[12] For example, Justiniano et al. (2015), Favilukis et al. (2017) and Kiyotaki et al. (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 et al. (2012) support the view that house price expectations played an important role in the boom episode. Using a quantitative model, Kaplan et al. (2017) suggest that both an exogenous change in lending terms and expectations of increasing house prices are necessary needs to match the dynamics of leverage and house prices.

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.[13, 14]

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.[15] 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.

My model 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 chapter regarding the relationship between house prices and income inequality. 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. [16] Määttänen and Terviö (2014) do not include mortgages and endogenous

[13] Adelino et al. (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.

[14] 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 et al. (2015) document that mortgage foreclosures had significant effects on house prices and employment.

[15] For example, Midrigan and Philippon (2016) and Mian et al. (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.

[16] 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 et al. (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.

default decision and thus cannot address the implications of a change in income inequality for this two variables.

Layout. The rest of this chapter is organized as follows. Section 1.2 presents an equilibrium model of housing and mortgage markets. Section 4 concludes. Appendix 1.C.2 provides additional analyses of the cross-sectional facts presented in Figure 1.2.

1.2 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.[17] In addition to their endowment income, each household receives a housing endowment of h. The housing endowment is symmetric across the income

[17] 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.

distribution.[18] 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.[19] 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^d_{2i} and c^r_{2i} denote consumption under default and repayment, respectively. The rational default rule may then be defined as:

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

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

$$\begin{aligned} \max_{h_{1i}, d_i, c_{1i}} \quad & U_1(c_{1i}, h_{1i}) + \\ & \beta E_\Omega \left\{ \max_{\mathbb{1}_i} \mathbb{1}_i U_2(c^d_{2i}(\omega, y_{1i})) + (1 - \mathbb{1}_i) U_2(c^r_{2i}(\omega, y_{1i}, h_{1i}, d_i)) \right\} \end{aligned} \tag{1.1}$$

subject to the constraint

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

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

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

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 qd_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.[20]

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 than the default risk, and is endogenous to the amount

[20]Here the foreclosure cost $(1-\theta)p_2(\omega)$ is assumed to be a deadweight loss consistent with the evidence from US that foreclosed properties sell for around 20-30% lower than other properties with similar characteristics.

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 et al. (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 assumed to depend on income growth realization and to be weakly pro-cyclical. 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

[21] Justiniano et al. (2015) also assume quasi-linear 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.

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.

1.3 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.

1.3.1 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:

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

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

$$U_2(c^d_{2i}) = \xi\omega y_{1i}$$

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

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

[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 et al. (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.

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]

1.3.2 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.

$$\bar{d}_i^L = (1-\xi)y_{1i}\omega^L + Ep_2(\omega^L)h_{1i} - \kappa$$
$$\bar{d}_i^H = (1-\xi)y_{1i}\omega^H + Ep_2(\omega^H)h_{1i} - \kappa$$

Note that $\bar{d}_i^L \leq \bar{d}_i^H$. The loan pricing schedule for a borrower with income y_{1i} who purchases housing h_{1i} is given by:

$$q(y_{1i}, d_i, h_{1i}) = \begin{cases} \frac{1}{R^f} & \text{if } d_i \leq \bar{d}_i^L \\ \frac{1}{R^f}\{\nu + (1-\nu)\theta Ep_2(\omega^L)\frac{h_{1i}}{d_i}\} & \text{if } \bar{d}_i^L < d_i \leq \bar{d}_i^H \\ 0 & \text{otherwise} \end{cases} \tag{1.2}$$

If $d_i \leq \bar{d}_i^L$, 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 $d_i > \bar{d}_i^H$, 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

[25] See Gete and Reher (2016) and Jeske et al. (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 et al. (2008) provide empirical evidence of double-trigger defaults. See Foote and Willen (2017) for a review of mortgage default research.

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 $d_i \leq \bar{d}_i^L$, 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 $\bar{d}_i^L < d_i \leq \bar{d}_i^H$, 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

$$\lambda_{LTV} \leq (1-\xi)\omega \frac{\lambda_{LTV}}{\lambda_{LTI}} + \frac{Ep_2(\omega^H)}{p_1} - \frac{\kappa}{h_1 p_1}$$

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:

$$\lambda_{LTV} \leq \frac{Ep_2(\omega^H)}{p_1}$$

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 et al. (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.

1.3.3 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 1.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 quasi-linear, 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 quasi-linear preferences and borrower impatience, when the loan is risk-free debt is $\bar{d}_i^L$, and when the loan is risky debt is $\bar{d}_i^H$. That is, for both mortgage contract types borrowers opt for the highest debt level.

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 1.3 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.

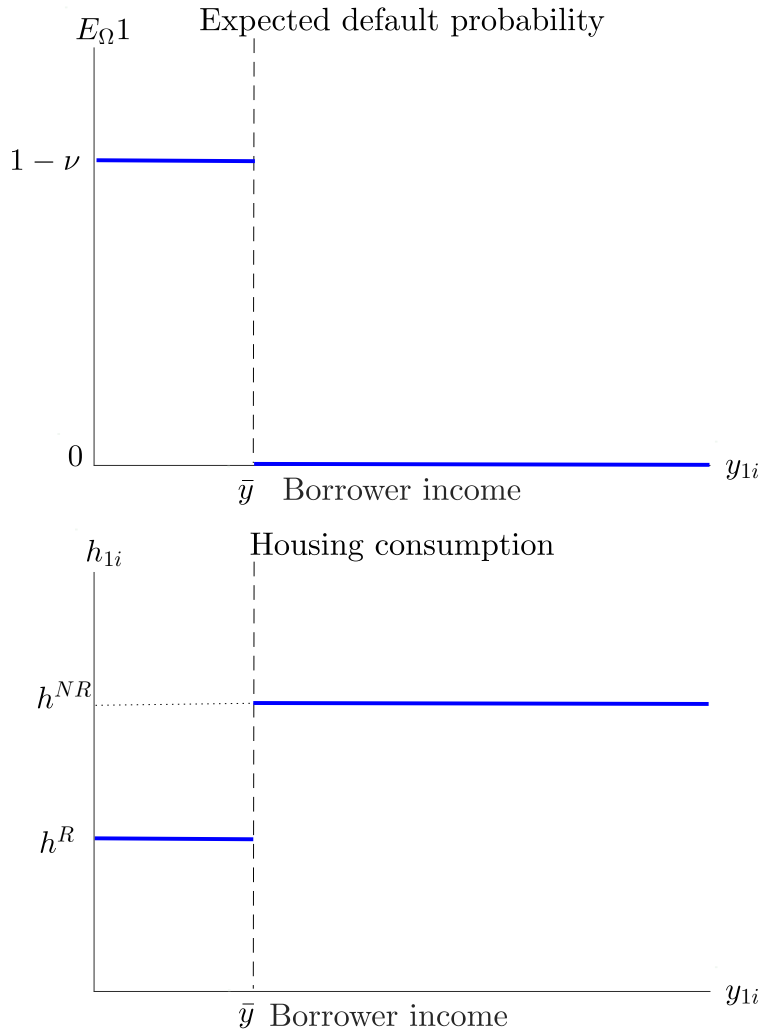
Lemma 1. *The down-payment of a risky loan is lower than a risk-free loan at all points in the income distribution.*

A sufficient condition is:

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

The down-payment for both risk type borrowers depends on the second period fixed housing transaction cost. This is because each borrower

FIGURE 1.3. 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}.

optimally selects the highest level of debt that is associated with their debt repayment frequency, which is a function of fixed transaction cost as described in (1.2). 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.

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:

$$\theta \leq \theta^{max} \quad where \quad \theta^{max} = 1 - (1 - \beta R^{f}) \left(\frac{Ep_2(\omega^H)}{Ep_2(\omega^L)} - 1 \right) \frac{\nu}{1 - \nu}$$

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]

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

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

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

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. $\frac{Ep_2(\omega^H)}{Ep_2(\omega^L)}$ is close to 1, housing consumption is high under a risk-free loan.

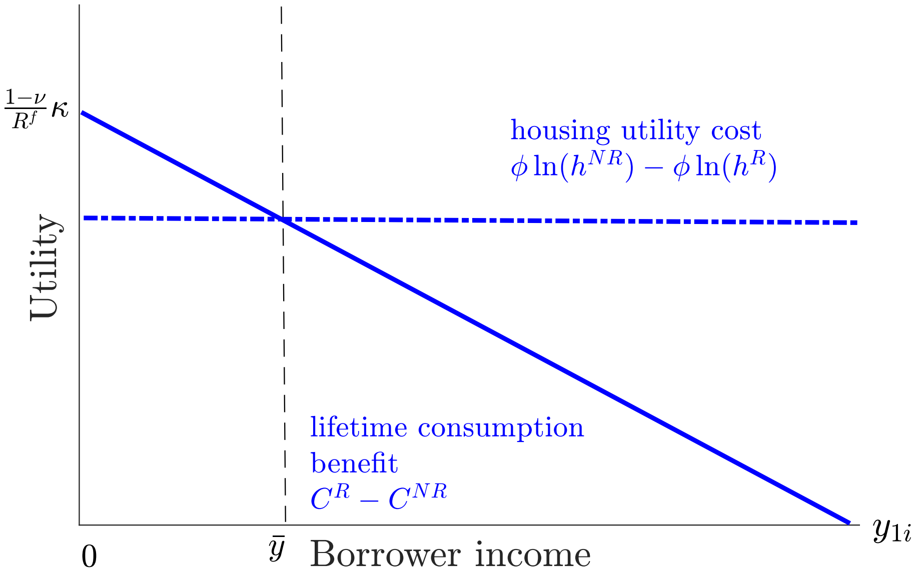
The third component of the contract choice is the expected utility derived from second period consumption. Since preferences are linear in consumption in the second period, a difference in consumption levels directly translates to a difference in utility. Expected second period consumption is higher 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 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 1.4. 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. The higher the transaction cost in the housing market, the larger is the gain under a risky loan.

Figure 1.4 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

29

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

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

utility loss. This is the benchmark specification that I use to study the consequences of income distribution changes.[30]

1.4 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 1.1 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 1.2 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:

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

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

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

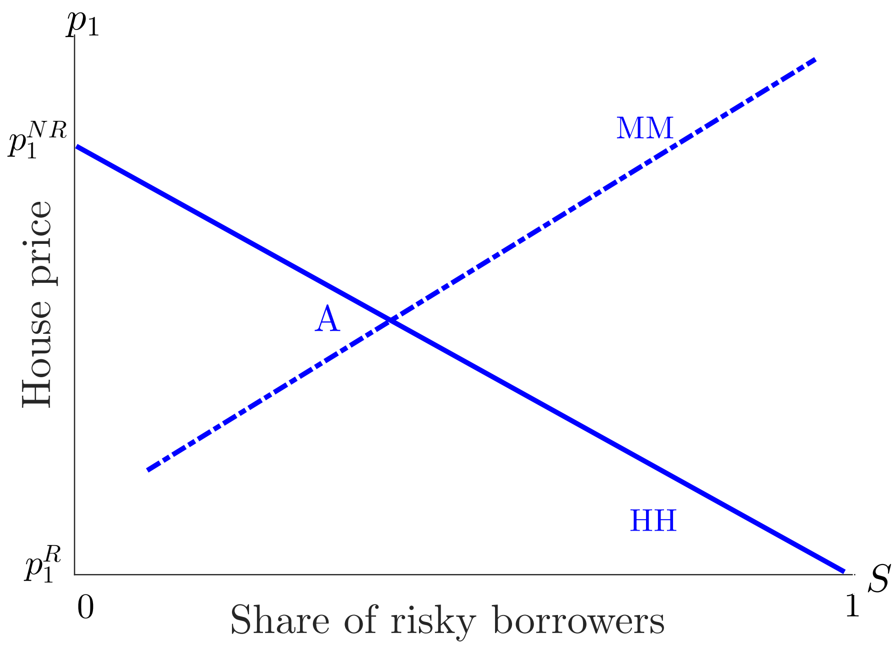
where $\Psi(\bar{y}(p_1))$ is the share of borrowers with income less than $\bar{y}$, and thus S is the share of risky borrowers.

- *The HH curve is downward sloping in S*

[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 et al. (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 MM curve is upward sloping in S*

FIGURE 1.5. General equilibrium of the model



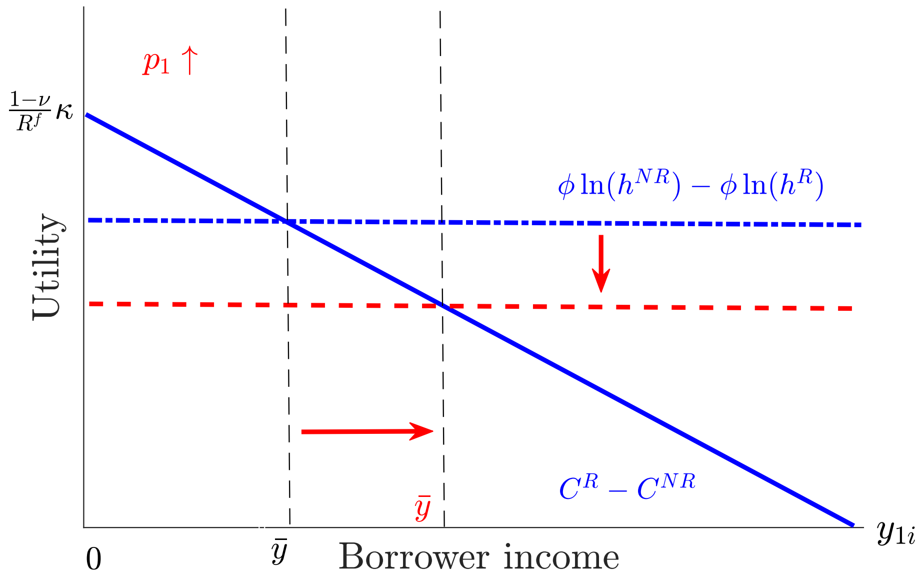
Note: The *HH* curve represents equilibrium in the housing market. The *MM* curve represents equilibrium in the mortgage market.

Figure 1.5 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 1.6 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*

FIGURE 1.6. Effect of an increase in house prices on mortgage market partial equilibrium

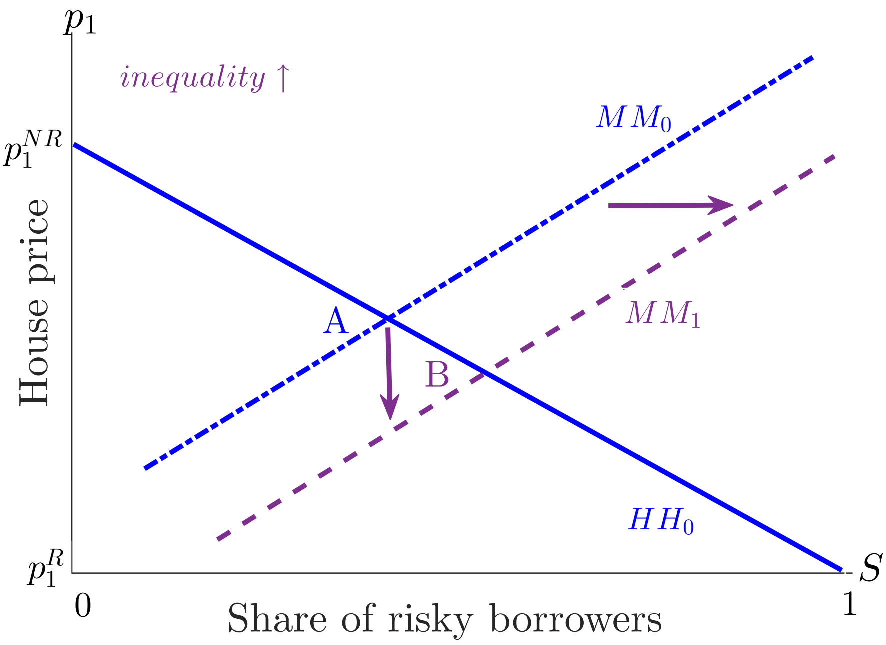


Note: The diagram plots the utility costs and benefits from switching to a risky loan for different levels of borrower income. For borrowers with income below $\bar{y}$, the utility benefits exceed the utility costs.

to shift, which then implies a movement along HH. These experiments are the topic of subsequent sections.

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

FIGURE 1.7. The general equilibrium impact of a mean-preserving increase in income inequality



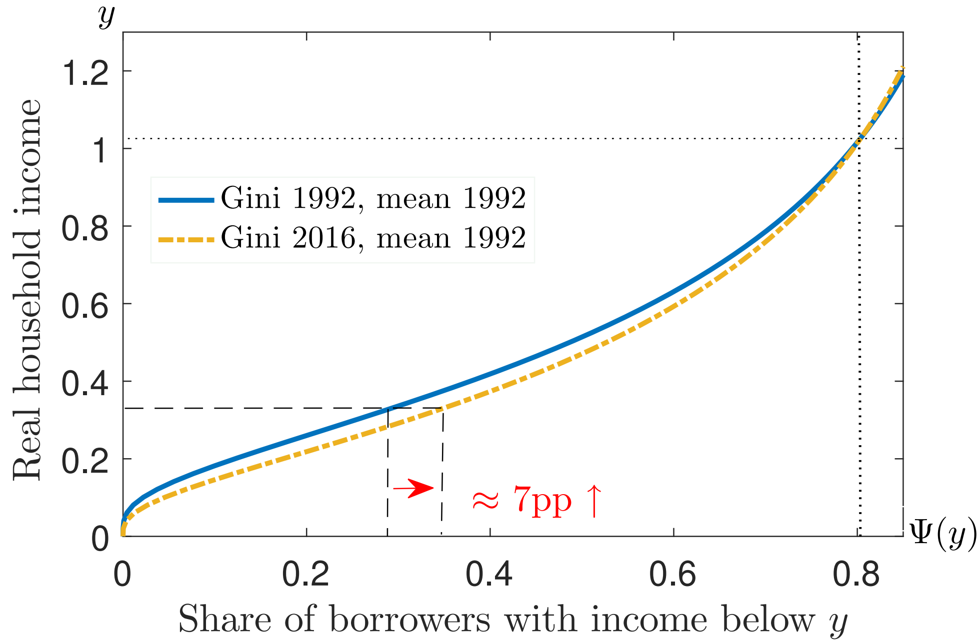
Note: The HH curve represents equilibrium in the housing market. The MM curve represents equilibrium in the mortgage market for a given house price. A mean-preserving change in income inequality shifts MM_0 to MM_1. The equilibrium of the model moves from point A to point B.

I 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] 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 1.7.

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.

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

FIGURE 1.8. Effect of a mean-preserving increase in income inequality on income percentiles

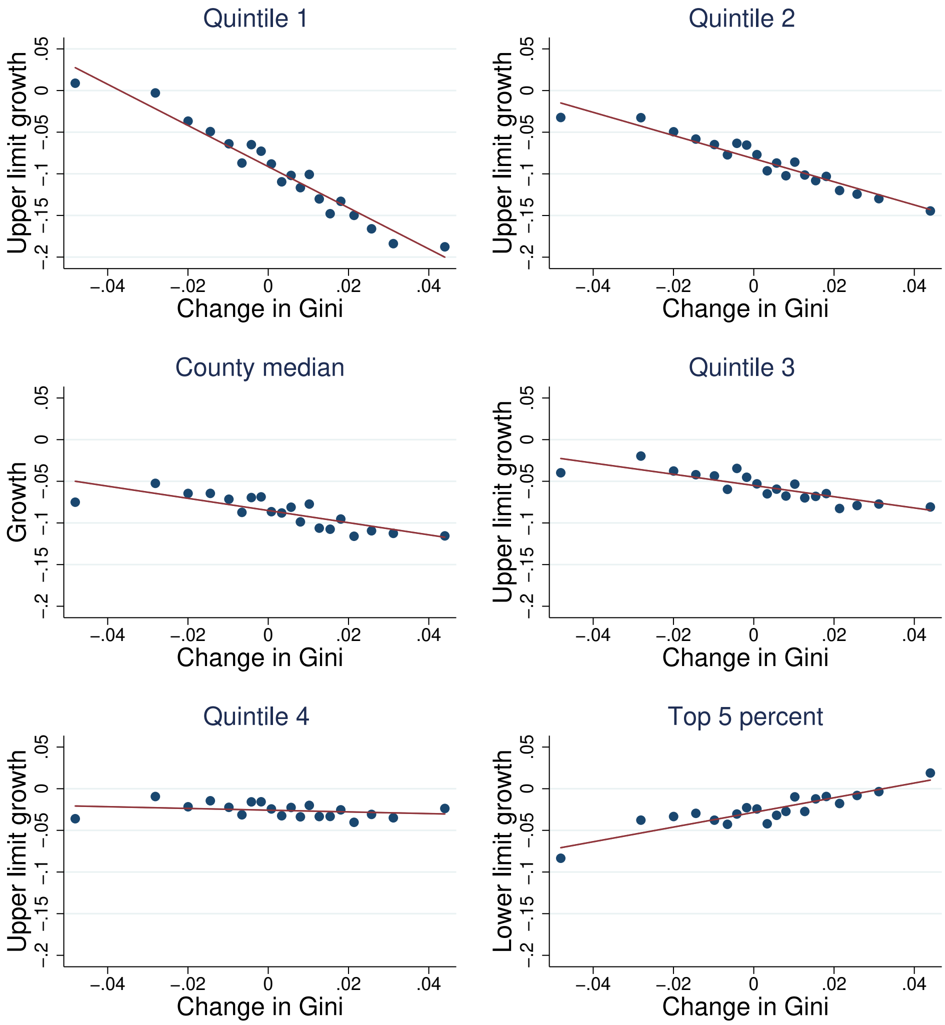


Note: This is a parametric representation of a change in income inequality calibrated using US data and assuming a log-linear income distribution. The y-axis shows income levels, and the x-axis the cumulative density with incomes below this level. The blue solid line matches the Gini coefficient and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

Figure 1.8 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.

[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 1.9. 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.

A mean preserving increase in income inequality is consistent with the data. Figure 1.9 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 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.

1.5.1 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 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.

1.5.2 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

[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.

median. The share of risky borrowers will 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 necessary 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

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

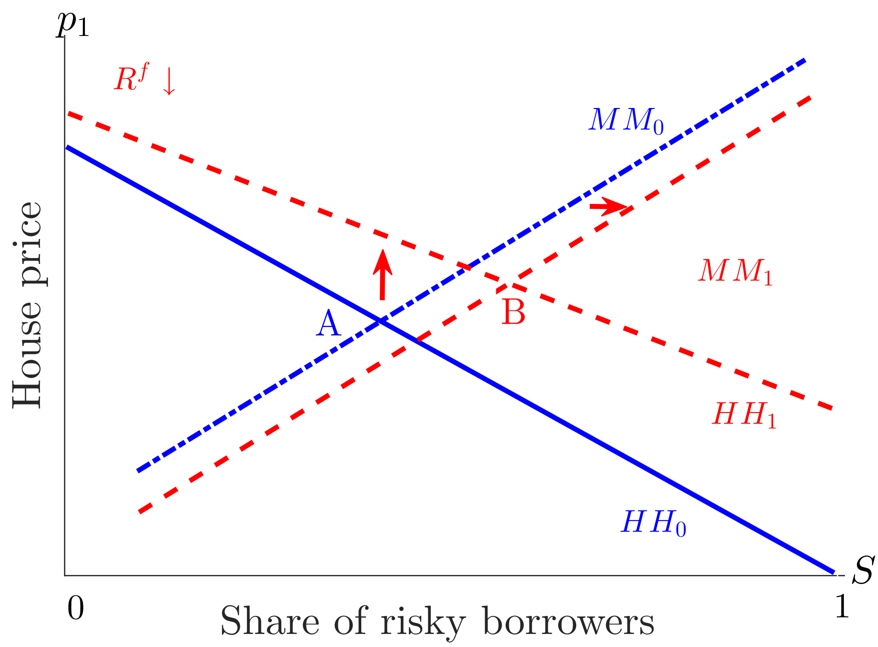
For the log-normal distribution, an increase in inequality with mean income held constant leads even some incomes above the median to decline. Given the rates of defaults in the data, the sufficient condition is likely to hold. In the calibrations of Figure 1.8, $e^{\sigma^2} median$ is around the 80^{th} income percentile. Data from the US counties in Figure 1.9 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.

1.6 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.

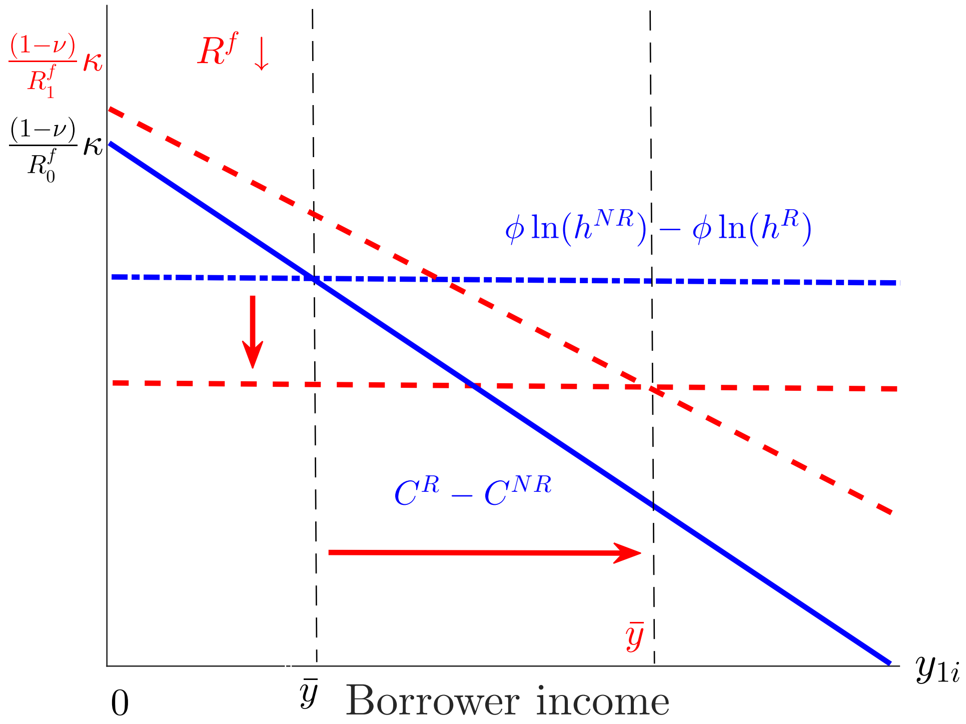
FIGURE 1.10. The general equilibrium impact of a decline in the risk-free rate



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

FIGURE 1.11. Effect of a decline in the risk-free rate in the mortgage market partial equilibrium



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.

is sufficiently high. The response of the housing market equilibrium is shown by the red dashed *HH* line in Figure 1.10.

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 1.11 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 1.10.

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*

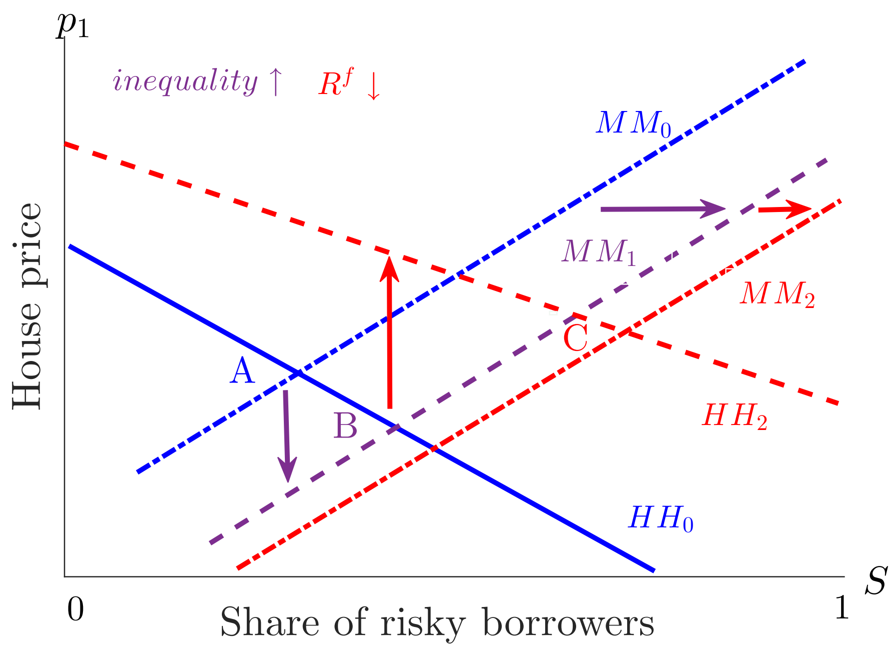
$$\frac{\partial \Psi(\bar{y}(p_1))}{\partial R^f} < 0$$

The general equilibrium effect of a decline in the risk-free rate is an increase in aggregate mortgage default risk. While the source of decline in the real rates is not micro-founded in the current paper, it implies that policies that can limit this decline could contribute to financial stability. Such examples are taxes on capital inflows or expansionary monetary policy. The effect on the house price depends on the relative shifts of the MM and the HH curves.

1.7 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 1.12 adds the effects of a real interest rate decline to those of an increase in inequality which were depicted in Figure 1.7. 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.

FIGURE 1.12. 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*.

1.8 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. In this chapter, I first show that US counties that experienced highest increases in income inequality has also experienced largest (i) declines in house prices, (ii) increases in mortgage delinquencies and (iii) declines in mortgage debt. That is, the cross sectional and aggregate trends are at odds. I then present a theoretical model that disentangles the effect of income inequality from macroeconomic developments, particularly the direct effect of declining real rates. I find that, in isolation, rising income inequality is associated with declines in real house prices and mortgage debt, but a rise in mortgage delinquencies. Finally, 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.

Appendix

1.A Borrower optimization

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

1.A.1 Risk-free Loan

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

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

subject to

$$d_i \leq \bar{d}^L_i = h_{1i}Ep_2(\omega^L) + (1-\xi)y_{1i}\omega^L - \kappa$$
$$d_i \geq 0$$
$$q(y_{1i}, d_i, h_{1i}) = \frac{1}{R^f}$$

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:

$$d_i: \quad -\beta + \frac{1}{R^f} - \lambda_1 + \lambda_2 = 0$$
$$h_i: \quad -p_1 + \lambda_1 Ep_2(\omega^L) + \frac{\phi}{h_1} + \beta\{\nu Ep_2(\omega^H) + (1-\nu)Ep_2(\omega^L)\} = 0$$

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

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

$$h^{NR} = \frac{\phi}{p_1 - \frac{1}{R^f}Ep_2(\omega^L) - \beta\nu(Ep_2(\omega^H) - Ep_2(\omega^L))}$$

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.

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

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

$$\begin{aligned} down - payment = \quad & \phi \underbrace{\frac{p_1 - \frac{1}{R^f} E p_2(\omega^L)}{p_1 - \frac{1}{R^f} E p_2(\omega^L) - \beta \nu (E p_2(\omega^H) - E p_2(\omega^L))}}_{\geq 1} \\ & - \frac{1}{R^f}((1-\xi)\omega^L y_{1i} - \nu) \end{aligned}$$

and the expected second period consumption is:

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

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

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

1.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:

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

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

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

subject to

$$d_i \leq \bar{d}_i^H = h_{1i}Ep_2(\omega^H) + (1-\xi)y_{1i}\omega^H - \tau$$

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

$$q(y_{1i}, d_i, h_{1i}) = \frac{1}{R^f}\left\{\nu + (1-\nu)\frac{\theta Ep_2(\omega^L)h_{1i}}{d_i}\right\}$$

where

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

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

$$c_{2i}^d(\omega^L) = \xi y_1 \omega$$

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. The first order conditions for the borrower optimization problem are then:

$$\begin{aligned} d_i: & \quad \nu(-\beta + \frac{1}{R^f}) - \lambda_1 + \lambda_2 = 0 \\ h_{1i}: & \quad -p_1 + \frac{1}{R^f}(1-\nu)\theta Ep_2(\omega^L) + \lambda_1 Ep_2(\omega^H) - \lambda_2 Ep_2(\omega^L) + \\ & \quad \frac{\phi}{h_{1i}} + \beta\nu Ep_2(\omega^H) = 0 \end{aligned}$$

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

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

$$h_1^R = \frac{\phi}{p_1 - \frac{1}{R^f}(\nu Ep_2(\omega^H) + \theta(1-\nu)Ep_2(\omega^L))}$$

$$c_{1i}^R = p_1 h + y_{1i} - \underbrace{(h^R p_1 - \frac{1}{R^f}((1-\xi)\nu\omega^H y_{1i} - \kappa\nu + h^R(\theta(1-\nu)Ep_2(\omega^L) + \nu Ep_2(\omega^H)))}_{down-payment}$$

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:

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

The lifetime utility derived from non-durable consumption is

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

1.B Proofs

1.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:

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

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

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

$$down - payment^{NR} = \phi \underbrace{\frac{p_1 - \frac{1}{R^f}Ep_2(\omega^L)}{p_1 - \frac{1}{R^f}Ep_2(\omega^L) - \beta\nu(Ep_2(\omega^H) - Ep_2(\omega^L))}}_{\geq 1} - \frac{1}{R^f}((1-\xi)\omega^L y_{1i} - \nu)$$

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:

$$\theta \leq \theta^{max} \quad where \quad \theta^{max} = 1 - (1 - \beta R^f)\left(\frac{Ep_2(\omega^H)}{Ep_2(\omega^L)} - 1\right)\frac{\nu}{1-\nu}$$

Proof. Optimality condition under a risky loan is:

$$\frac{\phi}{h_{1i}} = \underbrace{p_1}_{\frac{-\partial c_{1i}}{\partial h_{1i}}} \underbrace{- \frac{1}{R^f}(1-\nu)\theta Ep_2(\omega^L)}_{\frac{\partial q(y_{1i}, d_i, h_{1i})D}{\partial D}} - \lambda^R \underbrace{Ep_2(\omega^H)}_{\frac{\partial \bar{d}_i^H}{\partial h_{1i}}} + \beta \underbrace{\nu Ep_2(\omega^H)}_{\frac{\partial Ec_{2i}^r(\omega^H)}{\partial h_{1i}}}$$

Optimality condition under a risk-free loan is:

$$\frac{\phi}{h_{1i}} = \underbrace{p_1}_{\frac{-\partial c_{1i}}{\partial h_{1i}}} - \lambda^{NR} \underbrace{Ep_2(\omega^L)}_{\frac{\partial \bar{d}_i^L}{\partial h_{1i}}} - \beta \underbrace{\{\pi Ep_2(\omega^H) + (1-\pi)Ep_2(\omega^L)\}}_{\frac{\partial c_{2i}^r}{\partial h_{1i}}}$$

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

$$\begin{aligned}\frac{\phi}{h^{NR}} - \frac{\phi}{h^{R}} = & \quad \nu(\frac{1}{R^f} - \beta)Ep_2(\omega^H) - (\frac{1}{R^f} - \beta)Ep_2(\omega^L) \\ - & \quad (1-\nu)(\beta - \frac{\theta}{R^f})Ep_2(\omega^L)\end{aligned}$$

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

$$\theta \leq 1 - (1 - \beta R^f)\left(\frac{Ep_2(\omega^H)}{Ep_2(\omega^L)} - 1\right)\frac{\nu}{1-\nu}$$

■

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

Proof.

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

$$Ec_{2i}^{NR} = (\nu\omega^H + (\nu + \xi)\omega^L)y_{1i} + h^{NR}\nu(Ep_2(\omega^H) - Ep_2(\omega^L))$$

■

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

■

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

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 $\Psi(\bar{y}) \leq 0.95$. ■

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

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

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 $\bar{y} \le \bar{M}e^{\frac{\sigma^2}{2}} = e^{\mu+\sigma^2}$, since median is e^{μ}, then the sufficiency condition can be written as

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

■

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

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

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 $\frac{\pi\omega^H}{\omega^L} \ge 1$ 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:*

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

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

Proof.

1. $$\epsilon^{NR} = \frac{\partial \ln(h^{NR})}{\partial R^f} = -Ep_2(\omega^L)\frac{h^{NR}}{\phi(R^f)^2} < 0$$
$$\epsilon^{R} = \frac{\partial \ln(h^{R})}{\partial R^f} = -(\theta(1-\nu)Ep_2(\omega^L) + \nu Ep_2(\omega^H))\frac{h^{R}}{\phi(R^f)^2} < 0$$
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
$$\left(\underline{\theta}(1-\nu) + \nu\frac{Ep_2(\omega^H)}{Ep_2(\omega^L)}\right)\frac{h^R}{h^{NR}} = 1$$
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
$$\underline{\theta}(1-\nu) + \nu\frac{Ep_2(\omega^H)}{Ep_2(\omega^L)} = \frac{h^{NR}}{h^R} < 1$$
Since $\underline{\theta} = \theta^{max} + \varepsilon$, left hand-side becomes
$$(1-\nu)\varepsilon + 1 + \beta R^f\left(\frac{Ep_2(\omega^H)}{Ep_2(\omega^L)} - 1\right) > 1$$
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:
$$p^R = \frac{\phi}{h} + \frac{1}{R^f}(\theta(1-\nu)Ep_2(\omega^L) + \nu Ep_2(\omega^H))$$
$$p^{NR} = \frac{\phi}{h} + \frac{1}{R^f}Ep_2(\omega^L)$$
Then
$$\frac{\partial p^R}{\partial R^f} = -\frac{1}{(R^f)^2}(\theta(1-\nu)Ep_2(\omega^L) + \nu Ep_2(\omega^H)) = \epsilon^R\frac{\phi}{h^R}$$
$$\frac{\partial p^{NR}}{\partial R^f} = -\frac{1}{(R^f)^2}Ep_2(\omega^L) = \epsilon^{NR}\frac{\phi}{h^{NR}}$$

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. ■

1.C Cross-sectional analyses on the relationship between income inequality, house prices and mortgage debt: US counties

In this section I first describe the data used to derive Figure 1.2 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.

1.C.1 County level data

This paper primarily uses data from the U.S. Census and the American Community Survey (ACS) 5-year averages.[34] 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.[35]

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.[36] 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 1.2 includes

[34]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.

[35]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.

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

2093 US counties that have data for both house prices and mortgage variables.

1.C.2 Income inequality and house price growth: County level evidence

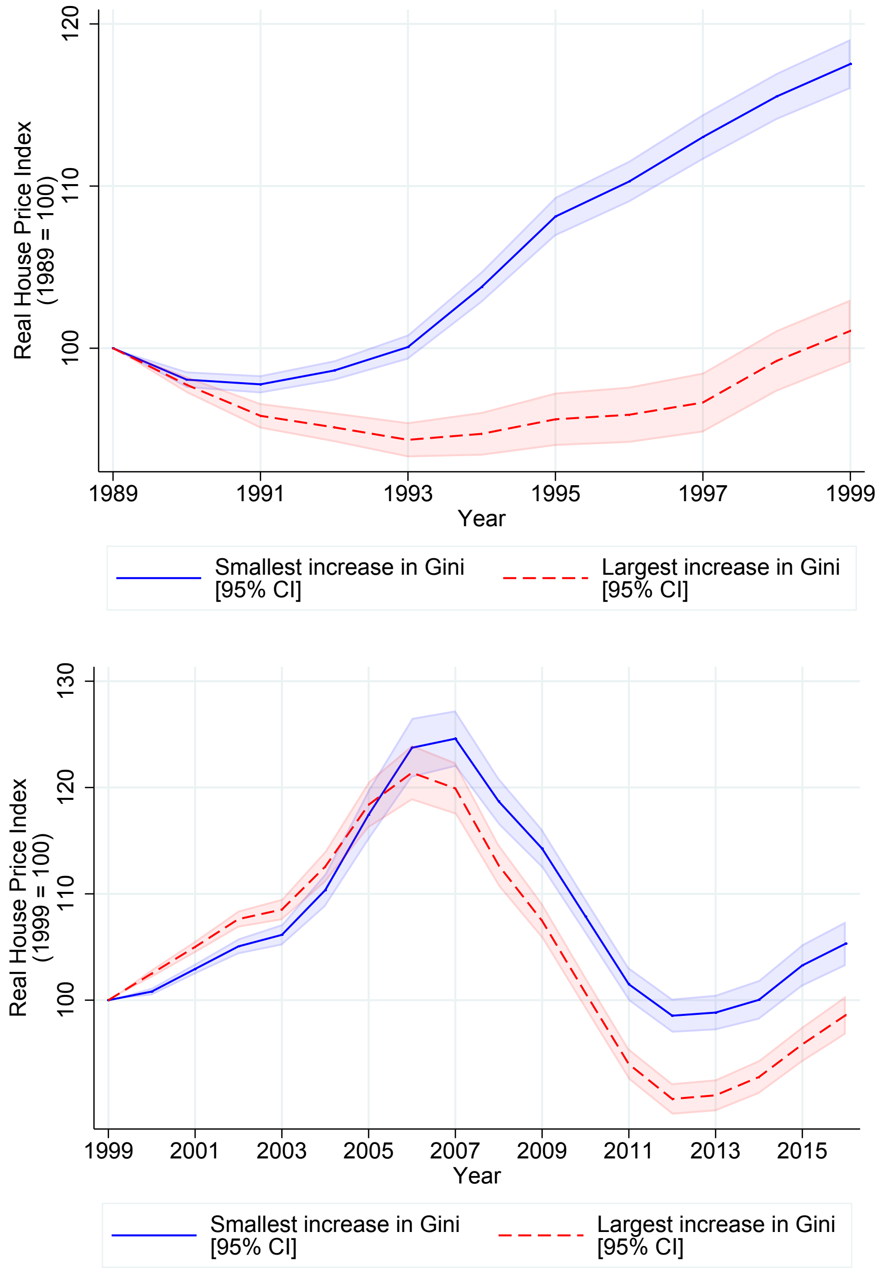
In this section I provide nonparametric evidence regarding the correlation between real house prices and income inequality growth. This complements the evidence in Figure 1.2. Inequality is measured by the Gini coefficient. A higher value of the Gini coefficient corresponds to greater income inequality. Each panel of Figure 1.D.2.1 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.[37] 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 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.

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 1.D.2.1 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.

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

FIGURE 1.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.

1.C.3 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 1.D.2.1 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 1.9.

Figure 1.D.2.2 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 1.D.2.3 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 1.D.2.4 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 1.D.2.5 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.

1.D Robustness Checks: County level data

1.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 1.D.2.6 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.[38] Therefore, even when controlled for housing supply elasticity, cross-sectional correlations qualitatively remain

[38] 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.

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 1.2.

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 1.D.2.7 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 1.D.2.7 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 1.D.2.8 displays the partial correlations having controlled for county characteristics and points into the same conclusion as Figure 1.D.2.7. Therefore, the results in Figure 1.2 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 1.D.2.9 and 1.D.2.10 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.

1.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.[39]

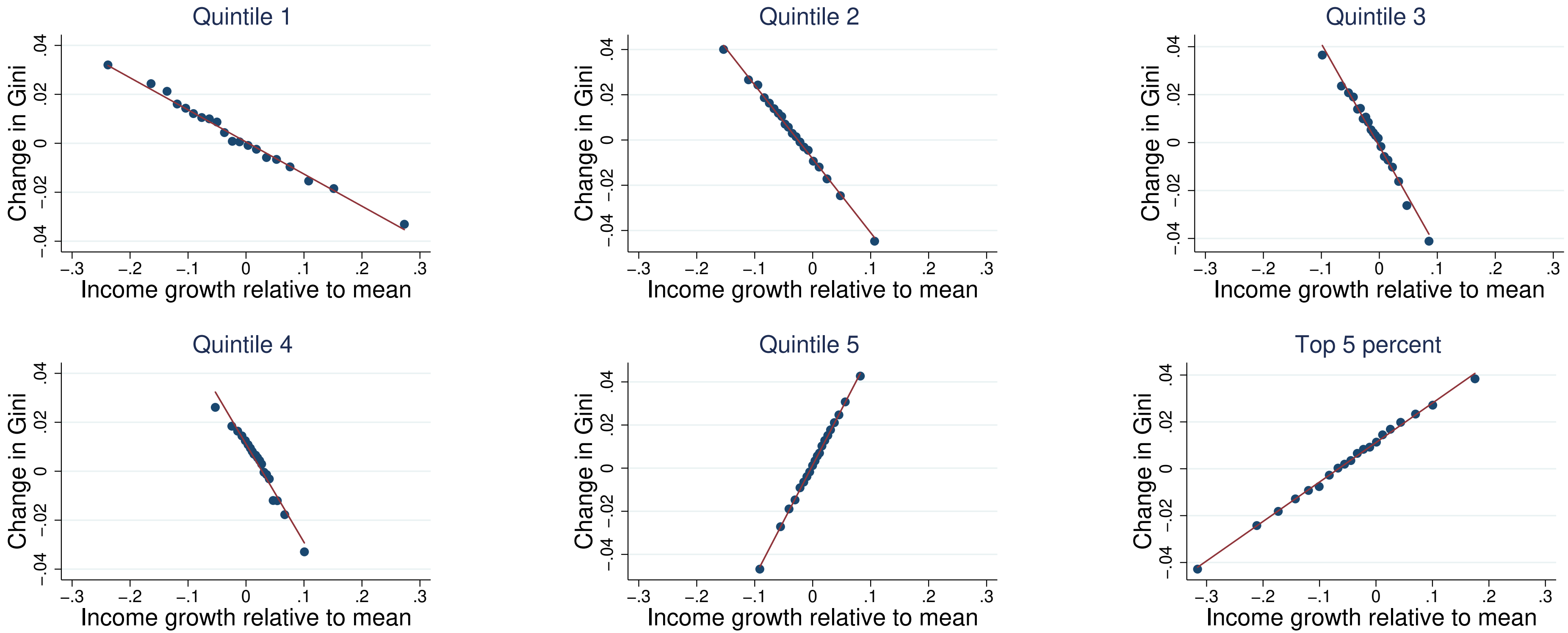
I first consider whether the relationship between income inequality and mortgage debt growth differs across high and low subprime credit population areas. Figure 1.D.2.11 displays the simple correlations. I group counties into three categories depending on their subprime population share. First panel in Figure 1.D.2.11 corresponds to the counties at the lowest tercile of subprime borrower share. The figure shows that house price growth and change in income inequality is negatively correlated at the cross-section, independent of the subprime population share. Figure 1.D.2.12 displays the partial correlations having controlled for county characteristics. Similar to Figure 1.D.2.11, Figure 1.D.2.12 shows that

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

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 1.D.2.13 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 1.D.2.14 displays the partial correlations having controlled for county characteristics and confirms the empirical findings of this paper for different subsamples of US counties.

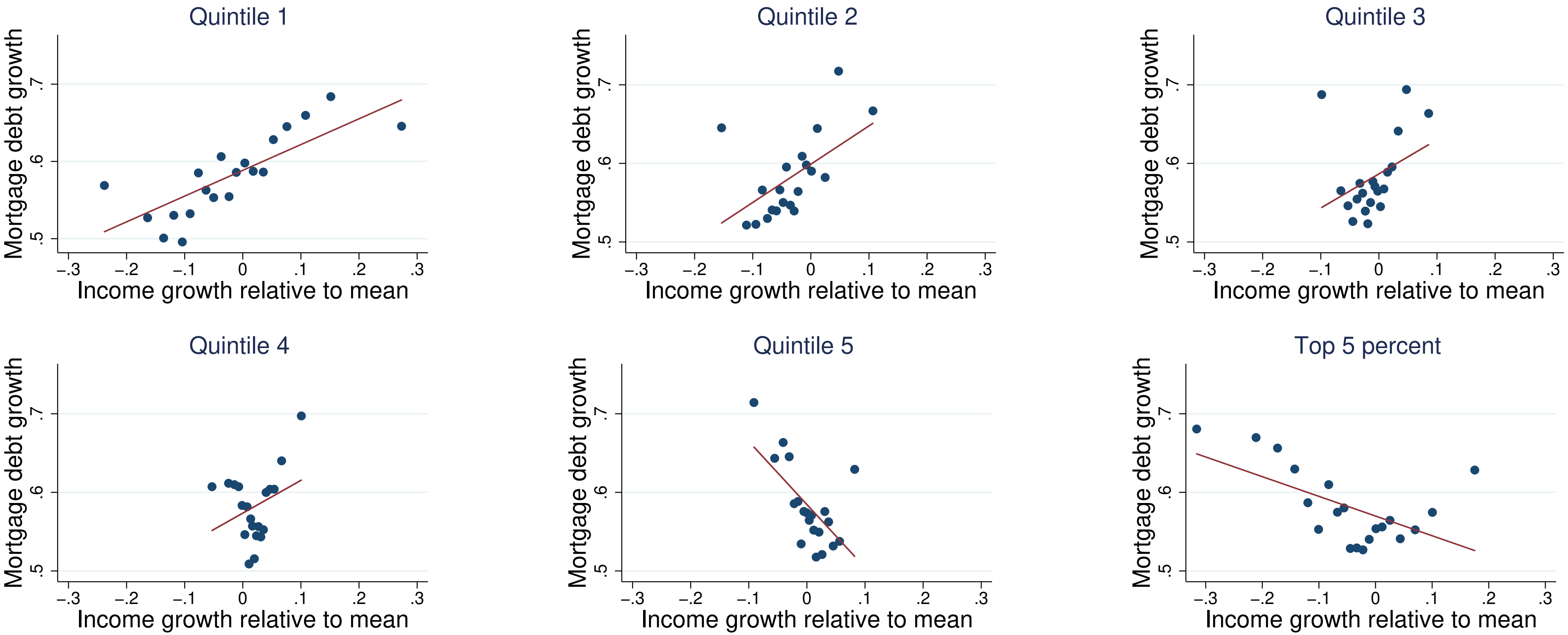
FIGURE 1.D.2.1. Income inequality change and quintile relative income growth between the years 1999 and 2011



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.

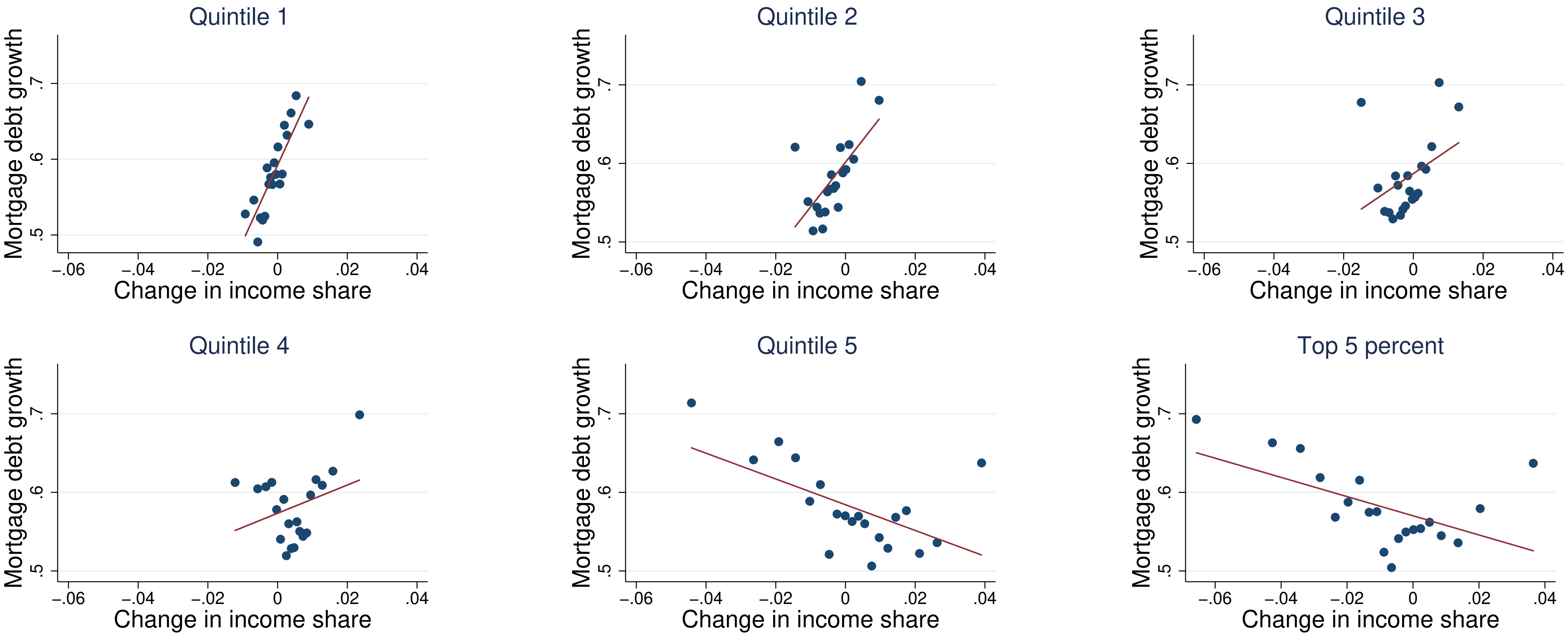
FIGURE 1.D.2.2. Real mortgage debt growth and quintile relative income growth between the years 1999 and 2011



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.

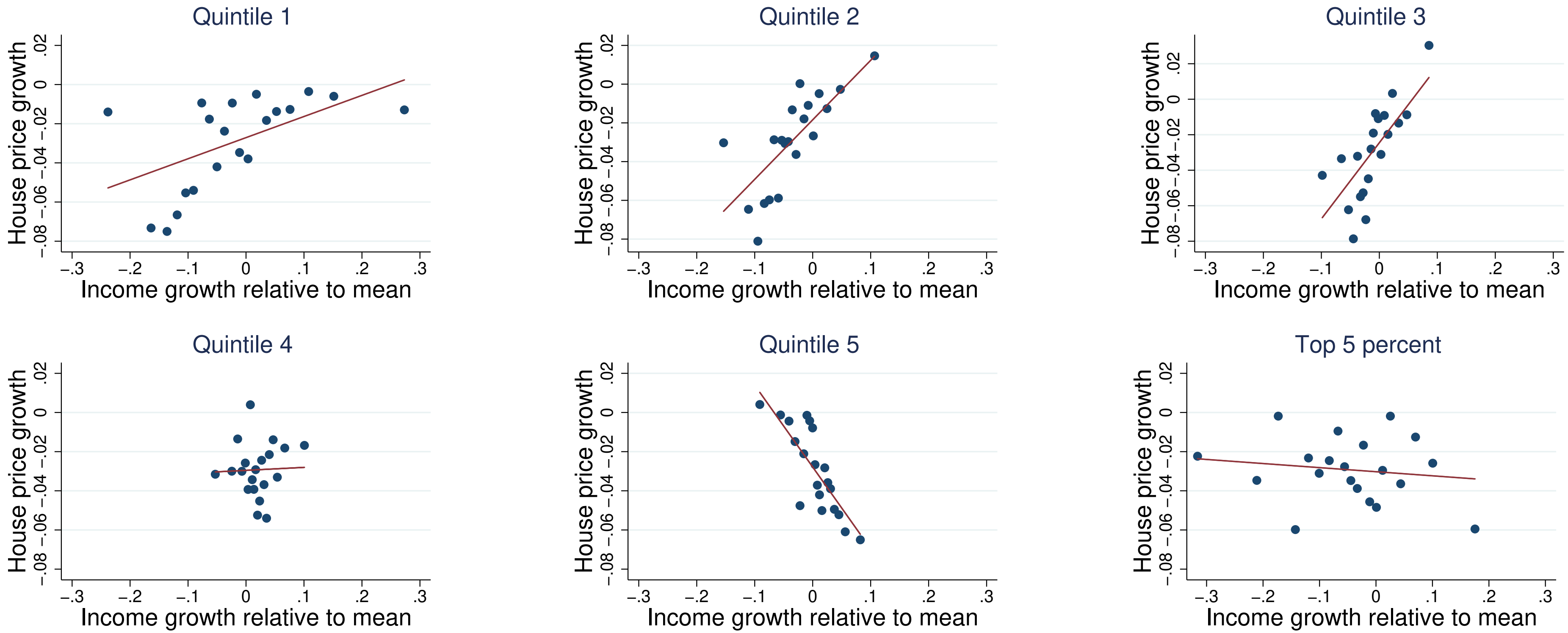
FIGURE 1.D.2.3. Real mortgage debt growth and change in quintile income share between the years 1999 and 2011



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.

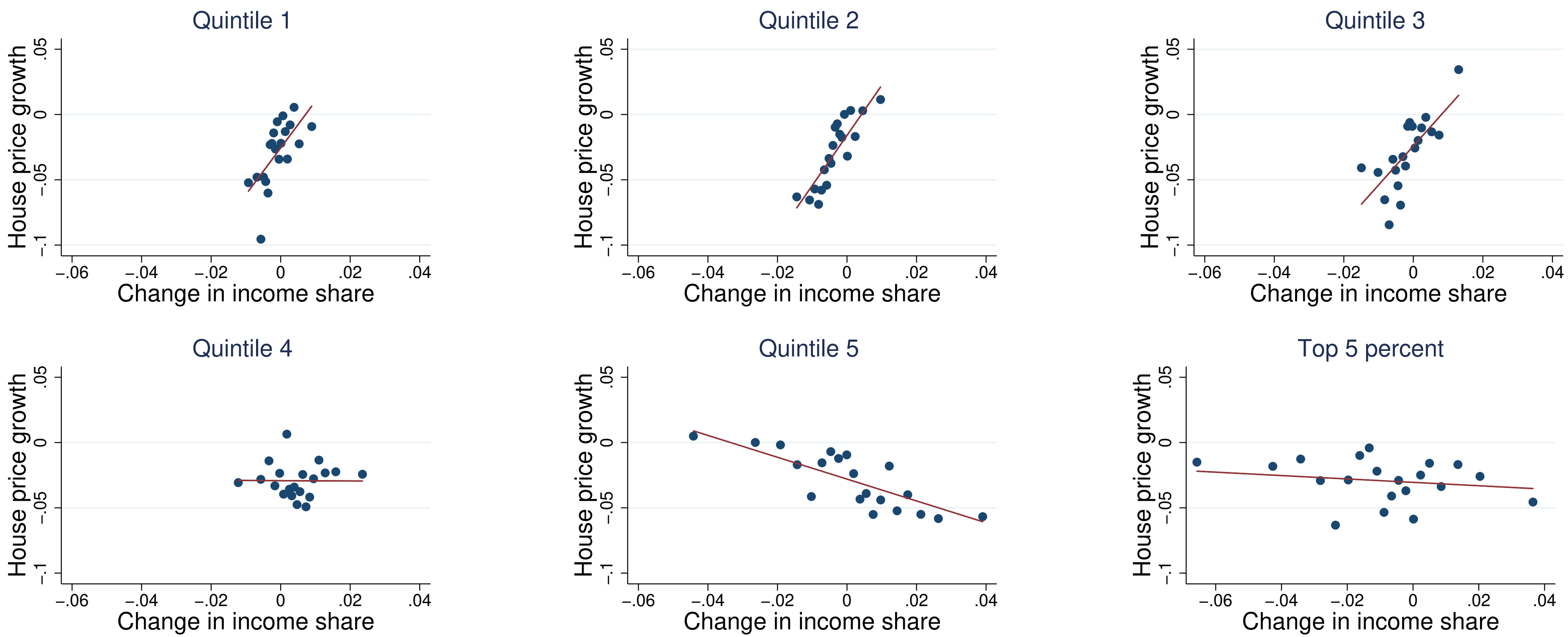
FIGURE 1.D.2.4. Real house price growth and quintile relative income growth between the years 1999 and 2011



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.

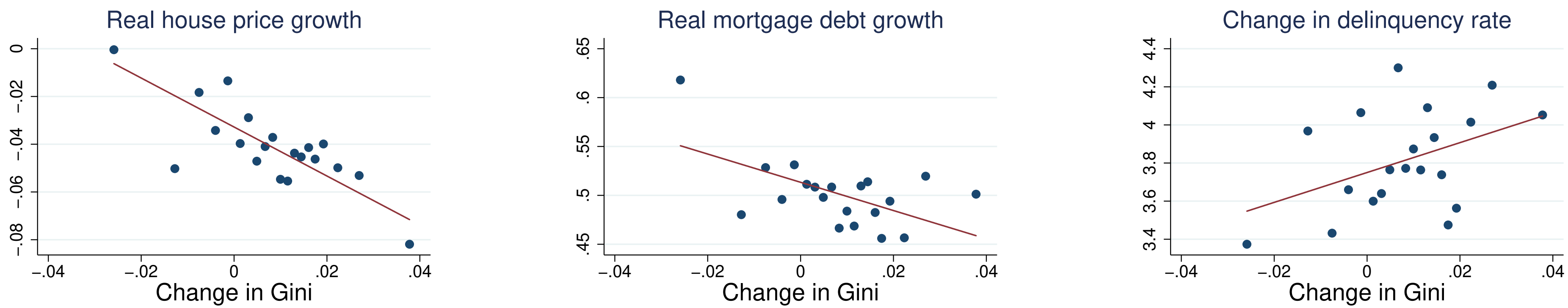
FIGURE 1.D.2.5. Real house price growth and change in quintile income share 1999 - 2011



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.

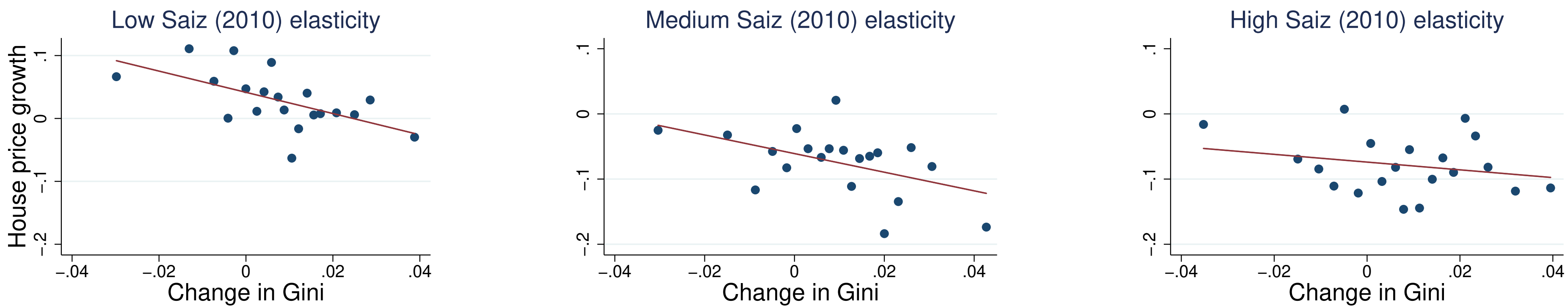
FIGURE 1.D.2.6. Changes in income inequality, real house price growth, mortgage debt growth and change in mortgage delinquency rate over US counties (1999-2011)



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.

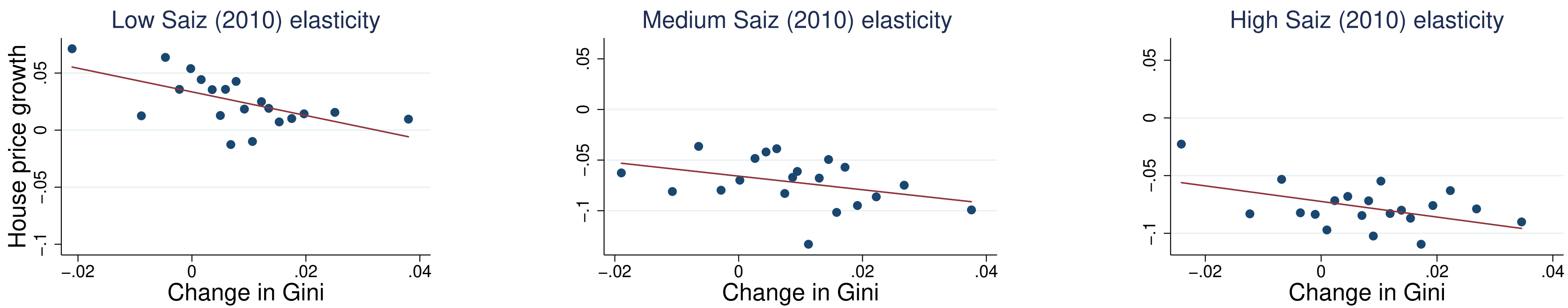
FIGURE 1.D.2.7. Changes in income inequality and real house price growth between the years 1999 and 2011 over US counties with different housing supply elasticity



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.

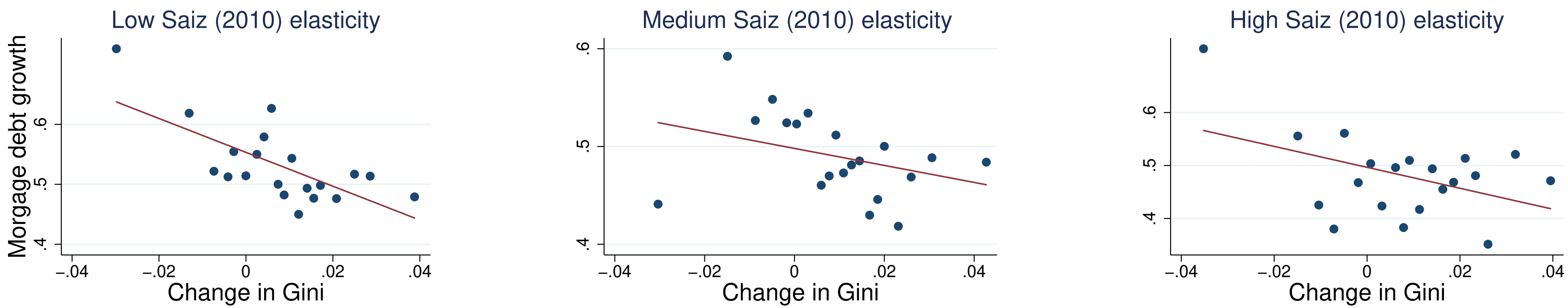
FIGURE 1.D.2.8. Changes in income inequality and real house price growth in US counties with different housing supply elasticity (1999-2011)



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.

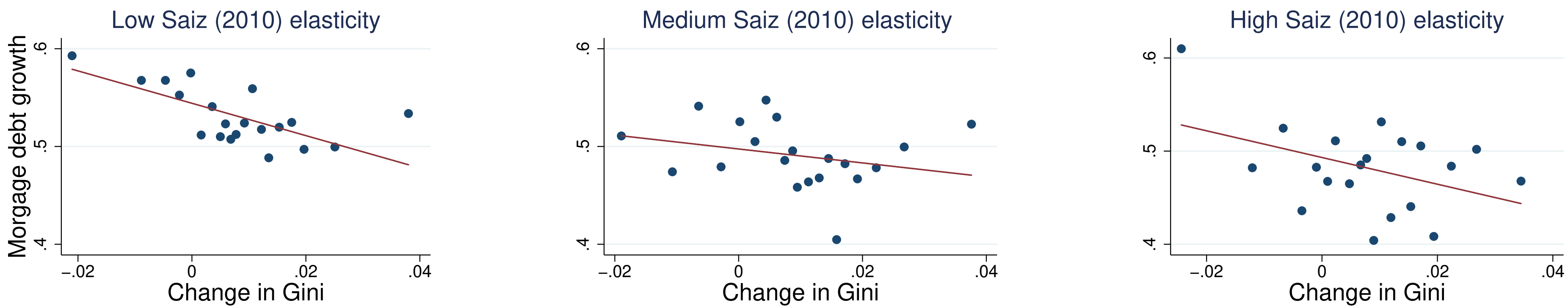
FIGURE 1.D.2.9. Changes in income inequality and real mortgage debt growth between the years 1999 and 2011 over US counties with different housing supply elasticity



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.

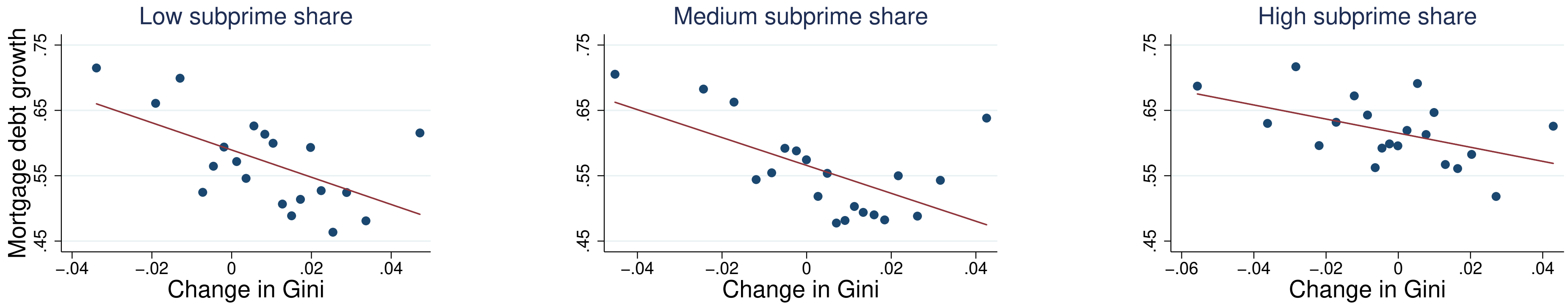
FIGURE 1.D.2.10. Changes in income inequality and real mortgage debt growth in US counties with different housing supply elasticity (1999-2011)



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.

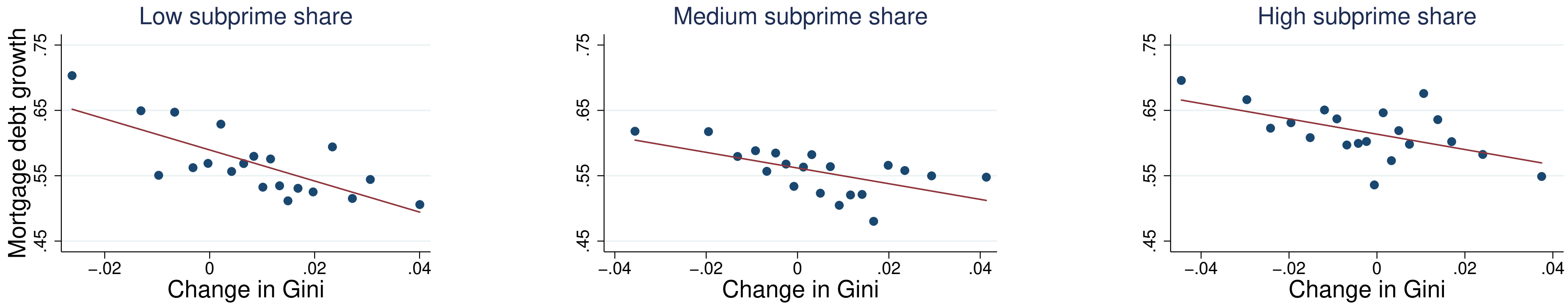
FIGURE 1.D.2.11. Changes in income inequality and real mortgage debt growth in US counties with different initial subprime credit population share (1999-2011)



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.

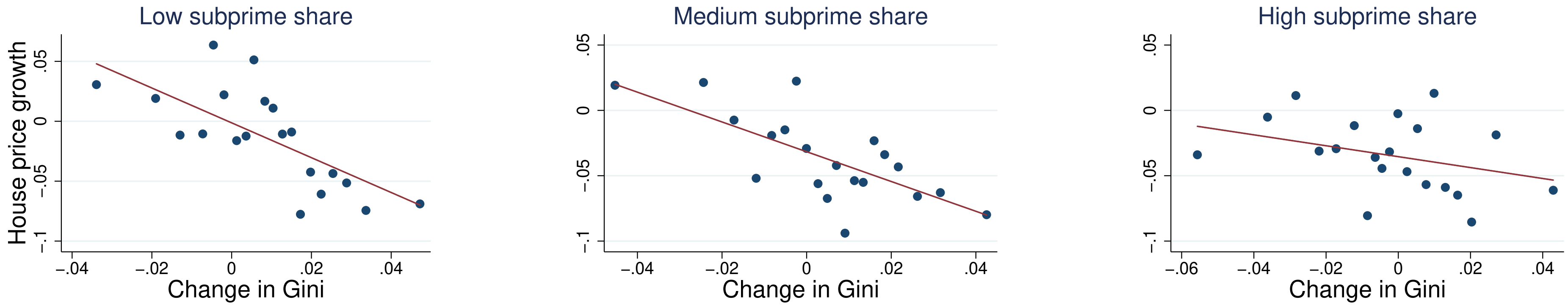
FIGURE 1.D.2.12. Changes in income inequality and real mortgage debt growth in US counties with different initial subprime credit population share (1999-2011)



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.

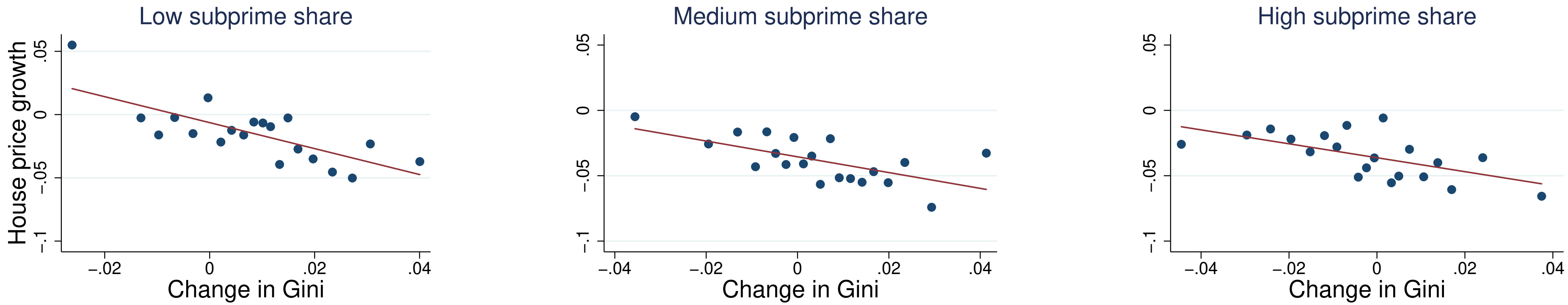
FIGURE 1.D.2.13. Changes in income inequality and real house price growth in US counties with different initial subprime credit population share (1999-2011)



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 1.D.2.14. Changes in income inequality and real house price growth in US counties with different initial subprime credit population share (1999-2011)



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.

Chapter 2

Income Inequality, Mortgage Debt and House Prices: A Panel Data Analysis

In this chapter I study how income inequality is associated with house prices, mortgage debt and mortgage delinquency using panel data of US states. In order to isolate the effect of income inequality from that of the declining real rates, I use year fixed effects in the specifications, in addition to state fixed effects and covariates that vary both by year and state. I find that the data verifies the predictions of the theoretical framework presented in Chapter 1 of this thesis. That is, 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. Moreover, changes in the long-term real interest rate alters the responses to changes in income inequality. A decline in real rates mitigate the negative relation between income inequality and house prices at the cost of amplifying association between income inequality and mortgage delinquencies.

2.1 Introduction

To verify the model's predictions presented in the first chapter of this thesis, I turn to a panel of US states. The model 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

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.[1] 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.

2.2 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.

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

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.[2] 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.[3] 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.[4] I construct long-term real rates by subtracting 10-year inflation forecasts from Survey of 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.[5]

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.

2.3 Empirical Strategy and Results

This section describes 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

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

[3] 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.

[4] 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.

[5] See Frank (2014) for the construction of Gini and other income inequality measure for US states. Updated measures are available in http://www.shsu.edu/eco_mwf/inequality.html

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.

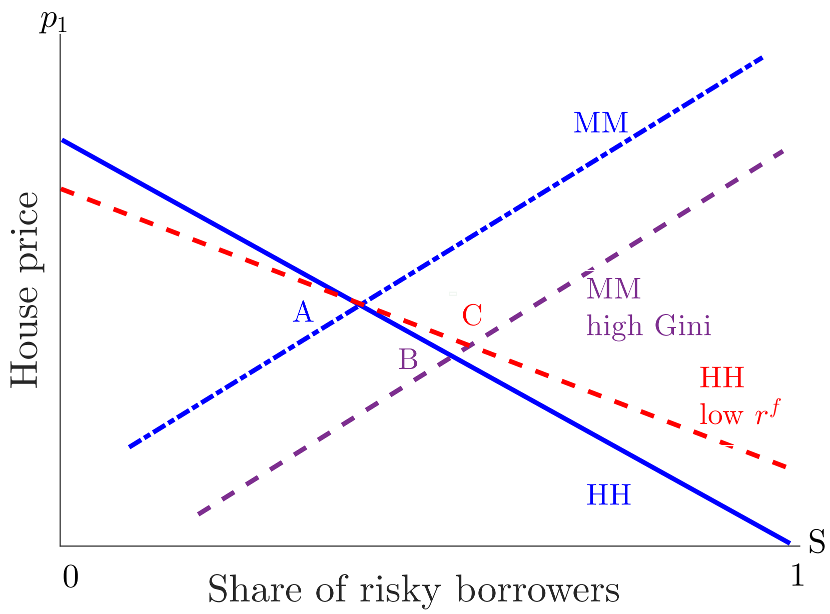
I use the following regression specification:

$$Y_{s,t} = \alpha_s + \alpha_t + \beta Gini_{s,t} + \Gamma X_{s,t} + \epsilon_{s,t} \tag{2.1}$$

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

FIGURE 2.1. 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 *MM*high Gini. The slope of the *HH* curve increases with the real rate.

interaction of the Gini coefficient with the real interest rate. Note that the year fixed effects absorb all variation in the real rate itself.

$$Y_{s,t} = \alpha_s + \alpha_t + \beta Gini_{s,t} + \mu Gini_{s,t} \times Rate_t + \Gamma X_{s,t} + \epsilon_{s,t} \tag{2.2}$$

Figure 2.1 provides model based guidance regarding the interaction between inequality and the interest rate environment. The figure is a variant of Figure 1.10 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.

2.3.1 Result 1: House prices decline with income inequality

Table 2.1 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 around 20% decline in house prices. Equivalently, a one standard

TABLE 2.1. 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.

deviation increase in income inequality corresponds to a 7.7% decline in real house prices.[6] 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 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.

Next I examine the effect of a low interest environment on the income inequality-house price nexus. Figure 2.1 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 2.2 presents estimation results when the model is estimated without controls. The results imply that a one

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

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.

TABLE 2.2. 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.

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

TABLE 2.3. Income inequality and real house prices - different sample subperiods

Dependent variable: Log real FHFA house price index

	(1)	(2)	(3)	(4)	(5)
Gini	-1.605***	-2.232***	-1.320**	-1.686***	-1.519***
	(0.243)	(0.330)	(0.526)	(0.267)	(0.318)
Log real mean income	1.060***	1.007***	0.408**	1.087***	0.177
	(0.144)	(0.181)	(0.169)	(0.142)	(0.328)
Log population	0.272*	0.164	2.514***	0.257*	1.563*
	(0.146)	(0.138)	(0.296)	(0.139)	(0.876)
Homeownership rate	0.010***	0.006**	0.003	0.010***	-0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Log new permits	-0.000	0.003	-0.001	0.000	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)
year fe	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes
R-squared within	0.812	0.851	0.754	0.810	0.632
R-squared overall	0.162	0.356	0.006	0.180	0.000
Observations	1200	800	300	1100	100
Years	1992-2015	1992-2007	2010-2015	no 2008 & 2009	2008-2009

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

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.

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 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.

Table 2.3 shows that the negative association between income inequality and real house prices hold when we look at different subperiods of the sample. The first column replicates the results in the third column of Table 2.1. Note that the association between income inequality is higher in the period before the Great Recession displayed in the second column, compared to after as shown in the third one. This is not surprising since the latter time period is associated with historically low levels in interest rates, which according to my model mitigates the effect of income inequality on house prices.

2.3.2 Result 2: The mortgage delinquency rate increases with income inequality

Next, I analyze how income inequality affects mortgage market stability. Table 2.4 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.

TABLE 2.4. 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.

Figure 2.1 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 2.5 shows that, in high interest rate environments a one percentage point increase in income inequality implies a smaller increase in

TABLE 2.5. 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. 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.

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 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.

Finally, I consider the relationship between income inequality and mortgage delinquencies in different subperiods of the sample. Given that the time period is only 13 years in this panel, these findings should be taken with a pinch of salt. The first period replicates the finding of Table 2.4. The second column shows that income inequality and mortgage delinquencies are negatively associated in the period between 2003 and 2007, when the Fed has been following a contractionary monetary

TABLE 2.6. Income inequality and mortgage delinquency - different sample subperiods

Dependent variable: Percent of Mortgage Debt Balance 90+ Days Delinquent

	(1)	(2)	(3)	(4)	(5)
Gini	12.641**	-9.575**	19.740	18.803***	34.339***
	(4.963)	(4.202)	(12.033)	(5.653)	(10.410)
Log real mean income	-14.387***	-4.110**	-11.512	-11.289**	-15.823
	(5.172)	(1.875)	(9.302)	(4.343)	(13.010)
Log population	-0.945	-1.103	-18.821	-2.405	-41.725
	(4.753)	(5.357)	(17.976)	(4.123)	(31.597)
Homeownership rate	0.091	0.045	0.121	0.024	0.003
	(0.059)	(0.030)	(0.086)	(0.052)	(0.156)
year fe	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes
R-squared within	0.677	0.550	0.652	0.692	0.772
R-squared overall	0.061	0.000	0.062	0.033	0.139
Observations	650	250	300	550	100
Years	2003-2015	2003-2007	2010 -2015	no 2008 & 2009	2008-2009

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

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.

policy. Note that my model implies that low interest rate environments amplify the implications of income inequality on mortgage delinquencies, therefore, the environment with rising interest rates might have overturned the effect in the period before the 2008-2009 financial crisis. The regression results in the subperiod including the financial crisis and thus low interest rate episodes show positive associations between income inequality and mortgage delinquencies. Column 4 shows that even when 2008-2009 period is excluded, the finding holds.

2.3.3 Result 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 2.7 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 is associated with a 13.7% decline in real mortgage

TABLE 2.7. 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.

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 2.8. I find no significant effect of the real rate across all the different specifications.

Finally, I study the robustness of the negative association between income inequality and mortgage debt in different subsamples. Table 2.9 displays the estimation results. The first column displays the results for the full sample. I find that in the run-up to the crisis the negative association between mortgage debt and income inequality is stronger than the case with the full sample, however, it is insignificant in the period after the crisis. The latter period also corresponds to a low interest rate environment which might have mitigated the effect of inequality on mortgage debt.

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

Figures 2.2 to 2.4 display 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, respectively. These figures

TABLE 2.8. 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

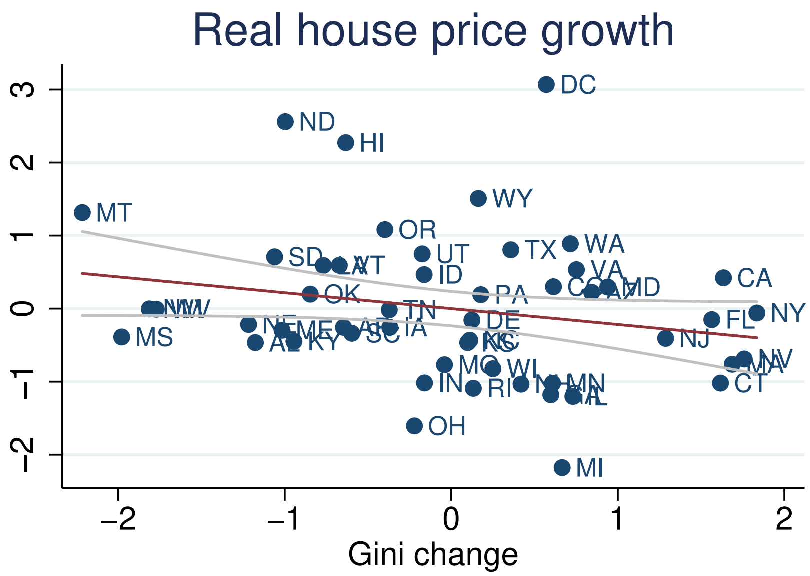
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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. 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.

provide 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 house price growth that is about three standard deviations above the mean over states for this time period. Qualitatively, Figures 2.2 to 2.4 display results in line with those for US counties depicted in Figure 1.2, despite the source of the Gini coefficient being different and averages being calculated over a larger number of time periods.[7]

[7]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.

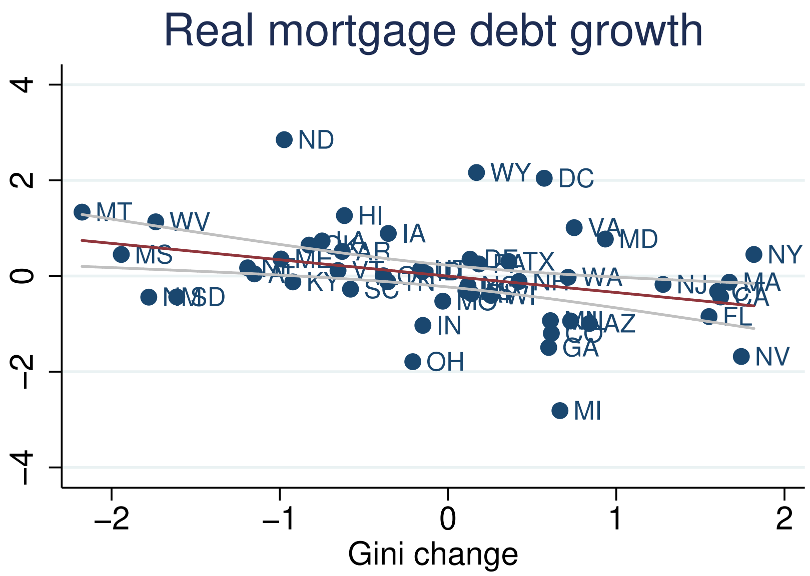
FIGURE 2.2. Between regression result: income inequality and real house prices



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.

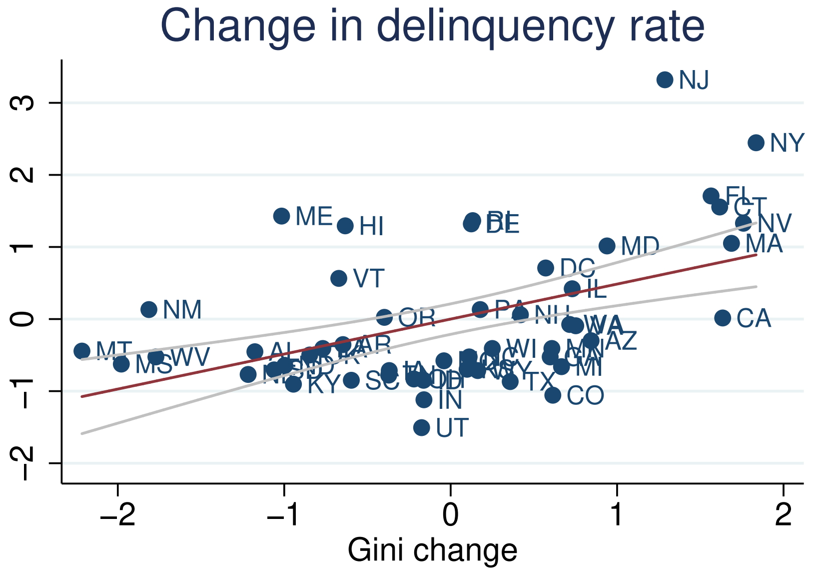
FIGURE 2.3. Between regression result: income inequality and mortgage debt



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.

FIGURE 2.4. Between regression result: income inequality and mortgage delinquency rate



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.

TABLE 2.9. Income inequality and mortgage debt - different sample subperiods

Dependent variable: Real Mortgage Debt Balance per Capita (excluding HELOC)

	(1)	(2)	(3)	(4)	(5)
Gini	-1.016***	-1.904***	0.337	-0.973***	-0.432**
	(0.237)	(0.555)	(0.456)	(0.240)	(0.204)
Log real mean income	0.616***	0.004	-0.194	0.709***	0.315
	(0.098)	(0.144)	(0.232)	(0.103)	(0.211)
Log population	0.634**	0.802	0.767	0.551**	1.631***
	(0.252)	(0.483)	(0.736)	(0.252)	(0.540)
Homeownership rate	0.009*	0.001	0.002	0.006	0.003
	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)
year fe	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes
R-squared within	0.791	0.865	0.785	0.753	0.580
R-squared overall	0.051	0.054	0.002	0.066	0.028
Observations	649	249	300	549	100
Years	2003-2015	2003-2007	2010 -2015	no 2008 & 2009	2008-2009

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

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.

2.3.5 Robustness check: other measures of income inequality

The model's theoretical predictions relate housing and mortgage market developments to that of the Gini coefficient as the measure of income inequality. In this section, I test whether the empirical findings are robust under different measures of income inequality. Additional measures of income inequality considered are relative mean income deviation, Atkinson index, Theil's entropy index and income shares of top 10%, 5% and 1% of the income distribution.[8] Note that, income inequality measures other than the top income shares considers the entirety of the income distribution similar to the Gini coefficient. The purpose of this section is to provide a robustness analysis, rather than taking a stance on what the best measure of income inequality is in explaining housing and mortgage market dynamics.[9] I use the same empirical specifications of 2.1 and 2.2 with state fixed effects, year fixed effects and controls.

[8]All measures are available at Mark Frank's income inequality website https://www.shsu.edu/eco_mwf/inequality.html.

[9]Frank (2014) describes how each inequality measure is calculated and Table 2.2 displays their summary statistics.

First, I document that the negative association between income inequality and house prices is robust under different measures of income inequality. Table 2.5 provides the estimation results. Column (1) replicates the finding from column (3) of Table 2.1 in which mean income, population, home-ownership rate and new housing permits are included as controls. In particular, it is worth noting that a rise in top income shares is associates with declines in house prices rather than an increase. This finding goes against the explanations of local house price movements related to rich getting richer and pushing house prices up in a given location. Similarly, Figure 1.D.2.5 provides county level evidence negating the effect of high income quintiles in determining house price developments. Table 2.6 validates the finding that when the real interest rate is low, the effect of an increase in income inequality corresponds to a small decline in house prices. That is, the coefficient of the interaction term is negative for each of the income inequality measure employed in the regressions, although statistically significant only for the Gini coefficient and relative mean deviation.

Second, I look at the association between mortgage delinquencies and income inequality measures and their interaction with the real rate. Table 2.7 shows the estimation results. Among all alternative inequality measures other than the Gini coefficient, only relative mean income deviation implies a positive association between income inequality and mortgage delinquencies. The mechanism in this paper suggests that a mean preserving increase in the Gini coefficient gives rise to an increase in the aggregate mortgage default risk. This is because a rise in inequality is associated with an increase in the share of population below a threshold income level that determines the selection into risky loans. A mean preserving increase in relative mean deviation can be associated with decreases in incomes below the mean and decreases in incomes above the mean, without changing their population shares. If that is the case then the model would imply that a rise in income inequality should not affect risk in the mortgage market. Alternatively, an increase in relative mean deviation could arise due to polarization of income via increase in population shares of both low and high income households. My model in this case implies that a rise in relative mean income deviation should give rise to an increase in the share of risky borrowers, which is the finding in Column (2) of Table 2.7.[10] As far as top income shares are concerned, the estimation results

[10] Table 2.4 shows that Gini coefficient has the highest Spearman correlation with relative mean income deviation.

in the last three columns of Table 2.7 show that an increase in top income shares is associated with a decline in mortgage delinquencies. While this finding is interesting in its own right, the analytical model employed in this paper might not include all potential channels that can relate the top incomes to housing and mortgage market dynamics.[11] Similar to the Gini coefficient, Theil's and Atkinson indices are measures of inequality for the entirety of the income distribution. Frank (2014) computes the Atkinson index with an inequality aversion parameter that is more sensitive to inequality at the upper income levels and the negative association between income inequality and mortgage delinquencies might be consistent with mechanisms that cannot be addressed with current modeling framework.[12] Lastly, I consider how interest rate environment alter the effect of rising income inequality in mortgage delinquency rate. I find that the interaction term is negative and statistically significant across all income inequality measures implying a rise in real rates contribute to financial stability for a given level of income inequality.

Finally, estimation results in Table 2.9 confirms the third empirical contribution of this paper that an increase in income inequality is associated with a decline in mortgage debt. It's worth noting that the relationship between top income shares and mortgage debt implies that the data is not supportive of the supply side mechanism proposed by Kumhof, Rancière and Winant (2015) at the state level. This evidence still should not be interpreted as a rejection of their theory as the mortgage market does not face the same geographic segmentation as the housing market and mortgage markets. This is particularly the case for the period I consider as it is after the deregulation in the banking sector in the US that allowed nationwide interstate banking.[13] Year fixed effects in my empirical specification allows me to control for any time varying development that would give rise to an increase in the availability of credit at the national level, including that of rising income inequality at the national level as is

[11]Note also that the mechanism in my model works through income levels not income shares and thus a one-to-one mapping as is the case with relative mean deviation is not straight forward. A rise in the top income shares might arise such that incomes increase across the income distribution and population below the income risk cut-off decline and thus risk in the mortgage market also declines.

[12]The relationship between supply of credit and income inequality cannot be addressed with my model. Kumhof, Rancière and Winant (2015) employs a mechanism in which an increase in top 5 % income share gives rise to an increase in the supply of credit and this increases the crisis risk in the economy. Thus at the cross-section a within state interpretation of this mechanism might not hold.

[13] The Riegle-Neal Act allowed the banks hold nationwide branch networks after mid 1997.

the case discussed in Kumhof, Rancière and Winant (2015). In Table 2.10 I show that the level of interest rates does not alter the effect of income inequality on mortgage debt in a statistically significant way, no matter which income inequality measure is considered.

2.4 Conclusions

Income inequality, real house prices and household debt have increased enormously in the US in the last few decades. In this chapter I conduct a panel data analysis that controls for national developments, including declining real rates to study the empirical relationship between income inequality and housing and mortgage markets. I find that a rise income inequality is associated with (i) a decline in house prices, (ii) an increase in mortgage delinquencies and (iii) a decline in mortgage debt. While this finding is at odds with aggregate trends in the US, it verifies the predictions of the theoretical model in Chapter 1 of this thesis.

Tables

TABLE 2.1. Panel data summary statistics: US states (1992-2015)

Variable		Mean	St. 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
Real 10-year rate		1.900	1.273	-0.629	3.658	T = 24
Population in 2015 (thousands)		6406	7150	586	39032	n = 50

Source: FHFA and US Census Bureau.

TABLE 2.2. Panel data summary statistics of income inequality measures: US states (1992-2015)

Variable		Mean	St. 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
Atkinson's entropy index	overall	0.273	0.038	0.207	0.411	N = 1200
	between		0.030	0.227	0.360	n = 50
	within		0.023	0.192	0.348	T = 24
Relative mean deviation	overall	0.827	0.052	0.728	1.016	N = 1200
	between		0.040	0.763	0.931	n = 50
	within		0.034	0.720	0.916	T = 24
Theil's index	overall	0.796	0.189	0.443	1.498	N = 1200
	between		0.166	0.554	1.251	n = 50
	within		0.094	0.434	1.193	T = 24
Top 10% income share	overall	43.258	5.004	32.241	62.171	N = 1200
	between		4.043	36.013	54.278	n = 50
	within		3.000	33.431	52.951	T = 24
Top 5% income share	overall	31.683	5.069	21.421	54.430	N = 1200
	between		4.186	24.981	44.273	n = 50
	within		2.918	19.366	41.840	T = 24
Top 1% income share	overall	16.853	4.510	9.017	36.069	N = 1200
	between		3.701	12.137	27.547	n = 50
	within		2.629	6.668	26.823	T = 24

Source: FHFA and Frank (2014).

TABLE 2.3. Panel data summary statistics: US states (2003-2015)

Variable		Mean	Std. dev	Min	Max	Observations
Log real mortgage debt per capita	overall	4.496778	0.368	3.510	5.438	N = 650
	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	3.049892	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
Gini	overall	0.605039	0.035	0.536	0.711	N = 650
	between		0.029	0.558	0.680	n = 50
	within		0.021	0.551	0.682	T = 13
Atkinson's entropy index	overall	0.286967	0.037	0.216	0.411	N = 650
	between		0.035	0.235	0.387	n = 50
	within		0.015	0.243	0.341	T = 13
Relative mean deviation	overall	0.85041	0.049	0.738	1.016	N = 650
	between		0.045	0.779	0.974	n = 50
	within		0.020	0.776	0.909	T = 13
Theil's index	overall	0.839338	0.204	0.443	1.498	N = 650
	between		0.190	0.564	1.373	n = 50
	within		0.078	0.591	1.152	T = 13
Top 10% income share	overall	45.00692	4.942	34.401	62.171	N = 650
	between		4.503	37.227	57.660	n = 50
	within		2.125	36.444	51.683	T = 13
Top 5% income share	overall	33.25482	5.147	23.262	54.430	N = 650
	between		4.801	25.960	48.006	n = 50
	within		1.965	26.178	40.551	T = 13
Top 1% income share	overall	18.08757	4.611	10.620	36.069	N = 650
	between		4.217	12.767	30.816	n = 50
	within		1.951	11.700	25.006	T = 13

Source: NY Fed Consumer Credit Panel and Frank (2014).

TABLE 2.4. Spearman correlations between income inequality measures: US states (2003-2015)

	Gini	Theil's entropy index	Relative mean deviation	Atkinson's index	Top 10% income share	Top 5% income share	Top 1% income share
Gini	1						
Theil's entropy index	0.495	1					
Relative mean deviation	0.736	0.850	1				
Atkinson's index	0.479	0.979	0.825	1			
Top 10% income share	0.560	0.668	0.779	0.654	1		
Top 5% income share	0.598	0.850	0.826	0.849	0.898	1	
Top 1% income share	0.608	0.905	0.787	0.905	0.764	0.934	1

Source: Frank (2014).

TABLE 2.5. Income inequality and real house prices with different measures of income inequality

Dependent variable: Log real FHFA house price index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.605***						
	(0.243)						
Relative mean deviation		-1.177***					
		(0.419)					
Atkinson index			-0.854*				
			(0.493)				
Theil's entropy index				-0.225**			
				(0.092)			
Top 10% income share					-0.014***		
					(0.002)		
Top 5% income share						-0.013***	
						(0.003)	
Top 1% income share							-0.017***
							(0.004)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	no	no	no	no	no	no	no
R-squared within	0.812	0.795	0.790	0.792	0.808	0.802	0.804
R-squared overall	0.162	0.157	0.186	0.186	0.158	0.174	0.184
Observations	1200	1200	1200	1200	1200	1200	1200
Years	1992-2015	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. Control variables are log real mean income, log population, homeownership rate and log new housing permits. House price index and income variables are deflated by CPI-UR-S series.

TABLE 2.6. Income inequality and real house prices with different measures of income inequality: the effect of the interest rate environment

Dependent variable: Log real FHFA house price index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.339***						
	(0.310)						
Gini x Real 10-year rate	-0.229*						
	(0.134)						
Relative mean deviation		-1.155***					
		(0.417)					
Relative mean deviation x Real 10-year rate		-0.189**					
		(0.093)					
Atkinson index			-0.726				
			(0.522)				
Atkinson index x Real 10-year rate			-0.166				
			(0.131)				
Theil's entropy index				-0.205**			
				(0.096)			
Theil's entropy index x Real 10-year rate				-0.025			
				(0.023)			
Top 10% income share					-0.013***		
					(0.003)		
Top 10% income share x Real 10-year rate					-0.001		
					(0.001)		
Top 5% income share						0.007**	
						(0.003)	
Top 5% income share x Real 10-year rate						-0.001	
						(0.002)	
Top 1% income share							-0.015***
							(0.004)
Top 1% income share x Real 10-year rate							-0.001
							(0.001)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	no	no	no	no	no	no	no
R-squared within	0.815	0.799	0.791	0.793	0.811	0.658	0.805
R-squared overall	0.190	0.177	0.201	0.201	0.173	0.238	0.201
Observations	1200	1200	1200	1200	1200	1200	1200
Years	1992-2015	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. Control variables are log real mean income, log population, homeownership rate and log new housing permits. 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.

TABLE 2.7. Income inequality and mortgage delinquency with alternative measures of income inequality

Dependent variable: Percent of Mortgage Debt Balance 90+ Days Delinquent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	12.641**						
	(4.963)						
Relative mean deviation		1.896					
		(10.175)					
Atkinson index			-30.923**				
			(12.508)				
Theil's entropy index				-5.715**			
				(2.237)			
Top 10% income share					-0.109*		
					(0.054)		
Top 5% income share						-0.079	
						(0.064)	
Top 1% income share							-0.048
							(0.087)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	no	no	no	no	no	no	no
R-squared within	0.677	0.668	0.675	0.676	0.672	0.669	0.668
R-squared overall	0.061	0.087	0.000	0.002	0.049	0.059	0.066
Observations	650	650	650	650	650	650	650
Years	2003-2015	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. Control variables are log real mean income, log population and home-ownership rate. House price index and income variables are deflated by CPI-UR-S series.

TABLE 2.8. Income inequality and mortgage delinquency with alternative measures of income inequality: the effect of the interest rate environment

Dependent variable: Percent of Mortgage Debt Balance 90+ Days Delinquent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	19.925***						
	(6.143)						
Gini x Real 10-year rate	-8.580*						
	(4.377)						
Relative mean deviation		-5.045					
		(8.492)					
Relative mean deviation x Real 10-year rate		-9.658***					
		(2.491)					
Atkinson index			-22.249*				
			(11.917)				
Atkinson index x Real 10-year rate			-11.763***				
			(3.196)				
Theil's entropy index				-4.152*			
				(2.180)			
Theil's entropy index x Real 10-year rate				-2.131***			
				(0.594)			
Top 10% income share					-0.081		
					(0.064)		
Top 10% income share x Real 10-year rate					-0.091***		
					(0.023)		
Top 5% income share						-0.175**	
						(0.081)	
Top 5% income share x Real 10-year rate						-0.102***	
						(0.027)	
Top 1% income share							-0.051
							(0.092)
Top 1% income share x Real 10-year rate							-0.094***
							(0.029)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	no	no	no	no	no	no	no
R-squared within	0.687	0.694	0.702	0.703	0.698	0.672	0.694
R-squared overall	0.006	0.000	0.007	0.005	0.029	0.138	0.002
Observations	650	650	650	650	650	650	650
Years	2003-2015	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. Control variables are log real mean income, log population and home-ownership rate. 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.

TABLE 2.9. Income inequality and mortgage debt with alternative measures of income inequality

Dependent variable: Real Mortgage Debt Balance per Capita (excluding HELOC)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.016***						
	(0.237)						
Relative mean deviation		-2.506***					
		(0.454)					
Atkinson index			-2.352***				
			(0.603)				
Theil's entropy index				-0.411***			
				(0.117)			
Top 10% income share					-0.018***		
					(0.002)		
Top 5% income share						-0.023***	
						(0.002)	
Top 1% income share							-0.025***
							(0.003)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	no	no	no	no	no	no	no
R-squared within	0.791	0.803	0.786	0.786	0.815	0.830	0.821
R-squared overall	0.051	0.059	0.128	0.103	0.099	0.102	0.114
Observations	649	649	649	649	649	649	649
Years	2003-2015	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. Control variables are log real mean income, log population and home-ownership rate. House price index and income variables are deflated by CPI-UR-S series.

TABLE 2.10. Income inequality and mortgage debt with alternative measures of income inequality: the effect of the interest rate environment

Dependent variable: Real Mortgage Debt Balance per Capita (excluding HELOC)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.120***						
	(0.332)						
Gini x Real 10-year rate	0.122						
	(0.185)						
Relative mean deviation		-2.496***					
		(0.440)					
Relative mean deviation x Real 10-year rate		0.014					
		(0.110)					
Atkinson index			-2.498***				
			(0.638)				
Atkinson index x Real 10-year rate			0.198				
			(0.158)				
Theil's entropy index				-0.435***			
				(0.125)			
Theil's entropy index x Real 10-year rate				0.034			
				(0.031)			
Top 10% income share					-0.018***		
					(0.002)		
Top 10% income share x Real 10-year rate					0.001		
					(0.001)		
Top 5% income share						-0.010***	
						(0.003)	
Top 5% income share x Real 10-year rate						0.003*	
						(0.002)	
Top 1% income share							-0.025***
							(0.003)
Top 1% income share x Real 10-year rate							0.000
							(0.001)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	no	no	no	no	no	no	no
R-squared within	0.792	0.803	0.789	0.789	0.816	0.703	0.821
R-squared overall	0.049	0.058	0.108	0.089	0.094	0.016	0.113
Observations	649	649	649	649	649	649	649
Years	2003-2015	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. Control variables are log real mean income, log population and home-ownership rate. 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.

Appendix

2.A Additional panel regression results with all measures of income inequality

TABLE 2.A.1. Income inequality and real house prices with different measures of income inequality

Dependent variable: Log real FHFA house price index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.701***						
	(0.538)						
Relative mean deviation		-0.626					
		(0.676)					
Atkinson index			-0.632				
			(0.658)				
Theil's entropy index				-0.208			
				(0.126)			
Top 10% income share					-0.013***		
					(0.004)		
Top 5% income share						-0.009**	
						(0.004)	
Top 1% income share							-0.013**
							(0.006)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	yes	yes	yes	yes	yes	yes	yes
R-squared within	0.813	0.794	0.793	0.794	0.806	0.798	0.801
R-squared overall	0.274	0.299	0.315	0.321	0.291	0.321	0.330
Observations	1200	1200	1200	1200	1200	1200	1200
Years	1992-2015	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. Control variables are log real mean income, log population, home-ownership rate and log new housing permits. House price index and income variables are deflated by CPI-UR-S series.

TABLE 2.A.2. Income inequality and real house prices with different measures of income inequality: the effect of the interest rate environment

Dependent variable: Log real FHFA house price index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.317***						
	(0.368)						
Gini x Real 10-year rate	-0.493***						
	(0.183)						
Relative mean deviation		-0.840					
		(0.728)					
Relative mean deviation x Real 10-year rate		-0.301*					
		(0.152)					
Atkinson index			-0.691				
			(0.547)				
Atkinson index x Real 10-year rate			-0.360**				
			(0.136)				
Theil's entropy index				-0.220**			
				(0.091)			
Theil's entropy index x Real 10-year rate				-0.069***			
				(0.023)			
Top 10% income share					-0.010***		
					(0.003)		
Top 10% income share x Real 10-year rate					-0.003***		
					(0.001)		
Top 5% income share						0.013***	
						(0.003)	
Top 5% income share x Real 10-year rate						-0.002*	
						(0.001)	
Top 1% income share							-0.013***
							(0.004)
Top 1% income share x Real 10-year rate							-0.003***
							(0.001)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	yes	yes	yes	yes	yes	yes	yes
R-squared within	0.828	0.804	0.800	0.802	0.816	0.704	0.812
R-squared overall	0.378	0.392	0.366	0.375	0.331	0.253	0.378
Observations	1200	1200	1200	1200	1200	1200	1200
Years	1992-2015	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. Control variables are log real mean income, log population, home-ownership rate and log new housing permits. 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.

TABLE 2.A.3. Income inequality and mortgage delinquency with alternative measures of income inequality

Dependent variable: Percent of Mortgage Debt Balance 90+ Days Delinquent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	15.995						
	(9.782)						
Relative mean deviation	7.823						
		(19.916)					
Atkinson index			-35.297				
			(30.378)				
Theil's entropy index				-6.512			
				(5.583)			
Top 10% income share					-0.236**		
					(0.107)		
Top 5% income share						-0.138	
						(0.117)	
Top 1% income share							-0.038
							(0.170)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	yes	yes	yes	yes	yes	yes	yes
R-squared within	0.714	0.708	0.712	0.712	0.717	0.710	0.708
R-squared overall	0.003	0.003	0.013	0.011	0.007	0.005	0.005
Observations	650	650	650	650	650	650	650
Years	2003-2015	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. Control variables are log real mean income, log population and home-ownership rate. House price index and income variables are deflated by CPI-UR-S series.

TABLE 2.A.4. Income inequality and mortgage delinquency with alternative measures of income inequality: the effect of the interest rate environment

Dependent variable: Percent of Mortgage Debt Balance 90+ Days Delinquent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	21.919**						
	(10.678)						
Gini x Real 10-year rate	-14.402**						
	(5.522)						
Relative mean deviation		-22.733					
		(16.104)					
Relative mean deviation x Real 10-year rate		-14.336***					
		(2.681)					
Atkinson index			-44.724**				
			(18.350)				
Atkinson index x Real 10-year rate			-18.728***				
			(3.893)				
Theil's entropy index				-7.978**			
				(3.403)			
Theil's entropy index x Real 10-year rate				-3.473***			
				(0.688)			
Top 10% income share					-0.202**		
					(0.093)		
Top 10% income share x Real 10-year rate					-0.126***		
					(0.022)		
Top 5% income share						-0.388***	
						(0.144)	
Top 5% income share x Real 10-year rate						-0.147***	
						(0.033)	
Top 1% income share							-0.144
							(0.145)
Top 1% income share x Real 10-year rate							-0.143***
							(0.022)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	yes	yes	yes	yes	yes	yes	yes
R-squared within	0.734	0.744	0.752	0.755	0.751	0.712	0.745
R-squared overall	0.013	0.021	0.025	0.023	0.011	0.057	0.013
Observations	650	650	650	650	650	650	650
Years	2003-2015	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. Control variables are log real mean income, log population and home-ownership rate. House price index and income variables are deflated by CPI-UR-S series.

TABLE 2.A.5. Income inequality and mortgage debt with alternative measures of income inequality

Dependent variable: Real Mortgage Debt Balance per Capita (excluding HELOC)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.004**						
	(0.404)						
Relative mean deviation		-2.467***					
		(0.723)					
Atkinson index			-3.032***				
			(1.063)				
Theil's entropy index				-0.566***			
				(0.188)			
Top 10% income share					-0.023***		
					(0.003)		
Top 5% income share						-0.026***	
						(0.003)	
Top 1% income share							-0.027***
							(0.006)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	yes	yes	yes	yes	yes	yes	yes
R-squared within	0.809	0.821	0.812	0.814	0.843	0.846	0.838
R-squared overall	0.053	0.035	0.094	0.084	0.101	0.115	0.120
Observations	649	649	649	649	649	649	649
Years	2003-2015	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. Control variables are log real mean income, log population and home-ownership rate. House price index and income variables are deflated by CPI-UR-S series.

TABLE 2.A.6. Income inequality and mortgage debt with alternative measures of income inequality: the effect of the interest rate environment

Dependent variable: Real Mortgage Debt Balance per Capita (excluding HELOC)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gini	-1.024**						
	(0.460)						
Gini x Real 10-year rate	0.048						
	(0.236)						
Relative mean deviation		-2.673***					
		(0.584)					
Relative mean deviation x Real 10-year rate		-0.097					
		(0.145)					
Atkinson index			-2.999***				
			(1.047)				
Atkinson index x Real 10-year rate			0.065				
			(0.243)				
Theil's entropy index				-0.562***			
				(0.185)			
Theil's entropy index x Real 10-year rate				0.010			
				(0.045)			
Top 10% income share					-0.023***		
					(0.003)		
Top 10% income share x Real 10-year rate					0.001		
					(0.001)		
Top 5% income share						-0.010**	
						(0.004)	
Top 5% income share x Real 10-year rate						0.002	
						(0.002)	
Top 1% income share							-0.028***
							(0.005)
Top 1% income share x Real 10-year rate							-0.001
							(0.001)
year fe	yes	yes	yes	yes	yes	yes	yes
state fe	yes	yes	yes	yes	yes	yes	yes
controls	yes	yes	yes	yes	yes	yes	yes
population weight	yes	yes	yes	yes	yes	yes	yes
R-squared within	0.809	0.822	0.812	0.814	0.844	0.758	0.839
R-squared overall	0.052	0.035	0.089	0.081	0.095	0.011	0.131
Observations	649	649	649	649	649	649	649
Years	2003-2015	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. Control variables are log real mean income, log population and homeownership rate. 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.

Chapter 3

Global Banks and International Transmission of Financial Shocks

This chapter analyses the role of global banks in international transmission of shocks under financial sector heterogeneity across countries. In particular, (i) bank capital requirements and (ii) firm borrowing constraints are different across countries. I show that a financial shock might give rise to a global decline in real output if the shock originates in the country with loose firm borrowing constraints. Moreover, tight borrowing constraints and high bank capital requirements are associated with limited economic contraction and fast recovery following a financial shock, independent of its origin.

3.1 Introduction

Recent financial crisis has shown how a shock undergone in developed countries turned into a global slump and highlighted the importance of the contraction in global banking activity. The decline in global lending during the crisis was observed along two dimensions: the drying-up of international interbank market and the decrease in intra-banking group lending of the multinational banks. Although, the two sources are of similar order of magnitude (Cetorelli and Goldberg (2012b)), during the financial crisis intra-group positions did not fall as sharply as interbank flows between unaffiliated parties (CGFS (2010)). Moreover, Cetorelli and Goldberg (2012a) show that internal funding reallocation has been a common characteristic of global banks' conduct, observable in normal times and not just in times of crisis.[1] Thus a better understanding of the underlying transmission channel is of great significance to design policies to prevent such financial turmoils and minimize the costs in the event of a crisis.

The Synchronized declines in global economic and banking activity renewed attention to the role of financial markets for the international transmission of shocks.[2] Recent literature reaches a common conclusion that introducing a financial sector into the benchmark international business cycle model helps improve the model predictions regarding the business cycle correlations across countries.[3] Kalemli-Ozcan et al. (2013) and Kollmann et al. (2011) show that financial shocks to a global bank's assets forces the global bank to decrease lending globally. This gives rise to a simultaneous decline in output across countries as entrepreneurs need bank loans to finance expenses. On the other hand, both papers predict a negative international spillover of a real shock similar to Backus et al. (1992). Therefore, the degree of business cycle synchronization depends on whether real or financial shocks dominate the economy.

The above mentioned studies assume that the countries that comprise the world economy are symmetric not only in the technology but also in the

[1] CGFS (2010) also shows that multinational banks raise liquidity from various jurisdictions and conduct liquidity management activating the internal markets to shift liquidity to regions experiencing relative scarcity.

[2] See among many others Perri and Quadrini (2018), Mendoza and Quadrini (2010), Dedola and Lombardo (2012) and Ueda (2012)

[3] Backus et al. (1992) show that following a productivity shock, the country experiences an increase in marginal product of its inputs, receives capital from the rest of the economy and thus GDP increases. However, the capital outflow from the nonaffected country implies decline in economic activity and thus negative spillovers.

degree of financial frictions. In this paper, I relax the second assumption within the framework of a two-country international business cycle model with a global bank and show that the asymmetry in the financial sector has important implications for the dynamics of the global economic activity.[4] Specifically, two types of asymmetries are considered: first, a global bank faces different bank capital constraints across countries; and second, the countries differ in the level of borrowing constraints faced by firms. A global bank manages liquidity centrally and reallocates resources across its offices in different countries and it is costly to deviate from the required bank capital ratio in each location. Therefore, through managing the liquidity in the central treasury and transferring funds from one office to the other, it can minimize the total capital requirement cost. The rest of the economy is rather standard. Each country is comprised of households and entrepreneurs. Households provide labor to the domestic firm and allocate resources to consumption and savings in terms of deposits with the global bank. Entrepreneurs in both countries produce a homogeneous good with the same technology using capital and labor and this good can be traded freely. An entrepreneur accumulates capital and borrows from the global bank to finance investment. However, only an exogenous fraction of investment can be covered with bank loans. As I assume that the countries are symmetric in the real side of the economy. Therefore, the higher is the fraction of investment that can be financed with bank loans, the higher is credit-to-GDP ratio.

In the benchmark calibration, I assume that one of the countries is characterized by both higher bank capital requirement and lower firm borrowing constraint compared to the other.[5] I define this country as the most developed-most regulated country.[6] First, I show that a real shock implies divergence in GDP dynamics across countries as is the case under conventional international business cycle models (e.g. Backus et al. (1992)). Following a negative productivity shock, GDP declines

[4]Mendoza and Quadrini (2010), Mendoza et al. (2009), Caballero et al. (2008), Aoki et al. (2009) assume heterogeneous degree of domestic financial development across countries. However, these models do not incorporate a global bank that can use internal capital market as in this paper. Therefore, the implications of intra-banking group positions cannot be analyzed within the framework of these papers.

[5]Kollmann et al. (2011) suggest that bank capital ratio is 7-8% for the US global banks, where as same ratio is 4-5% for the European ones. Although, the aim of this paper is not to focus on US-EU business cycle synchronization, I use this calibration as the benchmark.

[6]Note that this definition of financial development can equally be interpreted as degree of exposure to the global bank lending or a country's share in total bank assets. Throughout the paper, I use these terms interchangeably. My definition of financial development is similar to that of Aoki et al. (2009) that assumes heterogeneous collateral constraints for firm borrowing across countries.

as investment and consumption decrease in the country that is hit by the shock. Lower investment implies lower demand for bank loans and intra-banking group lending flows to the nonaffected country as it has relatively higher productivity. Higher supply of loans available gives rise to an increase in investment and GDP in the nonaffected country. Although the countries differ in the domestic financial market structure, a productivity shock in either country results in a similar international transmission and GDP in each country responds in a symmetric way. Thus, the first important finding of this paper is to show that for the international transmission of a productivity shock, the source of the shock is immaterial. This is not the case for the financial shocks, which is the second important finding of this paper.

A financial shock results in a decline in GDP in both countries. However, the severity of global downturn and the difference in the GDP dynamics across countries depends on whether the financial crisis started in the most developed-most regulated country or not. Since the bank dividends from each country are perfect substitutes for the bank shareholder, the source of the bank capital loss does not matter when allocating the loans to each country but it affects the significance of the contraction in financial intermediation. A financial shock that hits the most developed-most regulated country gives rise to a more pronounced global GDP decline compared to a similar shock in the least developed-least regulated country. Since the most developed country comprises a higher share of total bank assets compared to the other country, a default shock in this country implies a significant bank capital loss and global bank decreases total loans available to a larger extent than a default shock in the least developed country would call for. Following a financial shock, loans to least developed-least regulated country increase but loans to the most developed-most regulated country decrease. Therefore, investment increases in the least regulated-least developed country and decreases in the other as the entrepreneurs in each country are constrained and need bank loans to finance their investment. GDP recovers after a short period of time in least developed-least regulated country; on the other hand, GDP decline lasts for a longer time in the most developed-most regulated country. Thus, the differences in the financial constraints across countries gives rise to differences in the duration of a recession and have implications for the business cycle synchronization.

To analyze the relevance of each financial constraint separately, I calibrate the model so that countries so that they differ in one constraint at a time. First, I consider the case with equal regulation and different levels of financial development. Following a default shock in either country, the less developed a country is, the lower is the GDP decline and the shorter the recession lasts compared to the other one. More developed country undergoes a persistent GDP decline due to a decline in bank loans and thus in investment. Moreover, the higher is the financial development in a country, the higher is the global GDP decline following a financial shock in that country. Second, I analyze the relevance of difference across countries in banking regulation and thus the countries are assumed to be equal in the level of financial development. Following a financial shock, the less regulated a country is, the shorter the recession lasts and the economy starts to expand after a short period of time. On the other hand, the most regulated country experiences a persistent GDP fall, amount of which is higher the higher is the constraint on bank capital. Finally, once the countries are assumed to be symmetric in both banking regulation and the level of financial development, it does not matter for the global GDP dynamics which country is hit by the financial shock and GDP in each country displays the same dynamics. This finding is consistent with those of Kollmann et al. (2011) and Kalemli-Ozcan et al. (2013). The contribution of this paper is to show that once symmetric countries assumption is relaxed, the global implications of financial shocks crucially depends on the underlying financial conditions in the country from which the financial turmoil originates.

Although the paper does not include a policy or welfare analysis, the findings still have intuitive policy implications. First, prudential policy of reducing the bank borrowing via increasing the borrowing margin can lower the global cost of a financial crisis.[7] A national financial policy of this kind is beneficial for the other countries as well. Second, decreasing the bank capital requirement as an ex-post policy intervention might mitigate the costs of a financial crisis. In contrast to the prudential policy, lowering the national bank capital requirement might imply negative international repercussions. Therefore, international cooperation in both prudential and ex-post financial policies might matter for global welfare.

The remainder of this paper is organized as follows. Section 2 highlights the differences in modeling assumptions of the current paper and the related literature. Section 3 introduces the quantitative model. Section 4

[7] The borrowing margin can be increasing by applying a tax on borrowing or tightening the borrowing constraint as suggested by Bianchi (2011).

presents the impulse response analysis. Section 5 concludes and discusses policy implications.

3.2 Related Literature

In this section I review the theoretical literature on international transmission of shocks with two different types of financial intermediaries: multinational intermediaries that operate locally in both countries and international intermediaries that engage in cross-border lending and borrowing.[8]

This paper is closest to the papers in the first line of literature, in particular, to Kollmann et al. (2011) and Kalemli-Ozcan et al. (2013). Both papers model a global bank intermediating in two symmetric countries by taking deposits and issuing loans. While Kollmann et al. (2011) assumes perfect financial integration, Kalemli-Ozcan et al. (2013) models the world such that only an exogenous fraction of each economy has access to global bank intermediation. Both papers find that following a financial shock, the global bank decreases loans to both countries and financial integration gives rise to higher business cycle synchronization. This paper shows that this finding is a result of the assumption that the countries are symmetric. To reach this conclusion I introduce two types of heterogeneities across countries. First, I assume that the global bank is constrained with possibly differing levels in both countries. This is because the subsidiaries of global banks are separate legal entities and are subject to bank capital requirement in the host country. Kollmann et al. (2011) assumes that the global bank faces a single aggregate bank capital constraint although it operates in two different countries.[9] In this paper I show that different levels of bank capital requirement has important implications for business cycle synchronization.

Second, in my model the firms face a borrowing constraint, i.e. they can finance only a given fraction of their investment via bank lending. Kollmann et al. (2011) focuses only on implications of financially constrained lenders, thus this aspect is absent in their model. Kalemli-Ozcan et al. (2013) assumes that the firms face a working capital constraint

[8] Although this paper is related to the international business cycles literature in the broadest sense, to emphasize the contribution of this paper I focus on a narrower branch of this literature in which financial intermediaries are at play. See also Buch et al. (2018) for the results from internationally coordinated project by the International Banking Research Network (IBRN) on the transmission of monetary policy through global banks across countries.

[9] This type of modeling is consistent with a global bank structure with a branch instead of a subsidiary.

and have to borrow from a bank to pay the wages, which is uniform across countries. I assume that the entrepreneurs in each country face different levels of borrowing constraints and show that this heterogeneity matters significantly for the transmission of financial shocks. Finally, in this paper having a global bank does not necessarily mean perfect financial integration unless the firms are unconstrained. That is, although a global bank implies perfectly integrated capital markets, the degree of exposure to the international financial market developments differ with the borrowing constraint; higher borrowing constraint in a country implies lower share in total banks assets and less dependence on or ability to access bank loans. A failure in global banking activity is then of less cost for the country that finances a relatively less share of investment via bank lending.

Finally, the assumptions of this paper has implications also for the determination of optimal portfolio of the global bank balance sheet and the rates of deposits and loans. In my model, the optimal portfolio is endogenously determined and the global bank can charge different loan and deposit rates across countries which is consistent with reality. Kollmann et al. (2011) and Kalemli-Ozcan et al. (2013) imposes that global bank charges equal rates across countries, which results only as a special case in this paper.[10] While determining the optimal balance sheet, Kollmann et al. (2011) assumes a deposit in the utility function, which produces a deposit supply and avoids balance sheet indeterminacy. Moreover, Kalemli-Ozcan et al. (2013) assumes a given asset portfolio with a given fraction of the risky asset, innovations to price of which is the financial shock.

While the above studies employ a multinational bank set up, to analyze the relevance of financial integration Ueda (2012) and Dedola and Lombardo (2012) use models with financial intermediaries that are located in one of the countries and engage in cross-border lending and borrowing. Both papers employ credit contracts based on the financial accelerator model by Bernanke et al. (1999) and assume that the financial intermediaries are credit constrained as in this paper. Following a financial shock, the net worth of the financial intermediary deteriorates and lending to both countries' entrepreneurs declines and thus GDP drops in both countries. As is standard in the literature, these papers focus also on symmetric countries in terms of financial frictions. An exception is

[10] Kollmann et al. (2011) model implies that effective loan rates, loan rate net of expected default rate, to equal across countries. In this paper, the difference in loan rates depends on the differences in deviations from bank capital requirement in each country.

Mendoza and Quadrini (2010), which allow the countries to differ in stages of financial development. Similar to this paper, the definition of financial development is associated with the borrowing constraint for both households and entrepreneurs. Another commonality with this paper is that the bank in each country is subject to a capital requirement, however, it is assumed to be uniform across countries. Mendoza and Quadrini (2010) considers a financial shock only in the most developed country and show that it gives rise to a decrease in bank lending in both countries. The absence of internal capital markets of a global bank and different banking regulations might be the source of the difference in predictions across two models. As mentioned elsewhere intra-banking group flows that are optimally set in this paper are important in size and understanding their properties is crucial for the international transmission of shocks, which is missing in the existing models with heterogeneous levels of financial development across countries.

3.3 Model

In this section I develop a two-country model with a representative global bank operating in both countries. In each country there is a representative household and a representative firm. The representative bank collects deposits from households and makes loans to entrepreneurs both in *Home* and *Foreign* country. The entrepreneurs get a loan to finance a given fraction of their investment. The countries differ in the level of financial development, which is associated with the fraction of investment that can be financed via bank borrowing. An identical final good is produced in both countries using labor and capital. While the final good is traded freely across countries, the inputs of production are not.

The representative global bank manages cash flows in the central treasury and transfers liquidity between its offices in order to maximize the shareholder's utility, who consumes bank dividends. In doing so it faces different capital requirement constraints across countries deviations from which incurs costs. Thus, the global bank optimally sets the amount of intra-banking group transfers and thus bank capital held in each country. Difference across countries in financial constraints faced by firms and global banks determine whether *Home* or *Foreign* office of a global bank transfers liquidity to the other office.

3.3.1 Households

In each country there is a continuum of identical infinitely lived households whose preferences are given by:

$$\max_{C_t, N_t, D_{t+1}} \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \tag{3.1}$$

Each period households decide on level of consumption, C_t, and savings in the form of domestic bank deposits, D_{t+1}. They receive labor income $w_t N_t$, where w_t is the wage rate, and dividends π_t from firms.[11] The deposits set in the previous period yield a gross rate of return Q_t. Therefore the household's budget constraint is:

$$C_t + D_{t+1} = w_t N_t + Q_t D_t + \pi_t \tag{3.2}$$

Consumers' problem is to choose consumption, labor, and bank deposits to maximize life-time utility defined in Equation 3.1 subject to Equation 3.2 taking as given the deposit rates and wages. Substituting consumption from the budget constraint gives the following first order conditions:

$$U_c(C_t, N_t) w_t = -U_l(C_t, N_t) \tag{3.3}$$

$$U_c(C_t, N_t) = \beta E_t \{Q_{t+1} U_c(C_{t+1}, N_{t+1})\} \tag{3.4}$$

where U_C and U_l are marginal utility from consumption and disutility from labor, respectively. Therefore at steady state Q is given by $1/\beta$. As will be shown in the following sections, the deposit rate will equal across countries and implies perfect risk sharing.[12]

3.3.2 Firms

Firms in both countries use capital K_t and labor N_t to produce the consumption good with a constant return to scale technology. They accumulate capital, finance investment with loans from the bank and pay back next period with gross loan rate of R^l_{t+1}. This assumption relates the real economy and the bank intermediation. I assume that a firm can finance only a fraction θ of the investment via bank loans. A higher θ implies that the firm faces a lower borrowing constraint or the global bank is more willing to provide loans. Thus, it can also be interpreted as a measure for the level of financial development.

[11] As in Kalemli-Ozcan et al. (2013) I assume *Home* bias in equity holding.

[12] Log utility in both countries implies equal rate of increase in consumption.

A firm sets labor demand N_t, loan demand L_{t+1} and investment X_t in order to maximize discounted dividend income. Since I assume that the entrepreneurs are part of the household, the dividend income is discounted by household marginal utility. Capital next period follows a capital accumulation function where there are quadratic adjustment costs. Therefore, the firms problem is given as

$$\max_{N_t, L_{t+1}, X_t, K_{t+1}} \sum_{t=0}^{\infty} \beta U_c(C_t, N_t)\pi_t \tag{3.5}$$

where

$$\pi_t = A_t F(K_t, N_t) + L_{t+1} - w_t N_t - (R_t - \iota_t)L_t - X_t \tag{3.6}$$

subject to

$$L_{t+1} \leq \theta X_t \tag{3.7}$$

$$K_{t+1} = (1-\delta)K_t + X_t - \frac{\phi}{2} K_t \left(\frac{X_t}{K_t} - \delta \right)^2 \tag{3.8}$$

$$K_0 \tag{3.9}$$

where π_t is the period t dividend of a firm which is given by the value of production plus the current period loans from the bank, minus the wage bill, interests payments on loans from the previous period and investment, δ is the depreciation rate and ϕ is the magnitude of capital adjustment cost. The payment for the previous period loans might exogenously get lower than the loan rate charged by the bank, with a rate of ι_t per loan borrowed. One may interpret this as a partial default on loans.[13]

I assume that the firm borrowing constraint binds at all times $L_{t+1} = \theta X_t$.[14] Substituting this into the firms' optimization problem above gives

[13]Kollmann et al. (2011) model loan default shock as a ratio to the loan rate $(1 - \iota_t)R_t$.

[14]Both Kalemli-Ozcan et al. (2013) and Kollmann et al. (2011) abstract from constraints on the firm side and thus this kind of heterogeneity in a framework with a global bank is not addressed in these papers.

the following first order conditions:

$$N_t: \qquad A_t F_N(K_t, N_t) - w_t = 0 \tag{3.10}$$

$$X_t: \qquad -(1-\theta)U_c(C_t, N_t) + \mu_t\left(1 - \phi\left(\frac{X_t}{K_t} - \delta\right)\right) - \beta E_t\{(R_{t+1} - \iota_{t+1})U_c(C_{t+1}, N_{t+1})\theta\}\} = 0 \tag{3.11}$$

$$K_{t+1}: \qquad \beta\mu_{t+1}\left(1 - \delta + \phi E_t\left\{\frac{X_{t+1}^2}{K_{t+1}^2} - \delta^2\right\}\right) - \mu_t + \beta E_t\{U_c(C_{t+1}, N_{t+1})A_{t+1}F_k(K_{t+1}, N_{t+1})\} = 0 \tag{3.12}$$

where μ_t is the Lagrange multiplier associate with the capital accumulation rule 3.8 and $F_i(.,.)$ is the derivative of the production function with respect to input $i = K_t, N_t$.

Since labor market is perfectly competitive, the workers are paid their marginal product. Note that Equation (3.11) implies to a downward sloping loan demand curve. that is, ceteris paribus, higher loan rate implies lower investment and thus lower loan demand.

Finally, as is standard in the literature, I assume that the log productivity and the partial default follow AR(1) processes:

$$\ln A_t = \rho_a \ln A_{t-1} + \epsilon_{a,t} \tag{3.13}$$

$$\iota_t = (1 - \rho_\iota)\iota + \rho_\iota \iota_{t-1} + \epsilon_{\iota,t} \tag{3.14}$$

where ι steady state level of partial default.

3.3.3 Global Banks

A representative global bank collects deposits from households and lend to firms in both countries. Moreover, there are intra-banking groups transfers such that both *Foreign* and *Home* office of a global bank might lend to the office of its banking group in the other country. Table 3.1 displays the balance sheet of a representative global bank. In period t, the *Home* office of a global bank receives deposits D_{t+1} from households and makes loans L_{t+1} to firms in *Home* country. *Home* office can also transfer funds H_{t+1} to and receive funds F_{t+1} from the *Foreign* office of the banking group. Ψ_{t+1} is then bank capital of a global bank in *Home* country.

TABLE 3.1. Global Banks' balance sheet in *Home* and *Foreign* country

***Home* Subsidiary**		***Foreign* Subsidiary**	
Assets	Liabilities	Assets	Liabilities
L_{t+1}	D_{t+1}	L^*_{t+1}	D^*_{t+1}
H_{t+1}	F_{t+1}	F_{t+1}	H_{t+1}
	Ψ_{t+1}		Ψ^*_{t+1}

In this paper a global bank manages liquidity centrally and decides on allocating bank capital across locations in order to maximize total dividends from operating in both countries. By moving liquidity raised in one country to the other, a global bank can also minimize the total cost of intermediation, which can result from different bank capital regulations in each country.[15]

Bank capital of each office should be more than a given fraction of the loans issued to firms by the bank office: $\gamma(L_{t+1} + H_{t+1}) \leq \Psi_{t+1}$ and $\gamma^*(L_{t+1} + F_{t+1}) \leq \Psi^*_{t+1}$. One may interpret this as a legal requirement or as an exogenous targeted leverage which might be a result of market pressures in each location.[16] Organizational structure that is in line with the legal requirement explanation is *Foreign* office being a subsidiary, which is subject to the capital requirement regulations in the *Foreign* country; instead of a branch, which is subject to the requirements in the *Home* country.[17]

Similar to Gerali et al. (2010), I assume the bank faces a quadratic cost if it deviates from the targeted capital ratio in each country. Therefore, it is costly to hold both excess and an insufficient amount of bank capital. Excess bank capital in *Home* bank office is then given as:

$$\Omega_t = \Psi_{t+1} - \gamma(L_{t+1} + H_{t+1}) = (1-\gamma)(L_{t+1} + H_{t+1}) - F_{t+1} - D_{t+1} \quad (3.15)$$

[15] CGFS (2010) reviews the funding patterns of globally active banks and one reason for the centralization of liquidity management is to minimize the total cost of intermediation as the banking group.

[16] Kiyotaki and Moore (2005) assume that the banker can abscond a fraction γ of the bank's assets without a cost. Incentive compatibility then implies that the bank capital(equity) cannot fall below the assets with which the banker can walk away with: $\Psi_{t+1} \geq \gamma L_{t+1}$. This type of modeling is an example for market pressures approach to have required level of capital, which ensures that the bank shareholders act in the interest of the depositors.

[17] Following the financial crisis, one can argue that the difference between a branch and subsidiary mode of representation in a host country has declined. This is because global banks that have high foreign representation in a host country, i.e. global systemically important banks, are also subject to additional capital buffers even if they have only branches in a host economy.

For the *Foreign* office excess bank capital is[18] :

$$\Omega_t^* = \Psi_{t+1}^* - \gamma^*(L_{t+1}^* + F_{t+1}) = (1-\gamma^*)(L_{t+1}^* + F_{t+1}) - H_{t+1} - D_{t+1}^* \tag{3.16}$$

Note that, if a bank falls short of the bank capital requirement, then, excess bank capital is a negative amount and banks bear a cost. This can be interpreted as a portfolio adjustment cost for the bank. The idea is that when the bank has less than required level of capital, equivalently more leveraged than the target, it will have to tap interbank market or to find out creative ways of finance which will be costly. A quadratic cost function implies that it is also costly to hold excess capital, although it doesn't violate the legal capital requirement. One can argue that holding excess capital is foregone dividends for a global bank's shareholders and thus deviations from a target bank capital ratio is also costly.

A representative global bank maximizes the shareholder's utility derived from consuming total banking group dividends, where bank dividends raised in *Home* and *Foreign* offices are perfect substitutes

$$max \sum_{t=0}^{\infty} \beta^b U(B_t) = \sum_{t=0}^{\infty} \beta^b \frac{B_t^{1-\sigma^b}}{1-\sigma^b} \tag{3.17}$$

where B_t is the total dividends from operating in *Home* and *Foreign* countries, σ^b is the risk aversion parameter. The dividends earned from intermediation in each country are defined as:

$$B_t = q_t + q_t^* \tag{3.18}$$

$$q_t = D_{t+1} - L_{t+1} - (H_{t+1} + F_{t+1}) + (R_t - \iota_t)L_t - R_t^f(F_t - H_t) - Q_t D_t - \frac{\xi}{2}\Omega_t^2 \tag{3.19}$$

$$q_t^* = D_{t+1}^* - L_{t+1}^* + (H_{t+1} + F_{t+1}) + (R_t^* - \iota_t^*)L_t^* - Q_t^* D_t^* + R_t^f(F_t - H_t) - \frac{\xi}{2}\Omega_t^{*2} \tag{3.20}$$

where q_t and q_t^* are dividends from the *Home* and the *Foreign* office, respectively. Again, R_t is the loan rate and Q_t is the deposit rate in *Home* country. Different than Kalemli-Ozcan et al. (2013) and Kollmann et al. (2011), I allow the loan rate R_t^* and deposit rate Q_t^* to differ from those in *Home* country. I assume that banks face a partial default risk or credit loss risk ι_t (ι_t^*) per unit of loan issued in *Home* (*Foreign*) country, which is non

[18]Note that excess capital Ω_t can also be written as excess inverse leverage $\tilde{\Omega}_t = \frac{K_{t+1}^b}{N_{t+1}} - \frac{1}{\gamma}$ as in Gerali et al. (2010) , thus $\tilde{\Omega}_t = \frac{\Omega_t}{L_{t+1}}$.

zero at steady state.[19] Note that since the income flow is managed centrally, deposit payments and interest earned on deposits from interoffice lending cancel out. This is consistent with the centralized business model.

The problem implies the following first order conditions:

$$L_{t+1}: \quad U'(B_t)(1+\xi(1-\gamma)\Omega_t) = \beta^b E_t\{(R_{t+1}-\iota_{t+1})U'(B_{t+1})\} \quad (3.21)$$
$$L^*_{t+1}: \quad U'(B_t)(1+\xi(1-\gamma^*)\Omega^*_t) = \beta^b E_t\{(R^*_{t+1}-\iota^*_{t+1})U'(B_{t+1})\} \quad (3.22)$$
$$D_{t+1}: \quad U'(B_t)(1+\xi\Omega_t) = \beta^b Q_{t+1} E_t U'(B_{t+1}) \quad (3.23)$$
$$D^*_{t+1}: \quad U'(B_t)(1+\xi\Omega^*_t) = \beta^b Q^*_{t+1} E_t U'(B_{t+1}) \quad (3.24)$$
$$F_{t+1}: \quad \xi\Omega_t = \xi(1-\gamma*)\Omega^*_t - \lambda^*_t \quad (3.25)$$
$$H_{t+1}: \quad \xi(1-\gamma)\Omega_t = \xi\Omega^*_t + \lambda_t \quad (3.26)$$
$$CQ: \quad H_{t+1}\lambda_t = 0 \quad (3.27)$$
$$CQ: \quad F_{t+1}\lambda^*_t = 0 \quad (3.28)$$

Increasing loans to *Home*, L_{t+1}, implies lower dividends and higher excess capital at time t, but results in higher expected interest earnings at period $t+1$. Therefore, Equation (3.21) shows that optimal amount of L_{t+1} equalizes marginal cost to marginal benefit of increasing L_{t+1} at time t. Moreover, it gives the upward sloping loan supply in *Home*: everything else constant, higher loan rate implies higher excess capital and thus higher loans. Similarly, higher deposits from *Home*, D_{t+1}, increases dividends at time t and lowers the excess capital and thus the cost related to it, however, implies higher interest payment at period $t+1$ as shown in Equation (3.23).

Equation (3.26) shows that setting the intra-group transfers is an intra temporal choice and optimal H_{t+1} is such that the cost of increasing excess regulative capital in *Home* country office is equal to benefit from decreasing the same cost in the *Foreign* office, through increasing excess bank capital in *Home* and decreasing it in the *Foreign* country. Equation (3.25) states the same for deposits of *Foreign* office in *Home* one. Constraint qualification conditions ensure that both H_{t+1} and F_{t+1} are non-negative. As it will be shown in the next section, in equilibrium, only one of the bank offices lend to the other one.

[19]Introducing steady state partial default is in the same fashion as introducing an intermediation cost. This is a standard assumption in the literature when the banks operate under perfect competition, see for example Kollmann et al. (2011) and Kalemli-Ozcan et al. (2013), which ensures that at steady state the loan spread is positive.

In this paper, the bank portfolio of loans, intra-group lending and deposits in each country are endogenously determined in equilibrium.[20] That is, bank capital requirement and the borrowing constraint on the entrepreneur side across countries give rise to a unique bank balance sheet.[21]

3.3.4 Equilibrium

The equilibrium is a collection of prices $\{Q_t, Q_t^*, R_t, R_t^*, w_t, w_t^*\}$ and quantities $\{C_t, C_t^*, D_t, D_t^*, K_t, K_t^*, N_t, N_t^*, L_{t+1}, L_{t+1}^*, q_t, q_t^*, X_t, X_t^*\}$ and exogenous processes $\{A_t, A_t^*, \iota_t, \iota_t^*\}$ such that both goods and financial intermediation markets clear.

Market clearing for the final good requires:

$$C_t + C_t^* + X_t + X_t^* + B_t = A_t F(k_t, N_t) + A_t^* F(k_t^*, l_t^*) - \frac{\psi}{2}\Omega_t^2 - \frac{\psi^*}{2}\Omega_t^{*2} \quad (3.29)$$

Similar to Kollmann et al. (2011) I assume that excess capital costs are in units of consumption goods of the country of the bank office. Then, I define *Home* GDP, Y_t, as final good production net of inputs used by the bank to pay the excess capital cost:

$$Y_t = A_t F(K_t, N_t) - \frac{\psi}{2}\Omega_t^2 \quad (3.30)$$

Therefore, total world output is sum of household consumption, investment and bank dividends in both countries:

$$C_t + C_t^* + X_t + X_t^* + B_t = Y_t + Y_t^*$$

Financial intermediation market equilibrium requires that the global bank's balance sheet is balanced.[22]

$$L_{t+1} + L_{t+1}^* = D_{t+1} + D_{t+1}^* + \Psi_{t+1} + \Psi_{t+1}^* \quad (3.31)$$

[20] Kalemli-Ozcan et al. (2013) assumes a given portfolio of assets for the global bank. In particular, the a given fraction of total assets of the global bank are loans issued to the entrepreneurs and the remaining fraction is invested in a risky asset.

[21] To solve for the bank balance sheet, i.e. portfolio of loans and deposits, Kollmann et al. (2011) impose that interest rates on loans net of default are equal across countries and assume a deposit in the utility function. In this paper, equal loan rate arises in equilibrium only under homogeneous capital requirement across countries.

[22] Note that intra-banking group transfers, i.e. deposits in *Foreign* office deposited by *Home* office, or vice versa, appears on both sides of the consolidated balance sheet and cancel out.

Finally, loan demand equals loan supply in both countries.

$$L_{t+1} = \theta X_t \tag{3.32}$$

$$L^*_{t+1} = \theta^* X^*_t \tag{3.33}$$

Then I define current account as *Home* GDP net of consumption, investment and half of the total bank dividends:[23]

$$CA_t = Y_t - C_t - X_t - 0.5B_t \tag{3.34}$$

3.3.5 Calibration

I derive a numerical solution using standard linearization techniques and functional form assumptions. The elasticity of final good output with respect to capital is set at $\alpha = 0.33$. One period corresponds to one quarter. Accordingly, I set the depreciation rate of physical capital at $\delta = 0.025$, as commonly done in quarterly macro models. Following Kalemli-Ozcan et al. (2013) I set capital adjustment cost at $\phi = 0.43$. The households are assumed to have log utility, $\sigma = 1$ and the bank shareholder is risk neutral, $\sigma^b = 0.01$. I assume $\beta = \beta^* = 0.99$ and the bank shareholder is more patient than households, $\beta^* = 0.999$.

I assume that the firms can finance only 20% of their investment by bank loans in the *Home* country, $\theta = 0.2$, on the other hand, *Foreign* entrepreneurs are unconstrained, $\theta^* = 1$. This implies that the assets held in the *Home* country comprise a smaller fraction of all assets of the global bank. I also consider the case where both countries are characterized by unconstrained firms and thus have equal weight in the asset portfolio of the global bank as is the case in both Kollmann et al. (2011) and Kalemli-Ozcan et al. (2013).

Required bank capital ratio in *Home* country is set at $\gamma = 0.04$ and in *Foreign* country is taken as $\gamma^* = 0.08$. Empirically, the capital ratios of the major EA banks (i.e., ratios of bank equity to total (non risk-weighted) assets) have typically ranged 3 to 5% in the period 1995 to 2010, while the capital ratios of US commercial banks have generally been in the range 7 to 8% (Kollmann et al. (2011)). I use this findings as the benchmark case and then I also consider the case where both countries have equal capital requirement ratios.

[23] As in Kollmann et al. (2011) I assume that half of the total bank dividends are spent in each country. Therefore, total consumption in *Home* country is the sum of household consumption and half of the total bank dividends. Assigning unequal weights for the dividend share does not change the cyclical dynamics of the current account.

In this paper, I allow bank capital to be held either more or less than the regulated level at the steady state, which is determined by optimality conditions of global banks' shareholder's utility maximization. Calibrating the magnitude of cost of excess capital $\xi = \xi^* = 0.45$ gives $\Omega = \Omega^* = 0.022$.[24] This implies that at steady state bank capital-to-loan ratio is 0.39 in *Home* and 0.15 in *Foreign* country, both of which are higher than the regulated level of 0.04 and 0.08, respectively in *Home* and *Foreign* country. Under this calibration, *Home* office of the global bank lends to the *Foreign* office. Thus the country with higher financial development receives savings from the less developed country as is the case in Mendoza et al. (2009) and Mendoza and Quadrini (2010). Then intra group lending H, *Home* loans and *Foreign* loans comprises 17%, 14% and 69% of the total assets of the global bank, respectively.

At steady state the bank capital ratio is 16%, or equivalently, leverage of the consolidated bank balance sheet is 6.25.[25] Parameter assumptions imply steady state loan rates of $R = 8.11\%$ and $R^* = 7.94\%$ and deposit rate of $Q = 4\%$ per annum.[26] I assume that only 1% of the loans are defaulted at the steady state in both countries, that is, $\iota = \iota^* = 0.01$.[27]

I calibrate the parameters of the exogenous shock processes similar to Kollmann et al. (2011) The persistence and the variance of the productivity is calibrated uniformly across countries, i.e. $\rho_a = \rho_a^* = 0.95$ and $\sigma_a = \sigma_{a*} = 0.0053$. As far as the financial shocks are concerned, I assume that loan default shocks follow AR(1) processes with persistence $\rho_\iota = \rho_\iota^* = 0.8$.[28] Finally, the standard deviation of each financial shock is 0.0001.

[24]Different calibrations of the excess capital cost changes only the steady state bank portfolio but doesn't affect the dynamics of the model.

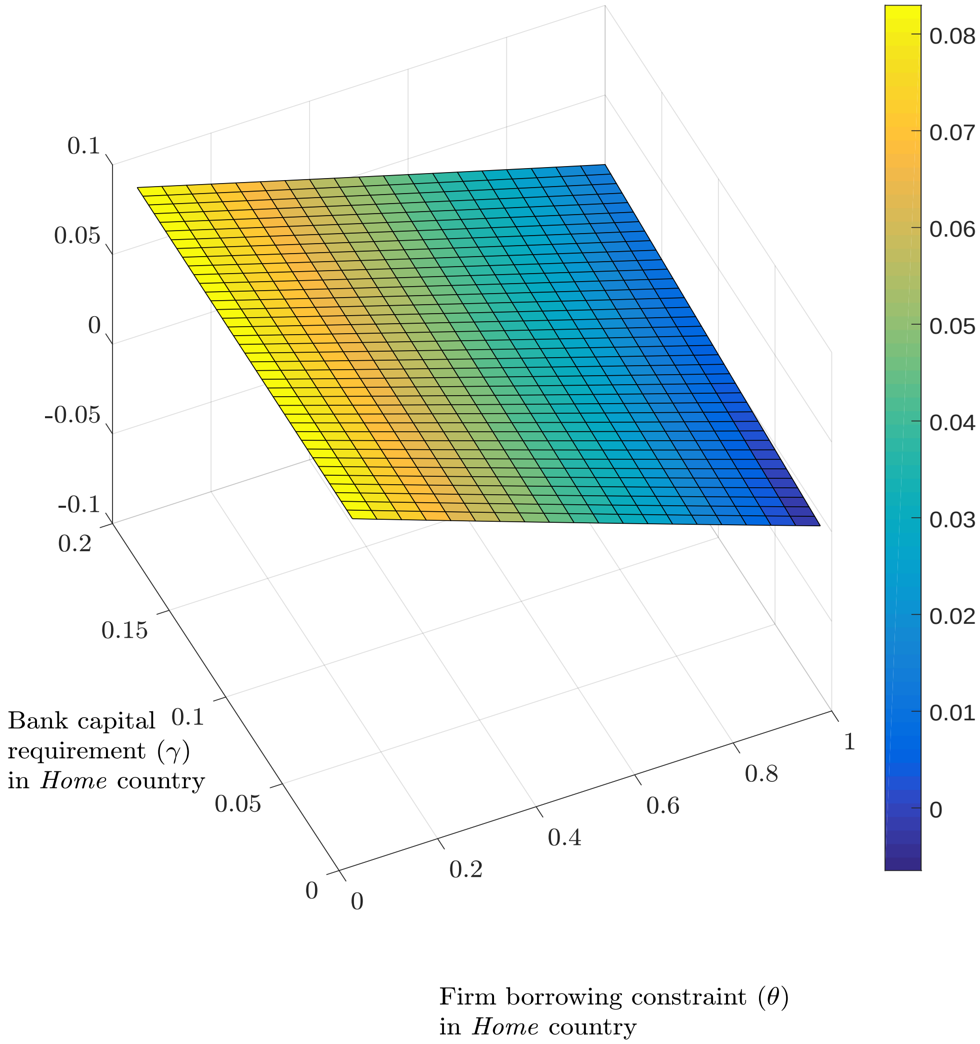
[25]Bank capital ratio=$\frac{\Psi_{t+1}+\Psi^*_{t+1}}{L_{t+1}+L^*_{t+1}+H_{t+1}}$. Imposing no excess capital implies very high levels of steady state leverage, which is 20 in Kollmann et al. (2011).

[26]Keeping everything else constant, decreasing the capital requirement in *Home* country, $\gamma = 0.03$, implies a higher intra-banking group lending, 16.7% of total assets and higher loan rate in *Home* country, $R = 8.16\%$ per annum.

[27]This number is interpreted as an intermediation cost rather than default and calibrated as 4% in Kalemli-Ozcan et al. (2013) to get reasonable loan spread, in this paper higher intermediation cost, i.e. 4%, would imply around 20% loan rate.

[28]The financial shocks are calibrated this way for standard business cycle movements. However, in the impulse response analysis part I will present the results for unexpected one-time increase in default shocks as in Kollmann et al. (2011) to analyze the implications of sudden drop in bank's revenues due to unusual defaults as the case in 2007-2009 financial crisis.

FIGURE 3.1. Intra-banking group lending under different calibrations of borrowing and bank capital constraints in *Home* country



Level of intra-banking group lending for different values of *Home* bank capital regulation, γ, and *Home* borrowing constraint, θ, when the corresponding parameters are taken as the benchmark case for the *Foreign* , i.e. $\theta^* = 1$ and $\gamma^* = 0.08$.

3.3.6 Determinants of intra-banking group lending at steady state

Figure 3.1 displays the steady state level of intra-banking group lending for different calibrations of *Home* capital regulation, γ, and *Home* borrowing constraint, θ, when corresponding parameters are kept as the benchmark case for *Foreign* country, i.e. $\theta^* = 1$ and $\gamma^* = 0.08$.

For a given level of capital regulation, intra-banking group lending H decreases as the borrowing constraint is relaxed, i.e. θ increases, in *Home* country. This implies that as for a representative global bank, lending to *Home* firms increase, intra-banking group lending from *Home* to *Foreign* declines to satisfy local demand for loans. Inter office deposits increase only slightly with capital regulation for a given level of borrowing constraint. For some parameter calibrations at steady state the *Foreign* office deposits in the *Home* office instead.[29]

3.4 Impulse Response Analysis

In this section I present responses of macroeconomics variables in both countries to real and financial shocks. The main results of this analysis is that as far as productivity shocks are concerned, heterogeneity in the firm borrowing constraint and bank capital requirements across countries does not interact with the transmission into real outcomes. That is, an own negative productivity shock gives rise to an equal decline in GDP in each country although one is characterized by a financial market with both higher borrowing constraints and bank capital requirement than the other. A corollary of this result is that a real shock in one country spills over to the other one symmetrically whether the shock country comprises a high share of bank assets or not. On the other hand, the country that a financial shock originates from affects the degree of global GDP decline. Moreover, the recovery from a global downturn is heterogeneous across countries. I first discuss a real shock and then a financial shock in both countries.

3.4.1 Impulse responses to productivity shocks

Figure 3.1 displays the responses to a 1% negative shock productivity in *Home* country. All variables are expressed as percentage deviation from

[29]Deposits of *Home* office at the *Foreign* office, H, constitute 2% of total banks assets, and deposits of *Foreign* office at the *Home* office, F, constitute 1% of total banks assets for bank capital requirements of 20% and 0% respectively, when $\theta = \theta^* = 1$ and $\gamma^* = 0.08$.

steady state, except for the interest rates and spreads, which are deviations in percentage points. Current accounts are in levels.

Following a negative productivity shock to *Home* productivity, GDP, consumption and investment decreases in *Home* country. Lower productivity implies lower demand for loans and lowers the loan rate charged to *Home* entrepreneurs. This gives rise to an increase in intra-banking group transfer from *Home* office in *Foreign* country. Therefore, supply of loans available to the *Foreign* entrepreneurs increases and thus lowers the loan rate also in *Foreign* country. Higher loans result in higher investment and higher GDP in the *Foreign* country although consumption decreases. Spillover of *Home* productivity shock to the *Foreign* real activity is rather limited initially. The increase in *Foreign* GDP is 0.02% in the first period but investment increases significantly, which strengthens the spillover effect and increases *Foreign* GDP over time.

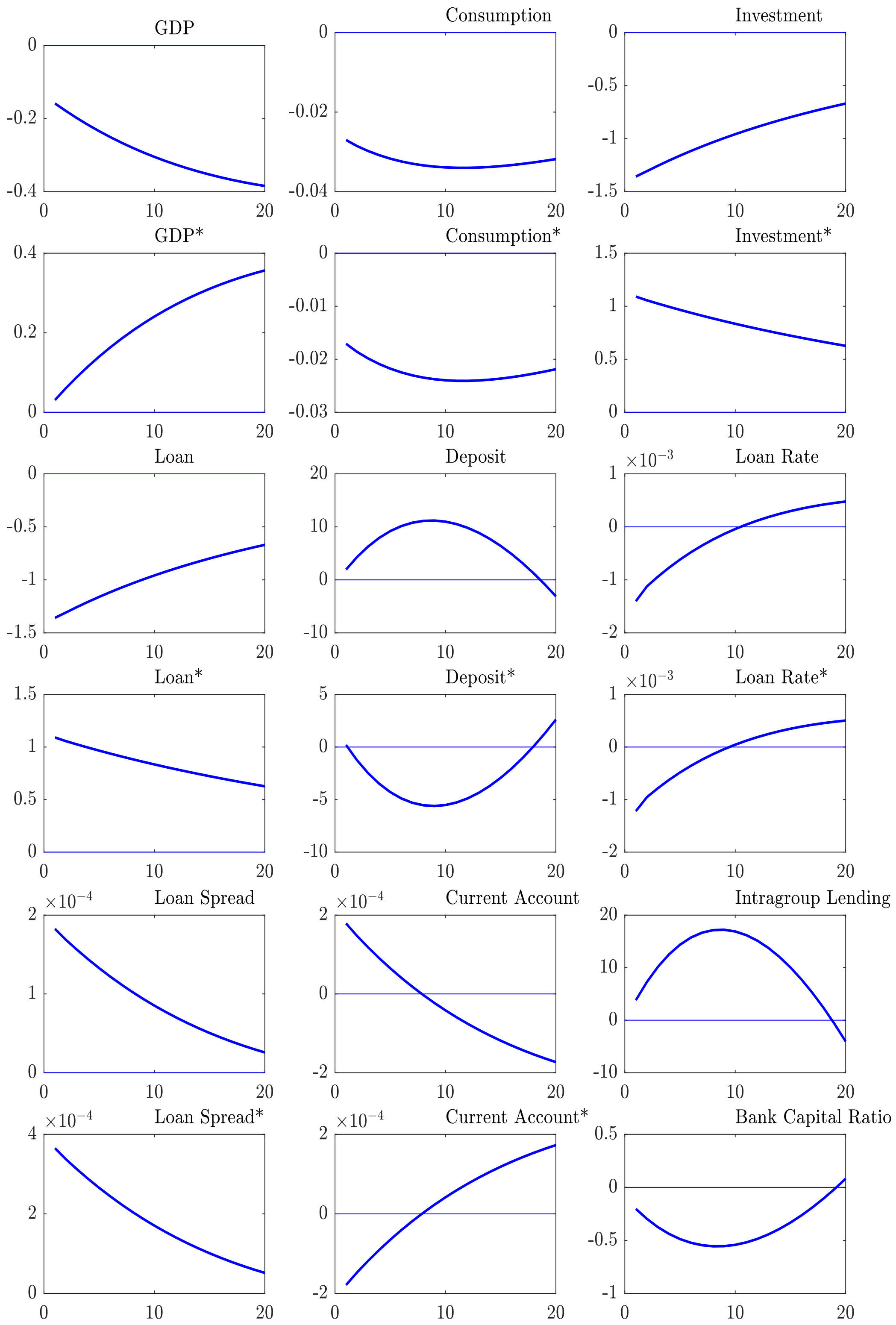
Bank optimality conditions imply that excess bank capital and deposit rate changes need to be symmetric across countries[30], deposit demand in both countries adjust. Since a rise in interbank lending increases excess bank capital in *Home* country and decreases that in *Foreign* country, deposit demand increases in the former and decreases in the latter. In effect excess bank capital declines in both locations and deposit rates also decline, however, loan spreads increase. Therefore, the model implies a negative correlation between loan spreads and total bank capital; and also gives rise to a counter cyclical current account consistent with data.

Allowing the bank to charge different interest rates and the assumption that the loans are used to finance a given fraction of investment allows investment to respond significantly to productivity shocks in both countries. Thus the spillover effect is stronger in this paper compared to Kollmann et al. (2011) which abstracts from borrowing constraints on firms. This is consistent with the findings of Kalemli-Ozcan et al. (2013) that higher financial integration implies less output comovement across countries by moving resources from the country hit by a negative productivity shock.

Figure 3.2 displays the responses to a 1% negative shock to *Foreign* productivity. The responses are similar to the ones with a *Home* productivity shock. The intra-group lending decreases as *Home* is relatively more productive and loan demand is higher there. The only difference in responses to the productivity shocks is that of the loan spread. Following a *Home* productivity shock deposit rate increases, on the other hand, it

[30]Note that this is equivalent to having the same deposit rates across countries as steady state level is also the same.

FIGURE 3.1. Impulse responses to a negative *Home* productivity shock



Responses to 1% negative shock to *Home* productivity. Interest rates, ratios and spreads are expresses in percentage points, other variables are in percentage deviations from steady state. Current accounts are in levels.

decreases following a *Foreign* productivity decline. However, the model implies a negative correlation between bank capital ratio and loan spreads as is the case with *Home* productivity shock.

As far as productivity shocks are concerned, the magnitude of the responses of variables don't change with the country that faces a productivity decline. That is, responses of *Home* country quantities in Figure 3.2 are the same as those of *Foreign* country quantities in Figure 3.1. This is not the case for financial shocks as I show in the next section.

3.4.2 Impulse responses to financial shocks

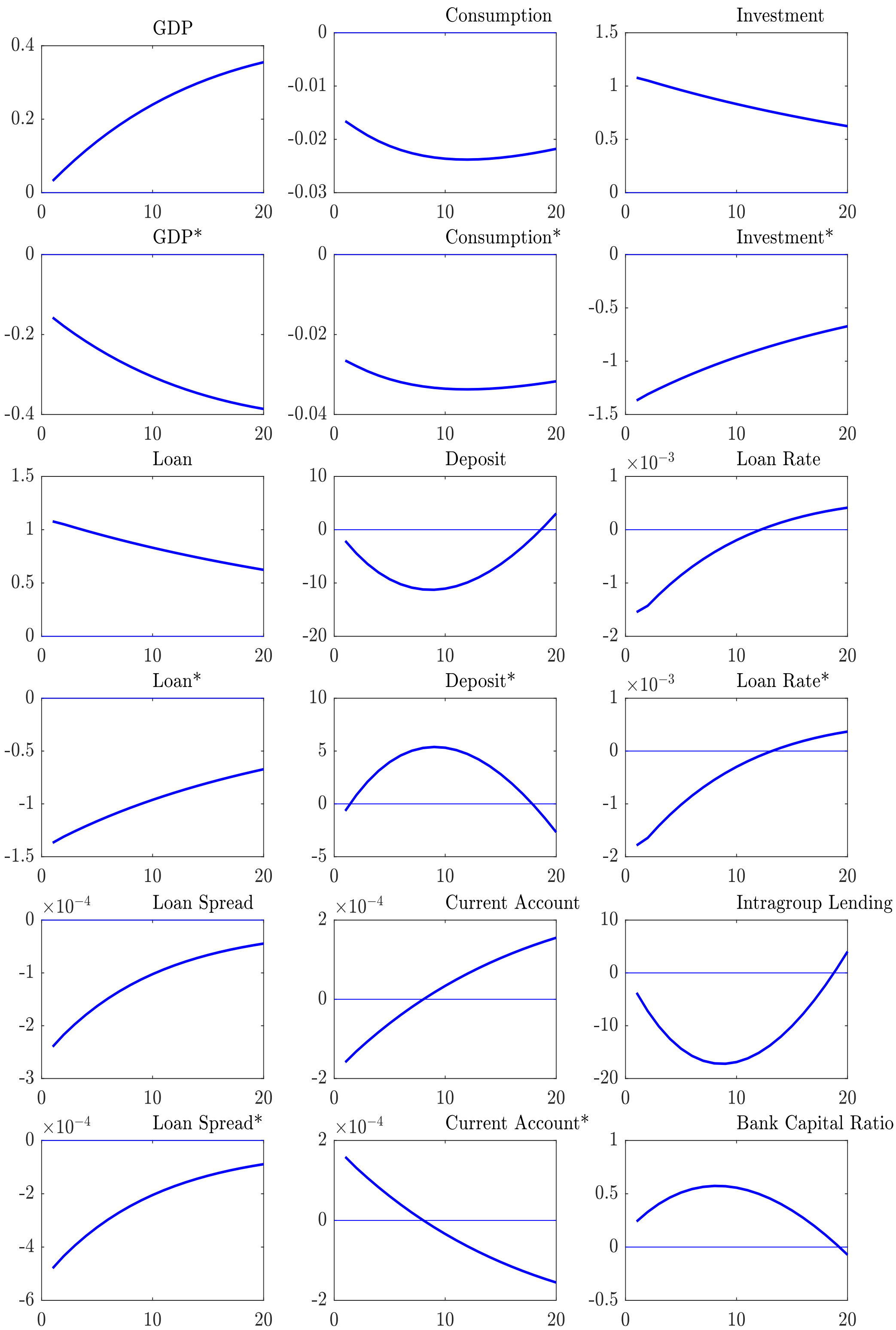
In this section I consider a temporary shock to partial loan default. The shock calibrated here is that ι and $\iota*$ increase to 0.05 at the period of the shock and returns to its steady state value of 0.01 the next period.[31] Kollmann et al. (2011) calibrates this shock so that credit loss is 5% of steady state world GDP, in order to capture exceptional events of 2007-2009 which roughly corresponds to the credit losses originating in the US during that period. Note that in the benchmark calibration of my paper, *Home* loans constitute only 14% of loans issued by the global bank at steady state. Thus the financial shock approximates to a credit loss of 1% of steady state *Home* GDP and 5% of steady state *Foreign* GDP. Therefore, here I consider a more conservative financial turmoil compared to Kollmann et al. (2011).

Figure 3.3 and Figure 3.4 display responses to a one-time 1 percentage point unexpected increase in partial loan default in *Home* country and *Foreign*, respectively. Variables are expressed as percentage deviation from steady state, interest rates, ratios and spreads are in percentage points. Current accounts are in levels. An increase in loan default implies lower bank dividend income due to lower return on loans in period of the shock.

Two main findings arise from the impulse responses to loan default shocks. First, tightly linked to the assumptions regarding the degree of heterogeneity in firm borrowing constraints across countries. *Foreign* loans of a global bank is 5 times more than that of *Home*. Therefore, symmetric shock implies a larger dividend income shock for a global bank shareholder and thus responses in Figure 3.4 are roughly 5 times more than that of Figure 3.3. The decrease in bank capital ratio is higher compared to the case in Figure 3.4 as *Foreign* loans constitute a higher share of total bank assets. Thus bank capital loss and total loan supply decrease are more pronounced in this case, which translates into a deeper global recession.

[31]Thus responses to loan default shock are calibrated with $\rho_\iota = \rho_{\iota^*} = 0$.

FIGURE 3.2. Impulse responses to a negative *Foreign* productivity shock



Responses to 1% negative shock to *Foreign* productivity. Interest rates, ratios and spreads are expresses in percentage points, other variables are in percentage deviations from steady state. Current accounts are in levels.

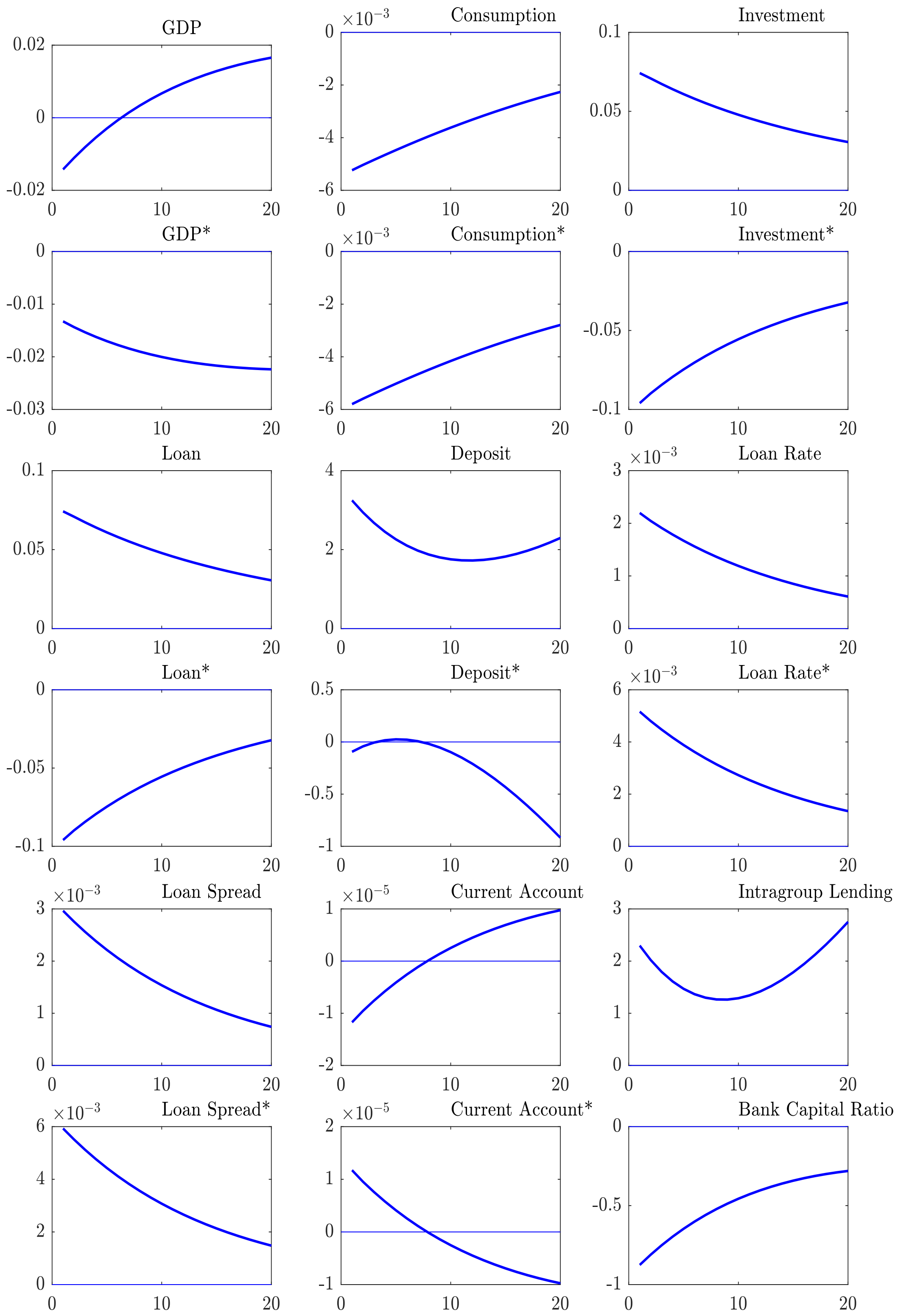
Second main finding is that following a partial default shock in either *Home* or *Foreign* country, Figures 3.3 and 3.4 display that GDP declines in both countries. However, the decline in GDP lasts only six quarters in *Home* country and then *Home* economy starts to expand. This is because dividends from each office are perfect substitutes for a global bank and a loss resulting from one office affects the bank's lending in both. As it is costly to deviate from the required capital in both countries, a global bank lowers the total supply of loans but the decomposition matters for the transmission dynamics. In particular, *Home* loans increase but *Foreign* loans decreases although even when default originates from *Home* country. Intra-banking group transfers also decline. Since loans increase, investment also increases and results in current account deficit in *Home*. As the increase in investment slows down, current account improves and *Home* GDP goes back to its steady state level in six periods and then begins to improve.

Asymmetric dynamics of GDP across countries results from that of the investment. *Foreign* loans decrease and thus investment decreases, which makes the GDP decline deeper in *Foreign* country. As *Foreign* loans constitute 69% of the total assets of the global bank and they decrease more than the increase in *Home* loans, the bank capital ratio declines following a default shock in *Home* country.

Figure 3.4 displays responses to the default shock in *Foreign* country. Responses of all macroeconomic variables are qualitatively same as the case where the default shock hits the *Home* office, except for intra-group lending and thus the current account. This is because, following a default shock in *Foreign* country, deposits increase and thus demand for intra-group lending decreases. Current account improves in *Foreign* as both investment and consumption decrease.

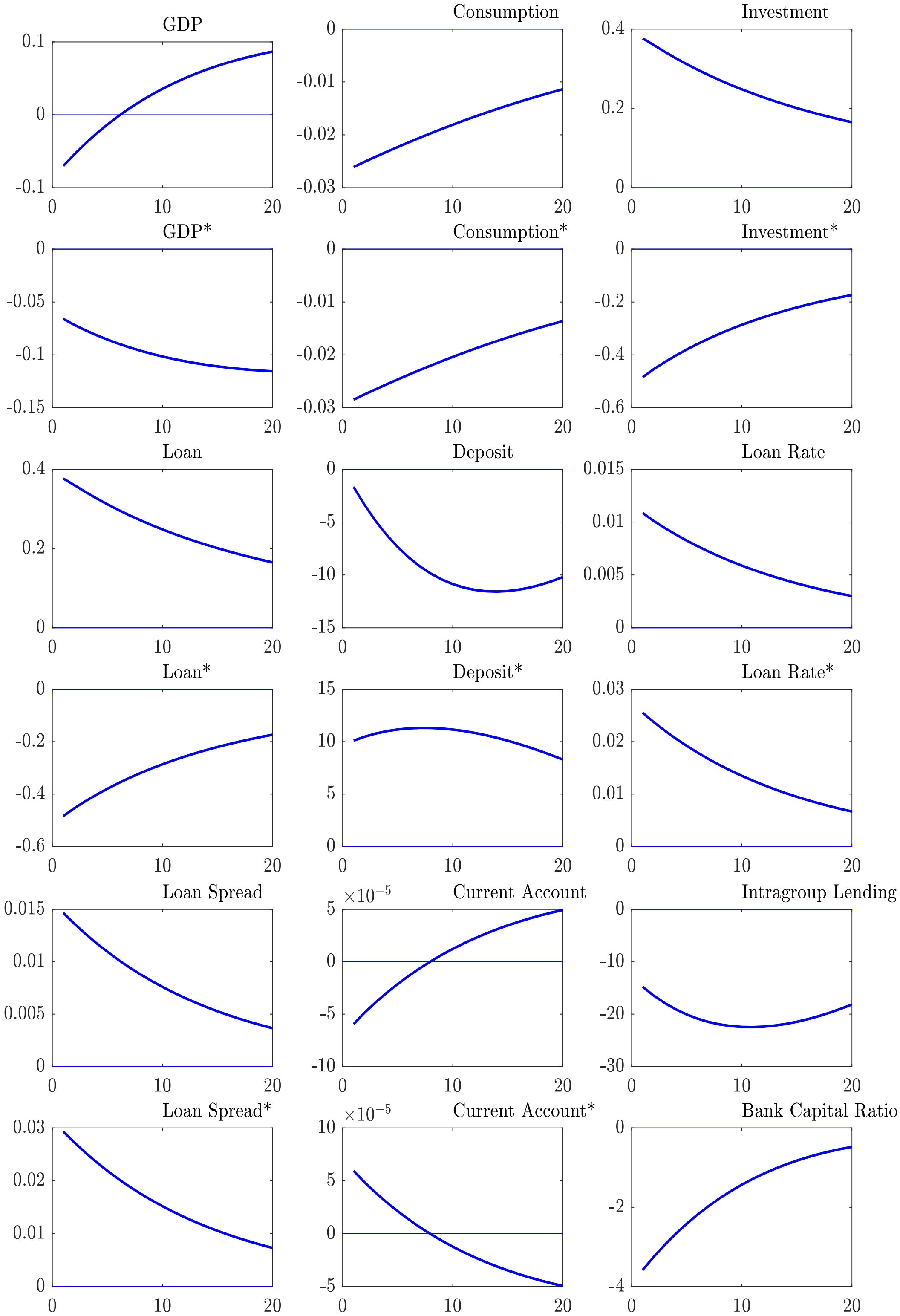
These findings contrast with those of Kalemli-Ozcan et al. (2013) and Kollmann et al. (2011), where GDP contraction lasts equally long periods of time. Therefore, a financial shock does not result in a decline in the economic activity globally once the homogeneity assumption is relaxed. I address the implications of the two types of heterogeneity for GDP and bank loan portfolio dynamics separately in the next section.

FIGURE 3.3. Impulse responses to a *Home* loan default shock



Responses to one-period increase in partial loan default in *Home* country, ι_t, from 1% to 5%. Interest rates, ratios and spreads are expresses in percentage points, other variables are in percentage deviations from steady state. Current accounts are in levels.

FIGURE 3.4. Impulse responses to a *Foreign* loan default shock



Responses to one-period increase in partial loan default in *Foreign* country, ι_t^*, from 1% to 5%. Interest rates, ratios and spreads are expresses in percentage points, other variables are in percentage deviations from steady state. Current accounts are in levels.

3.5 Implications of one type of financial heterogeneity at a time

Figures 3.5 to 3.8 demonstrate the responses to financial shocks when the countries are homogeneous either in bank capital regulation or in the borrowing constraint, respectively. In all figures the solid line corresponds to the case with homogeneous countries: no borrowing constraint on the firm side, $\theta = 1$, and 8% bank capital requirement.

Figure 3.5 and 3.6 display the case when both countries have equal bank capital regulation and *Home* firms face a binding borrowing constraint with different levels of tightness and *Foreign* firms are unconstrained. When the countries are symmetric as in Kollmann et al. (2011) and Kalemli-Ozcan et al. (2013), GDP decline lasts equally long periods in both countries following a financial shock in each country. Similarly, loans and loan spreads decrease by the same amount across countries independent of the origin of the shock. However, the dynamic responses change with the source of the financial shock once the countries differ in the borrowing constraint. Declining θ means *Home* can finance a declining fraction of their investments via bank lending which is equivalent to having a smaller share in total assets of the bank. If the global bank is hit with the financial shock in *Home*, the effect of it in GDP of both countries gets smaller with θ, or equivalently the size of steady state *Home* loans. Still due to differences in bank lending across countries, *Home* GDP recovers but *Foreign* GDP fails to do so. However, if the global bank faces a loan default shock at *Foreign*, which constitutes a larger share of total assets of the bank, *Home* faces a small period of contraction as in the benchmark case and *Foreign* goes to through a deeper recession as loans to *Foreign* and thus *Foreign* investment decrease significantly. Increase in *Home* loans translates into an increase in GDP after a short period of time.

Figures 3.7 and 3.8 show impulse responses to financial shocks when both countries are financially unconstrained. Therefore, at steady state each country comprises 50% of the total assets of the global bank and there are no intra-group transfers. When countries are symmetric, following financial shocks the dynamics of GDP and financial variables are the same independent of the country that is hit by the shock. The origin of the shock does not matter even if the countries have different regulation policies. That is, once they are equal in loan size, the transmission of the shock across countries is symmetric but the dynamics vary with the degree of heterogeneity in regulation. Figures 3.7 and 3.8 both show that following a financial shock, GDP declines in both countries initially but *Foreign* recovers faster as *Home* office faces higher capital regulation. This is because the global bank provides more loans to *Foreign* and less to *Home* as it is less costly to hold excess capital in less regulated country.

Figures 3.5 to 3.8 imply that the country that comprises a higher share of the total assets of the global bank suffers more from financial shock, even if it does not originate from defaulting domestic entrepreneurs. Higher bank capital regulation depresses bank loans further and deepens the effects of the financial shocks. Once the assumption of symmetric countries is relaxed, the transmission of financial shocks significantly differ across countries.

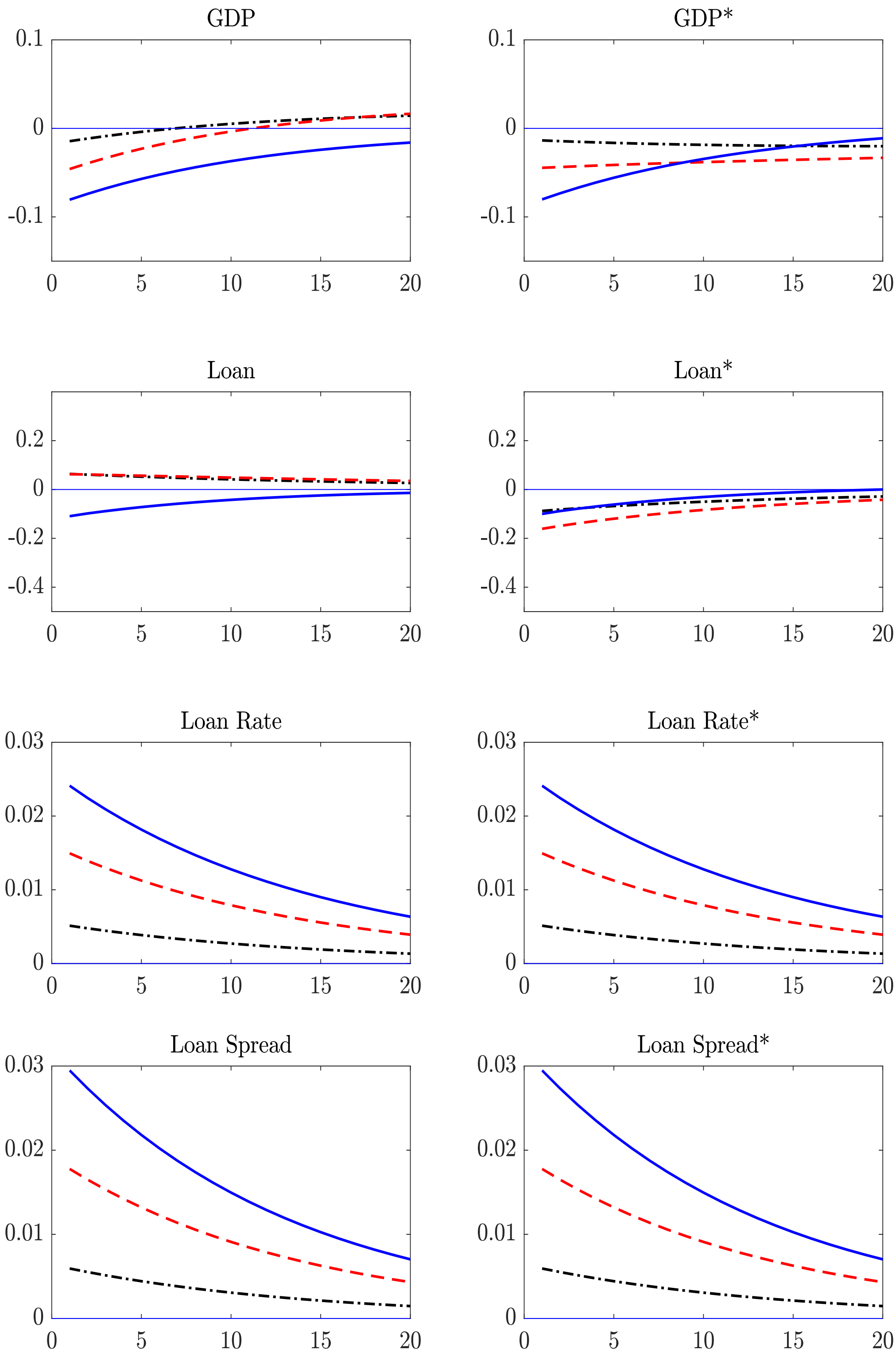
3.6 Conclusions

The 2008-2009 financial crisis is characterized by synchronized drops in economic and banking activity across countries. However, the recovery from this episode was heterogeneous, in particular across developed and developing countries. This highlighted the importance of a better understanding of how global banks transmit a financial shock originating in one country to the others. This question is addressed in the literature by assuming that the countries that comprise the world economy are symmetric in both the real and the financial side of the economy. In this chapter, I relax the latter assumption by allowing for different levels of financial development, which is measured as high share of bank finance in investment, and bank capital requirements across countries. Although this type of asymmetry across countries is overlooked in the literature, I show that it has important global implications. Specifically, a financial shock in the country with a higher level of financial development gives rise to a deeper global GDP drop than a similar shock in the less financially developed country. Moreover, although GDP declines simultaneously in both countries in a financial turmoil, the recession lasts shorter in the country with lower financial development and bank capital requirement compared to the other country. Finally, perhaps not surprisingly, the transmission of a real shock is symmetric across countries independent of whether the source of the productivity shock is the most developed economy or not. The modeling framework lends itself to several extensions.

A natural extension would involve incorporating differences in the real sector across countries, i.e. economic size, technological or factor endowment differences. This would provide a further step towards bringing the model closer to the real world. Then, interactions between both types of asymmetries might affect the global implications not only of the financial shocks but also of the real ones. This would allow us to analyze the potential differences in global implications of financial crises in the developed and the developing countries, the latter can be thought of less financially developed and of a smaller economic size compared to a developed country.

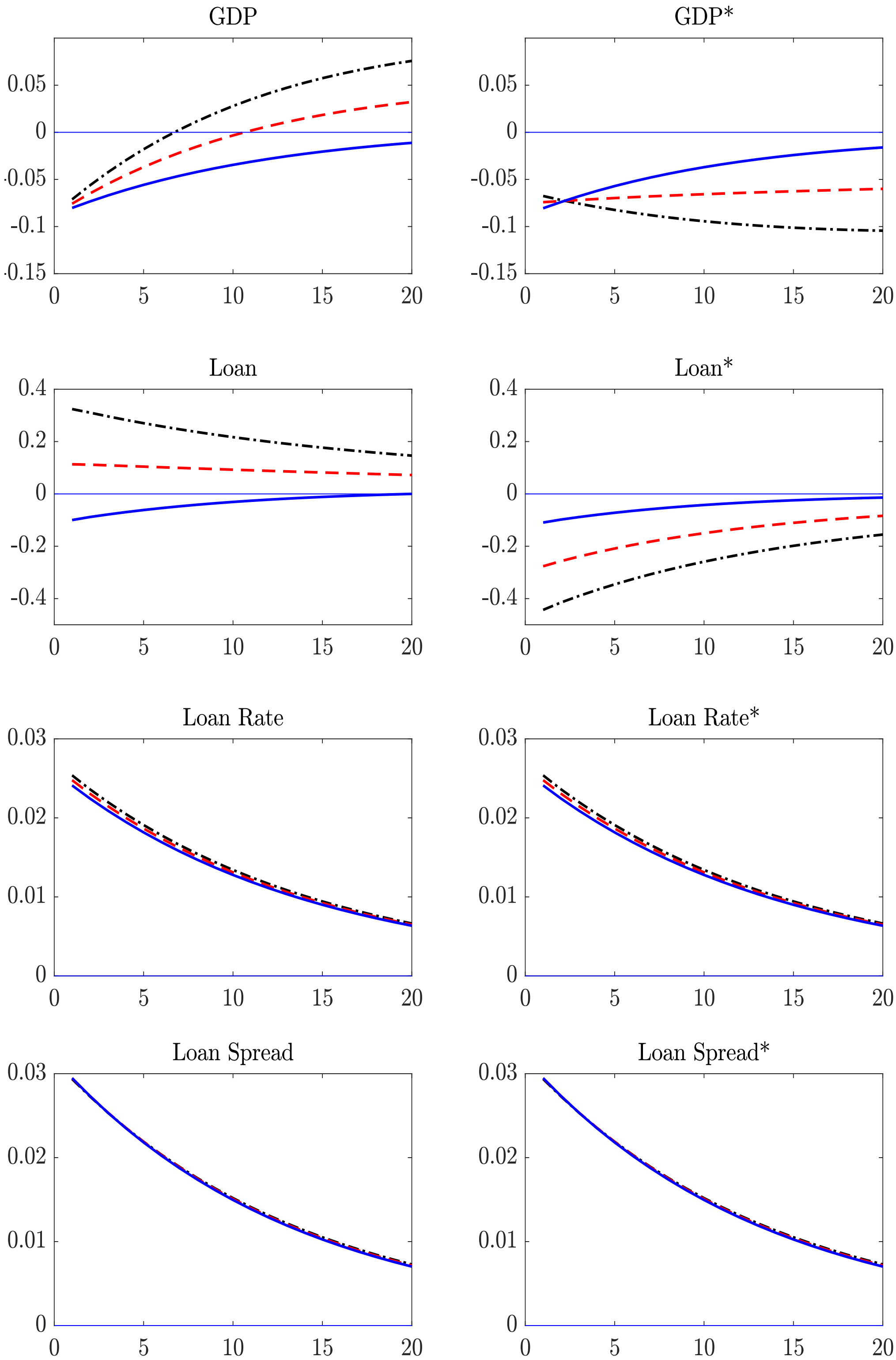
The model developed here implies that discouraging borrowing from the global bank gives rise to a lower GDP decline following a financial shock. Therefore, lowering the credit-to-GDP ratio arises as a prudential policy prescription. One way to implement this policy is tightening the borrowing margin as suggested by Bianchi (2011). Moreover, the model implies that the country with lower bank capital requirement faces a shorter period of recession. Thus, lowering the bank capital requirement in response to a financial shock might help mitigate the contractionary effects of a financial crisis ex-post. These sovereign policy actions are beneficial for the country that exercises them. However, the international implications of the proposed policies also matter. Although, a prudential policy implies lower GDP decline in both countries, lowering the bank capital requirement might come at the cost of deepening the crisis in the other country. This implies that uncoordinated policies regarding global bank regulation might imply a global welfare cost and can be interpreted as a need for a supranational authority that takes into account the international spillovers. A different financial policy design could be a mix of both measures proposed as suggested by Jeanne and Korinek (2013). As they target different financial constraints a mix of the two might be optimal both at the national and the international level. Thus, a further interesting extension would involve introducing financial policy responding to financial and macroeconomic conjecture and a rigorous analysis of welfare implications of different policies.

FIGURE 3.5. Selected impulse responses to a *Home* financial shock under symmetric bank capital requirement across countries



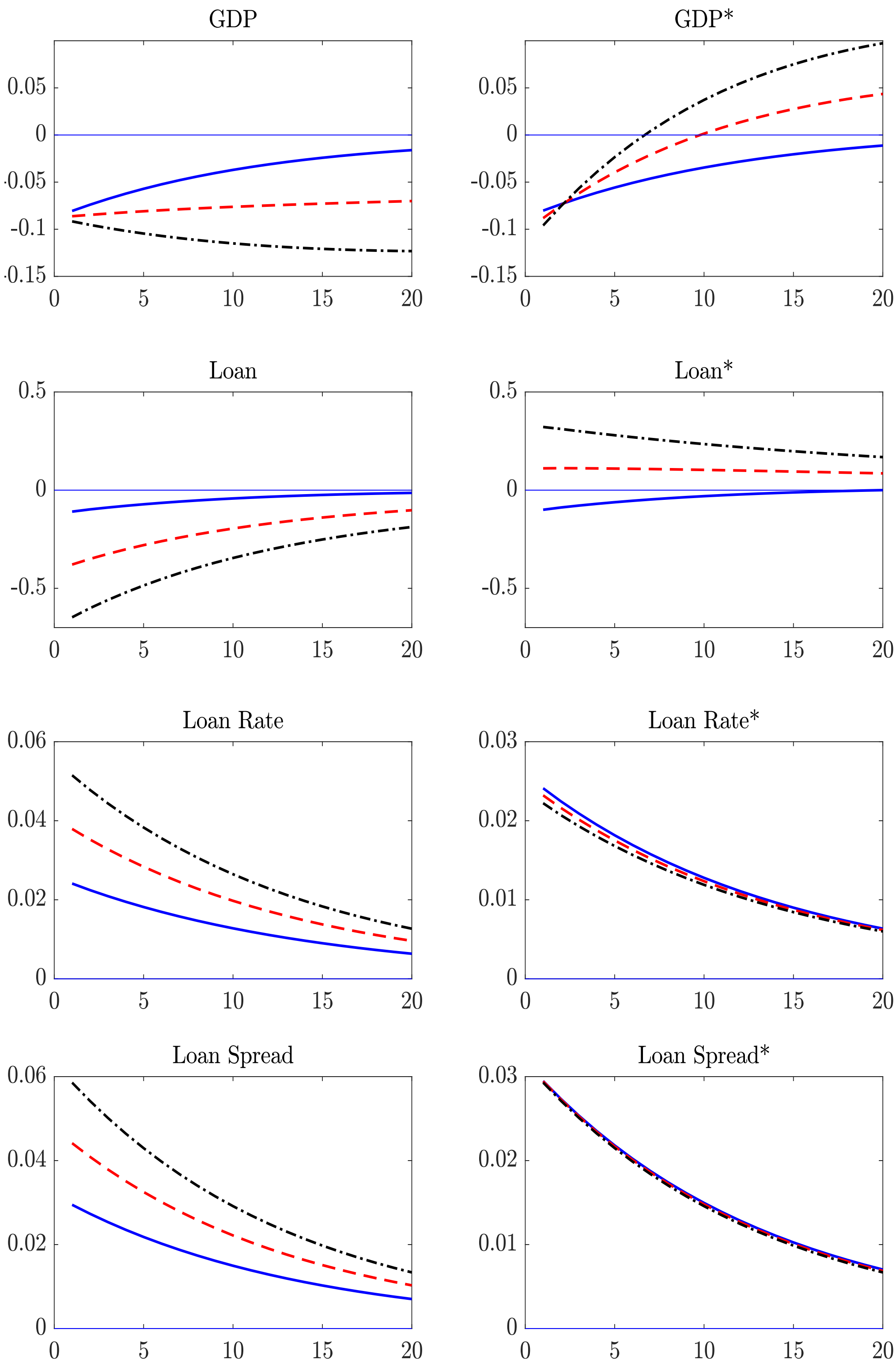
Selected impulse responses to one-period increase in partial *Home* loan default, ι_t from 1% to 5%. $\gamma = \gamma^* = 0.08$ and $\theta^* = 1$, solid line: $\theta = 1$, dashed line: $\theta = 0.6$, dash-dotted line: $\theta = 0.2$

FIGURE 3.6. Selected impulse responses to a *Foreign* financial shock under symmetric bank capital requirement across countries



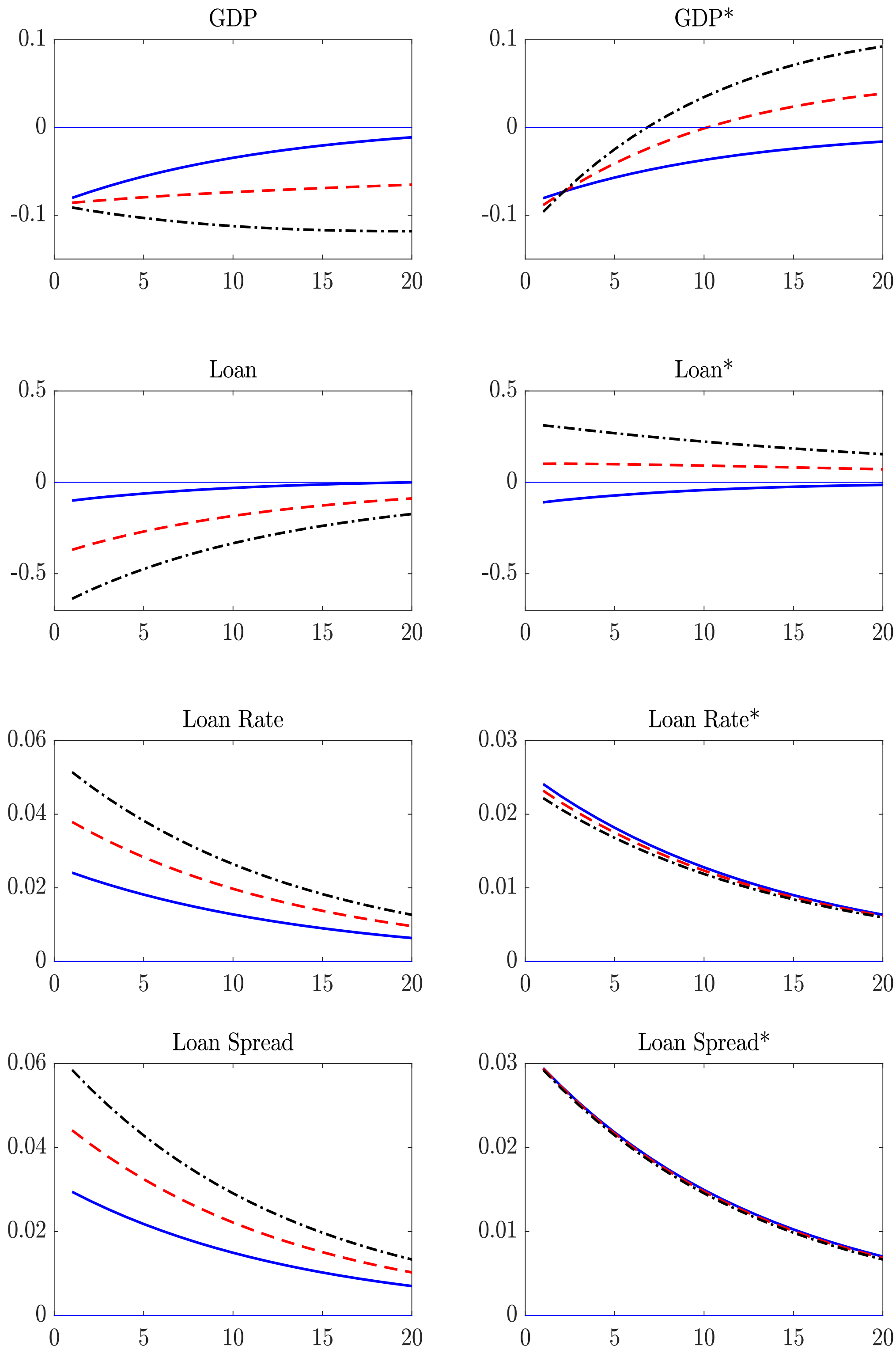
Selected impulse responses to one-period increase in partial *Home* loan default, ι_t^* from 1% to 5%. $\gamma = \gamma^* = 0.08$ and $\theta^* = 1$, solid line: $\theta = 1$, dashed line: $\theta = 0.6$, dash-dotted line: $\theta = 0.2$

FIGURE 3.7. Selected impulse responses to *Home* financial shock under symmetric borrowing constraint across countries



Responses to one-period increase in partial loan default, ι_t from 1% to 5%. $\theta = \theta^* = 1$ and $\gamma^* = 0.08$, solid line: $\gamma = 0.08$, dashed line: $\gamma = 0.12$, dash-dotted line: $\gamma = 0.16$.

FIGURE 3.8. Selected impulse responses to a *Foreign* financial shock under symmetric borrowing constraint across countries



Responses to one-period increase in partial loan default, ι_t^* from 1% to 5%. $\theta = \theta^* = 1$ and $\gamma^* = 0.08$, solid line: $\gamma = 0.08$, dashed line: $\gamma = 0.12$, dash-dotted line: $\gamma = 0.16$.

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