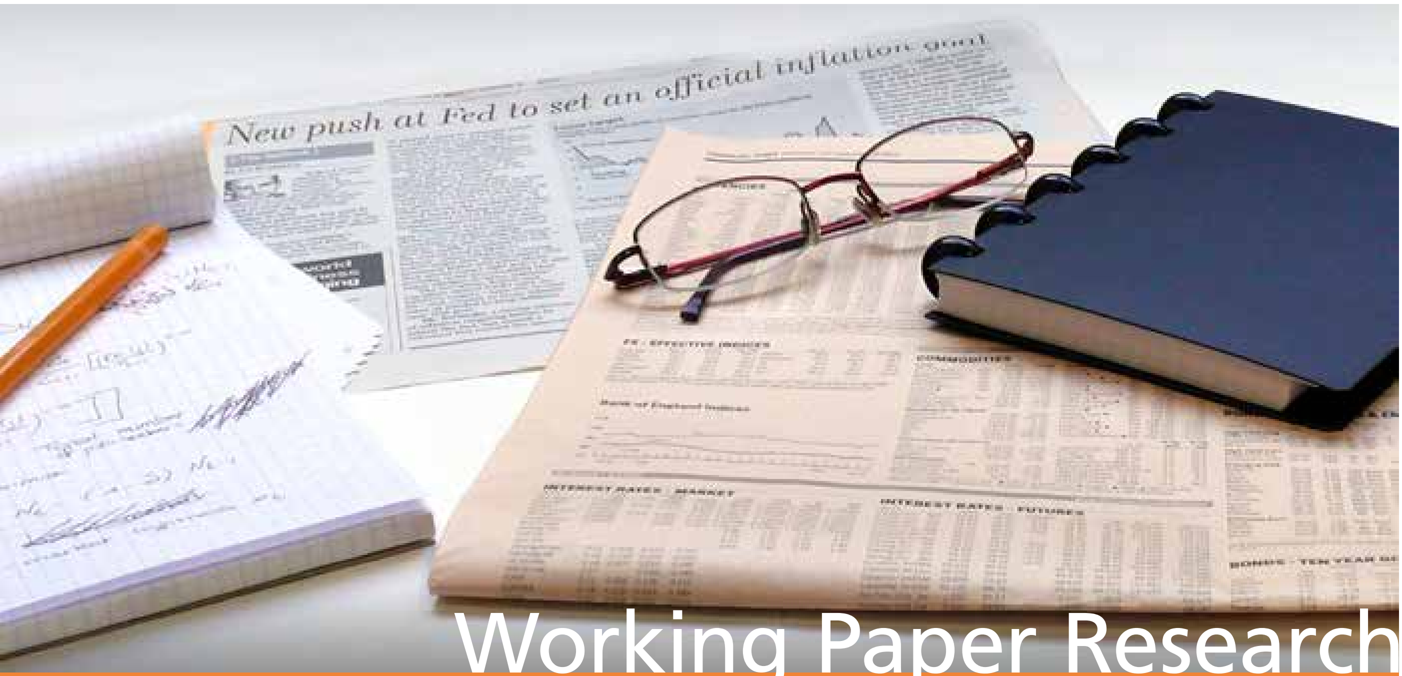
Inequality, the risk of secular stagnation and the increase in household debt



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Abstract

I investigate the effect of rising income inequality on the natural rate of interest in an economy with "rich" households with preferences over wealth and "non-rich" households, a housing market and credit market frictions. Simulating the increase in interpersonal and functional income inequality over the 1981-2016 period replicates the downward trend in the natural rate of interest estimated by Laubach and Williams (2016), most of the increase in the debt-to-income ratio of the bottom 90 % of households and the upward trend in house prices observed during this period.

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Keywords: Income inequality, natural rate of interest, secular stagnation.

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1 Introduction

The extended period of low interest rates on safe assets in advanced economies since the financial crisis of 2007-2009 and the downward trend observed even before then suggests that the so called natural rate of interest, i.e. the interest rate consistent with a closed output gap and stable inflation, might have declined. According to the widely discussed estimates by Laubach and Williams (2016), the natural rate in the United States displays a downward trend since the 1980s, interrupted briefly during the 1990s. Some observers have labeled this phenomenon “Secular Stagnation” (e.g. Summers (2014), Eggertsson et al. (2018)). Laubach and Williams (2016) filter their natural rate estimate using a small semistructural macroeconomic model featuring inter alia an aggregate demand equation (supposed to proxy a consumption Euler equation) and a Phillips Curve. They decompose the natural rate into a component driven by trend GDP growth and an unexplained residual (the so-called “z component”). As can be obtained from Figure 3 below, their estimate attributes most of the estimated decline in the natural rate to this residual, which represents essentially an exogenous decline in aggregate demand. The large role of the “z component” has been confirmed by recent extensions of the Laubach and Williams model (e.g. Brand and Mazelis (2019), Krustev (2018)). Similarly, using estimated DSGE models of the US economy, Gerali and Neri (2017) and Del Negro et al. (2017) attribute a large role to shocks which directly increase the demand of households for safe assets at the expense of consumption and investment. What is more, Rachel and Summers (2019) argue that the the results of Laubach and Williams (2016) mask an even more dramatic decline in the “private sector” natural rate of about 7% across advanced economies since the 1970s, which was partially offset by the expansionary effects of the simultaneous increase in government debt, as well as the obligations implied by the presence of pay-as-you go pensions systems and government funded healthcare.

I investigate to which extend changes in the distribution of income can contribute to explaining the downward trend in the US natural rate since the 1980s. Such a role is suggested by Summers (2014) and Rachel and Smith (2017), who observe that the downward trend in real rates coincides with an increase in inequality. For instance, according to the World Inequality Database (WID) developed by Thomas Piketty, Emmanuel Saez and their collaborators, the income share of the bottom 90% of US households declined by about 12% from 1980 to 2007 (see Figure 3 below, Alvaredo et al. (2016) and Piketty et al. (2018)). In principle, a secular increase in inequality could depress the natural rate of interest if the marginal propensity to save out of permanent income changes is higher for richer households, as found by Dynan et al. (2004). I formalize this mechanism in a model with two distinct groups of households, one of which represents the top 10% of the income distribution (referred to as “the rich”), and the other the remainder. Crucially, the rich derive utility from the level of their wealth, a motive first suggested by Max Weber (1958). Such “Capitalist Spirit” type preferences (CSP) have been found useful to replicate a range of puzzling phenomena, including the aforementioned higher marginal propensity to save of rich households (Kumhof et al. 2015), the magnitude of the wealth-to-income ratio of rich households (e. g. Carrol

(2000), Francis (2009) and Piketty (2011)) and stock market volatility (Bakshi and Chen 1996). I assume that the two types of households supply distinct types of labor to firms and that only the rich earn the profits of monopolistically competitive firms. Income inequality in the economy may thus increase to due an exogenous increase in the relative demand for rich household labor or decrease in product market competition.

I first show that in an economy where the bottom 90% are hand-to-mouth consumers and the only asset available to the rich are government bonds, the natural rate declines strongly in response to a decline in the bottom 90% income share in the presence of CSP, regardless of whether the decline is caused by an increase in the price markup or an increase in the relative demand for rich household labor. The non-rich lower their consumption by the amount of their income decline, while at the initial interest rate, the rich attempt to save part of the increase in their permanent income. Thus the interest rate needs to decline to equilibrate the government bond market and thus reduce equilibrium saving of the rich to zero.

I then extend the assets available to the rich in the model by allowing for home ownership by both income groups and a housing market, a credit market subject to frictions where the non-rich borrow from the rich via financial intermediaries using their home as collateral, and physical capital as an additional factor of production owned by the rich. In this setup, in the presence of CSP a given increase in inequality continues to lower the natural rate, though by less than in the simple model. The main reason for the smaller decline in the natural rate is that the non-rich postpone the decline in their consumption of goods and housing services by increasing their borrowing in response to the lower interest rate they face. Therefore the house price increases as well, which contributes to relaxing the borrowing constrained faced by the non-rich. By contrast, without CSP, an increase in inequality does not lower the natural rate and causes a decline in household borrowing.

I then replicate the decline in bottom 90% income share observed over the 1981-2014 period and the post 2001 decline in the labor share (i.e. the increase in functional income inequality) within the model. As can be obtained from Figure 3, the simulated increase in inequality generates a decline in the natural interest rate by between 3 and 4 percentage points, in line with the component the natural rate decline Laubach and Williams (2016) attribute to factors other than trend GDP growth (labeled "z_LW" in the graph). At the same time, the simulation broadly captures the upward trend in the debt-to-income ratio and LTV of the bottom 90% of households observed over the 1981-2007 period, as well as the simultaneous upward trend of the value of the housing stock. The simulation thus suggests that the decline in the natural rate of interest and the pre-crisis upward trend in in household indebtedness and house prices are to a significant extent both consequences of a more skewed income distribution. Put differently, the increase in income inequality meant that the Federal Reserve had to accept a downward trend of the Federal Funds rate and the associated rise in household debt and house prices if it wanted to continue to meet its inflation target. The simulation thus formalizes the scenario sketched in Summers (2014).

The focus of my contribution are US developments, while, as mentioned above, the downward trend in safe real interest rates is a phenomenon observed across advanced economies. There appears to be a global upward trend in within country inequality as measured by the top 10% income share too, but speeds differ across countries (see Alvaredo et al. 2018), with a substantially larger increase observed in the US and UK than in continental Europe. My result that a given decline in the bottom 90% income share causes a larger decline in the natural rate in the simple model where non-rich households cannot borrow than in the model with borrowing by the non-rich may suggest that in economies with tighter regulations of household borrowing like Germany or Italy, a smaller increase in inequality might suffice to trigger a given decline in the natural rate. However, I leave an investigation of the causes of the decline of the natural rate outside the US to future research.

There is an evolving literature modeling a link between the increase in inequality and the decline of the natural rate. Most of these contributions assume the incomes gains (losses) experienced by the rich (non-rich) to be transitory in some sense. For instance, Eggertsson and Merothra (2018) show that an increase in inequality within the middle generation of a three generation OLG model with credit constraints may reduce the natural rate if both the young and poor middle aged are credit constrained, which requires that the poor middle aged expect their income to increase upon retirement. By contrast, Eggertsson et al. (2018) emphasize that an increase in inequality persisting across all ages does not change the natural rate in their model. Lancastre (2016) extends this approach by adding a bequest motive where agents care about the sum of the bequest and their children's middle age income, and that parent's and children's "middle age" income is negatively correlated, which appears at odds with the evidence (e.g. Charles and Hurst (2003), Lee and Solon (2009), Bjoerklund and Jaentti (2012)). He finds that replicating the increase of the top 10% income share over the 1985-2015 period reduces the interest rate by one percentage point and expands the borrowing of the young generation by about 16%. By contrast, the US mortgage debt-to-GDP ratio increased by about 63% over the same period, corresponding to 20% of GDP. In the heterogenous agent models of Auclert and Rognlie (2018) and Rachel and Summers (2019), an increase in inequality driven by higher income uncertainty increases precautionary saving and thus lowers the natural interest rate. By contrast, Auclert and Rognlie (2018) find that higher inequality resulting from permanently enriching some households at the expense of others has only marginal effects on the natural rate. However, Kopczuck et al. (2010) and De Baecker et al. (2013) provide evidence that increases in permanent (not transitory) earnings variance drove the increase in inequality observed in recent decades in the US. Furthermore, Kopczuck et al. (2010) report that short and long term income mobility has been either stable or declining since the 1950s. Both Auclert and Rognlie (2018) and Rachel and Summers (2019) find that rising inequality reduced the natural rate by about 0.8 percentage points. An exception is Straub (2017), who considers permanent labor income changes in a heterogenous agent 65 generation OLG model where all agents have non-homothetic preferences over bequests, which generates a positive relationship between permanent income and saving. When replicating the increase in US labor income inequality since the 1970s, he finds a decline in of the interest rate of 1%.

Furthermore, unlike the aforementioned contributions, my paper shows how the increase in inequality may have caused both the increase in the indebtedness of the non-rich and the decline of the natural rate. A link between the increase in inequality and rising indebtedness has been argued by Rajan (2010) and modeled by Kumhof et al. (2015) in an endowment economy. I extend their analysis by modeling the housing market and thus the main source of collateral used to secure US household debt. This modification fleshes out the transmission from changes in the income distribution to household indebtedness, as well as generating predictions regarding the effects on the bottom 90% LTV and the value of the housing stock.

Other contributions investigating the potential drivers of the decline in the natural rate have focused on the increase in life expectancy and the the old-age dependency ratio, and found those factors to have an ongoing negative effect on the natural rate by increasing pension related saving and the capital labor ratio, thereby reducing demand for capital goods (e.g. Eggertsson et al. (2018), Bielecki et al. (2018) and Papetti (2018)).

Finally, my modeling approach forms part of a literature analyzing macroeconomic consequences of household heterogeneity by dividing households into two or three distinct groups which differ regarding important characteristics, for instance their consumption smoothing opportunities or asset holdings (or lack thereof) and their impatience. Debortoli and Gali (2018), Bilbie (2018), Broer et al. (2018), and Ravn and Sterk (2016) show that this approach captures relevant mechanisms and dynamics absent from the representative agent model, while at the same time being much more tractable and easier to interpret than conventional heterogenous agent models. Earlier examples of this modeling strategy comprise Galí et. al. (2007) and Bilbiie (2008), as well as Iacoviello (2005).

The remainder of the paper is structured as follows. Section 2 develops and analyses the simple model without household borrowing. Section 3 develops the model with household borrowing and a housing market, which I refer to as "full model". Section 4 discusses the results in the full model, including the aforementioned historical simulation of the decline of the income share of the bottom 90% of households over the 1981-2014 period.

2 A simple model

The model features two distinct household groups, namely rich and non-rich households, as well as monopolistically competitive firms owned by rich households and employing rich and non-rich household labor. The model thus precludes the possibility that the observed increase in income inequality might be the consequence of greater income mobility of individual households between different income groups. However, Kopczuck et al. (2010) and De Baecker et al. (2013) provide evidence that increases in permanent (not transitory) earnings variance drove the increase in inequality observed in recent decades. Furthermore, Kopczuck et al. (2010) report that short and long term income mobility has been either stable or declining since the 1950s.

2.1 Households

Throughout, I index rich households with the subscript S. Rich households derive utility from consumption $C_{S,t}$, and their stocks of safe real financial assets $b_{S,t}$ (consisting of government bonds). Their objective function is thus given by

$$E_t\left\{\sum_{i=0}^{\infty}\beta_S^i\left[\frac{C_{S,t+i}^{1-\sigma_S}}{1-\sigma_S}C_{S,t+i}^{1-\sigma_S}+\frac{\phi_b}{1-\sigma_b}\left(b_{S,t+i}\right)^{1-\sigma_b}\right]\right\}$$

where β_S denotes their utility discount factor, and ϕ_b, σ_S and σ_b are a non-negative constants. A rich household's budget constraint is given by

$$b_{S,t}=\frac{R_{t-1}}{\Pi_t}b_{S,t-1}+w_{S,t}N_{S,t}+\Xi_t-T_{S,t}-C_{S,t}$$

where R_t, $w_{S,t}$, Ξ_t, $T_{S,t}$ and Π_t denote the nominal interest rate on safe assets, the real wage, the real profits firms, real lump sum taxes and the inflation rate, respectively. The assumption that only the rich own firms and government bonds is motivated by the extreme concentration of stocks, business ownership and bonds (e. g. Kuhn and Rios-Rull (2015)).

Preferences over wealth have been found useful, or indeed necessary, to explain a wide range of phenomena, the most conventional example being liquidity preference used to explain the presence of money in agents portfolios. Krishnamurthy and Vissing Jorgenson (2012) argue that liquidity preference may extend to assets with a positive yield if they have money-like qualities, and provide supporting evidence in the form of a positive relationship between the supply of US government debt and the differential between its yields and the yield of other debt-securities. More recently, preferences over safe assets have been shown to considerably alleviate the so called "forward guidance puzzle", i.e. the finding that in DSGE models, the effect of forward guidance is implausibly strong (e.g. Rannenberg (2019), Michaillat and Saez (2018)).

A complimentary motivation is the so called "Capitalist Spirit" type argument, which says that the rich derive utility from accumulating wealth in various forms due to the sense of prestige and power it provides. Several authors have argued that "Capitalist Spirit" type preferences are necessary to explain the saving behavior of rich households in US data. Kumhof et al. (2016) show that preferences over wealth allow to replicate the empirical finding that wealthy households have a positive marginal propensity to save out of an increase in their permanent income (see Dynan et al. (2004) and Kumhof et al. (2016)). Furthermore, Carroll (2000) and Francis (2009) show that the standard life cycle model substantially under-predicts the level of wealth rich households hold relative to their permanent income, and that preferences over wealth eliminate this puzzle. Here I adopt the "Capitalist Spirit" type rationale, which however does not rule out the liquidity preference motive as far as preferences over real financial assets are concerned. From now on, I will refer to the model where the rich derive utility from their wealth (i.e. $\phi_b > 0$) on top of consumption as the model with "Capitalist Spirit" type Preferences (CSP), while I refer to the $\phi_b = 0$ case as NOCSP.

The first order conditions with respect to consumption and government bonds are given by

$$\Lambda_{S,t} = \frac{1}{C_{S,t}^{\sigma_S}} \tag{1}$$

$$\Lambda_{S,t} = \beta_S E_t \left\{ \Lambda_{S,t+1} \frac{R_t}{\Pi_{t+1}} \right\} + \phi_b \left(b_{S,t} \right)^{-\sigma_b} \tag{2}$$

where $\Lambda_{S,t}$ denotes the marginal utility of consumption. If $\phi_b > 0$, $\phi_b \left(b_{S,t} \right)^{-\sigma_b}$ represents an extra marginal benefit from saving over and above the utility associated with the future consumption opportunity saving entails (represented by $\beta_S E_t \left\{ \Lambda_{S,t+1} \frac{R_t}{\Pi_{t+1}} \right\}$). CSP weakens the effect of an increase in permanent income and thus a decline of $\Lambda_{S,t+1}$ on $\Lambda_{S,t}$, since the two become less than proportional. To gain some intuition, compare the bond market equilibrium in the CSP and NOCSP case, assuming that the economy is initially in the steady state in both period t and $t+1$. The presence of the extra benefit $\phi_b \left(b_{S,t} \right)^{-\sigma_b}$ with CSP implies that for the bond market to clear, the present value $\beta_S \frac{R_t}{\Pi_{t+1}}$ the household attaches to $\Lambda_{S,t+1}$ -the net effect of the reward of waiting and her impatience- has to be smaller than in the NOCSP case, thus reducing the importance she attaches to a decline in $\Lambda_{S,t+1}$. Furthermore, this weakening of intertemporal consumption smoothing compounds the more distant in time the anticipated future consumption increase is located, as $\Lambda_{S,t+1}$ is no longer proportional to $\Lambda_{S,t+2}$ either, and so on and so forth. As a result, with CSP a one percent permanent increase in saver household income will ceteris paribus not cause a one percent increase in consumption, but instead an increase in both saving and consumption. The marginal propensity to save out of a permanent income increase will be larger the smaller the curvature parameter σ_b.

Furthermore, the above implies that for $\phi_b > 0$,

$$R_t < \frac{1}{E_t \left\{ \frac{\beta \Lambda_{S,t+1}}{\Lambda_{S,t} \Pi_{t+1}} \right\}} \equiv DIS_t \tag{3}$$

i.e. the nominal interest rate may be smaller than the discount rate the household applies to future income streams DIS_t.

I assume that non-rich households, denoted as CC, simply consume their disposable income. Their behavior is thus described by

$$C_{CC,t} = w_{CC,t} N_{CC,t} - T_{CC,t}$$

Households are endowed with a fixed amount of hours N_S and N_{CC} they supply to firms.

2.2 Firms

There is a continuum of monopolistically competitive firms owned by rich households which each produce a variety j from a CES basked of goods. Retailer j combines labor supplied by the two household types using a Cobb Douglas technology:

$$Y_t(j) = A_t N(j)_{S,t}^{(1-\omega_{CC}-d_{CC,t})} N(j)_{CC,t}^{(\omega_{CC}+d_{CC,t})} \tag{4}$$

where $d_{CC,t}$ represents a shock to the production elasticity of rich and non-rich households which I will use to generate increases in household income inequality not accompanied by a decline in the labor share. A negative value of $d_{CC,t}$ lowers the demand for non-rich household labor and thus their real wage, while increasing the demand for rich household labor. The shock can be viewed as a proxy for skill biased technological change and the "Race between education and technology" (Goldin and Katz (2007)). Note that under my assumption of flexible prices (and thus an exogenous price markup) the shock will not change the overall labor income share. The firms first order conditions are given by

$$w_{S,t} = mc_t \left(1 - \omega_{CC} - d_{CC,t}\right) \frac{Y_t}{N_{S,t}} \tag{5}$$

$$w_{CC,t} = mc_t \left(\omega_{CC} + d_{CC,t}\right) \frac{Y_t}{N_{CC,t}} \tag{6}$$

$$\frac{1}{\mu_P + d_{\mu,t}} = mc_t \tag{7}$$

where μ_P denotes the steady state markup of prices over marginal costs and $d_{\mu,t}$ a shock to the markup, which I will use to generate increases in inequality which are accompanied by a decline in the labor share.

2.3 Government

There is a government consuming G_t units of output. It levies lump sum taxes on households in order to keep the government debt-to-GDP ratio and the GDP share of government expenditure constant. For simplicity, I assume that fiscal policy keeps total lump sum taxes of non-rich households constant. Hence fiscal policy is described by

$$b_{gov,t} = \frac{R_{t-1}}{\Pi_t} b_{gov,t-1} + G_t - T_{S,t} - T_{CC,t} \tag{8}$$

$$Target_{bgov2GDP} = \frac{b_{gov,t}}{4Y_t} \tag{9}$$

$$Target_{G2GDP} = \frac{G_t}{Y_t} \tag{10}$$

$$T_{CC,t} = T_{CC} \tag{11}$$

where $Target_{bgov2GDP}$ and $Target_{G2GDP}$ and denote the governments targets for its debt-to-GDP ratio and the GDP share of government expenditure on goods and services, respectively. The central bank successfully pursues a perfect inflation target:

$$\Pi_t = \Pi \tag{12}$$

implying that the actual real interest rate equals the natural rate.

2.4 Equilibrium

Equilibrium in goods, capital and labor markets implies

$$Y_t = C_{S,t} + C_{CC,t} + G_t \tag{13}$$

$$b_{S,t} = b_{gov,t} \tag{14}$$

$$N_{CC,t} = N_{CC} \tag{15}$$

$$N_{O,t} = N_O \tag{16}$$

The only exogenous variables are the shocks to the production elasticity of households $d_{CC,t}$ and the price markup $d_{\mu,t}$.

2.5 Calibration

Without loss of generality, I assume a labor endowment (N_{CC}, N_S) of $\frac{1}{3}$ for both household types. I assume a price markup μ_p of 1.25 (see Table 1). I calibrate the remaining parameters such that the steady state values in the model match the empirical targets reported in Table 2. In the model without CSP type preferences (i.e. where $\phi_b = 0$), there are in total 5 parameters calibrated in this fashion, marked with a *, namely the rich consumption utility curvature σ_S, the rich household discount factor β_S, the non-rich share in labor income ω_{CC} and the governments expenditure and debt targets $Target_{bgov2GDP}$ and $Target_{G2GDP}$. The empirical targets are the intertemporal elasticity of substitution, which I set to 0.5, in line with the mean estimate reported in the meta-analysis of Havranek (2015), the real ex-post federal funds rate, the GDP-share of

Table 1: Parameters simple model

Parameter	Parameter name	Value NOCSP ($\theta = 1$)	Value CSP ($\theta = 0.97$)
β_S	Rich household utility discount factor	0.9951*	0.9652*
σ_S	Rich utility curvature consumption	2*	2*
N_{CC}, N_S	Labor endowments	$\frac{1}{3}$	$\frac{1}{3}$
ω_{CC}	Non-rich share in total labor income	0.85*	0.85*
μ_P	Price markup	1.25	1.25
$Target_{bgov2GDP}$	Gov. debt-to-GDP ratio	0.38*	0.38*
$Target_{G2GDP}$	Government-expenditure-to-GDP ratio	0.2*	0.2*
$\frac{T_{CC}}{T_{CC}+T_S}$	Share of the non-rich in the total tax burden	67%	67%
σ_b	Rich utility curvature of real financial assets	-	0.19*
ϕ_b	Rich utility weight on real financial assets	0	0.32*

Table 2: Targets simple model

Target	Value NOCSP	Value CSP	Source
IES $\frac{1}{\sigma_S}$	0.5	0.5	Havranek (2015)
Real short term interest rate $\frac{R}{\Pi}$	2%	2%	Federal Funds rate minus Core-PCE inflation, APR, (1973-1980 average), FRED
$\frac{G}{Y}$	20%	20%	Government expenditure GDP share (1973-1980 average), BEA
$\frac{b_{gov,S,}}{4Y}$	44%	44%	Federal Debt held by the public, percentage of GDP, (1981-2016 average)
Non-rich income share $\frac{w_{CC}N_{CC}}{Y+b_{gov}\left(\frac{R}{\Pi}-1\right)}$	67%	67%	Bottom 90% net national income share, pre-tax, (1973-1980 average), WID
MPS top 10%	0	0.52	Target CSP case: Dynan et al (2004)
Discounting wedge θ	1.0	0.97	Target CSP case: Literature discount rates (see Table 3)

Note: FRED=Federal Reserve Bank of St. Louis Economic Database. BEA=Bureau of Economic Analysis. IES=Intertemporal Elasticity of Substitution. WID=World Inequality Database, see Alvaredo et al. (2016) and Piketty et al. (2018) for the US data used here for details.

government expenditure, the government debt-to-GDP ratio, and the income share of the bottom 90% of households, which I assume to be the real world counterparts of the non-rich in the model. I compute all targets as averages over the 1973-1980 period, as the historical simulation of Section 4.2 starts in 1981 (the bottom 90% income share is essentially constant during 1973-1980), with the exception of the government debt-to-GDP ratio and the government expenditure share. These targets I compute as averages over the 1981-2016 period since I hold these variables constant throughout the paper. Finally, set the share of the non-rich in the total tax burden equal to their pre-tax income share.

In the model with CSP, I calibrate the two CSP related parameters (ϕ_b, σ_b) by using two additional empirical targets. The first target is an estimate of the "discounting wedge" θ_t, defined as

$$\theta_t \equiv \frac{R_t}{DIS_t}$$

where DIS_t denotes the nominal individual discount rate which the household applies to future nominal income streams (defined by equation 3), with $\theta = \beta_S \frac{R}{\Pi}$ in the steady-state. I assume that $\theta = 0.97$ and discuss this choice below. Note that $\theta < 1$ implies a smaller value of β_S than in the

Table 3: Empirical evidence on θ

Sample period	$DIS_t - 1$(APR)	$R_t - 1$ (APR)	Implied θ	Source of DIS_t; R_t used for comparison	Estimate of DIS_t based on
1929-1948	33.0*	0.8*	0.82	Friedman (1962,1957); real treasury maturity$\geq$ 10 years	Tests of PIH
1960	19.6*	2.0*	0.96	Heckman (1976); real 10 year treasury	Estimated life cycle earnings model
1979	27.4	9.5	0.96	Cylke et al. (1982); 5 year treasury	US Military reenlistment decisions
1972; 1978; 1980	54.7; 64.0; 72.1*	2.9;1.9;2.8*	0.9; 0.89; 0.88	Ruderman et al. (1984), Median; 10 year real treasury	Price of household appliances
1982-1989	18.3	8.6	0.98	Ausubel (1991); one month certificate of deposit	US credit card interest rates
1992-1993	18.7	6.3	0.97	Warner and Pleter (2001), 20 year treasury	US officers severance package choices
1996	22.5	4.2	0.96	Harrison et al. (2002); 1 year money market rate	Experiment, income rich households
2008	28.2/19.0	1.82/3.7	0.9/0.97	Wang et al. (2016); see note.	Experiment, US economics students, hyp. discounting

Notes: If information on the horizon of the choice of the agent under observation was available, $R_t - 1$ is the the safe (e.g. government) interest rate with a maturity as close as possible to this horizon during the year the decision was made. In most other cases, I use the 10 year government bond yield. Numbers marked with a * are estimates of the *real* personal discount rate. The corresponding R I use to compute θ is therefore a measure of the real interest rate, where expected inflation is assumed to equal the average CPI inflation rate over the preceding 10 years. In case of Friedman (1962, 1957), I calculated the relevant i_t as the difference between the average interest rate on long term government bonds (maturity 10 yeas or more, the only long term government bond series for this period I am aware of) over this period, and the average PCE deflator inflation rate.

Ausubel's (1991) investigation of the US market for credit cards is frequently cited as evidence in favor of high personal discount rates. In his sample, more than three quarters of customers holding credit credit cards incur finance charges on substantial outstanding balances in spite of credit card interest rates ranging between 18 and 19%, and he cites industry publications saying that about 90% of an issuers outstanding balance accrue interest.

Wang et al. (2016) allow for hyperbolical discounting and therefore allow the discount rate applied to a payment received one year ahead to exceed the discount rate between any future period. I report both rates and thus two values of theta. The interest rates use to compute θ are the one year treasury bond rate, and the 9 year forward rate one year hence implied by the one and 10 year treasury bond rate.

NOCSP case (which corresponds to $\theta = 1$), given the unchanged target for the real interest rate. Conditional on an assumption for σ_b, the steady state relationship implied by the Euler equation (20) allows to back out ϕ_b as

$$\phi_b = (1-\theta)\,\Lambda_S\,(b_S)^{\sigma_b} \tag{17}$$

To obtain an empirical target for calibrating θ_t, I draw on estimates of the -time varying- nominal individual discount rate which the household applies to future nominal income streams, $DIS_t = \frac{1}{E_t\left\{\frac{\beta\Lambda_{S,t+1}}{\Lambda_{S,t}\Pi_{t+1}}\right\}}$ (as the constant discount rate the household applies to future utility streams β_S is unobservable). All available estimates of DIS_t are point estimates (rather than time series). However, given such a point estimate of DIS_t, I exploit the fact that for sufficiently small values of ϕ_b (i.e. implying θ smaller than but close to one), $\theta_t = \frac{R_t}{DIS_t}$ is approximately constant across time. This property is a consequence of intertemporal substitution by the household: An increase in R_t shifts consumption from t to $t+1$, thus increasing DIS_t.[1] Hence $\theta \approx \frac{R_t}{DIS_t}$. Therefore I estimate θ using point estimates of the personal discount rate and an appropriate market interest rate.

Economists have attempted to estimate the personal discount rate at least since Friedman's (1957) seminal tests of the permanent income hypotheses by studying economic agents behavior when faced with a variety of inter temporal trade-offs (see Table 3). These range from trading off the energy efficiency and price price of household appliances (Ruderman et al. (1984)) to the effects of paying bonuses (Cylke et al. (1982)) or severance packages (Warner and Pleeter (2001)) as a lump sump sums instead of installments, as well as field experiments where probants choose between an immediate payment and a larger deferred payment (Harrison et al. (2002)). As can be obtained from Table 3, the elicited discount rates are quite high, although typically below the estimate of 33% of Friedman (1962,1957). What is more, they also typically exceed safe market interest rates on safe investments with a comparable maturity observed at the time the discount rates were elicited, yielding an implied value of θ smaller than one, sometimes substantially so. The contributions of Harrison et al. (2002) and Warner and Pleeter (2001) are of particular relevance in my context. Harrison et al. (2002) report estimates for (income-) rich households, while Warner and Pleeter's (2002) elicit discount rate of officers of the United States armed forces choosing between two severance packages during the 1992-1995 military draw-down.[2]

Finally, following Kumhof et al. (2015), the second target I use to calibrate the CSP-type preferences is an estimate of the rich household's marginal propensity to save (MPS) out of an increase in their permanent income. Here I draw on the evidence by Dynan et al. (2004), who

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[1] More formally, rearranging equation (20) as $1 - \frac{\phi_b b_{S,t}^{-\sigma_b}}{\Lambda_{S,t}} = \beta R_t E_t \frac{\Lambda_{S,t+1}}{\Pi_{t+1}\Lambda_{S,t}}$, defining $\theta_t = \frac{R_t}{DIS_t} = 1 - \frac{\phi_b b_{S,t}^{-\sigma_b}}{\Lambda_{S,t}}$ and linearizing yields $d\theta_t = \frac{\phi_b (b_S)^{-\sigma_b}}{\Lambda_S}\left(\hat{\Lambda}_{S,t} + \sigma_b \hat{b}_{S,t}\right) = (1-\theta)\left(\sigma_b \hat{b}_{S,t} - \frac{1}{\sigma_S}\hat{C}_{S,t}\right)$. Hence for $1-\theta$ close to zero and reasonable calibrations of σ_S and σ_b even large deviations of $\hat{C}_{S,t}$ and $\hat{b}_{S,t}$ would lead to tiny movements in θ_t, implying that $\theta \approx \frac{R_t}{DIS_t}$ is a good approximation.

[2] The authors report that virtually all of the officers in their sample have a college degree, while according to the Current Population survey the same was true for only 24.5% of individuals in the same age group.

estimate the MPS for households in the top 5% of the income distribution. To compute the rich household MPS, I perform a microsimulation, described in Appendix A.

2.6 An increase in inequality in the simple model

All simulations in this paper are performed using the deterministic nonlinear solution algorithm of the Matlab package Dynare (see Adjemian et al. (2011)). Figure 1 displays separately the effect of a permanent increase in the markup (black lines) and the labor income share of rich households (red lines line). Both shocks are calibrated such that the share of non-rich households in total household income declines by 1 percentage point on impact. In this highly simplified model, both distribution shocks also have effects of identical magnitudes on the consumption of rich (which increases) and non-rich households (which decreases), while the labor share is affected only by the markup shock. Furthermore, CSP do not change the effect of the increase in inequality on any of the variables except for the interest rate and the non-rich income share. The interest rate declines by about 1 percentage point. Hence, in the presence of CSP, the increase in rich households permanent income does not in itself trigger an increase in rich household consumption of the same size. Since rich household wealth $b_{s,t}$ is constant as a result of the government's fiscal policy (see equation 9), for bond and goods markets to clear, the interest rate has to decline (see equation 2). The interest rate decline partially compensates for the increase in labor or profit income of the rich, implying that the non-rich income share recovers by about 0.2 percentage points in the second quarter.

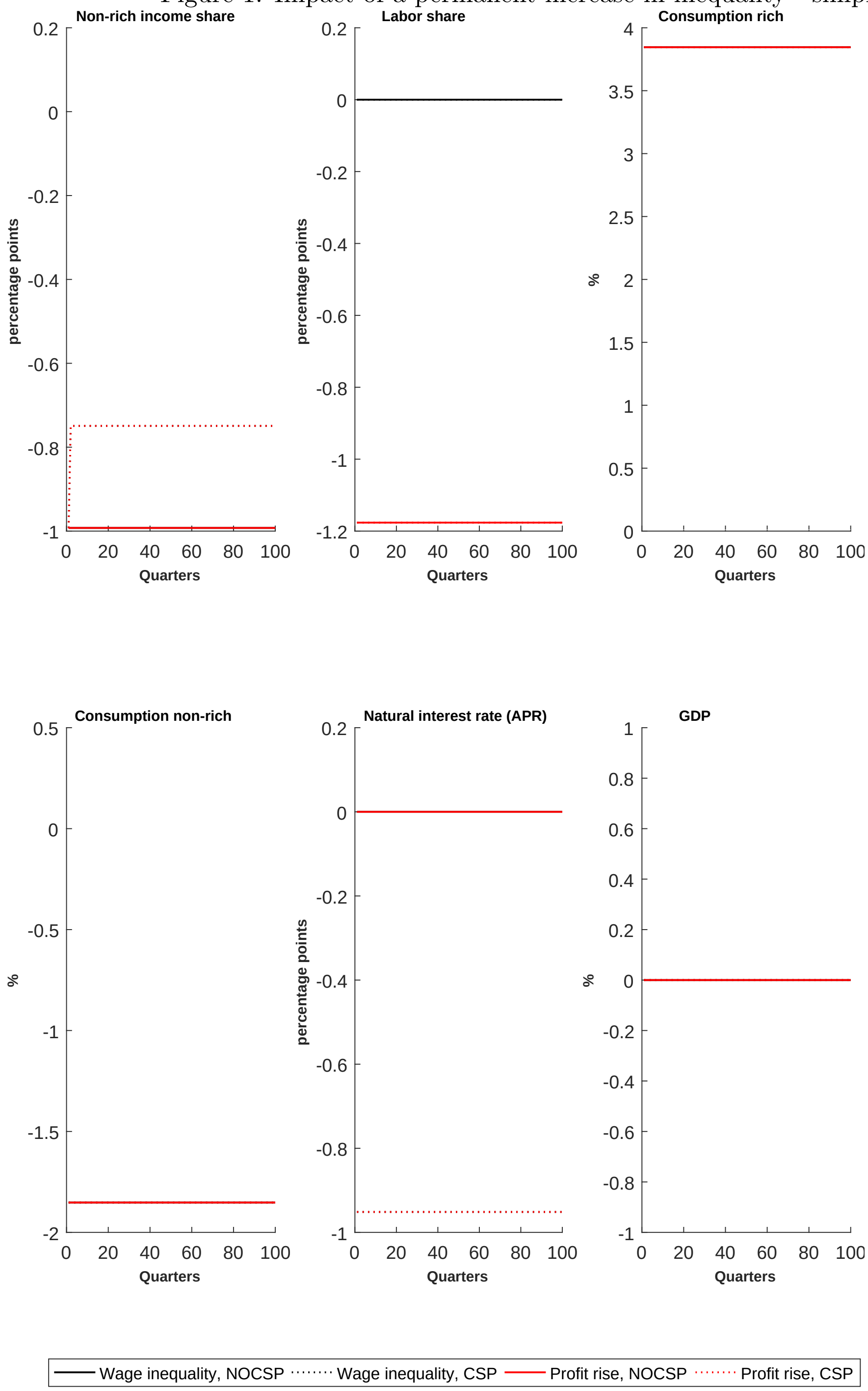
3 The full model

The full model allows rich households to invest in financial intermediary deposits, physical capital and housing (on top of the government bonds of the simple model). They derive utility from all of these assets. Non-rich households derive utility from consumption and housing and borrow from financial intermediaries. These extensions constitute a robustness checks of the simple models predictions by offering rich households alternative asset classes, which might a priori be expected to reduce the impact of rising inequality on the interest rate on government bonds. Furthermore, they allow to generate predictions regarding the impact of rising inequality on the borrowing and LTV of the bottom 90%, which likewise displayed trends during the 1981-2016 period.

3.1 Rich households

Rich households derive utility from consumption $C_{S,t}$, their stocks of safe real financial assets $b_{S,t}$ (consisting of financial intermediary deposits and government bonds), the value of their physical capital $Q_t K_t$ and their housing stock $H_{S,t}$. Their objective function is thus given by

Figure 1: Impact of a permanent increase in inequality - simple model



$$E_t\left\{\sum_{i=0}^{\infty}\beta_S^i\left[\frac{C_{S,t+i}^{1-\sigma_S}}{1-\sigma_S}C_{S,t+i}^{1-\sigma_S}+\frac{\phi_{H,S}}{1-\sigma_{H,S}}H_{S,t+i}^{1-\sigma_{H,S}}+\frac{\phi_b}{1-\sigma_b}\left(b_{S,t+i}\right)^{1-\sigma_b}+\frac{\phi_K}{1-\sigma_K}\left(Q_{t+i}K_{t+i}\right)^{1-\sigma_K}\right]\right\}$$

From now on, I will refer to the model where the rich derive utility from real financial assets and physical capital (i.e. $\phi_b, \phi_K > 0$) on top of housing and consumption as the CSP model, while I refer to the case where the rich do not derive utility from these two assets ($\phi_b = \phi_K = 0$) as the model without CSP (NOCSP). A rich household's budget constraint is given by

$$\begin{aligned} b_{S,t} = {} & \frac{R_{t-1}}{\Pi_t}b_{S,t-1}+w_{S,t}N_{S,t}+r_{K,t}K_{t-1}+\Xi_t \\ & -Q_{H,t}\left(H_{S,t}-H_{S,t-1}\right)-T_{S,t}-C_{S,t}-\left(I_t+K_{t-1}\Phi\left(\frac{I_t}{K_{t-1}}\right)\right) \end{aligned}$$

with

$$K_t = \left(1-\delta\right)K_{t-1}+I_t$$

where $r_{K,t}$, $Q_{H,t}$, Ξ_t, I_t and δ denote the the real capital rental, the real house price, real profits of the firms, investment and the depreciation rate of physical capital, respectively. $\Phi\left(\frac{I_t}{K_{t-1}}\right)$ denotes convex capital stock adjustment costs, with

$$\Phi\left(\frac{I_t}{K_{t-1}}\right)=\frac{\epsilon_I}{2}\left(\frac{I_t}{K_{t-1}}-\delta\right)^2 \tag{18}$$

The first order conditions with respect to consumption, financial assets, capital, investment and housing are given by

$$\Lambda_{S,t} = \frac{1}{C_{S,t}^{\sigma_S}} \tag{19}$$

$$\Lambda_{S,t} = \beta_S E_t\left\{\Lambda_{S,t+1}\frac{R_t}{\Pi_{t+1}}\right\})+\phi_b b_{S,t}^{-\sigma_b} \tag{20}$$

$$Q_t = E_t\left\{\beta_S\frac{\Lambda_{S,t+1}}{\Lambda_{S,t}}\left[r_{K,t+1}+\frac{I_{t+1}}{K_t}\Phi'\left(\frac{I_{t+1}}{K_t}\right)-\Phi\left(\frac{I_{t+1}}{K_t}\right)+\left(1-\delta\right)Q_{t+1}\right]+Q_t\frac{\phi_K\left(Q_tK_t\right)^{-\sigma_K}}{\Lambda_{S,t}}\right\} \tag{21}$$

$$1+\left(\Phi'\left(\frac{I_t}{K_{t-1}}\right)\right)=Q_t \tag{22}$$

$$Q_{H,t}=\frac{\phi_{H,S}}{H_{S,t}^{\sigma_{H,S}}\Lambda_{S,t}}+\beta_S E_t\left\{\frac{\Lambda_{S,t+1}}{\Lambda_{S,t}}Q_{H,t+1}\right\} \tag{23}$$

where Q_t denotes the real value of an additional unit of capital to the household.

3.2 Borrower (non-rich) households

Borrowing households are indexed with CC and derive utility from consumption and housing. The objective of a borrower household is given by

$$E_t\left\{\sum_{i=0}^{\infty}\beta_{CC}^{i}\left[\frac{C_{CC,t+i}^{1-\sigma_{CC}}}{1-\sigma_{CC}}C_{CC,t+i}^{1-\sigma_S}+\frac{\phi_{H,CC,t+i}}{1-\sigma_{H,CC}}H_{S,t+i}^{1-\sigma_{H,CC}}\right]\right\}$$

where I allow the utility weight on housing to be time varying (but exogenous to the individual borrower household). I assume that non-rich households are sufficiently impatient such that their borrowing is positive in equilibrium. Furthermore, I assume that borrowing is subject to a costly friction, possibly in the form of a default cost. The friction becomes more severe the larger a household's Loan to Value (LTV) ratio $\frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}$, possibly because the likelihood of (strategic) default increases. The financial intermediary passes these costs fully to borrower households, implying that the borrowers expected total cost of borrowing $E_t\left\{R_{L,t+1}\right\}$ on her period t borrowing is determined by

$$\frac{E_t\left\{R_{L,t+1}\right\}}{R_t}=\left(1+E_t\left\{f\left(\frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}\right)\right\}\right) \tag{24}$$

with $f'\left(\right)>0$. These assumptions capture in a simple fashion the empirical finding that non-rich households are more likely to be subject to borrowing constraints, but that their constraint is lessened by an increase in the value of their home, as argued by Mian and Sufi (2014, 2011). In Appendix B, I show that a positive relationship between the households LTV and her cost of borrowing may be microfounded by assuming idiosyncratic shocks to the value of a borrowers house, costly strategic default, and that the borrower's house serves as collateral in a state contingent debt contract, following Onorante et al. (2017). The simulation results I discuss in Section 4 of the main text are broadly robust to adopting this microfoundation (see Appendix C for details).

The budget constrained of borrowing households is given by

$$\frac{R_{L,t}}{\Pi_t}b_{CC,t-1}+C_{CC,t}+Q_{H,t}\left(H_{CC,t}-H_{CC,t-1}\right)=b_{CC_t}+w_{CC,t}N_{CC,t}-T_{CC,t} \tag{25}$$

The FOCs with respect to consumption $C_{CC,t}$, real loans $b_{CC,t}$, housing $H_{CC,t}$, and the expected loan interest rate $R_{L,t+1}$ imply

$$\Lambda_{CC,t} = \frac{1}{C_{CC,t}^{\sigma_{CC}}} \tag{26}$$

$$\Lambda_{CC,t} = \beta_{CC} E_t \left\{ \Lambda_{CC,t+1} \left[\frac{R_{L,t+1}}{\Pi_{t+1}} + \frac{\frac{dR_{L,t+1}}{db_{CC,t}}\left(\frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}\right)}{\Pi_{t+1}} b_{CC,t} \right] \right\} \tag{27}$$

$$Q_{H,t} = \frac{\phi_{H,CC,t}}{\Lambda_{CC,t} H_{CC,t}^{\sigma_{H,CC}}} + \beta_{CC} E_t \left\{ \frac{\Lambda_{CC,t+1}}{\Lambda_{CC,t}} \left(Q_{H,t+1} - \frac{\frac{dR_{L,t+1}}{dH_{CC,t}}\left(\frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}\right)}{\Pi_{t+1}} b_{CC,t} \right) \right\} \tag{28}$$

where $\frac{dR_{L,t+1}}{db_{CC}}\left(\frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}\right)$ denotes the effect of an increase in borrowing $b_{CC,t}$ on the loan rate $R_{L,t+1}$ implied by the loan supply curve (24). Hence when trading off today's and tomorrow's consumption, borrower households take into account both the expected interest rate on the additional unit of borrowing $\frac{R_{L,t+1}}{\Pi_{t+1}}$ and the expected increase in the interest rate burden on their existing stock of borrowing $\frac{dR_{L,t+1}}{db_{CC}}\left(\frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}\right)$ resulting from the worsening of the borrowing friction. Correspondingly, $\frac{dR_{L,t+1}}{dH_{CC,t}}\left(\frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}\right)$ denotes the implied (negative) effect of an increase in the housing stock on the loan rate (holding $b_{CC,t}$ constant). I assume that $f\,()$ is described by a simple linear function

$$f\left(LTV_t\right) = \chi_{CC} LTV_t \tag{29}$$

with $LTV_t = \frac{b_{CC,t}}{H_{CC,t}Q_{H,t+1}}$.

Finally, I assume that the utility weight on housing of the non-rich $\phi_{H,CC,t}$ may depend on lagged rich household total consumption (including housing consumption) $C_{T,S,t-1}$

$$\phi_{H,CC,t} = \phi_{H,CC} \left(\left(\frac{C_{T,S,t-1}}{C_S} \right)^{\nu_{cascade}} \right)^{\sigma_{H,CC}} \tag{30}$$

$$C_{T,S,t} = C_{S,t} + \left(\frac{\phi_{H,S}}{\Lambda_{S,t} H_{S,t}^{\sigma_{H,S}}} \right) H_{S,t} \tag{31}$$

with $\phi_{H,CC} > 0$ and $\nu_{cascade} \geqq 0$. Hence a one percent increase in lagged total rich household consumption $C_{T,S,t-1}$ increases the housing demand of the non-rich by $\nu_{cascade}$ percent. $\left(\phi_{H,S}\frac{1}{\Lambda_{S,t}H_{S,t}}\right)$ denotes rich households' "shadow rent", i.e. the value of an additional unit of housing to rich households expressed in consumption units. The motivation for this assumption is the so called "catching up with the richer Joneses (Drechsel-Grau and Schmid 2014)" type behavior. Specifically, there is microeconometric evidence that households care about their consumption relative to a reference group richer than themselves, and that an increase in the consumption of that richer reference group boosts their own consumption (see Kuhn et al. (2011), Drechsel-Grau and Schmid (2014), Bertrand and Morse (2016)), thus giving rise to so called "consumption cascades" (Frank et al. 2014). I limit the consumption cascade effect to the non-rich utility from housing due to the evidence in Bertrand and Morse (2016), who find that in response to a one percent increase increase in the (total) consumption of the top 10% of households in a given state, the bottom 90% increase both the amount of housing services they consume and the share of housing in their consumption basket.[3] They provide evidence that the disproportional effect on non-rich housing consumption maybe related to the high visibility and thus status intensity of housing consumption. In the historical simulation of Section 4.2, this feature will help the model to match the upward trend of the value of the housing stock relative to GDP and the bottom 90% debt-to-income ratio observed during the pre-crisis period by boosting the effect of rising inequality on housing demand, which in turn relaxes the borrowing constraint of non-rich households by lowering their LTV_t.

3.3 Firms

The Firms' technology now features physical capital and is thus given by

$$Y_t\left(j\right) = A_t N\left(j\right)_{S,t}^{(1-\omega_{CC}-d_{CC,t})(1-\alpha_K)} N\left(j\right)_{CC,t}^{(\omega_{CC}+d_{CC,t})(1-\alpha_K)} K\left(j\right)_t^{\alpha_K} \tag{32}$$

implying the following FOCs:

$$r_{K,t} = mc_t \alpha_K \frac{Y_t}{K_{t-1}} \tag{33}$$

$$w_{S,t} = mc_t\left(1-\alpha_K\right)\left(1-\omega_{CC}-d_{CC,t}\right)\frac{Y_t}{N_{S,t}} \tag{34}$$

$$w_{CC,t} = mc_t\left(1-\alpha_K\right)\left(\omega_{CC}+d_{CC,t}\right)\frac{Y_t}{N_{CC,t}} \tag{35}$$

$$\frac{1}{\mu_P + d_{\mu,t}} = mc_t \tag{36}$$

3.4 Government

I assume that the government sets the share of non-rich agents in total lump sum taxes payable equal to their share in total net national households income:

[3]See Table 2, column 3, and Internet Appendix Table A9, rows 2 and 4.

$$Target_{T_{CC}2T_t} = \frac{T_{CC,t}}{T_{S,t} + T_{CC,t}} \tag{37}$$

$$Target_{T_{CC}2T_t} = \frac{w_{CC,t}N_{CC,t} - \frac{R_{L,t}}{\Pi_t}b_{CC,t-1}}{Y_t - I_t - b_{CC,t-1}f\left(LTV_t\right)\frac{R_{t-1}}{\Pi_t} + \left(\frac{R_{t-1}}{\Pi_t} - 1\right)b_{gov,t-1}} \tag{38}$$

These equations replace equation (11), while the remaining equations of the government sector remain unchanged.

3.5 Equilibrium

Equilibrium in the goods market, the market for safe assets and the housing market are given by

$$\begin{aligned} Y_t = {} & C_{S,t} + C_{CC,t} + \left(I_t + \Phi\left(\frac{I_t}{K_{t-1}}\right)K_{t-1}\right) + G_t \\ & + b_{CC,t-1}f\left(LTV_t\right)\frac{R_{t-1}}{\Pi_t} \end{aligned} \tag{39}$$

$$b_{S,t} = b_{CC,t} + b_{gov,t} \tag{40}$$

$$H = H_{S,t} + H_{CC,t} \tag{41}$$

where I assume a constant economy wide housing stock H . Thus the endogenous variables of the model are determined by (19)-(41) and (5)-(12). The only exogenous variables are the shocks to the production elasticity of households $d_{CC,t}$ and the price markup $d_{\mu,t}$.

3.6 Calibration

I set the capital stock adjustment cost curvature $\epsilon_I = 7$, in line with the estimate of Cummins et al. (2006) (see Table 5). The rate of depreciation δ equals 0.025. In line with the literature on housing in DSGE models, I assume a partial equilibrium income effect on housing demand of 1% (i.e. $\sigma_{H,S} = \sigma_{H,CC} = \sigma_{CC} = \sigma_S$ (e.g. Iacoviello (2005, 2014), Iacoviello and Neri (2010) and Clerc et al. (2015)). Without loss of generality, the labor endowments are set to $\frac{1}{3}$ for both agent types. As in the simple model, I set the remaining parameters in order to match a range of empirical targets, reported in Table 4, with the rich corresponding to the top 10% of households. In the full model without CSP-type preferences, there are in total 11 parameters calibrated in this fashion (σ_S, β_S, β_{CC}, $\phi_{H,S}$, $\phi_{H,CC}$, μ_p, α_K, ω_{CC}, $Target_{G2GDP}$, $Target_{bgov2GDP}$, χ_{CC}). They are pinned down by the intertemporal elasticity of substitution (as estimated by Havranek (2015)), the real short term interest rate, the borrower debt-to-annual income ratio, the residential-housing-stock-to-annual-GDP ratio, the share of borrowers in total residential real estate, the labor share, the share of non-residential fixed investment in GDP, the share of borrowers in total net national income, the

GDP share of government expenditure on goods and services, the government-debt-to-GDP ratio, and a measure of the spread of the mortgage rate over the risk free rate.

The CSP-type preferences of the rich are now described by four parameters, σ_b, ϕ_b, σ_K and ϕ_K, two more than in the simple model of Section 2. Therefore I ad two additional empirical targets to calibrate the preference parameters, on top of the marginal propensity to save of the rich and the discounting wedge θ. The first is the spread between the return on capital $r_K - \delta$ and the real risk free rate $\frac{R}{\Pi}$. I measure this spread as a simple average of an empirical estimate of the external finance premium and the equity risk premium (see Table 4 for details). The second is the evidence of Gale and Orszag (2004), Engen and Hubbard (2004) and Laubach (2009) on the effect of a one percentage point increase in the government debt-to-annual-GDP ratio on the real interest rate on US government bonds, for which these authors find a range of 0.03 to 0.06 percentage points. I assume that the corresponding model counterpart is the effect of a one percentage point permanent increase of the government debt-to-annual-GDP ratio on the steady-state real interest rate. In practice, the value of $\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$ implied by the model is closely linked to the value of σ_b.[4]

Unless explicitly mentioned, I assume that there is no effect of rich household consumption on the utility borrower household derive from housing ($\nu_{cascade} = 0$) . Otherwise, I set $\nu_{cascade} = 0.7$, in line with the evidence of Bertrand and Morse (2016), who find that a 1% increase in the total consumption of the top 10% households increases the consumption of housing services by the bottom 90% of households living in the same state by about 0.7%.

4 Results in the full model

In this section, using the model developed in Section 3, I first investigate the effect of one-off wage inequality and price markup shocks (Section 4.1), and then perform a historical simulation which replicates the decline of the US labor share and the bottom 90% national income share over the 1981-2016 period. As shown in Appendix C, the results based on the model of Section 3 are broadly robust to explicitly modeling the borrowing friction assumed above.

4.1 A one-off permanent increase in inequality

I first consider the effect of a permanent decline in the share of borrower households in total labor income, caused by a permanent decline (increase) in the elasticity of output with respect to the labor supplied by borrower (rich) households, i.e. $d_{CC,t}$ becomes permanently negative (see Figure 2). I calibrate the value of $d_{CC,t}$ such that the on-impact decline of the borrower household income share equals approximately 1%. Without CSP (solid black line), rich households increase their consumption and housing demand on impact by approximately the magnitude of their permanent

[4] Note that the value of $\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$ implied by the calibration is at the upper bound of the empirical range. Targeting a lower value would imply a smaller value of σ_b and a larger value of σ_K, and would strengthen the results discussed in Section 4.

Table 4: Targets

Target	Value data	NOCSP	CSP	Source
Real short term interest rate $\frac{R}{\Pi}$	2%	2%	2%	Federal Funds rate minus core-PCE inflation, (APR, 1973-1980 average), FRED
IES $\frac{1}{\sigma_S}$	0.5	0.5	0.5	Havranek (2015)
$\frac{w_O N_O + w_{CC} N_{CC}}{Y}$	62.8%	62.8%	62.8%	Labor share non-farm business sector, (1973-1980 average), BLS
$\frac{I}{Y}$	12.3%	12.3%	12.3%	Share of non-residential fixed investment in GDP, (1973-1980 average), BEA
$\frac{G}{Y}$	20%	20%	20%	Government expenditure as percentage of GDP, (1981-2016 average), BEA
$\frac{b_{gov,S,}}{4Y}$	44%	44%	44%	Federal Debt held by the public, percentage of GDP, (1981-2016 average), FRED
Borrower net income share $\frac{w_{CC}N_{CC} - \left(\frac{R_L}{\Pi}-1\right)b_{CC}}{Y+\left(\frac{R}{\Pi}-1\right)b_{gov} - I - f(LTV)\frac{R}{\Pi}b_{CC}}$	67%	67%	67%	Bottom 90% net national income share, pre-tax, (1973-1980 average), WID
Residential housing stock to GDP $\left(\frac{Q_H H}{4Y}\right)$	106%	106%	106%	Flow of Funds (1973-1980 average), Federal Reserve Board
Borrower share in total residential real estate $\left(\frac{Q_H H_{CC}}{Q_H H}\right)$	70%	70%	70%	Bottom 90% share in residential real estate, Survey of Consumer Finances, 1983
Borrower debt-to-annual income ratio	38%	38%	38%	Debt secured by primary residence, Survey of Consumer Finances, 1983
Mortgages rate minus risk free rate $R_L - R$	1.68%	1.68%	1.68%	30 year mortgage rate minus 30 year treasury (APR, 1981-2016 average), FRED
MPS top 5%	0.52	0	0.56	Dynan et al (2004)
Discounting wedge θ	0.97	1.0	0.97	Target CSP case: Literature discount rates (see Table 3)
Return on capital minus risk free rate $r_K - \delta - \left(\frac{R}{\Pi}-1\right)$	4%	0	4%	Target CSP case: See note below for details
$\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$	$0.03 - 0.06 p.p.$	0	$0.058\ p.p.$	Target CSP case: See note below for details.

Note:

- For the calibration of θ, see Table 3.
- Since the Federal Reserve board publishes comprehensive summary statistics for the Survey of consumer Finances only starting 1989, the 1983 data required to compute the bottom 90% mortgage-debt-to-income ratio, their share in residential real estate and their LTV were computed as follows:
  - Bottom 90% mean income: Computed from Table 1 in Avery et al. (1984a), Table 1, which divides the household population into different household income intervals.
  - Bottom 90% mean mortgage debt (secured by primary residence): From Avery et al. (1984b), Table 1 (which reports mean mortgage debt and the incidence of owing mortgage debt for selected income groups), and using the aforementioned population shares as weights.
  - Bottom 90% and top 10% mean home value: From Avery et al. (1984a), Table 5 and 7, which contains home ownership incidence and net equity of homeowners for selected household income intervals.
- The target for the spread between the return on capital and the risk free rate $r_K - \delta - \left(\frac{R}{\Pi}-1\right)$ and the risk free rate is a simple average of
  - The spread between the yield on Moody's seasoned BAA rated corporate bonds and 10 year treasury bonds, 1981-2016 average, which equals 2.4%.
  - The average estimate of the equity risk premium reported in Duarte and Rosa (2015), Table 7, which equals 5.7%.
- The range of empirical estimates of $\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$ are obtained from Gale and Orszag (2004), Engen and Hubbard (2004) and Laubach (2009).
- FRED=Federal Reserve Bank of St. Louis Economic Database. BEA=Bureau of Economic Analysis. BLS=Bureau of Labor Statistics.

Table 5: Full model, parameter values

Parameter	Parameter name	Value NOCSP ($\theta = 1$)	Value CSP ($\theta = 0.97$)
β_S	Rich utility discount factor	0.9951$*$	0.9652$*$
β_{CC}	Borrower utility discount factor	0.9868$*$	0.9868$*$
σ_S, σ_{CC}	Utility curvature consumption	2*	2*
$\sigma_{S,H}, \sigma_{CC,H}$	Utility curvature housing	2	2
N_{CC}, N_S	Labor endowments	$\frac{1}{3}$	$\frac{1}{3}$
$\phi_{H,S}$	Rich utility weight on housing	0.03*	1.25$*$
$\phi_{H,CC}$	Borrower utility weight on housing	0.44$*$	0.44$*$
$\nu_{cascade}$	Consumption cascade	0	0/0.7
μ_p	Price markup	1.26$*$	1.26$*$
α_K	Output elasticity w.r.t. capital	0.21$*$	0.21$*$
ω_{CC}	Borrower share in labor income	0.95$*$	0.95$*$
δ	Depreciation rate physical capital	0.025	0.025
ϵ_I	Capital adjustment cost curvature	7	7
χ_{CC}	Financial intermediation cost, linear	0.0136*	0.0136*
$Target_{bgov2GDP}$	Government debt target	44%	44%
$Target_{G2GDP}$	Government expenditure share target	20%	20%
σ_b	CSP: Utility curvature, real financial assets	$-$	0.5$*$
σ_K	CSP: Utility curvature, physical capital	—	4$*$
ϕ_b	CSP: Utility weight on real financial assets	0$*$	3.13$*$
ϕ_K	CSP: Utility weight on physical capital	0$*$	72.68$*$

Note: Values marked with a * are set to match the targets reported in Table 4.

income change, similar to the simple model (Figure 1). Similarly, borrower households lower their consumption by approximately the decrease in their permanent income, and permanently reduce their borrowing and housing demand. As a result, without CSP, the effect on the natural interest rate is small, and actually positive on impact before returning to zero.

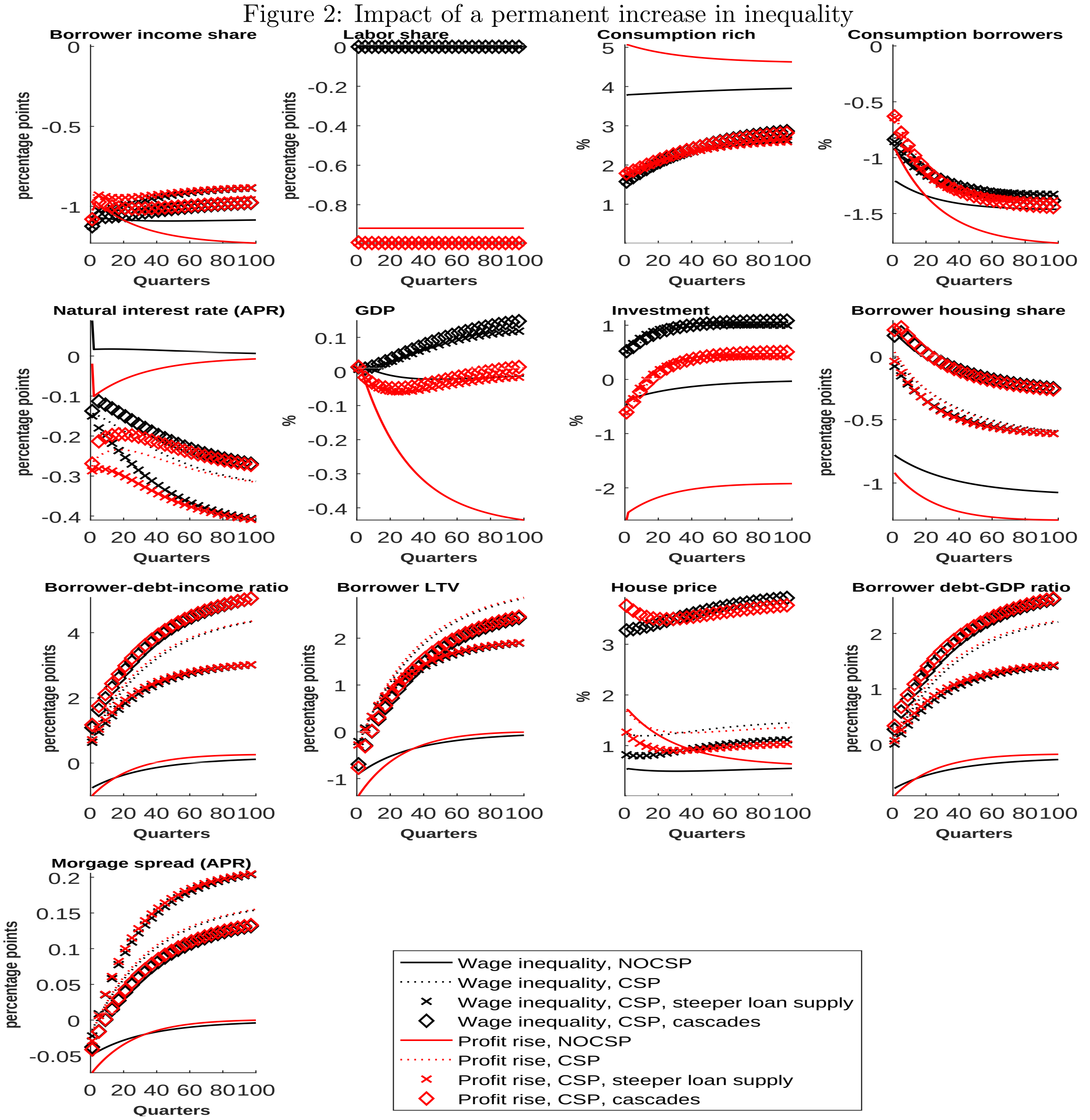
By contrast, with CSP (dotted black line), rich households increase their consumption by only half as much as without CSP, implying that in order to equilibrate capital and goods markets, the natural interest rate declines. The decline in the natural rate is initially fully passed on to borrowers, which motivates them to postpone the decline in their consumption of goods and housing services, implying a higher trajectory of borrower consumption and housing demand than in the NOCSP case, as well as an increase in their debt. At the same time, the lower interest rate than in the absence of CSP increases the relative housing demand of both rich and non-rich households, implying that the value of the housing stock increases substantially more than without CSP. The increase in house prices tends to relax the borrower households borrowing constraint, which tends to further strengthen their consumption and housing demand. As a result, their debt-to-income ratio steeply increases, while their LTV actually decreases during the first year before turning positive.

Apart from expanding their lending to borrower households via the financial intermediary, saver households also use their additional income to increase their investment, as the decline in the safe interest rate and the decline in the marginal utility of consumption relative to the marginal utility of physical capital renders physical capital relatively more attractive. As a result, the physical capital stock and GDP increase.

To illustrate the role of borrowing friction, the graph also displays the response of the economy to the wage inequality shock assuming a loan supply curve twice as steep as in the baseline case (i.e. $\chi_{CC} = 0.0276$). With steeper loan supply, an increase in inequality generates a smaller increase in borrowing than with linear loan supply, as well as of the LTV in the medium and long run (see the black cross line). The smaller increase in borrowing implies that the natural rate has to decline by more to equilibrate capital and goods markets.

Allowing for a role of spending cascades ($\nu_{cascade} = 0.7$) on top of CSP strongly raises the effect of an increase in wage inequality on household debt and the value of the housing stock (see the black diamond lines). The increase in rich household consumption increases the housing demand of borrowers, which they fund via additional debt. The stronger rise of the house price implies that, in spite of their higher debt trajectory, their LTV is actually smaller than in the absence of spending cascades (compare the black dotted and the black diamond line). By contrast, the observed decline in the natural interest rate is slightly smaller.

Figure 2: Impact of a permanent increase in inequality



Note: The black lines display the effect of a one-off permanent decline in the elasticity of output with respect to the labor supplied by non-rich (rich) households ($d_{CC,t}$ permanently declines, see equation (32)). The red lines display the effect of a one-off increase in the price markup ($d_{\mu,t}$ permanently increases). CSP refers to the model with Capitalist Spirit type Preferences. "Steeper loan supply" refers to the case where $\chi_{CC} = 0.0276$, i.e. double the value displayed in Table 5. "cascades" refers to the scenario where the effect of rich household total consumption on non-rich housing demand (see equation (30)) is active (i.e. $\nu_{cascade} > 0$). The safe interest rate R_t and the risk spread $E_t R_{L,t+1} - R_t$ are expressed as Annualized Percentage Rates. The borrower debt-to-income ratio is based on annualized borrower income. The borrower-debt-to-GDP ratio is based on annualized GDP.

An increase in inequality driven by a permanent rise in the price markup (the red lines) reduces the demand for capital goods by the monopolistically competitive firms and thus the capital rental $r_{K,t}$ earned by households (see equations (7) and (33)) and thus their incentive to invest. The decline in in their investment expenditure allows rich households to increase their consumption even more than for an increase in wage inequality, implying that house prices now increase more due to a larger wealth effect on rich households housing demand. Apart from these differences, the impact of the shock is very similar to the just discussed effect of an increase in wage inequality. The same is true for the effect of allowing for CSP, which again implies, inter alia, a decline in the natural rate, an increase in borrower household debt, an increase in house prices exceeding the increase observed in the absence of CSP and a higher trajectory for investment due to the lower real interest rate and the increase in the marginal utility of physical capital relative to the marginal utility of consumption.

Finally, note that due to the existence of additional uses for the savings of rich households not present in the simple model of Section 2 (i.e. residential housing, physical capital, lending to the non-rich via financial intermediaries), the simulated decline in the safe real interest rate is smaller than in Figure 1. Nevertheless, as discussed in the following section, when the actual decline of the income share of the bottom 90% of households over the 1981-2014 period are replicated in the model, the resulting decline in the natural rate is substantial.

4.2 Simulation of the empirically observed increase in inequality

Using the model with CSP, I now replicate two stylized facts of the US income distribution over the 1981-2016 period. The first of these is the recent decline of the US labor share, which starts at around the late 1990s (see Figure 3 first panel, the solid red line). In order to match the path of the labor share, I assume a sequence of of unexpected permanent positive shocks to the price markup $d_{\mu,t}$. Barkai (2017), De Loecker and Eckhout (2017), Gutierrez (2017) and Hall (2018) provide evidence that the decline in the US labor share can be attributed to an increase in product market price markups (rather than an increase in the role of physical capital in production). In order to remove purely cyclical labor share fluctuations, I match an 8 year moving average of the labor share. The peak increase in the price markup in the simulation equals 0.14, which is less than estimated by Hall (2018), and much less than estimated by Barkai (2017) and De Loecker and Eckhout (2017).

The second stylized fact is the decline of the pre-tax national income share of the bottom 90% of households reported in the World Inequality Database (WID) up until 2014. While the model abstracts from the potential role of progressive income taxation in attenuating the effect of rising pre-tax inequality on household finances, the bottom 90% post-tax disposable income share displays a very similar trend.[5] The decline in the bottom 90% income share began already in the early 1980s (see the first panel of Figure 3 , the solid black line) and until the early 2000s was mainly driven labor income dispersion (see Piketty et al. (2018)), consistent with the absence of

[5]Specifically, by 2014, the bottom 90% pre-tax national income share has declined by 12.7 percentage points, while the post-tax disposable national income share has declined by 10.7 percentage points. The post-tax disposable income series aims to describe post-tax, post transfer inequality, see Alvaredo et al. (2016).

a trend in the labor share during that period. This finding is also supported by microevidence.[6] Therefore, given the assumed sequence of price markup shocks and their effect on the household income distribution, I then assume a sequence of unexpected negative permanent shocks to the the relative labor productivity of borrower households $d_{CC,t}$ calibrated to set the path of the non-rich household income share in the model equal to the bottom 90% income share in the data. Since the WID data is available at an annual frequency only and my focus is on the trends in any case, I assume that the changes in $d_{CC,t}$ and $d_{\mu,t}$ occur every four quarters, starting with the first simulation quarter.

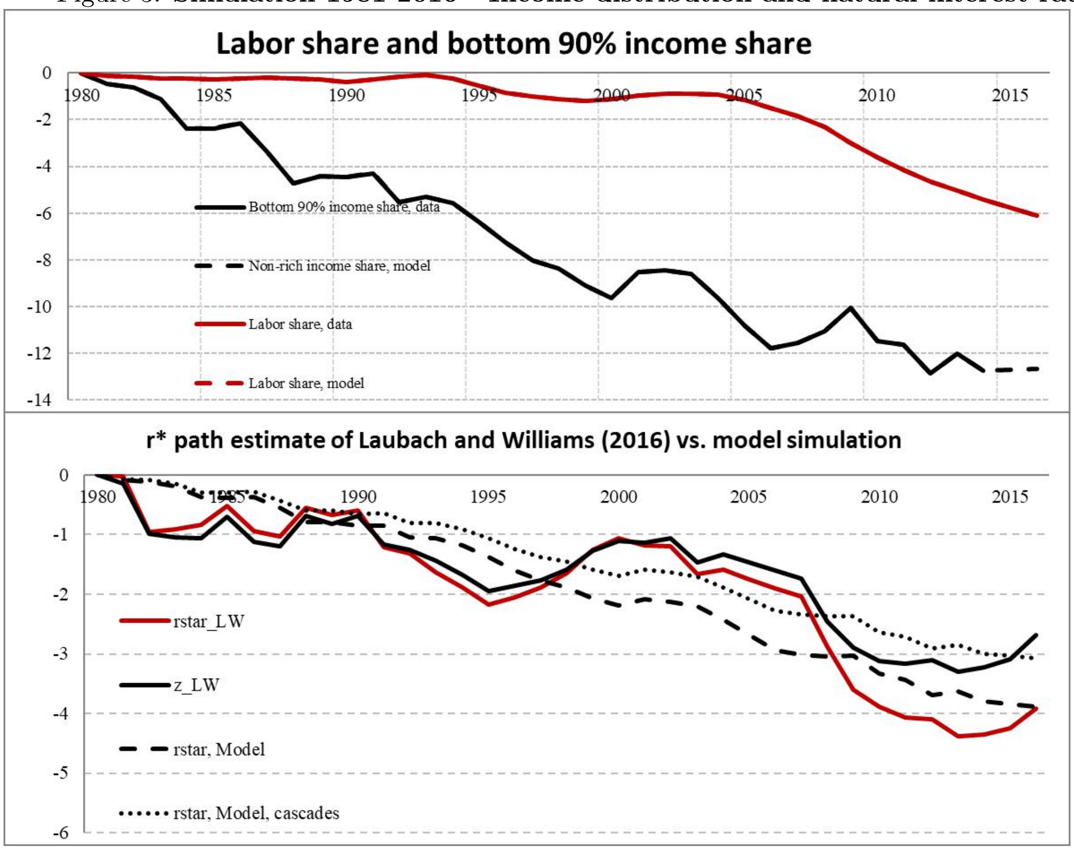
As can be obtained from the second panel of Figure 3, the simulated increase in inequality generates a decline in the natural interest rate by between 3 and 4 percentage points over the 1981-2016 period, depending on whether I allow for spending cascades. The simulation is thus able to replicate the downward trend of the part of the natural rate attributed by Laubach and Williams (2015) to factors other than trend GDP growth (labeled "z_LW" in the graph).

It should be remembered that the model's only drivers are the two aforementioned shocks to the income distribution, and that the model represents a hypothetical flexible price equilibrium, i.e. a situation where the output gap is closed. It thus abstracts from a multitude of potentially relevant influences, and would not be expected a priori to match the data year by year. That being said, the simulation speaks to a number of important trends observed during the 1980-2016 period. It closely tracks the upward trend of the bottom 90% of households mortgage debt-to-income ratio from the early 1980s until about 2001 (see Figure 4). While the simulation lags somewhat behind the data during the US housing price boom, it nevertheless replicates almost four fifths of the peak increase of the bottom 90% debt-to-income ratio (observed around 2007/2010) compared to its 1980 value. The simulation roughly tracks the rising trend of the bottom 90% LTV observed in the data up until 2010. During the following years, the model without spending cascades generates higher LTV trajectory than observed in the data, however this overprediction largely disappears if I allow for spending cascades.

The model also generates an empirically relevant rising trend of the nominal-residential housing-stock-to-GDP ratio and the household mortgage-debt-to-GDP ratio (see Figure 5). Apart from a rising trend, in the data both variables display substantial volatility, especially post 2001, which my simple simulation exercise cannot capture. Nevertheless, the model with spending cascades matches about two thirds of the peak increase of the residential-housing-stock-to-GDP and the household mortgage-debt-to-GDP ratio compared to their respective 1980 values (attained around 2008). Hence the model developed above is able to broadly match the post 1980 downward trend of the natural rate of interest estimated by Laubach and Williams (2016), the upward trend of measures of the observed increase of the indebtedness of the bottom 90% of households, and (if to a lesser extend) macro-level measures of the increase in household debt, as well as the upward trend of the value of the residential housing stock.

[6] At the microlevel, the increase in US labor earnings has been documented using different data sources for instance by Kopczuk et al. (2010) and De Backer (2013)

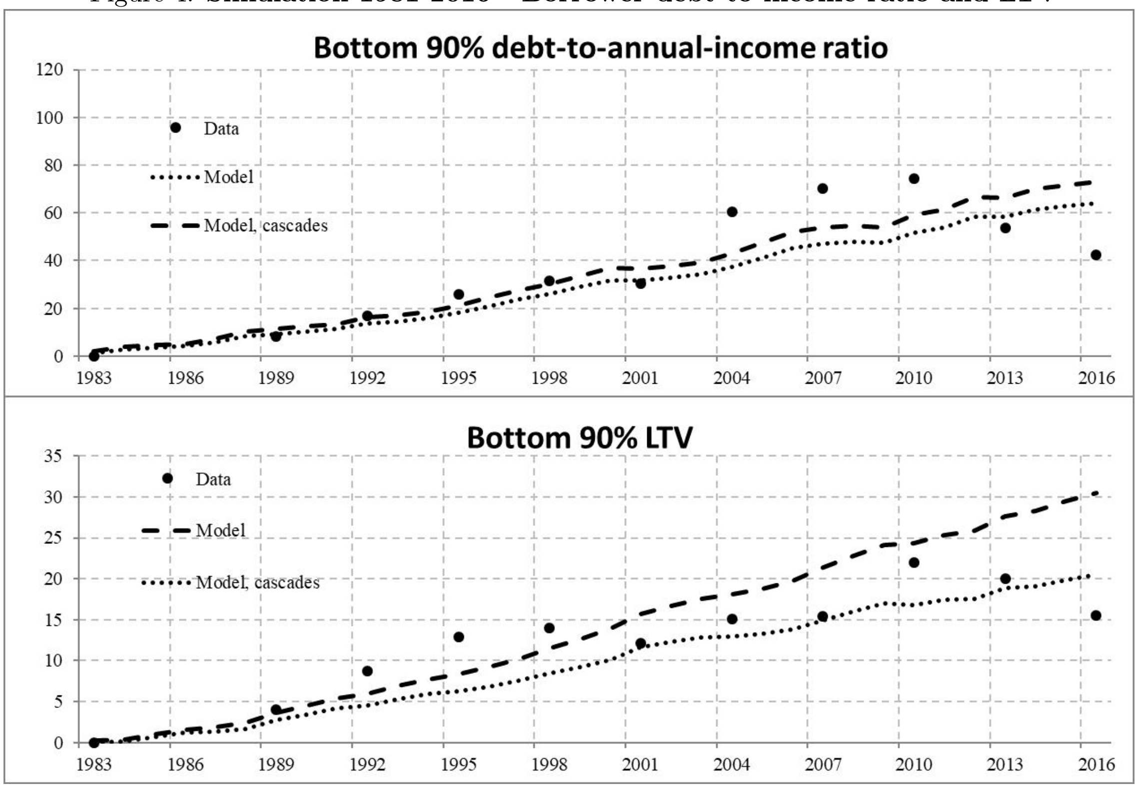
Figure 3: **Simulation 1981-2016 - Income distribution and natural interest rate**



Note: The label "model" indicates the results of simulation using the model developed in Section 3. The simulation subjects the model to a sequence of unexpected but permanent shocks to the price markup $d_{\mu,t}$ and the labor income share of non-rich households $d_{CC,t}$ calibrated to replicate the empirically observed path of the labor share and the share of the bottom 90% of households in net national income. Changes in $d_{CC,t}$ and $d_{\mu,t}$ occur every four quarters, starting with the first simulation quarter. The line labelled "model, cascades" indicates an effect of rich household total consumption on non-rich housing demand (i.e. $\nu_{cascade} > 0$, see equation (30)). Note that the corresponding 1980 value has been subtracted from all displayed series. Data sources:

- rstar_LW denotes the Natural rate estimated by Laubach and Williams (2015). z_LW denotes the component of rstar_LW attributed to factors other than trend GDP growth. Estimates were downloaded from the Federal Reserve Bank of St. Francisco web-page.
- Labor share, data: Labor share non-farm business sector, BLS, 8 year moving average.
- Bottom 90% income share, data: Bottom 90% of households share in pre-tax net national income, World Inequality Database.

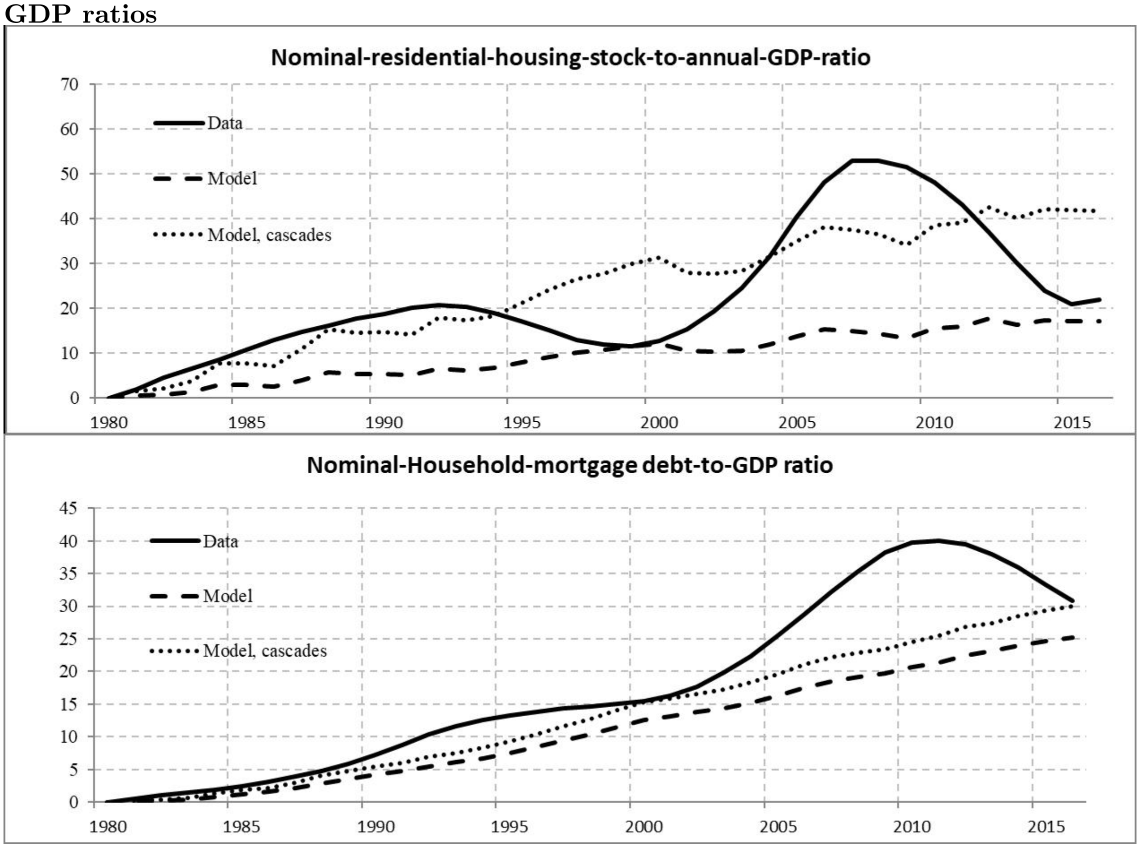
Figure 4: **Simulation 1981-2016 - Borrower debt-to-income ratio and LTV**



Note: See the note below Figure 3 for details on the meaning of the labels "Model" and "cascades". Note that the corresponding 1980 value has been subtracted from all displayed series. Data sources:

- Bottom 90% debt-to-income ratio and LTV, data: The 1989-2016 values are based on summary statistics provided by the Federal Reserve Board's Survey of Consumer Finances 1989-2016 in excel format.
  - Bottom 90% mean income: Table 1
  - Bottom 90% mean mortgage debt (secured by primary residence): Table 13 and Table 13 means.
  - Bottom 90% mean home value (primary residence): Table 13 and Table 13 means.
- Regarding the computation of the 1983 value, see the note below Table 4.

Figure 5: **Simulation 1981-2016 - Nominal housing stock and total mortgage debt-to-GDP ratios**



Note: See the note below Figure 3 for details on the meaning of the labels "Model" and "cascades". Note that the corresponding 1980 value has been subtracted from all displayed series. Data sources:

- Nominal residential housing stock-to-GDP ratio $\frac{P_t Q_{H,t} H_t}{P_t Y_t}$: Own calculation based on data from the Federal Reserve Board/Flow of Funds, Bureau of Economic Analysis, 8 year moving average.

- Nominal household-mortgage-debt-to-GDP ratio $\frac{P_t b_{CC,t}}{P_t Y_t}$: Own calculation based on data from the Federal Reserve Board/Flow of Funds, Bureau of Economic Analysis, 8 year moving average.

5 Conclusion

In this paper, I formally link four empirical trends observed during the post 1980 period: The upward trend in the income share of the top 10% of US households, the downward trend of the natural rate of interest, as estimated by Laubach and Williams (2016), the simultaneous increase in measures of the indebtedness of the bottom 90% of households, and the increase in the value of the residential housing stock relative to GDP. I do so by developing a model with two household groups, the bottom 90% and the top 10%, where rich households have Capitalist Spirit type Preferences (CSP) over their wealth. I first show that in an economy where the bottom 90% are hand-to-mouth consumers and the only asset available to the rich are government bonds, the natural rate declines strongly in response to a decline in the bottom 90% income share in the presence of CSP, regardless of whether the decline is caused by an increase in the price markup or an increase in the relative demand for rich household labor. The non-rich lower their consumption by the amount of their income decline, while at the initial interest rate, the rich attempt to save part of the increase in their permanent income. Thus the interest rate needs to decline to equilibrate the government bond market and thus reduce equilibrium saving of the rich to zero.

I then extend the assets available to the rich in the model by allowing for home ownership by both income groups and a housing market, a credit market where the non-rich borrow from the rich via financial intermediaries using their home as collateral, and physical capital as an additional factor of production owned by the rich. In this setup, in the presence of CSP a given increase in inequality continues to lower the natural rate, though less than as in the simple model. The main reason for the smaller decline in the natural rate is that the non-rich postpone the decline in their consumption of goods and housing services by increasing their borrowing in response to the lower interest rate they face. Therefore the house price increases as well, which contributes to relaxing the borrowing constraint faced by the non-rich. By contrast, without CSP, an increase in inequality does not lower the natural rate and causes a decline in household borrowing.

I then replicate the decline in bottom 90% income share observed over the 1981-2014 period and the post 2001 decline in the labor share (i.e. the increase in functional income inequality) within the model. The simulated increase in inequality generates a decline in the natural interest rate by between 4 and 5 percentage points, in line with the decline of the natural rate estimated by Laubach and Williams (2016). At the same time, the simulation also replicates the major part of the increase in the bottom 90% debt-to-income ratio, roughly tracks the increase in the bottom 90% Loan-To-Value (LTV) ratio and replicates about two thirds of the peak increase of the value of the housing stock relative to GDP. The simulation thus suggests that the decline in the natural rate of interest and the pre-crisis upward trend in in household indebtedness and house prices are to a significant extent both consequences of a more skewed income distribution. Put differently, the increase in income inequality meant that the Fed had to accept a downward trend of the Federal Funds rate and the associated rise in household debt and house prices if it wanted to continue to meet its inflation target.

The main implication of the above analysis for monetary policy is that the natural rate may remain at its current low level for a long time, as the distribution of income tends to change only slowly, and thus the scope for "conventional" monetary policy to stabilize the US economy may remain limited. Furthermore, to the extent that the tax and transfer system may change the distribution of income in an efficient manner, it implies a potentially important role for fiscal policy in determining the distance of the economy from the Zero Lower Bound (ZLB) and the overall level of household debt in the economy.

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A For online publication only: Microsimulation used to compute saver households MPS

I describe the microsimulation I use to calibrate the wealth curvature parameter for the case of the simple model of Section 2, but the procedure in the full model is fully analogous. For the purpose of the microsimulation, I exogenize the saver households non-interest net income, as well as the real interest rate, implying that her behavior is described by

$$b_{S,t} = \frac{R}{\Pi} b_{S,t-1} + Y_{S,t} - C_{S,t} \tag{42}$$

$$\Lambda_{S,t} = \frac{1}{C_{S,t}^{\sigma_S}} \tag{43}$$

$$\Lambda_{S,t} = \beta_S E_t \left\{ \Lambda_{S,t+1} \frac{R}{\Pi} \right\}) + \phi_b \left(b_{S,t} \right)^{-\sigma_b} \tag{44}$$

I then simulate an on impact permanent increase in $Y_{S,t}$ occurring in $t = 1$. I compute the marginal propensity to save over a horizon of 6 years (24 quarters) as

$$MPS_{S,1-24} = \frac{b_{S,24} - b_0}{\sum_{t=1}^{24} dY_{S,t}} \tag{45}$$

The reason for the six year horizon is that the empirical estimates of the MPS Dynant et al. (2004) uses data on saving rates which is six years apart (see Kumhof et al. (2015) for further details on how to compute the MPS in a way consistent with the empirical estimates). Finally, given the calibration of the other parameters as described in section 2.5, I use σ_b set $MPS_{S,1-24}$ to the empirical target value.

Note that in the presence of housing and physical capital, the numerator of (45) features the increase in the value of the holdings of these assets as well.

B For online publication only: A simple microfoundation of the borrowing friction

The increasing relationship between the loan rate $R_{L,t}$ and the borrower LTV assumed in the main text may be microfounded by assuming borrowing is subject to frictions similar to Onorante et al. (2017). Specifically, I assume that that the household's housing wealth is subject to idiosyncratic uncertainty which resolves at the beginning of the period, and that a household j defaults if her housing wealth is less than her real debt $\frac{R_{Lj,,t}}{\Pi_t} b_{CC,j,t-1}$. More formally, default occurs if

$$\omega_{j,t} H_{CC,j,t-1} Q_{H,j,t} < \frac{R_{L,j,t}}{\Pi_t} b_{CC,j,t-1}$$

where $\omega_{j,t}$ denotes an i.i.d. random variable with mean one. Hence the default threshold of household j is given by

$$\overline{\omega_{j,t}} = \frac{\frac{R_{L,j,t}}{\Pi_t} b_{CC,j,t-1}}{H_{CC,j,t-1} Q_{H,j,t}} \tag{46}$$

I assume that in case of a realization of $\omega_{j,t}$ below the default threshold and thus default by the household, the loss-given-default incurred by the financial intermediary is fixed at a fraction LGD of the loan, with $0 \leq LGD \leq 1$. Furthermore, in order to abstract from the effect of loan losses on the financial intermediary, I follow Bernanke et al. (1999) and assume that the debt-contract is contingent on the realization of aggregate variables to ensure that in every quarter, the financial intermediary earns an average nominal rate of return $R_{t-1}FIC$, where $FIC - 1$ represents, non-bankruptcy related costs of financial intermediation, which I assume to be a fixed fraction of the total loan amount. Hence the interest rate adjusts accordingly ex post, and is given by

$$R_{L,j,t} = \frac{R_{t-1}FIC}{1 - LGDJ\left(\overline{\omega_{j,t}}\right)} \tag{47}$$

where $J\left(\overline{\omega_t}\right)$ denotes the cumulative distribution function of $\omega_{j,t}$. This equation replaces the ad hoc loan supply relationship assumed in the main text (i.e. equation 24). Finally, defaulting households face a cost $LGD\frac{R_{L,j,t}}{\Pi_t}b_{CC,j,t-1}$, implying that otherwise identical defaulting and non-defaulting households face identical debt related payments at the beginning of period t.[7] After $\omega_{j,t}$ has been revealed and some households default, resources are redistributed between borrower households such that their housing wealth is again identical before they make their consumption and saving decisions. With these assumptions, the borrowing household's budget constraint is identical regardless of default, an I therefore drop the j subscript from now on:

$$\frac{R_{L,t}}{\Pi_t}b_{CC,t-1} + C_{CC,t} + Q_{H,t}\left(H_{CC,t} - H_{CC,t-1}\right) = b_{CC_t} + w_{CC,t}N_{CC,t} - T_{CC,t} \tag{48}$$

The FOCs with respect to consumption $C_{CC,t}$, real loans $b_{CC,t}$, housing $H_{CC,t}$, and the expected loan interest rate $R_{L,t+1}$ imply

$$\Lambda_{CC,t} = \frac{1}{C_{CC,t}^{\sigma_{CC}}} \tag{49}$$

$$\Lambda_{CC,t} = \beta_{CC}E_t\left\{\Lambda_{CC,t+1}\left[\frac{R_{L,t+1}}{\Pi_{t+1}} + \frac{\frac{dR_{L,t+1}}{db_{CC,t}}\left(\bar{\omega}_{t+1}, R_{L,t+1}, b_{CC,t}\right)b_{CC,t}}{\Pi_{t+1}}\right]\right\} \tag{50}$$

$$Q_{H,t} = \frac{\phi_{H,t,CC}}{\Lambda_{CC,t}H_{CC,t}^{\sigma_{H,CC}}} + \beta_{CC}E_t\left\{\frac{\Lambda_{CC,t+1}}{\Lambda_{CC,t}}\left(Q_{H,t+1} - \frac{\frac{dR_{L,t+1}}{dH_{CC,t}}\left(\bar{\omega}_{t+1}, R_{L,t+1}, H_{CC,t}\right)}{\Pi_{t+1}}b_{CC,t}\right)\right\} \tag{51}$$

where $\frac{dR_{L,t+1}}{db_{CC,t}}\left(\bar{\omega}_{t+1}, R_{L,t+1}, b_{CC,t}\right)$ and $\frac{dR_{L,t+1}}{dH_{CC,t}}\left(\bar{\omega}_{t+1}, R_{L,t+1}, H_{CC,t}\right)$ denote the implicit function derivatives of $R_{L,t+1}$ with respect to $b_{CC,t}$and $H_{CC,t}$, respectively, given by

[7]Specifically, at the beginning of period t, a non defaulting households repays $\frac{R_{L,,t}}{\Pi_t}b_{CC,t-1}$, while a defaulting household repays $(1 - LGD)\frac{R_{L,,t}}{\Pi_t}b_{CC,t-1}$ but faces default costs $LGD\frac{R_{L,,t}}{\Pi_t}b_{CC,t-1}$, which sums up to the same debt-related payment as the one of the non-defaulting households. This assumption is necessary to ensure that a change in the lending rate caused by an increase in the expected probability of default E_tJ_{t+1} has an effect on household behavior.

$$\frac{dR_{L,t+1}\left(\bar{\omega}_{t+1}, R_{L,t+1}\right)}{db_{CC,t}} = \frac{LGDJ'\left(\bar{\omega}_{t+1}\right)\frac{\bar{\omega}_{t+1}}{b_{CC,t}}R_{L,t+1}}{\left(1 - LGDJ\left(\bar{\omega}_{t+1}\right) - LGDJ'\left(\bar{\omega}_{t+1}\right)\bar{\omega}_{t+1}\right)} \tag{52}$$

$$\frac{dR_{L,t+1}}{dH_{CC,t}}\left(\bar{\omega}_{t+1}, R_{L,t+1}, H_{CC,t}\right) = \frac{-LGDJ'\left(\bar{\omega}_{t+1}\right)\frac{\bar{\omega}_{t+1}}{H_{CC,t}}R_{L,t+1}}{\left(\left(1 - LGDJ\left(\bar{\omega}_{t+1}\right)\right) - LGDJ'\left(\bar{\omega}_{t+1}\right)\bar{\omega}_{t+1}\right)} \tag{53}$$

For $\frac{dR_{L,t+1}(\bar{\omega}_{t+1}, R_{L,t+1})}{db_{CC,t}} > 0$ and $\frac{dR_{L,t+1}}{dH_{CC,t}}\left(\bar{\omega}_{t+1}, R_{L,t+1}, H_{CC,t}\right) < 0$ it has to be true that $\frac{1}{LGD} > J\left(\bar{\omega}_{t+1}\right) + J'\left(\bar{\omega}_{t+1}\right)\bar{\omega}_{t+1}$. A sufficient condition for this inequality to hold is that its right-hand-side is less than one, which is met under the assumptions I adopt below. I assume a logistic form for $J\left(\overline{\omega_t}\right)$

$$J\left(\overline{\omega_t}\right) = \frac{1}{1 + e^{-\frac{\bar{\omega}_t - 1}{\sigma_h}}} \tag{54}$$

Hence loan supply is now determined by the three parameters FIC, LGD and σ_h, while the slope parameter χ_{CC} is no longer needed. I pin down FIC by adopting a target value for ratio of non-bankruptcy-related-costs to net interest income $\frac{(FIC-1)}{R_L - R}$, which I estimate based on the FDIC Quarterly banking profile. Specifically, I calculate $\frac{\left(\frac{\text{Total noninterest expense}}{\text{Total Assets}}\right)}{\left(\frac{\text{Net interest income}}{\text{Total loans and leases}}\right)} \approx 59\%$. I set the steady state default rate $J\left(\bar{\omega}\right)$ equal to the average "Delinquency Rate on Single-Family Residential Mortgages, Booked in Domestic Offices, All Commercial Banks", which equals an annualized 4.2%. Using the (implied) values of FIC, $J\left(\bar{\omega}\right)$, the (unchanged) target value for $R_L - R$ and equation (47) pins down the required LGD value. Tables 6 and 7 display the complete list of targets and parameter values. Values which differ from the model with the ad hoc borrowing friction of the main text are in bold.

Figure 6 compares the loan supply curve implied by the ad hoc borrowing friction to the micro-founded loan supply curve (equation (47). The curves cross at an LTV of 0.31, which is the steady-state value implied by the empirical targets. Over the relevant LTV range (i.e. $LTV > 0.31$), the microfounded loan supply curve is steeper than the relationship based on the ad hoc borrowing friction.

C For online publication only: Results with the microfounded loan supply curve

With the microfounded, steeper loan supply curve, the positive effects of both wage inequality and price mark-up shocks on non-rich household borrowing and their LTV are lower, while the increase of the value of the housing stock and the decline of the natural interest rate are larger (compare the red and the black lines in Figure 7). Adopting the microfounded loan borrowing friction has thus qualitatively identical effects to assuming a steeper loan supply curve (a higher χ_{CC}) in the context of the ad hoc borrowing friction (see Figure 2), and the reasons are analogous, too (see the discussion in Section 4.1). These effects show up qualitatively as well when repeating the simulation of the observed decline in the labor share and the bottom 90% income share (see Figures 8 to 10, compare the red and black dashed and dotted lines). Quantitatively, the biggest effect of adopting microfounded loan supply shows up in the response of the value of the housing stock, which increases by about twice as much, thus outpacing the increase observed in the data, and the correspondingly the LTV, whose increase approximately halves (See Figures 10 and 9), while the the trajectories of the other variables change little.

Table 6: Targets

Target	Value data	NOCSP	CSP	Source
Real short term interest rate $\frac{R}{\Pi}$	2%	2%	2%	Federal Funds rate minus core-PCE inflation, (APR, 1973-1980 average), FRED
IES $\frac{1}{\sigma_S}$	0.5	0.5	0.5	Havranek (2015)
$\frac{w_O N_O + w_{CC} N_{CC}}{Y}$	62.8%	62.8%	62.8%	Labor share non-farm business sector, (1973-1980 average), BLS
$\frac{I}{Y}$	12.3%	12.3%	12.3%	Share of non-residential fixed investment in GDP, (1973-1980 average), BEA
$\frac{G}{Y}$	20%	20%	20%	Government expenditure as percentage of GDP, (1981-2016 average), BEA
$\frac{b_{gov,S,}}{4Y}$	44%	44%	44%	Federal Debt held by the public, percentage of GDP, (1981-2016 average), FRED
Borrower income share $\frac{w_{CC} N_{CC} - \left(\frac{R_L}{\Pi} - 1\right) b_{CC}}{Y + \left(\frac{R}{\Pi} - 1\right) b_{gov} - I - f(LTV) \frac{R}{\Pi} b_{CC}}$	67%	67%	67%	Bottom 90% net national income share, pre-tax, (1973-1980 average), WID
Residential housing stock to GDP $\left(\frac{Q_H H}{4Y}\right)$	106%	106%	106%	Flow of Funds (1973-1980 average), Federal Reserve Board
Borrower share in total residential real estate $\left(\frac{Q_H H_{CC}}{Q_H H}\right)$	70%	70%	70%	Bottom 90% share in residential real estate, Survey of Consumer Finances, 1983
Borrower debt-to-annual income ratio	38%	38%	38%	Debt secured by primary residence, Survey of Consumer Finances, 1983
Mortgages rate minus risk free rate $R_L - R$	1.68%	1.68%	1.68%	30 year mortgage rate minus 30 year treasury (APR, 1981-2016 average), FRED
MPS top 5%	0.52	0	0.56	Dynan et al (2004)
Discounting wedge θ	0.97	1.0	0.97	Target CSP case: Literature discount rates (see Table 3)
Return on capital minus risk free rate $r_K - \delta - \left(\frac{R}{\Pi} - 1\right)$	4%	0	4%	Target CSP case: See note below for details
$\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$	$0.03 - 0.06 p.p.$	0	$0.058\ p.p.$	Target CSP case: See note below for details.
Mortgage default rate (APR) $J()$	**4.2%**	**4.2%**	**4.2%**	**Single-Family Residential Mortgages, FRED (1991-2016)**
Non-default-costs-to-interest-income ratio $\frac{(FIC-1)}{R_L - R}$	**59%**	**59%**	**59%**	**FDIC QBP, (1984-2016), see note below for details**

Note:

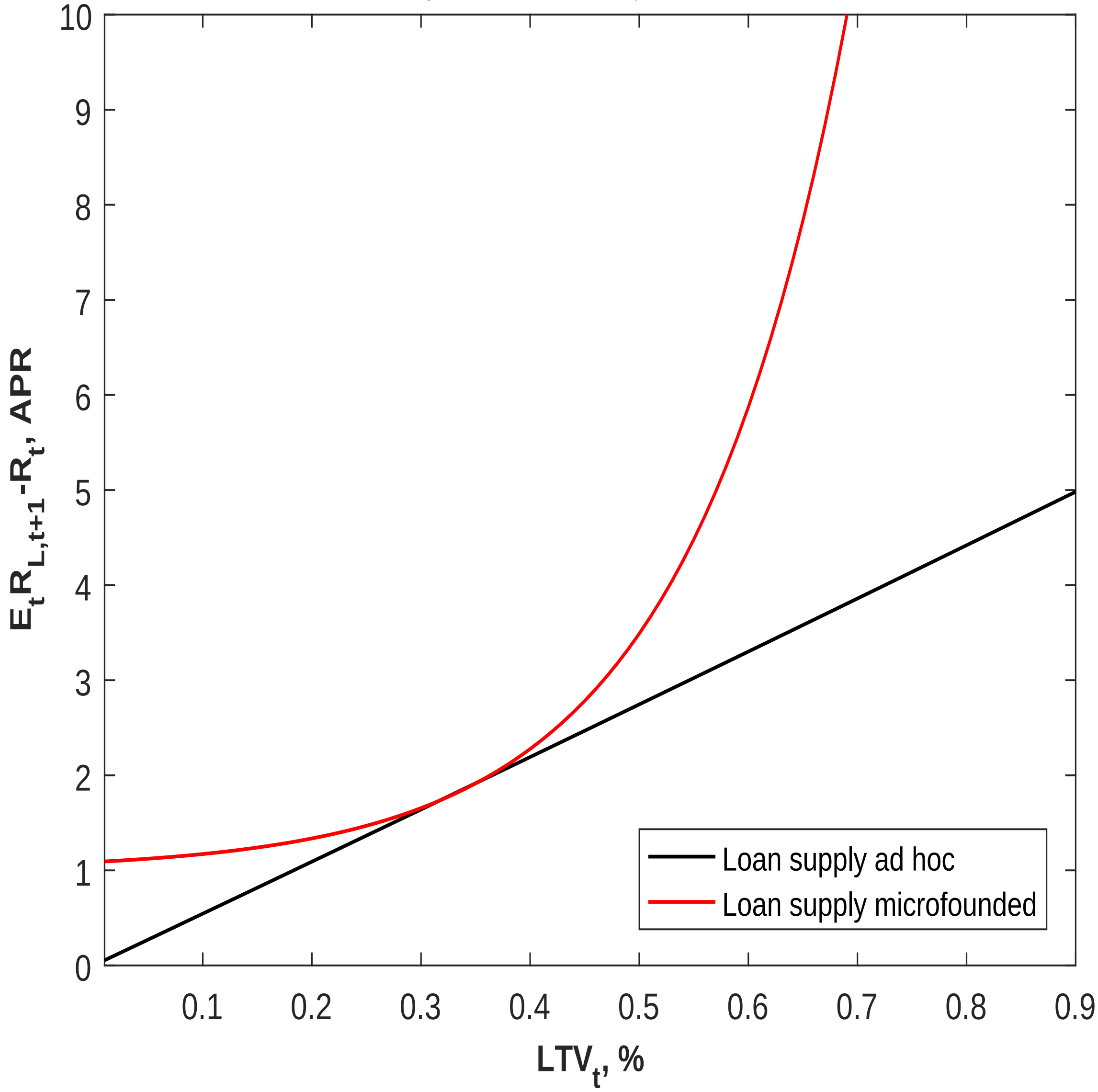
- For the calibration of θ, see Table 3.
- Since the Federal Reserve board publishes comprehensive summary statistics for the Survey of consumer Finances only starting 1989, the 1983 data required to compute the bottom 90% mortgage-debt-to-income ratio, their share in residential real estate and their LTV were computed as follows:
  - Bottom 90% mean income: Computed from Table 1 in Avery et al. (1984a), Table 1, which divides the household population into different household income intervals.
  - Bottom 90% mean mortgage debt (secured by primary residence): From Avery et al. (1984b), Table 1 (which reports mean mortgage debt and the incidence of owing mortgage debt for selected income groups), and using the aforementioned population shares as weights.
  - Bottom 90% and top 10% mean home value: From Avery et al. (1984a), Table 5 and 7, which contains home ownership incidence and net equity of homeowners for selected household income intervals.
- The target for the spread between the return on capital and the risk free rate $r_K - \delta - \left(\frac{R}{\Pi} - 1\right)$ and the risk free rate is a simple average of
  - The spread between the yield on Moody's seasoned BAA rated corporate bonds and 10 year treasury bonds, 1981-2016 average, which equals 2.4%.
  - The average estimate of the equity risk premium reported in Duarte and Rosa (2015), Table 7, which equals 5.7%.
- The range of empirical estimates of $\frac{d\text{Interest rate gov. bonds}}{d\text{Gov. Debt ratio}}$ are obtained from Gale and Orszag (2004), Engen and Hubbard (2004) and Laubach (2009).
- **The empirical counterpart of the non-default-costs-to-interest-income ratio** $\frac{(FIC-1)}{R_L - R}$ **is computed from the FDIC Quarterly Banking Profile as** $\frac{\left(\frac{\text{Total noninterest expense}}{\text{Total Assets}}\right)}{\left(\frac{\text{Net interest income}}{\text{Total loans and leases}}\right)}$.
- FRED=Federal Reserve Bank of St. Louis Economic Database. BEA=Bureau of Economic Analysis. BLS=Bureau of Labor Statistics.

Table 7: Full model, parameter values

Parameter	Parameter name	Value NOCSP ($\theta = 1$)	Value CSP ($\theta = 0.97$)
β_S	Rich utility discount factor	0.9951∗	0.9652∗
β_{CC}	**Borrower utility discount factor**	0.9876∗	0.9876∗
σ_S, σ_{CC}	Utility curvature consumption	2*	2*
$\sigma_{S,H}, \sigma_{CC,H}$	Utility curvature housing	2	2
N_{CC}, N_S	Labor endowments	$\frac{1}{3}$	$\frac{1}{3}$
$\phi_{H,S}$	Rich utility weight on housing	0.03*	1.25∗
$\phi_{H,CC}$	**Borrower utility weight on housing**	0.47∗	0.47∗
$\nu_{cascade}$	Consumption cascade	0	0/0.7
μ_p	Price markup	1.26∗	1.26∗
α_K	Output elasticity w.r.t. capital	0.21∗	0.21∗
ω_{CC}	Borrower share in labor income	0.95∗	0.95∗
δ	Depreciation rate physical capital	0.025	0.025
ϵ_I	Capital adjustment cost curvature	7	7
FIC	**Non-default intermediation cost**	0.0136*	0.0136*
σ_h	**Volatility housing value shock**	0.0136*	0.0136*
LGD	**Loss Given Default**	0.0136*	0.0136*
$Target_{bgov2GDP}$	Government debt target	44%	44%
$Target_{G2GDP}$	Government expenditure share target	20%	20%
σ_b	CSP: Utility curvature, real financial assets	−	0.5∗
σ_K	CSP: Utility curvature, physical capital	−	4∗
ϕ_b	CSP: Utility weight on real financial assets	0∗	3.13∗
ϕ_K	CSP: Utility weight on physical capital	0∗	72.68∗

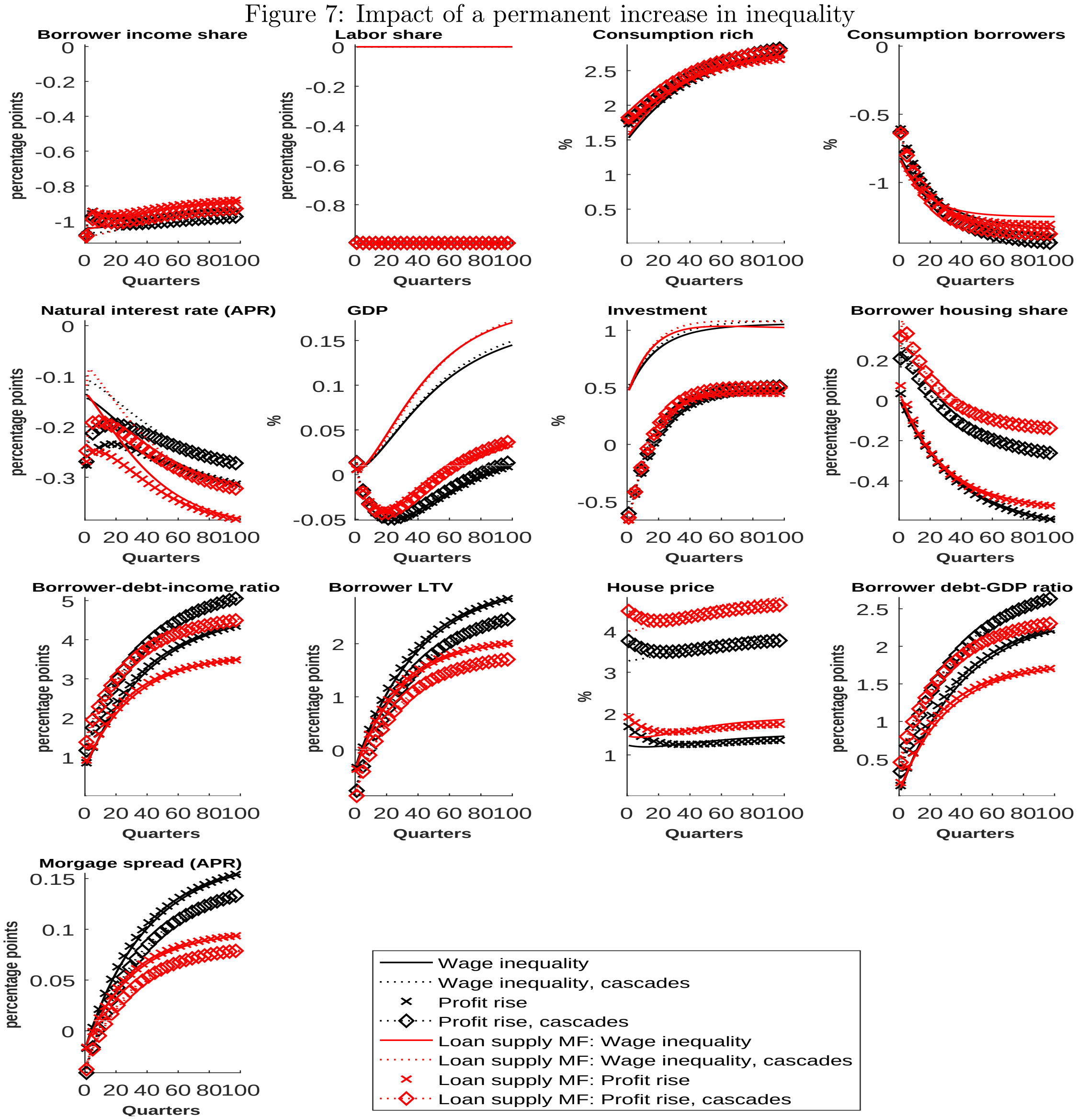
Note: Values marked with a * are set to match the targets reported in Table 6.

Figure 6: Loan supply curve



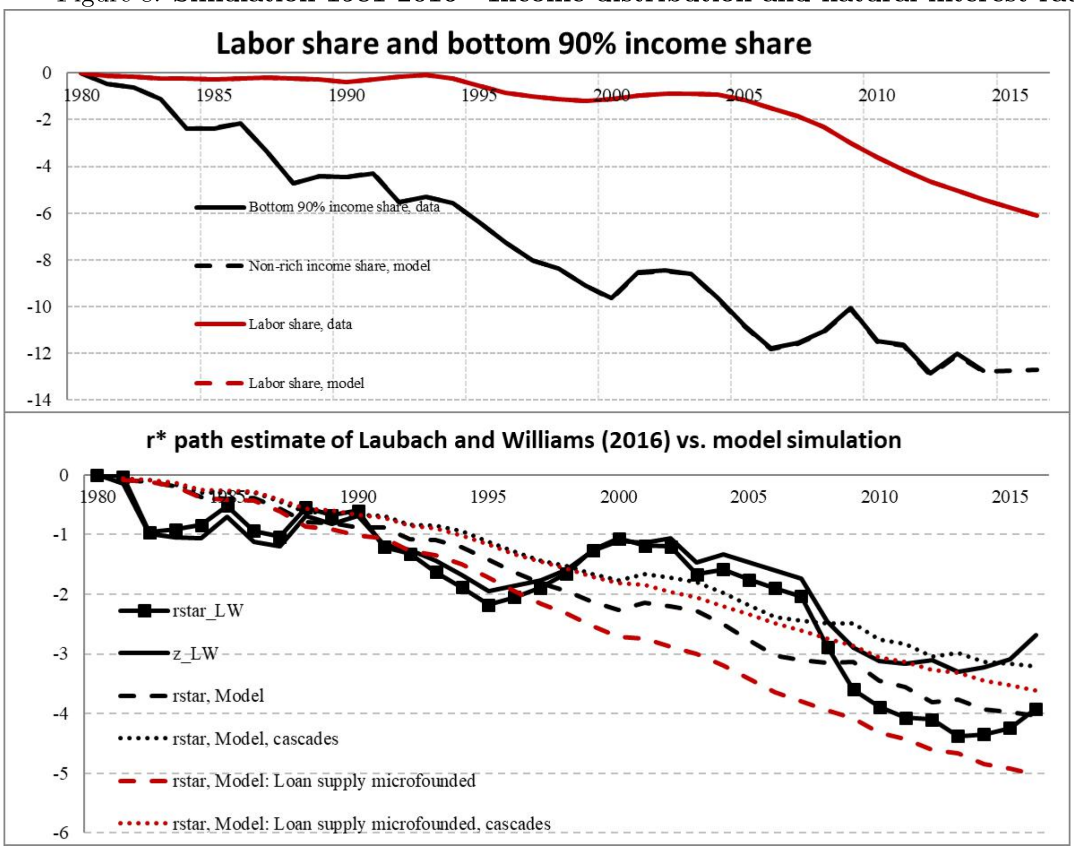
Note: The linear black line displays the relationship between the spread of the mortgage rate over the risk free rate (i.e.$E_t R_{L,t+1} - R_t$) and the loan-to-value ratio ($LTV_t = \frac{b_{CC,t}}{H_{CC,t} Q_{H,t+1}}$) implied by the borrowing friction assumed in the main text (see equations (29) and (24)), with χ_{CC} as in Table 5. The non-linear red line displays the analogous relationship implied by the microfounded borrowing friction derived in Appendix B (see equations 47, 46 54) and the calibration discussed in Appendix C.

Figure 7: Impact of a permanent increase in inequality



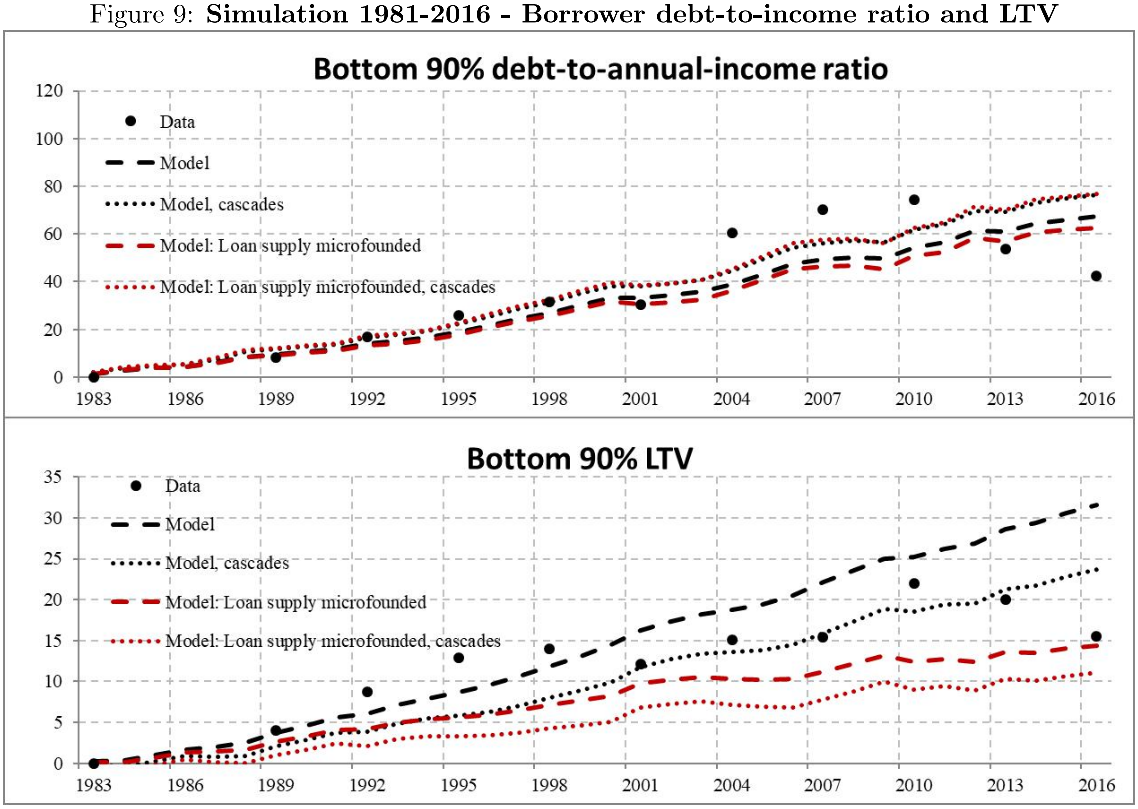
Note: All results in the Figure are computed assuming CSP. The black lines refer to results computed using the model of Section 3. The red lines ("Loan supply MF") refer to a modified version of the model where the borrowing friction is microfounded as described in Section B, implying that equations (47), (46) (54) replace equations (29) and (24). "Wage inequality" indicates a one-off permanent decline in the elasticity of output with respect to the labor supplied by non-rich (rich) households (i.e.$d_{CC,t}$ permanently declines, see equation (32)). "Profit rise" indicates a one-off increase in the price markup (i.e. $d_{\mu,t}$ permanently increases). "cascades" indiciates that the model allows for an effect of rich household total consumption on non-rich housing demand (i.e. $\nu_{cascade} > 0$, see equation (30)). The safe interest rate R_t and the risk spread $E_t R_{L,t+1} - R_t$ are expressed as Annualized Percentage Rates (APR). The borrower debt-to-income ratio is based on annualized borrower income. The borrower-debt-to-GDP ratio is based on annualized GDP.

Figure 8: **Simulation 1981-2016 - Income distribution and natural interest rate**



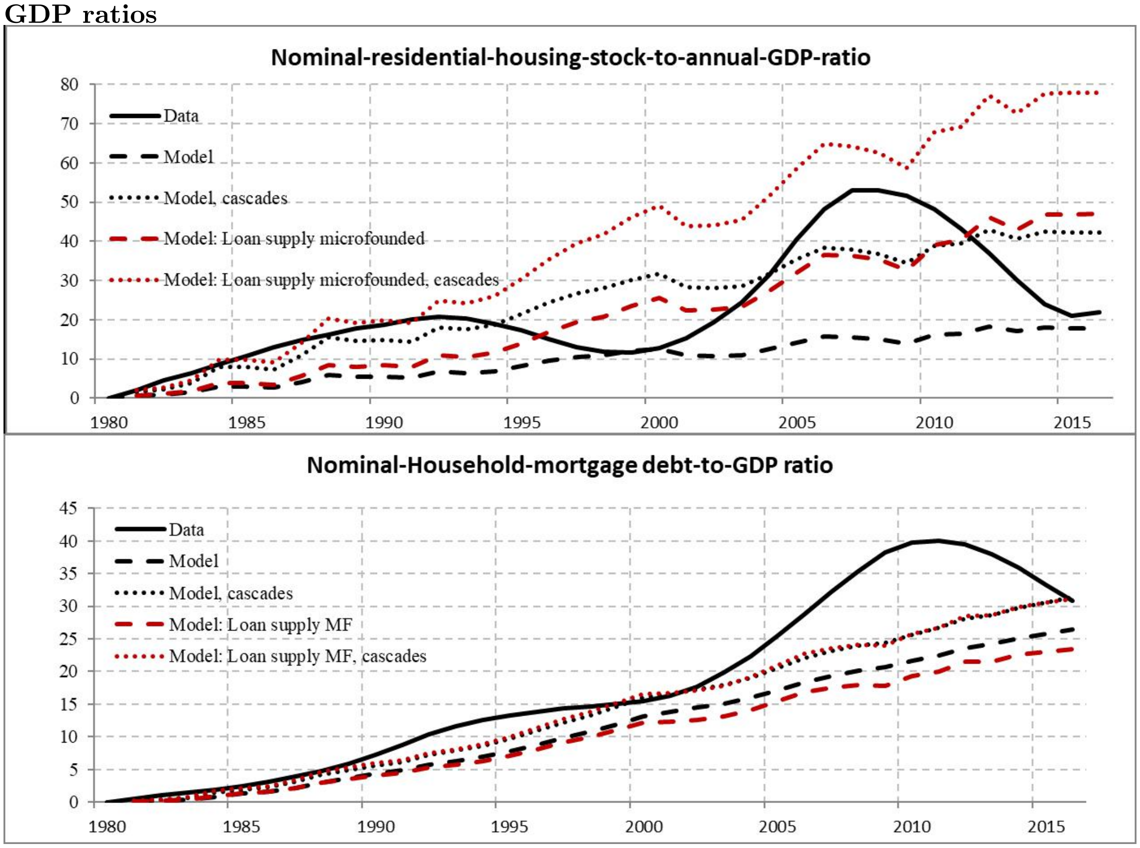
Note: The label "Model: Loan supply microfounded" refers to a modified version of the model where the borrowing friction is microfounded as described in Section B, implying that equations (47), (46) (54) replace equations (29) and (24). For details on the meaning of the other labels, see the note below Figure 3.

Figure 9: **Simulation 1981-2016 - Borrower debt-to-income ratio and LTV**



Note: See the note below Figure 8 for details on the labels reading “Model...”. See the note below Figure 4 for details on the data sources.

Figure 10: **Simulation 1981-2016 - Nominal housing stock and total mortgage debt-to-GDP ratios**



Note: See the note below Figure 8 for details on the labels reading "Model...". See the note below Figure 5 for details on the data sources.

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