Falling Behind: Has Rising Inequality Fueled the American Debt Boom?*

Moritz Drechsel-Grau   Fabian Greimel

Job Market Paper

October 25, 2019

latest version here

Abstract

The U.S. household debt boom since 1980 is considered one of the main drivers of the Great Recession of 2007–9. In lockstep with household debt, income inequality has risen to new extremes. We evaluate the hypothesis that rising inequality was a causal source of the debt boom. The mechanism builds on the observation that households care about their social status. To keep up with the ever richer Joneses, the middle class substitutes status-enhancing houses for status-neutral consumption. These houses are mortgage-financed, creating a debt boom across the income distribution. Using a stylized model we show analytically that aggregate debt increases as top incomes rise. In a quantitative general equilibrium model we show that *Keeping up with the Joneses* and rising income inequality generate sizable booms in mortgage debt and house prices. By contrast, the Global Saving Glut hypothesis gives rise to a similar debt boom, but has a much weaker effect on house prices.

Keywords: mortgages, housing boom, social comparisons, consumption networks, keeping up with the Joneses

JEL Codes: D14, D31, E21, E44, E70, R21

1 Introduction

The U.S. household debt boom was at the heart of the Global Financial Crisis of 2007 and the ensuing Great Recession. Mortgage debt was by far the most important driver of household debt since 1980 (see Figure 1a). In lockstep with mortgages, top income inequality has risen since 1980 and reached its peak in 2007 (see Figure 1b). While the bottom half of the population has seen stagnant real incomes, the incomes of the top 10% have more than doubled over this time period (see Figure 2a).

Prominent economists have argued that rising top income inequality fueled the boom in household debt (e.g. Rajan, 2010; Stiglitz, 2009; Frank, 2013)[1]. Underlying this argument is the assumption that non-rich households with stagnant incomes took out credit in an attempt to keep up with the rich. When the rich upgrade their houses as a result of rising top incomes, the non-rich substitute status-enhancing housing for status-neutral consumption. These home improvements are mortgage-financed, causing a debt boom across the whole income distribution.

The idea that people care about how their belongings compare to those of their neighbors is certainly not new (among others Veblen, 1899; Duesenberry, 1949). More recently, there has been a growing empirical literature showing that social comparisons shape people's decision-making (e.g. Kuhn, Kooreman, Soetevent, and Kapteyn, 2011; Luttmer, 2005; Bursztyn, Ederer, Ferman, and Yuchtman, 2014; De Giorgi, Frederiksen, and Pistaferri, 2019).

In this paper, we formally assess the macroeconomic consequences of this mechanism and compare it to two alternative mechanisms in the literature on the mortgage and house price booms: the Global Saving Glut hypothesis (e.g. Bernanke, 2005; Justiniano, Primiceri, and Tambalotti, 2014) and financial liberalization (e.g. Favilukis, Ludvigson, and Van Nieuwerburgh, 2017)[2]. In order to quantify the contribution of rising income inequality and *keeping up with the (richer) Joneses* to the observed increase in mortgage debt and house prices between 1980 and 2007, we build a heterogeneous agent general equilibrium model with non-durable consumption and housing goods, a realistic earnings process, a collateral constraint, elastic housing supply and a social comparison motive[3].

Using a state-of-the-art earnings process (Guvenen, Karahan, Ozkan, and Song, 2019) and calibrating the comparison motive to recent micro evidence on social comparisons in housing (Bellet, 2018), we find that rising top income inequality generates quantitatively significant mortgage and house price booms in the presence of *Keeping up with the Joneses*. Our model generates 60% of the increase in the mortgage-to-income ratio and 50% of the increase in house prices observed between 1980 and 2007. While rising inequality raises mortgages and house prices even in the absence of social comparisons, the *Keeping up with the Joneses* amplifies the effects by a factor of two.

---

[1] See the survey by van Treeck (2014) on the hypothesis that inequality caused the financial crisis.

[2] The expectations channel (Adam, Kuang, and Marcet, 2012; Kaplan, Mitman, and Violante, 2019) is another important channel, but it cannot be easily integrated into our model.

[3] Given the recent microevidence, we depart from the classic macroeconomic literature with Keeping up with the Joneses (e.g. Abel, 1990; Campbell and Cochrane, 1999; Ljungqvist and Uhlig, 2000) in two important ways. See Section 2.3.
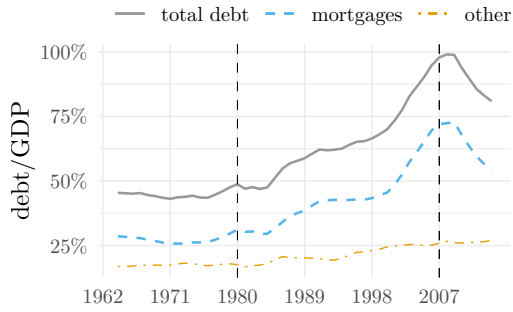
(A) The American household debt boom was mostly driven by mortgages.
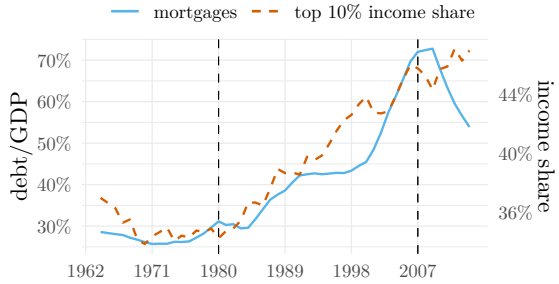
(B) Inequality and mortgages have grown in lockstep since 1980.

FIGURE 1: The American household debt boom and rising income inequality.

In comparison, the Saving Glut generates a similarly strong debt boom through lower interest rates. However, it does not generate a strong house price increase. Both mechanisms together can explain 75% of the increase in the mortgage-to-income ratio and 60% of the house prices boom. Between 1/3 and 2/3 of this increase[4] in debt and about 90% of the increase in house prices can be attributed to rising inequality and social comparisons. Financial innovation, i.e., relaxed collateral constraints, raises neither debt nor house prices significantly.

Extensive robustness checks show that our quantitative findings are robust to perturbations in the internally and externally calibrated parameters–including the strength of the comparison motive taken from Bellet (2018).

In a stylized version of the model, without idiosynchratic earnings risk, we show how top incomes can affect aggregate debt in closed form. In this infinite horizon network model (extending the one-period models in Ballester, Calvó-Armengol, and Zenou, 2006; Ghiglino and Goyal, 2010), we prove that an individual A's debt is increasing in top incomes if the household cares about the rich (directly or indirectly). This is because households substitute status-enhancing housing for status-neutral consumption and optimally finance their bigger houses with a mortgage. Moreover, we prove that if comparisons are upward looking (i.e., everybody cares about the rich directly or indirectly), aggregate debt is increasing in top incomes.

Contributions to the literature

Most generally, our findings constribute to the literature on distributional macroeconomics (e.g. Kaplan and Violante, 2014; Ahn, Kaplan, Moll, Winberry, and Wolf, 2017; Kaplan, Moll, and Violante, 2018), providing another reason why "inequality matters for macro". Rising income inequality has an effect on macroeconomic outcomes like house prices and aggregate mortgage debt.

More specifically, there is a growing literature on the macroeconomics of the mortgage and house price booms, building on a variety of mechanisms: looser collateral constraints (e.g. Favilukis et al., 2017), lending limits (Justiniano, Primiceri, and Tambalotti, 2019),

---

[4]The split depends on the order of switching on mechanisms.

3
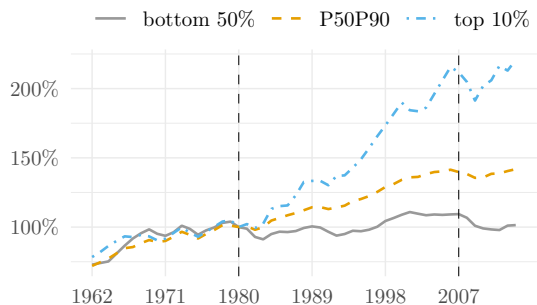
Real average pre-tax income growth from 1962 to 2014 in the US. Data are taken from Piketty, Saez, and Zucman (2018). Growth rates are relative to the base year 1980.

(A) Since 1980 real incomes have stagnated for the bottom 50 %.
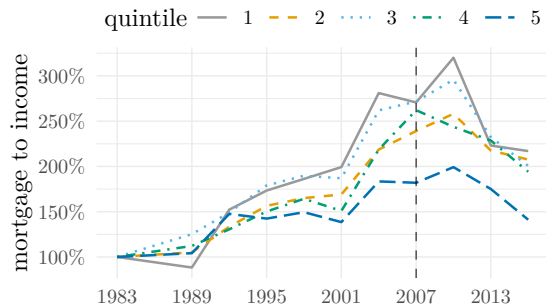
Growth of mean mortgage debt as a fraction of mean income by income quintiles. Use *OECD-modified equivalence scale* for income quintiles. Data from the Surveys of Consumer Finances.

(B) Mortgages rose across the whole income distribution.

FIGURE 2: Despite stagnating incomes, mortgage debt increased for the bottom 50 %.

FIGURE 3: Nominal: Case-Shiller Home Price Index for the USA. Real: Deflated by the Consumer Price Index. Source: http://www.econ.yale.edu/~shiller/data.htm

FIGURE 4: Relative change of housing expenditures and other expenditures over time. Data from (Bertrand and Morse, 2016, aggregated from the Survey of Consumer Expenditures) for the USA.

dynamics in foreign capital flows (Justiniano et al., 2014) and changes in house price expectations (Adam et al., 2012; Kaplan et al., 2019).
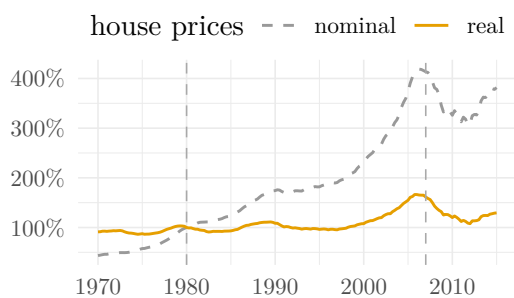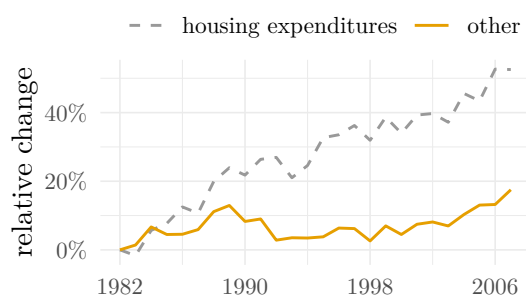
Besides introducing a novel mechanism into this literature, we provide new insights and confirm findings on two other mechanisms. First, consistent with Kiyotaki, Michaelides, and Nikolov (2011) and others, we find that relaxation of collateral constraints does not generate sizable effects on debt and house prices[5]. Second, we confirm that foreign capital inflows can have sizable effects on household debt. In our model, the Saving Glut generates effects similar to those in Justiniano et al. (2014). And third, we show that the Saving Glut channel is amplified by rising inequality and keeping up with the Joneses.

Kumhof, Rancière, and Winant (2015) formalize an alternative causal mechanism that links inequality and the debt boom in a model without housing. In their model, the debt boom is driven by the rich who derive utility from financial wealth, driving down interest rates. We provide an alternative causal mechanism that is consistent with micro-evidence and the fact that almost all of the debt boom was driven by mortgages (see Figure 1a).

A growing literature is analyzing the consumption response to house price changes (Guren, McKay, Nakamura, and Steinsson, 2018; Garriga and Hedlund, 2017; Berger, Guerrieri, Lorenzoni, and Vavra, 2018). It finds that consumption reacts more when houses are bigger. Our model implies that house values become an ever bigger share of lifetime income when top incomes rise. Thus rising top income inequality is amplifying the consumption response in financial crises.

A large empirical literature has established that social comparisons matter for well-being (e.g. Luttmer, 2005; Card, Mas, Moretti, and Saez, 2012; Perez-Truglia, 2019) and economic choices (Charles, Hurst, and Roussanov, 2009; Kuhn et al., 2011; Bursztyn et al., 2014; Bertrand and Morse, 2016; Bursztyn, Ferman, Fiorin, Kanz, and Rao, 2017; Bellet, 2018; De Giorgi et al., 2019). While the macroeconomic effects of keeping up with the Joneses have already been studied in the context of representative agent models (e.g. Abel, 1990; Campbell and Cochrane, 1999; Ljungqvist and Uhlig, 2000), we are the first to introduce social comparisons into a quantative heterogeneous agents model.

We build on the macroeconomic literature on keeping up with the Joneses and bring it closer to the empirical evidence. First, we distinguish between conspicuous and non-conspicuous goods. In our model households compare themselves only in their houses, arguable the most important conspicuous good (e.g. Solnick and Hemenway, 2005; Bertrand and Morse, 2016). And second, agents compare themselves to the rich (e.g. Card et al., 2012; Bellet, 2018). Households only lose satisfaction with their own house, when a big house is built.

Our analytical results build on the methods of network economics. The results extend those by Ghiglino and Goyal (2010) and Ballester et al. (2006) who show that agents' choices depend on the strengths of social links in a one-period model. We extend this model to infinite horizon and add a durable good (housing) to show that debt is increasing in the centrality of an agent. The centrality is reinterpreted as the weighted sum of incomes of the comparison group.

---

[5]This is in contrast to Favilukis et al. (2017) who generate sizable effects in their model with a large fraction of agent close to the collateral constraint.

Structure of the paper The rest of the paper is structured as follows: In Section 2 we will describe the model. In Section 3 we derive analytically how top incomes drive debt in a stylized version of the model. In Section 4 we describe the parameterization of the full model, followed by quantiative results in Section 5 and robustness checks in Section 5.3.

2 Model

We add social comparisons into an otherwise standard macroeconomic model of housing. Our model is a dynamic, incomplete markets general equilibrium model similar to the "canonical macroeconomic model with housing" in Piazzesi and Schneider (2016) and Achdou, Han, Lasry, Lions, and Moll (2017, extension in section 4.3). We formulate our model in continuous time to take advantage of the fast solution methods of Achdou et al. (2017).

We build our model with two aims in mind. First, we want to illustrate how rising top-incomes and social comparisons can lead to rising debt levels across the whole income distribution. And second, we want to quantify the effect of this channel on the increase in aggregate mortgage debt and house prices from 1980 to 2007.

2.1 Setup

Time is continuous and runs forever. There is a continuum of households that differ in their realizations of the earnings process. Households are indexed with their current portfolio holdings (a_t, h_t), where a_t denotes financial wealth and h_t denotes the housing stock, and their pre-tax earnings y_t. They supply labor inelastically to the non-durable consumption and housing construction sectors. The financial intermediary collects households' savings and extends short-term mortgages subject to a collateral constraint. The state of the economy is the joint distribution $\mu_t(\mathrm{d}a, \mathrm{d}h, \mathrm{d}y)$. There is no aggregate uncertainty.

2.2 Households

Households die at an exogeous mortality rate $m > 0$. The wealth of the deceased is redistributed to surviving individuals in proportion to their asset holdings (perfect annuity markets). Dead households are replaced by newborn households with zero initial wealth and earnings drawn from its ergodic distribution[6]. Households derive utility from a non-durable consumption good c and housing status s. They supply labor inelastically and receive earnings y. After-tax disposable earnings are given by

$$\tilde{y}_t = y_t - T(y_t),$$

---

[6]This follows Kaplan et al. (2018)

where T is the tax function. Households choose streams of consumption $c_t > 0$, housing $h_t > 0$ and assets $a_t \in \mathbb{R}$ to maximize their expected discounted lifetime utility

$$\mathbb{E}_0 \int_0^\infty e^{-(\rho+m)t} \frac{\left((1-\xi)c_t^\varepsilon + \xi s(h_t, \bar{h}_t)^\varepsilon\right)^{\frac{1-\gamma}{\varepsilon}}}{1-\gamma} dt,$$

where $\rho \geq 0$ is the discount rate and the expectation is taken over realizations of idiosyncratic earnings shocks. $1/\gamma > 0$ is the inter-temporal elasticity of substitution, $1/(1-\varepsilon) > 0$ is the intra-temporal elasticity of substitution between consumption and housing status and $\xi \in (0,1)$ is the relative utility-weight for housing status.

A household's utility from housing is a function of the *housing status* $s(h, \bar{h})$. Housing status is increasing in the household's housing stock h and decreasing in reference housing $\bar{h}$ which is a weighted average of other households' houses as introduced in the next section.

Housing is both a consumption good and an asset. It is modelled as a homogenous, divisible good. As such, h represents a one-dimensional measure of housing quality (including size, location and amenities). An agent's housing stock depreciates at rate δ and can be adjusted frictionlessly[7]. Home improvements and maintenance expenditures x_t have the same price as housing (p) and go into the value of the housing stock one for one.

The asset a serves both as a savings device and short-term mortgage. Saving and borrowing can be done at the equilibrium interest rate r, subject to an exogenous collateral constraint that sets the maximum possible loan-to-value ratio ω.

Households' assets evolve according to

$$\dot{a}_t = \tilde{y}_t + r_t a_t - c_t - p_t x_t,$$
$$\dot{h}_t = -\delta h_t + x_t,$$

subject to the constraints

$$a_t \geq -\omega p_t h_t \tag{1}$$
$$h_t > 0.$$

2.3 Social comparisons

We build on the macroeconomic literature (e.g. Abel, 1990; Gali, 1994; Campbell and Cochrane, 1999; Ljungqvist and Uhlig, 2000) on keeping up with the Joneses and bring it closer to the empirical evidence. These papers feature representative agent models with one good and one asset. Agents compare themselves in the single consumption good, and their references measure is the average consumption in the economy[8].

We depart from this literature in two ways. First, we assume that households compare themselves only in their houses. This captures that people compare themselves only in

---

[7]Frictionless adjustment is justified, because we will be comparing long-run changes (over a period of 27 years).

[8]In equilibrium the references measure has to be equal to the optimal choice of the representative agent.

conspicuous goods (such as housing, cars or jewelry) and that housing is one of the most visible goods–and the most important one in terms of expenditure share (e.g. Solnick and Hemenway, 2005; Bertrand and Morse, 2016).

Second, we allow the reference measure to be a function of the distribution of houses (and not necessarily its mean): $\bar{h}_i = \bar{h}_i(\mu_h)$. This reflects that the comparison motive is asymmetric, being strongest (and best documented) with respect to the rich (e.g. Clark and Senik, 2010; Ferrer-i-Carbonell, 2005; Card et al., 2012, on self-reported well-being). People buy bigger cars when their neighbors win in the lottery (Kuhn et al., 2011); non-rich move their expenditures to visible goods (such as housing) when top incomes rise in their state (Bertrand and Morse, 2016); and construction of very big houses leads to substantially lower levels of self-reported housing satisfaction for other residents in the same area–while the construction of small houses does not (Bellet, 2018).

For our analytical results we assume that $\bar{h}$ is weighted mean of the housing distribution and use $s(h, \bar{h}) = h - \phi \bar{h}$ for tractability. For the quantitative results, we set $\bar{h}$ to the 90th percentile of the housing distribution and use $s(h, \bar{h}) = \frac{h}{\bar{h}^\phi}$ based on empirical evidence (see Section 4).

2.4 Pre-tax earnings process

In our main experiment, we want to adjust life-time (permanent) income inequality without changing income risk to capture the way income inequality has changed over time. Guvenen et al. (2019) estimate a pre-tax earnings processes on administrative earnings data. The process[9] consists of (i) individual fixed effects (α_i), a persistent jump-drift process (z_{it}), a transitory jump-drift process (ϵ_{it}), and heterogeneous non-employment shocks (ν_{it}). Heterogeneity in α_i represents fixed ex-ante differences in earnings ability which is an important source of life-time inequality. The innovations of both the transitory and persistent process are drawn from mixture distributions to match higher order moments of income risk and impulse response functions. Finally, Guvenen et al. (2019) show that a non-employment shock with z-dependent shock probabilities greatly improves the model fit.[10]

If employed, individual pre-tax earnings are given by

$$y_{it}^{\text{pot}} = \exp(\tilde{\alpha}^i + z_{it} + \epsilon_{it}).$$

We will refer to y^{pot} as *potential earnings*. The actual pre-tax earnings (taking into account unemployment) are

$$y_{it} = (1 - \nu_{it}) y_{it}^{\text{pot}},$$

---

[9]We use version (7), where we take out the deterministic life-cycle profile. The only component that this version doesn't have are differences in deterministic income growth rates.

[10]The only component that is missing compared to the Benchmark process is fixed heterogeneous income profiles, i.e. ex-ante permanent heterogeneity in lifecycle income growth rates.

where

$$\tilde{\alpha}_i \sim \mathcal{N}(\mu_\alpha, \sigma_\alpha),$$
$$\mathrm{d}z_{it} = -\theta^z z_{it}\mathrm{d}t + \mathrm{d}J_{it}^z,$$
$$\mathrm{d}\epsilon_{it} = -\theta^\epsilon z_{it}\mathrm{d}t\mathrm{d}J_{it}^\epsilon.$$

J_{it}^z is a jump-process that arrives at rate λ^z. The size of the jump, η_{it}^z is drawn from a mixture of two normal distributions,

$$\eta_{it}^z = \begin{cases} \mathcal{N}\big(\mu^z(1-p^z), \sigma_1^z\big) & \text{with prob. } p^z \\ \mathcal{N}\big(-p^z\mu^z, \sigma_2^z\big) & \text{with prob. } 1-p^z. \end{cases}$$

Similarly, the jump process for the transitory process arrives at rate λ^ϵ and the jump size, η_{it}^z is drawn from a mixture of two normal distributions,

$$\eta_{it}^\epsilon = \begin{cases} \mathcal{N}\big(-\epsilon_{it} + \mu^\epsilon(1-p^\epsilon), \sigma_1^\epsilon\big) & \text{with prob. } p^\epsilon \\ \mathcal{N}\big(-\epsilon_{it} - p^\epsilon\mu^\epsilon, \sigma_2^\epsilon\big) & \text{with prob. } 1-p^\epsilon. \end{cases}$$

The key difference between the persistent and the transitory process is that the jumps in the former are added to the current state whearas the jumps in the latter process reset the process such that the post-jump state is centered around zero.

The nonemployment shock arrives at rate $\lambda_0^\nu(z_{it})$ and has average duration $1/\lambda_1^\nu$. Specifically, the arrival probability as a function of the current state of the persistent process is modelled as

$$\lambda_0^\nu(z_{it})\mathrm{d}t = \frac{\exp\big(a + bz_{it}\big)}{1 + \exp\big(a + bz_{it}\big)}.$$

2.5 Production

There are two competitive production sectors producing the non-durable consumption good c and new housing investment I_h, respectively.

Non-Durable Consumption Sector The final consumption good is produced using a linear production function

$$Y_c = N_c$$

where N_c are units of labor working in the consumption good sector. As total labor supply is normalized to one, N_c is also the share of total labor working in this sector. The equilibrium wage per unit of labor is pinned down at $w = 1$.[11]

---

[11] As there is no aggregate risk, households inelastically supply one unit of labor, and the wage is equal to 1, neither labor supply nor the wage appear in the earnings process.

Construction Sector   We model the housing sector following Kaplan et al. (2019) and Favilukis et al. (2017). Developers produce housing investment I_h from labor $N_h = 1 - N_c$ and buildable land $\bar{L}$, $I_h = (\Theta N_h)^\alpha (\bar{L})^{1-\alpha}$ with $\alpha \in (0, 1)$. Each period, the government issues new permits equivalent to $\bar{L}$ units of land, and these are sold at a competitive market price to developers. A developer solves

$$\max_{N_h} p_t I_h - w N_h \quad \text{s.t. } I_h = N_h^\alpha \bar{L}^{1-\alpha}$$

In equilibrium, this yields the following expression for optimal housing investment

$$I_h = (\alpha p)^{\frac{\alpha}{1-\alpha}} \bar{L}$$

which implies a price elasticity of aggregate housing supply of $\frac{\alpha}{1-\alpha}$.

2.6   Financial markets

The financial intermediary collects savings from households and issues mortgages to households. Lending is limited by the households' exgenous collateral constraint (1).

In addition, the intermediary has an exogenous net asset position with the rest of the world a_t^S. The equilibrium interest ensures that bank profits are zero and the asset market clears,

$$\int a_t(a, h, y) \mathrm{d}\mu_t = a_t^S. \tag{2}$$

2.7   Stationary Equilibrium

A stationary equilibrium is a joint distribution $\mu(a, h, y)$, policy functions $c(a, h, y, \bar{h})$, $x(a, h, y, \bar{h})$, $h(a, h, y, \bar{h})$, $a(a, h, y, \bar{h})$, prices (p, r) and a reference measure $\bar{h}$ satisfying the following conditions

- Policy functions are consistent with agents' optimal choices $(c_t, h_t, a_t)_{t>0}$ given incomes $(y_t)_{t>0}$, prices p, r and the reference measure $\bar{h}$.

- $\mu(a, h, y)$ is stationary. That is, if the economy starts at μ, it will stay there.

- Asset market clears (2) and housing housing investment equals housing production $\int x(a, h, y) d\mu = I_h$.

- The reference measure is consistent with choices: $\bar{h} = \bar{h}(\mu)$.

3   Analytical Results

In this section we use a stylized version of the model described in section 2 to illustrate how rising top incomes can lead to rising mortgage levels across the whole income distribution via social comparisons. In this section we show analytically the following results.

In Proposition 1 we provide formulas for optimal housing and consumption, as functions of their permanent incomes, and the permanent incomes of the direct and indirect reference groups. In Proposition 2 we show that optimal debt is increasing in the incomes

of the direct and indirect reference groups. In Proposition 3 we show that the impact of rising incomes $\tilde{y}_i$ on aggregate debt is increasing in type i's *popularity*. In Corollary 1 we show that total debt-to-income is increasing in top incomes if at least one person compares themselves to the rich. In Corollary 2 we show that under Cobb-Douglas aggregation ($\varepsilon = 0$), these results hold even under housing market clearing because they are independent of house prices p. In Corollary 3 we show that these results crucially depend on the fact the status good h is durable.

The assumptions needed to obtain tractability are that there is no idiosyncratic income risk; that the social status function is linear; and that the interest rate equals the discount rate (all of these assumptions are relaxed in the following sections).

Assumption 1. $r = \rho$.

Further, we assume that there is a finite number of types of households $i \in \{1, \ldots, N\}$. Agents vary by their initial endowments a_0 and flow disposable income $\tilde{y}$.

Assumption 2. Flow income $\tilde{y}_i$ is deterministic and constant over time, but varies across types i.

Without loss of generality, we assume that types are ordered by their permanent income $\mathcal{Y}_i = r a_0^i + \tilde{y}_i$,

$$\mathcal{Y}_1 \leq \mathcal{Y}_2 \leq \ldots \leq \mathcal{Y}_N.$$

We use bold variables to denote the vector variables for each type using the above ordering, e.g. $\boldsymbol{h} = (h_1, \ldots, h_N)^T$.

Assumption 3 (Tractable social comparisons)**.** The status function $s(h, \bar{h}) = h - \phi \bar{h}$ is linear and the reference measure $\bar{h}_i = \sum_{j \neq i} g_{ij} h_j$ is a weighted sum of other agent's housing stock (we assume $g_{ij} \geq 0$).

Note, that we can write the vector of reference measures as $\bar{\boldsymbol{h}} = (\bar{h}_1, \ldots, \bar{h}_N)^T = G \cdot \boldsymbol{h} := (g_{ij})(h_i)$. The matrix G can be interpreted as the adjacency matrix of the network of types capturing the comparison links between agents of each type. g_{ij} measures how strongly agent i cares about agent j.

We further require the comparisons to satisfy the following regularity condition.

Assumption 4. The Leontief inverse $(I - \phi G)^{-1}$ exists and is equal to $\sum_{i=0}^{\infty} \phi^i G^i$ for ϕ from Assumption 3.

This assumption is not very strong. This assumption is satisfied whenever the power of the matrix converges, $G^i \to G^\infty$. For example, if G represents a Markov chain with a stationary distribution or if G is nilpotent.

3.1 Characterizaton of the partial equilibrium

We solve for a simplified version of the equilibrium in Section 2.7. Agents solve their optimization problem given prices and the reference measure; the reference measure is

consistent; but for now, we don't require market clearing. We use a lifetime budget constraint instead of the implicit transversality condition.

Households optimal decisions are given in the following proposition.

Proposition 1. *Under assumptions 1, 2, 3 and 4 the optimal choices* $\boldsymbol{h} = (h_1, \ldots, h_N)^T$ *and* $\boldsymbol{a} = (a_1, \ldots, a_N)^T$ *are given by*

$$\boldsymbol{h} = \Big(\sum_{i=0}^{\infty} (\kappa_1 \phi G)^i\Big) \kappa_2 \boldsymbol{\mathcal{Y}}.$$

$$-r\boldsymbol{a} = \tilde{\boldsymbol{y}} - \kappa_3 \boldsymbol{\mathcal{Y}} + (1 - \kappa_3)\Big(\sum_{i=1}^{\infty} (\kappa_1 \phi G)^i\Big) \boldsymbol{\mathcal{Y}} \tag{3}$$

where $\kappa_1 = \frac{1}{\frac{p(r+\delta)}{\kappa_0} + 1} \in (0,1)$, $\kappa_2 = \frac{\kappa_1}{\kappa_0}$, $\kappa_3 = \frac{1}{1 + \frac{pr}{\delta p + \kappa_0}} \in (0,1)$ *and* $\kappa_0 = \Big((r+\delta)\frac{1-\xi}{\xi}p\Big)^{\frac{1}{1-\varepsilon}}$.

Proof. See appendix B.2. $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\square$

Households' choices depend on a weighted average of the permanent incomes of their (direct and indirect) reference groups. The weights are positive, whenever there is a direct or indirect social link between those agents. This is captured by the *income-weighted Bonacich centrality*, $B = \sum_{i=0}^{\infty} (C_1 \phi G)^i \boldsymbol{\mathcal{Y}}$. If the weight B_{ij} is positive, household j's lifetime income affects household i's choices. This is the case whenever j is in i's reference group (there is a direct link $g_{ij} > 0$), or if j is in the reference group of some agent k who is in the reference group of agent i (there is an indirect link of length two, $g_{ik}g_{kj} > 0$) or if there is any other indirect link ($\prod_{n=1}^{N-1} g_{\ell_n, \ell_{n+1}}$ where $\ell_1 = i$ and $\ell_{N-1} = j$).

These results are reminiscent of those in Ballester et al. (2006). They showed that the unique Nash equilibrium in a large class of network games is proportional to the (standard) Bonacich centrality.

3.2 Comparative statics

First, we show that optimal debt and optimal housing are increasing in incomes of the direct and indirect comparison groups.

Proposition 2. *For each type j in i's reference group (that is, $g_{ij} > 0$) and for each k that is in the reference group of the reference group (etc.) of i (that is, there is $j_1, j_2, \ldots, j_n$ such that $g_{ij_1}g_{j_1 j_2} \cdots g_{j_{n-1} j_n}g_{j_n k} > 0$), then h_i is increasing and a_i is decreasing in $\mathcal{Y}_j$ (or $\mathcal{Y}_k$).*

Proof. G is non-negative, so $\sum_i c^i G^i$ is non-negative for all $c \geq 0$. From the definition of the Leontief inverse, being the discounted sum of direct and indirect links it follows,

$$\frac{\partial h_i}{\partial \tilde{y}_j} > \kappa_2 \kappa_1 \phi g_{ij} > 0 \quad \text{and} \quad \frac{\partial h_i}{\partial \tilde{y}_k} > \kappa_2 (\kappa_1 \phi)^{n-1} g_{ij_1} g_{j_1 j_2} \cdots g_{j_{n-1} j_n} g_{j_n k} > 0.$$

Similarly

$$-\frac{\partial a_i}{\partial \tilde{y}_j} > (1 - \kappa_3)\kappa_1 \phi g_{ij} > 0 \quad \text{and} \quad -\frac{\partial a_i}{\partial \tilde{y}_k} > (1 - \kappa_3)(\kappa_1 \phi)^{n-1} \phi g_{ij_1} g_{j_1 j_2} \cdots g_{j_{n-1} j_n} g_{j_n k} > 0.$$

$\square$

Agent A's debt increases if agent B's lifetime income increases–as long as there is a direct or indirect link from A to B. That link exists, if agent A cares about agent B, or if agent A cares about some agent C who cares about agent B.

Second, we show how aggregage housing and debt react to changes in type j's income $\mathcal{Y}_j$. We first define the popularity of a type.

Definition 1 (Popularity)**.** We define the vector of popularities as

$$\boldsymbol{b}^T = \mathbf{1}^T \sum_{i=1}^{\infty} (\kappa_1 \phi G)^i,$$

and type i's popularity b_i as the ith component of $\boldsymbol{b}$.

The popularity is the sum of all paths that end at individual i. It measures how many agents compare themselves with i (directly and indirectly) and how strongly they do. The popularity of a type is crucial in determining how strongly their income will affect economic aggregates.

Proposition 3. *The impact of a change in type j's on aggregate housing and aggregate debt is proportional to its popularity.*

$$\frac{\partial}{\partial \tilde{y}_j} \sum_i h_i = \kappa_2 (1 + b_j)$$

$$\frac{\partial}{\partial \tilde{y}_j} \sum_i ra_i = (1 - \kappa_3)(1 + b_j).$$

Proof. Take the expressions from proposition 1 and plug in the definitions for $\mathcal{Y}$ and b (Definition 1), aggregate housing can be written as $\sum_{i=1}^{N} h_i = \kappa_2 \sum_{i=1}^{N} (1+b_i)(\tilde{y}_i + ra_0^i)$ and aggregate debt can be written as $-\sum_{i=1}^{N} ra_i = (1-\kappa_3) \sum \tilde{y}_i - \kappa_3 \sum a_0^i + (1-\kappa_3) \sum_{i=1}^{N} b_i (\tilde{y}_i + ra_0^i)$. The derivatives follow immediately. $\square$

Corollary 1. *If all types $i \neq j$ are connected to agent j and $\tilde{y}_j$ increases, then debt-to-income increases for all types $i \neq j$.*

Proof. By Proposition 2 debt of types $i \neq j$ increases, while their income is unchanged. It follows that debt-to-income rises. $\square$

Corollary 2. *Under Cobb-Douglas aggregation, the results for a in Propositions 1, 2 and 3 are independent of house prices.*

Proof. Under Cobb-Douglas κ_0 is divisible by p. This means that p cancels in κ_1 and κ_3. Thus, all p cancel in the expression for a in Proposition 1 and consequently doesn't show up in the respective expressions in Propositions 2 and 3. $\square$

The results on optimal debt in Propositions 2 and 3 and Corollary 1 break down if houses are not durable. When houses are non-durable, for any small time interval Δ, the depreciation rate has to be $\delta = \frac{1}{\Delta}$, so that the housing stock depreciates immediately,

$$(1 - \Delta\delta)h_t = 0.$$

To analyze this case in continuous time, we thus let the depreciation rate δ go to infinity.

Corollary 3. *When $\delta \to \infty$, optimal debt does not depend on others' incomes.*

Proof. It can be easily seen that $\kappa_3 \to 1$ as $\delta \to \infty$, thus $(1 - \kappa_3) \to 0$. Since all other terms in expression (3) are bounded, the part containing the Leontief inverse vanishes and becomes $-r\boldsymbol{a} = \tilde{\boldsymbol{y}} - \boldsymbol{\mathcal{Y}} = -r\boldsymbol{a}_0$. $\qquad\square$

3.3 How rising top incomes fuel the mortgage boom: Intuition

It is at the heart of the mechanism that there is a complementarity between a household's housing stock and their reference measure. When top incomes $\mathcal{Y}_N$ rise, households of type N will improve (or upsize) their housing stock h_N, increasing the reference measure $\bar{h}_i$ for all types i that care about type N directly or indirectly. Each of these agents will optimally substitute durable, status-enhancing housing for non-durable status neutral consumption.

For debt to be affected it is key that the status good is durable and the status-neutral good in non-durable. Agents want their stock of the durable good to be constant over time. They need to pay for the whole good ph upfront and only replace the depreciation δph in the future. Agents need to shift some of their lifetime income forward to finance their house. They use mortgages as an instrument to achieve that. The greater the value of the house, the bigger is the necessary mortgage.

Corollary 3 formalizes this intuition. It shows that if houses are non-durable ($\delta \to \infty$), the term containing the Leontief inverse of the adjacency matrix G vanishes.

3.4 Example: Upward comparisons with three types of agents

We now illustrate the results for the simple case of three types of agents, poor P, middle class M, and rich R. The poor type compares himself with both other types, the middle type compares himself only with the rich type, and the rich type not at all. Figure 5 shows the corresponding graph and its adjacency matrix.

$$G = \begin{array}{c} \\ P \\ M \\ R \end{array} \begin{array}{ccc} P & M & R \\ \begin{pmatrix} 0 & g_{PM} & g_{PR} \\ 0 & 0 & g_{MR} \\ 0 & 0 & 0 \end{pmatrix} \end{array}$$

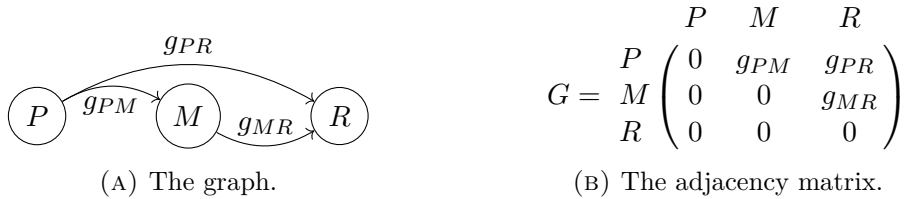(A) The graph.　　　　(B) The adjacency matrix.

FIGURE 5: The social network structure with three types, assuming upward comparisons. The network can be represented as a graph and as its adjacency matrix.

Since G is a triangular matrix with only zeros on the diagonal, it is nilpotent ($G^3 = \mathbf{0}$), and thus the Leontief inverse exists.

$$
G^2 = \begin{array}{c} \\ P \\ M \\ R \end{array} \begin{array}{c} \begin{array}{ccc} P & M & R \end{array} \\ \begin{pmatrix} 0 & 0 & g_{PM}g_{MR} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \end{array}, \quad G^3 = \mathbf{0}
$$

The matrix G^2 counts the paths of length 2. In our example there is only one such path–from type P to type R. Defining $\tilde{\phi} = \kappa_1 \phi$, the vector of Bonacich centralities is given by

$$
\sum_{i=0}^{\infty} \alpha^i G^i = I + \sum_{i=1}^{2} \alpha^i G^i = I + \begin{pmatrix} 0 & \alpha \cdot g_{PM} & \alpha \cdot g_{PR} + \alpha^2 \cdot g_{PM} \cdot g_{MR} \\ 0 & 0 & \alpha \cdot g_{MR} \\ 0 & 0 & 0 \end{pmatrix}
$$

The partial equilibrium choices for housing and debt are now given by

$$
\begin{pmatrix} h_P \\ h_M \\ h_R \end{pmatrix} = \kappa_2 \begin{pmatrix} 1 & \tilde{\phi} \cdot g_{PM} & \tilde{\phi} \cdot g_{PR} + \tilde{\phi}^2 \cdot g_{PM} \cdot g_{MR} \\ 0 & 1 & \tilde{\phi} \cdot g_{MR} \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \mathcal{Y}_P \\ \mathcal{Y}_M \\ \mathcal{Y}_R \end{pmatrix}
$$

$$
-r \begin{pmatrix} a_P \\ a_M \\ a_R \end{pmatrix} = \tilde{\boldsymbol{y}} - \kappa_3 \boldsymbol{\mathcal{Y}} + (1 - \kappa_3) \begin{pmatrix} 0 & \tilde{\phi} \cdot g_{PM} & \tilde{\phi} \cdot g_{PR} + \tilde{\phi}^2 \cdot g_{PM} \cdot g_{MR} \\ 0 & 0 & \tilde{\phi} \cdot g_{MR} \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \mathcal{Y}_P \\ \mathcal{Y}_M \\ \mathcal{Y}_R \end{pmatrix}
$$

An agent's housing choice increases linearly in own permanent income, $\mathcal{Y} = \tilde{y} + ra_0$, and on the permanent income of agents *in the reference group*. The poor agent's consumption increases through the direct links, but also indirect links (which are discounted more strongly). Agents' decisions to save or borrow depend on the ratio of initial wealth a_0 and income $\tilde{y}$. The higher the income relative to initial wealth, the greater the need to borrow.

4   Parameterization

Now we turn back to the full model. We parameterize the model to be consistent with the aggregate relationships of mortgage debt, house value and income in the beginning of the 1980s. We use the estimated income process from Guvenen et al. (2019) and assign eight parameters externally. The remaining two parameters (the discount rate ρ and the utility weight of housing status ξ) are calibrated internally so that in general equilibrium the aggregate net-worth-to-income ratio and aggregate loan-to-value ratio match these aggregate moments in the 1983 Survey of Consumer Finances.

Income Process   We translate the estimated income process from Guvenen et al. (2019) to continuous time. It has a permanent, a persistent and a transitory component and state-dependent unemployment risk. Guvenen et al. (2019) estimate it to data from the time
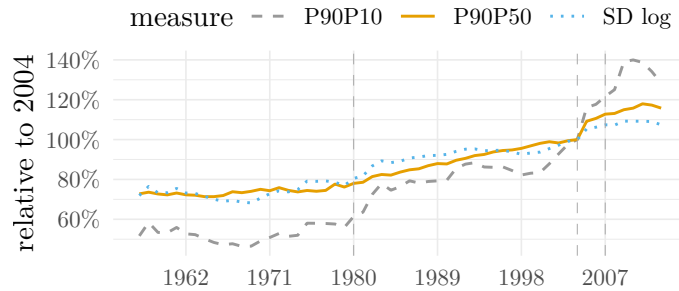
FIGURE 6: Change in the cross-sectional distribution of male earnings in the US. Vertical bars in 1980, 2004 and 2007. Source: Guvenen et al. (2018)

period 1994–2013. In order to construct the income process for the baseline economy $\mathcal{E}$ (corresponding to the year 1980) we rescale the permanent component following evidence on the changes in the income distribution from Kopczuk, Saez, and Song (2010), Guvenen, Ozkan, and Song (2014) and Guvenen, Kaplan, Song, and Weidner (2018).

The cross-sectional dispersion of incomes has increased substantially between 1980 and 2007. Figure 6 (taken from Guvenen et al., 2018, Figure 12) shows the variation of three common measures over time: the P90/P50 ratio, the P90/P10 ratio and the standard deviation of log-earnings. These changes in the variation of incomes can come from either component of the income process, or even a combination of them.

While there is no consensus yet,[12] as to which of those factors contributed how much, there is evidence that rising permanent inequality explains a substantial share in increased cross-sectional variation. Kopczuk et al. (2010, Figure V) find that almost all of the change in earnings variation came from increases in permanent inequality. This finding is supported by Guvenen et al. (2014, Figure 5) who show that the variances of earnings shocks have had a slight downward trend since 1980.

Given this evidence, we attribute all change in inequality to changes in permanent inequality (σ_α). In our income process, permanent income inequality is represented by the permanent component $\tilde{\alpha}$. So, given the discretized version of the process, we stretch the upper half of the $\tilde{\alpha}$-grid to match the changes in the cross-sectional P90/P50 ratio.

When translating the process to continuous time, we assume that shocks arrive on average once a year (instead of every year). Moreover, we replace the discrete time *iid* process by jump-drift process (ϵ_{it}) that is re-centered around zero whenever a shock hits so that shocks do not accumulate. The mean reversion rate of the persistent process (z_{it}) is the negative log of the discrete time persistence parameter which preserves the same annual autocorrelation. The exit rate out of nonemployment is chosen to match the average duration of nonemployment stays in the discrete time process. As households in our infinite horizon model die at a constant rate, we remove all age-dependence by setting the age profile constant (to the value at the mean age $\bar{t}$).[13] Table 1 shows all parameters of our continuous time earnings process.

---

[12]Carr and Wiemers (2016, 2018) show that depending on data source, sample selection, and statistical model one can find substantial differences in the decomposition into risk and permanent inequality.

[13]This affects the mean of log earnings as well as the arrival rate of nonemployment shocks.

TABLE 1: Earnings Process Parameters

Parameter		Value
Fixed Effects		
μ_α	mean	$2.7408 + 0.4989\bar{t} - 0.1137\bar{t}^2$
σ_α	standard deviation	0.467
Persistent Process		
λ^z	arrival rate	1.0
θ^z	mean reversion rate	$-\log(0.983)$
p^z	mixture probability	0.267
μ^z	location parameter	-0.194
σ_1^z	std. dev. of first Normal	0.444
σ_2^z	std. dev. of second Normal	0.076
σ_0^z	std. dev. of z_{i0}	0.495
Transitory Shocks		
λ^ϵ	arrival rate	1.0
θ^ϵ	mean reversion rate	0.0
p^ϵ	mixture probability	0.092
μ^ϵ	location parameter	0.352
σ_1^ϵ	std. dev. of first Normal	0.294
σ_2^ϵ	std. dev. of second Normal	0.065
Nonemployment Shocks		
a	constant	$-3.2740 - 0.8935\bar{t}$
b	slope	$-4.5692 - 2.9203\bar{t}$
λ_1^ν	exit rate	$1/0.9784$

We put the process on a discrete state space, using the approach of Kaplan et al. (2018). We discretize each component separately, obtaining continuous-time Markov chains[14] for the persistent and transitory components and combining them afterwards. Finally, we add the state-dependent non-employment risk.

Income Taxation We use the progressive income tax function from Heathcote, Storsletten, and Violante (2017),

$$T(y) = y - \tau_0 y^{1-\tau_1}.$$

If non-employed, households receive a fraction b of their potential earnings from unemployment insurance. Thus, the post-tax disposable income is given by

$$\tilde{y}_t = \begin{cases} y_{it}^{\text{pot}} - T(y_{it}^{\text{pot}}) & \text{if employed} \\ b y_{it}^{\text{pot}} & \text{otherwise.} \end{cases}$$

We follow Kaplan et al. (2019) in our choice of the parameters τ_0, τ_1. The progressivity parameter τ_1 is an estimate from Heathcote et al. (2017) and the scale parameter τ_0 is set to match the tax revenue from personal income tax and social security contribution as a share of GDP in 1980 (14.4%)[15]. We set the replacement rate to 32%, matching average

---

[14]Mostly called Poisson processes in the literature.

[15]Retrieved from https://taxfoundation.org/federal-tax-revenue-source-1934-2018/.

TABLE 2: Remaining baseline parameters

Parameter description		Source	Value
Preferences			
ϕ	strength of keeping up motive	Bellet (2017)	0.7
ρ	discount rate	internal	0.02
ξ	utility weight of housing	internal	0.277
$\frac{1}{1-\varepsilon}$	intra-temporal elasticity of substitution	Flavin and Nakagawa (2008, AER)	0.15
γ	inverse intertemporal elasticity of substitution	standard	1.5
$\frac{1}{m}$	constant mortality rate	45 years worklife	45.0
Housing and financial technology			
$\frac{\alpha}{1-\alpha}$	price elasticity of housing supply	Saiz (2010, QJE)	1.5
δ	depreciation rate of housing	Bureau of Economic Analysis	0.021
ω	maximum loan-to-value ratio	P95 of LTV	0.85
$a^S/\bar{y}$	exogenous net asst supply	cum. current account	-0.01
Taxation and Unemployment Insurance			
τ_0	level of taxes	internal	0.932
τ_1	progressivity	Heathcote et al. (2017)	0.15
b	replacement rate	Dept of Labor	0.32

unimployment insurance benefits, as a fraction of average wage, as reported by the US Department of Labor[16].

Preferences and demographics   The discount rate ρ and the utility weight of housing status ξ are internally calibrated to match the economy-wide mortgage-debt-to-income and loan-to-value ratios from the 1983 SCF. The interpretation of the utility weight ξ differs from other models, because ξ is the utility weight of housing status (not housing stock). It is internally calibrated.

The literature has not yet converged to a common value for the intratemporal elasticity of substitution $\frac{1}{1-\varepsilon}$. Estimates range from 0.13–0.24 (from structural models; e.g. Flavin and Nakagawa, 2008; Bajari, Chan, Krueger, and Miller, 2013) up to 1.25 (Ogaki and Reinhart, 1998; Piazzesi, Schneider, and Tuzel, 2007, using estimates from aggregate data). Many papers have picked parameters out of this range[17]. We follow the evidence from structurally estimated models and set the elasticity to 0.15.

The inverse intertemporal elasticity of substitution γ is set to the standard value 1.5. The constant annual mortality rate $m = 1/45$ is set to get an expected (working) lifetime of 45 years.

Social comparisons   For the status function we use a ratio-specification $s(h, \bar{h}) = \frac{h}{\bar{h}^\phi}$ as in Abel (1990). Bellet (2018) shows that this functional form captures the empirical finding that the utility loss from a big houses decreases with own house size. Households

---

[16]Retrieved from https://oui.doleta.gov/unemploy/DataDashboard.asp.

[17]Garriga and Hedlund (2017) use 0.13, Garriga, Manuelli, and Peralta-Alva (2019) use 0.5, many papers use Cobb-Douglas (that is, an elasticity of 1.0, e.g. Berger et al., 2018; Landvoigt, 2017) and Kaplan et al. (2019) use 1.25.

TABLE 3: Targeted moments

moment	model	data (80/83)
aggregate loan-to-value	0.24	0.24
aggregate networth-to-income	4.63	4.6
tax-revenue-to-income	0.14	0.14

with a medium sized house are more affected by top housing than households living in a small house[18].

We define the reference measure as the 90th percentile of the (endogenous) housing distribution, $\bar{h} = h_{P90}$. This follows Bellet (2018) who shows that households are only sensitive to changes in the top quintile of the house (size) distribution and strongest when the reference measure is defined as the 90th percentile[19].

The parameter ϕ pins down the strength of the comparison motive. It is the ratio of two utility elasticities

$$\phi = -\frac{\text{elasticity of utility w.r.t. } \bar{h}}{\text{elasticity of utility w.r.t. } h}.$$

If the reference houses improves by 1%, then agents would have to improve their own house ϕ% to keep utility constant. Bellet (2018) estimates ϕ to be between 0.6 and 0.8 when setting $\bar{h}$ equal to the 90th percentile of the housing distribution. We thus choose $\phi = 0.7$[20]. Note that Bellet (2018) estimates exactly this sensitivity allowing us to take his estimates without an intermediate indirect inference procedure.

Technology and Financial Markets   The construction technology parameter α is set to 0.6 so that the price elasticity of housing supply ($\frac{\alpha}{1-\alpha}$) equals 1.5, which is the median value across MSAs estimated by Saiz (2010). The maximum admissible loan-to-value ratio (ω) is set to 0.85, to match the 95th percentile of the LTV distribution in the SCF (Kaplan et al., 2019, use a similar approach for setting the debt-service-to-income constraint). Finally, we specfiy the exogenous net supply of assets a^S to match the net foreign debt position of the US. The net foreign debt position can be well approximated by the cumulative current account deficit of the US (Gourinchas, Rey, and Govillot, 2017), which was 1% of GDP in 1980 (see also figure 9).

4.1   Internal calibration and model fit

For the internal calibration we target the aggregate networth-to-income ratio and the aggregate loan-to-value ratio from the first wave of the Survey of Consumer Finances in 1983. We pick the utility weight of housing ξ and the the discount rate ρ so that simulated moments match their counterparts in the data. Table 3 shows the model fit.

---

[18]Note that the more tractable linear specification ($h - \phi\bar{h}$) as used in Campbell and Cochrane (1999), Ljungqvist and Uhlig (2000) and Section 3 would imply the opposite relationship between own house size and comparison strength.

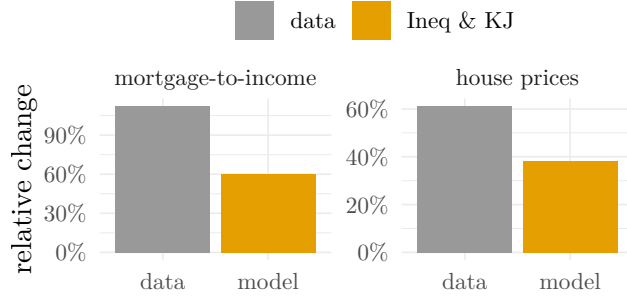[19]See figure 6 in Bellet (2018).

[20]See table 2 in Bellet (2018)

FIGURE 7: Comparison simulated changes in aggregate variables between the steady states in 1980 and 2007.

5 Quantitative Results

In this section we study how the model economy reacts to changes in the environment in the long-run. We compare the initial stationary equilibrium $\mathcal{E}$ (corresponding to 1980) with alternative stationary equilibria $\mathcal{E}^x$ where we adjust income inequality I, capital inflow (Saving Glut) S and and the collateral constraints ω to reflect the observed changes in the data.

In the first experiment we compare $\mathcal{E}$ to $\mathcal{E}^I$ where only income inequality rises. Afterwards we set these results into perspective, comparing them to equilibria that reflect other (combinations) of mechanisms like $\mathcal{E}^S$ (Saving Glut), $\mathcal{E}^\omega$ (relaxation of borrowing limit) and $\mathcal{E}^{IS\omega}$ (all three mechanisms).

5.1 Rising inequality, mortgages and house prices

We now move to the main experiment of the paper. We start from the steady-state calibrated to the U.S. economy in 1980. Then we raise income inequality to match the level in 2007 and compare the mortgage debt, house prices and housing production between 1980 and 2007. Before getting to the results, we describe how we model the increase in income inequality.

5.1.1 Modelling rising inequality

As we have discussed in Section 4, the cross-sectional dispersion of income has increased substantially between 1980 and 2007. Given the evidence in Kopczuk et al. (2010) and Guvenen et al. (2014) we attribute the whole change in cross-sectional inequality to changes in permanent inequality. In our model permanent inequality is reflected by the standard deviation of the distribution of the permanent component σ_α. Thus, we increase σ_α to match the increase in the cross-sectional P90/P50 ratio. In Section 5.3 we show that our results are robust to using different measures of income variation for the scaling and to attributing a fraction of the change to income risk.
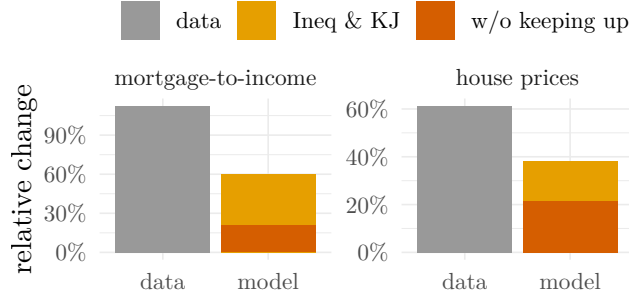
FIGURE 8: Comparison simulated changes in aggregate variables between the steady states in 1980 and 2007. "w/o keeping up" shows the changes when the reference measure $\bar{h}$ is kept fixed at level $\bar{h}_{1980}$ from the initial stationary equilibrium.

5.1.2 Results

Rising inequality and keeping up with the Joneses creates both a mortgage boom and a house price boom in our model. Figure 7 shows that our mechanism generates an increase in the mortgage-to-income ratio of about 60%—about half of the increase that is observed in the data. Similarly, we generate a house price boom (+38%) that generates 62% of the increase in the data.

Keeping up with the Joneses are a quantitatively important to generate the results. Figure 8 shows how much of the simulated debt and mortgage booms can be obtained with rising inequality, but without status concerns.[21] Without keeping up with the Joneses, the debt boom would be 71% weaker and the house price boom would be 44% weaker. The sizable effect of rising income inequality comes from general equilibrium effects. Rising inequality raises house prices and thus housing expenditures across the distribution. Since houses are financed by mortages, demand for credit increases. The interest rate rises to clear asset markets.

There are four channels at play. (*i*) Rising top incomes raise the demand for housing and house prices because the richer households want to live in bigger houses. (*ii*) Agents react to the new reference measure. They substitute houses for consumption to keep up with the Joneses. (*iii*) All households react to the higher house prices. Agents will spend a larger fraction of their income on houses, because houses and consumption are not perfects substitutes. (*iv*) The three channels above raise the demand for housing, and thus the demand for mortgages. Interest rates rise until demand for savings (i.e. credit supply) meets credit demand.

5.2 Horse race against alternative mechanisms

Rising inequality together with a "keeping up with the Joneses" motive is not the only possible explanation for the rise in mortgages and house prices. The main complementary mechanisms are the Global Saving Glut (capital inflow from emerging markets; Bernanke,

---

[21]Instead of recalibrating the model with $s(h, \bar{h}) = h$ one can use that for a given reference measure $\bar{h}$ that is constant across the population, the initial equilibrium $\mathcal{E}$ is equivalent to a parameterization with $s(h, \bar{h}) = h$ and housing weight $\tilde{\xi}$ such that $\frac{\tilde{\xi}}{1-\tilde{\xi}} = \frac{\xi}{1-\xi} \frac{1}{h^\phi}$. This holds because our specification of social comparisons, just reweights the utility of housing and consumption.
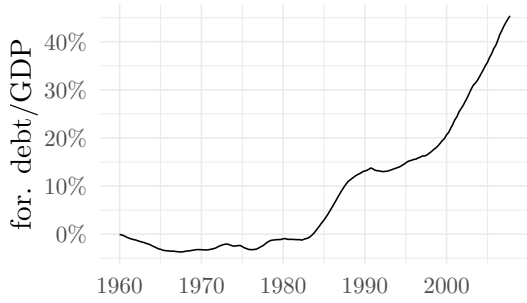
FIGURE 9: Cumulative current account deficit (which is approximately US external debt) as a fraction of GDP. Source: BEA and FRED. Details see Appendix A
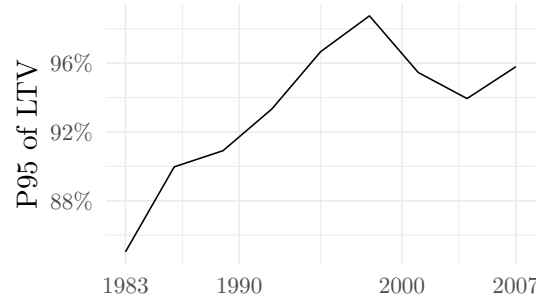

FIGURE 10: The 95th percentile of the loan-to-value (LTV) distribution, Source: Surveys of Consumer Finances 1983–2007. Details see Appendix A

2005), financial innovation (securitization allows banks to lend more liberally to less credit-worthy households; e.g. Favilukis et al., 2017) and a bubble in the housing market (house prices rose in expecation of rising house prices; e.g. Kaplan et al., 2019).

In this section compare the magnitudes of two competing channels (Saving Glut and relaxation of borrowing limits) with our main mechanism. Analyzing the role of expectations for the housing boom is beyond the scope of our model.

5.2.1 Global Saving Glut

Just like the US mortgage boom, growing international imbalances have been discussed as a source of instability leading to the Global Financial Crisis. Bernanke (2005, then Fed govenor) was one of the first to interpret these imbalances not in terms of trade imbalances, but as an accumulation of external debt: The cumulative current account deficit is approximately equal to the net foreign asset position. As seen in Figure 9 the cumulative current account reached -40% of GDP in 2006. That is, the US was a net debtor with net debt amounting to 40% of GDP[22]

Bernanke (2005) also provides a potential source for this rise in foreign debt: the steep increase in the global demand for savings, especially from China and India. He argues that these savings flowed into the US economy, building up the US debt position.

Through the lens of our model, the global saving glut changes the market clearing condition (2) of the asset and mortgage market. Exogenous asset supply is given by a_t^S, where $a_t^S/\bar{y}_t$ is the cumulative current account from Figure 9 ($\bar{y}_t$ is average pre-tax earnings, our measure of GDP).

Comparing the Saving Glut to our main mechanism, Figure 11 shows that the Saving Glut indeed causes a substantial increase in the mortgage-to-income ratio (at the same order of magnitued as inequality and keeping up with the Joneses) and only a very weak increase in house prices if inequality is held fixed at the 1980 level.

Note that the way we model the Saving Glut potentially biases the effects upwards. We assume that the capital inflow is purely driven by foreign demand for assets. If, on the

---

[22]Gourinchas et al. (2017) estimate that the precise net foreign asset position was less negative due to valuation effects.
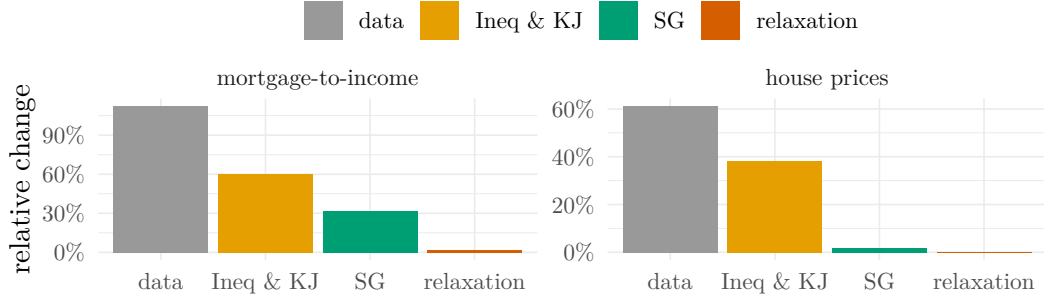
FIGURE 11: Compare simulated changes in aggregate variables for different scenarios. *Saving Glut*: Constant inequality and reference measure $\bar{h}$, varying a^S to match net foreign debt position (see Figure 9). *relaxation*: Constant inequality and reference measure $\bar{h}$, varying ω to match P95 of the LTV distribution (see Figure 10)

other hand, part of the capital inflow is driven by increased supply of assets (from higher demand for mortgages), the part of the external debt position might just be a symptom of a demand-side mechanism like ours. Assuming a small open economy (constant interest rate), our main mechanism generates a mortgage boom that is large enough to explain the build-up of external debt. Kumhof, Ranciere, Richter, Throckmorton, Winant, and Ozsögüt (2017) indeed find that rising top incomes are an important predictor of a current account deficits (and thus, foreign debt). In this case, the Saving Glut (the increased demand for assets) would be less powerful.

5.2.2 Financial liberalization and innovation

Another prominent explanation for debt boom is a relaxation of constraints in the financial sector. These might come from regulatory changes or financial innovation. In 2007, banks could give out more mortgages than in 1980 because law required lower collateral requirements on the banks' and the households' balance sheets. Moreover, banks' technology might have improved, so that they are no able to lend on worse terms (e.g. higher loan-to-value ratios). Favilukis et al. (2017) and Justiniano et al. (2019) have shown that under certain condition the relaxation of constraints can have sizable effects on total lending. We show, that in our model this is not the case because interest rates rise in general equilibrium.

We model financial liberalization and financial innovation in a reduced form way. We assume that the exogenous LTV limit (ω_t) increases over time. As a proxy for this borrowing limit, we use the 95th percentile of the LTV distribution in the Surveys of Consumer Finances, which is shown in Figure 10. In line with the data we assume that the LTV limit increases from 0.85 in 1980 to $\omega_{2007} = 0.96$.

Figure 11 shows that in general equilibrium, this mechanism doesn't contribute to the debt and house price booms. These results differ from Favilukis et al. (2017) because there are not many constrained agents in our equilibrium. Their equilibrium is constructed in a way that a big part of the population is at or close to the constraint. Moreover, they use an exogenous inflow of capital to keep the interest rate down.

FIGURE 12: Decomposition of the three mechanisms

5.2.3 Decomposition of the three mechanisms

Instead of looking at the channels individually, we will now analyze their marginal effects. We add three mechanisms to the baseline economy one by one and compute their marginal effects. In a first step we compare the baseline economy $\mathcal{E}$ with the Saving Glut economy $\mathcal{E}^S$. Then we compute the marginal effect of adding rising inequality and keeping up with the Joneses in $\mathcal{E}^{IS}$ and finally we compute the marginal effect of a relaxation of the collateral constraint in $\mathcal{E}^{IS\omega}$.

All three mechanisms together generate an increase in the mortgage-to-income ratio of 83% and an increase in house prices of 38%. In Figure 12 and Table 6 we provide a decomposition. The contributions of each channel depends on the ordering in which they are added. Rising inequality and social comparison contributes between 39% and 72% to the total generated increase in mortgage-to-income and more than 95% of the total generated house price boom. The Saving Glut contributes 21–55% to the debt boom and has only negligible effects on house prices. Relaxation of the collateral constraint has only a minor contribution to both.

Thus, rising inequality and keeping up with the Joneses are an important amplifier of the Saving Glut when it comes to mortgage debt. Moreover, among the three mechanisms, rising inequality and and keeping up with the Joneses is the only channel that generates a substantial increase in house prices.

5.2.4 Mortgages and houses across the income distribution

The mechanisms have different predictions on how housing and mortgage holdings change across the income distribution. Figure 13 shows the percentage change of house value (*ph*) and mortgage holdings as a fraction of income across the income distribution. In the data, there is in inverse-U shape in housing growth. The middle income quintiles had the strongest growth in house-value-to-income. Rising inequality and keeping up with the Joneses generates a very similar pattern, where the second and the third quintiles react strongest. The Saving Glut predicts only negligible effects on housing across the income distribution, and it does counterfactually predict that the effect is increasing over the income distribution.
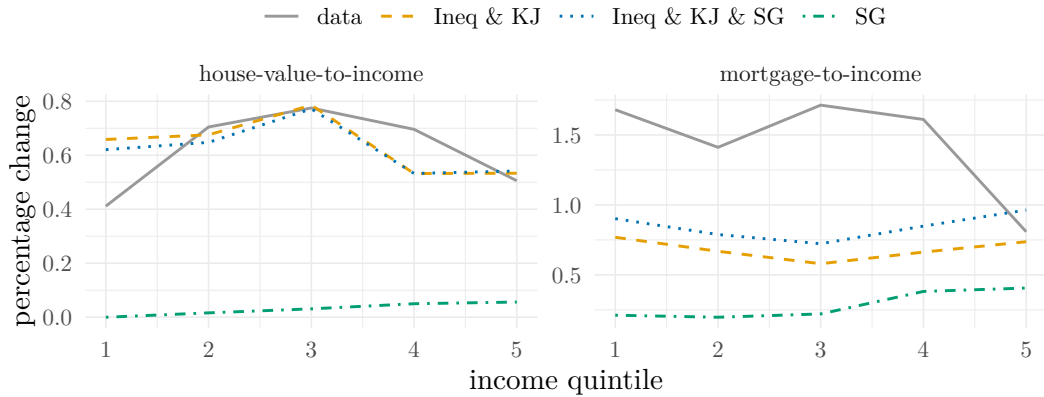
FIGURE 13: Compare simulated changes in housing and mortgages across the income distribution to the data (from the Survey of Consumer Finances).

5.3 Robustness

In the previous sections we have established the following qunantitative results.

1. Inequality and keeping up with the Joneses (RIKU) create strong mortgage and house price booms (in the range of 50% of the actual booms between 1980 and 2007).

2. The effect on mortgages is about as strong as that of the Saving Glut while the effect on house prices is much stronger.

3. RIKU amplifies the mortgage boom generated by the saving glut.

We will show that these findings are robust to (i) to a perturbation in the internally and externally calibrated parameters, including the strength of the comparison motive ϕ. And (ii) show what happens if not all of the increase in cross-sectional inequality is loaded on permanent income inequality.

5.3.1 Varying the calibrated parameters

We draw a sequence of pseudo-random Sobol points $(\theta_i)_{i=1}^n$ from a hypercube Θ contained in the parameter space. Each Sobol point θ_i is a vector in the parameter space. The generated sequence is equally distributed in the Θ. The advantage over uniformly distributed random vectors is that Sobol numbers tend to be more evenly distributed for finite samples.

The hypercube is

$$\Theta = [\rho_\ell, \rho_r] \times [(1/(1-\varepsilon))_\ell, (1/(1-\varepsilon))_r] \times [\xi_\ell, \xi_r] \times [\gamma_\ell, \gamma_r] \times [\delta_\ell, \delta_r] \times [\alpha_\ell, \alpha_r] \times [m_\ell, m_r].$$

It contains the calibrated parameter combination θ_{cali}. See Table 4 for the boundaries of the cube.

In the first exercise we keep ϕ constant, so that $\theta_i \in \Theta \times \{\phi = 0.7\}$. In a second step we will also allow ϕ to vary. $\theta_i \in \Theta_\phi = \Theta \times \{0.5, 0.6, 0.7\}$ constant. Later we allow it to vary as well.

TABLE 4: Boundaries of the hypercube Θ

	ρ	$\frac{1}{1-\varepsilon}$	ξ	γ	δ	$\frac{\alpha}{1-\alpha}$	$\frac{1}{m}$
lower bound	0.0	0.1	0.1	1.1	0.01	1.0	50.0
upper bound	0.01	0.5	0.5	2.5	0.03	2.33	40.0

Constant ϕ Each dot in Figures 14 and 15 represents one sobol point θ_i. It shows the generated booms under two different mechanisms. In the left panel of Figures 14 a dot below the 45-degree line means that the Saving Glut generates a stronger mortgage boom than RIKU.

Figure 14 shows that RIKU generates sustantial booms in mortgages and house prices. The generated mortgage booms are mostly within 30% and 60% for mortgages and 30% and 40% for house prices. Figure 14 also shows that RIKU consistently generates a much weaker price boom for the Saving Glut. Concerning mortgages, both mechanisms alone generate booms in the same order of magnitude. This is evidence by the dots lying close to the 45-degree line.

Figure 15 shows that adding RIKU to the Saving Glut gives stronger effects than the Saving Glut alone. We see that all points are above the 45-degree line, meaning that both channels together generate a stronger mortgage and house price boom than the Saving Glut channel alone.

Varying ϕ Now we show that results also to changes in the strength of the comparison motive ϕ. We now draw sobol vecters θ_i from Θ_ϕ. Figure 16 shows that the cloud of points tilts downwards, thus weaking the effect of RIKU on the mortgage and house price booms. However, the cloud still spans the interval from 0% to 80%. Figure 17 shows that for the majority of parameter combinations RIKU amplifies the effect of the Saving Glut.

6   Conclusion

Rising inequality and keeping up with the Joneses were an important driver of mortgage debt and house prices in the decades prior to the Great Recession. In our calibrated heterogenous agent macroeconomic model, rising inequality and keeping up with the Joneses generate an increase in the mortage-to-income ratio of around 60%, about half as much as observed in the data between 1980 and 2007.

Is also an important amplifier of alternative mechanisms that generate a debt boom. In a model with exogenous capital inflow (to capture the Global Saving Glut) and relaxing borrowing constraints (to capture financial liberalization) adding Keeping up with the Joneses and rising inequality boosts the debt boom by a factor of two (generating 83% instead of 38%). Among these three mechanisms, rising inequality and keeping up with the Joneses is the only mechanism that generates a sizable house price boom (generating 62% of that observed in the data).

Both of these results are robust to perturbations of the parameters.

FIGURE 14: Comparing the strength of generated housing booms between RIKU ($\mathcal{E}^I$) and Saving Glut ($\mathcal{E}^S$) for different parameter combinations. The color represents model fit. (Darker is better)

FIGURE 15: Comparing the strength of generated housing booms between Saving Glut alone ($\mathcal{E}^S$) and Saving Glut plus RIKU ($\mathcal{E}^{IS}$) for different parameter combinations. The color represents model fit. (Darker is better)

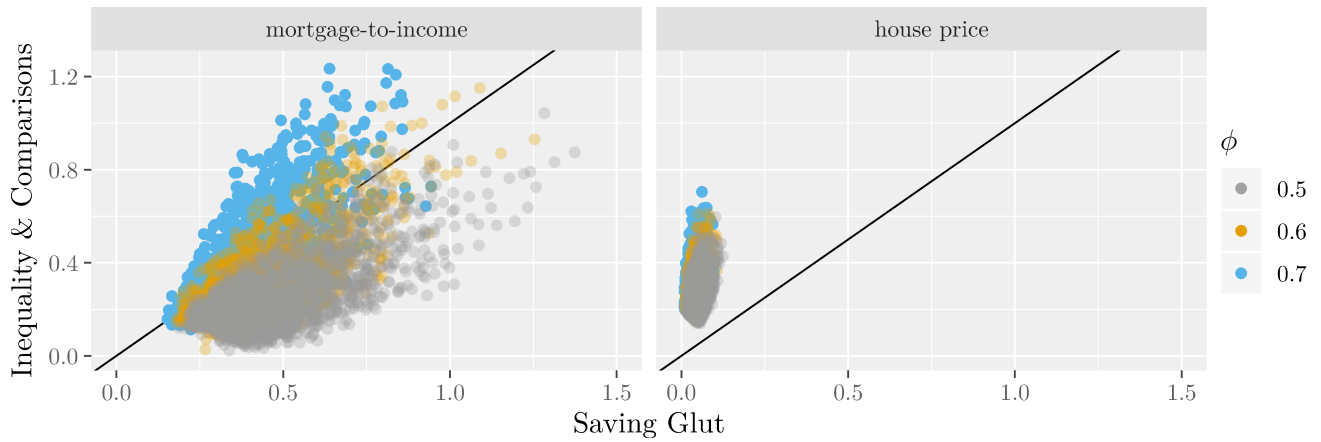FIGURE 16: Comparing the strength of generated housing booms between RIKU ($\mathcal{E}^S$) and Saving Glut ($\mathcal{E}^S$) for different parameter combinations and different strenghts of the comparison motive ϕ.

We show analytically that under social comparisons households' optimal debt level is increasing in incomes of the direct and indirect reference group. When everybody is directly or indirectly connected to the rich, aggregate debt rises in response to rising top incomes. Our tractable framework exposes how this mechanism works. Households substitute durable houses for non-durable consumption when top incomes rise because houses are a status good. Since houses are durable, they are optimally debt-finance. So an increase in the housing share also increase debt levels.

Avenues for future research With our mechanisms, rising inequality can be an important amplifier of financial crises. First, it amplifies the aggregate consumption response to house price shocks, because these *housing wealth effects* are increasing in the house share (Berger et al., 2018; Greimel and Zadow, 2019). Second, trends in top income inequality can lead to expectations of future house price growth, and thus serve as a trigger for the expectations channel of the housing boom and bust (Kaplan et al., 2019).

The insights from this paper can also lead to interesting research in international finance. It provides a different angle on the growing current account imbalances of the US. Rising demand for credit can attract foreign capital leading to a current account deficit.
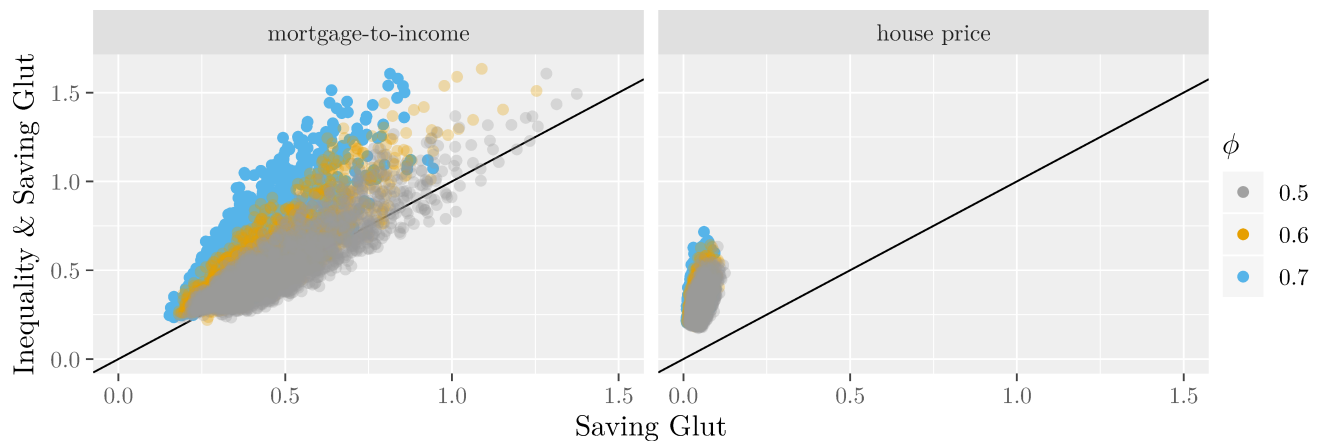
FIGURE 17: Comparing the strength of generated housing booms between Saving Glut alone ($\mathcal{E}^S$) and Saving Glut plus RIKU ($\mathcal{E}^{IS}$) for different parameter combinations and different strenghts of the comparison motive ϕ

References

ABEL, A. B. (1990): "Asset Prices under Habit Formation and Catching Up with the Joneses," *American Economic Review*, 80, 38–42.

ACHDOU, Y., J. HAN, J.-M. LASRY, P.-L. LIONS, AND B. MOLL (2017): "Income and wealth distribution in macroeconomics: A continuous-time approach," Tech. rep., National Bureau of Economic Research.

ADAM, K., P. KUANG, AND A. MARCET (2012): "House Price Booms and the Current Account," *NBER Macroeconomics Annual*, 26, 77–122.

AHN, S., G. KAPLAN, B. MOLL, T. WINBERRY, AND C. WOLF (2017): "When Inequality Matters for Macro and Macro Matters for Inequality," Working Paper 23494, National Bureau of Economic Research.

BAJARI, P., P. CHAN, D. KRUEGER, AND D. MILLER (2013): "A dynamic model of housing demand: Estimation and policy implications," *International Economic Review*, 54, 409–442.

BALLESTER, C., A. CALVÓ-ARMENGOL, AND Y. ZENOU (2006): "Who's Who in Networks. Wanted: The Key Player," *Econometrica*, 74, 1403–1417.

BELLET, C. (2017): "The Paradox of the Joneses - Superstar Houses and Mortgage Frenzy in Suburban America," CEP Discussion Paper 1462, Center for Economic Performance.

——— (2018): "The McMansion Effect: Top Size Inequality, House Satisfaction and Home Improvement in US Suburbs," .

BERGER, D., V. GUERRIERI, G. LORENZONI, AND J. VAVRA (2018): "House Prices and Consumer Spending," *The Review of Economic Studies*, 85, 1502–1542.

BERNANKE, B. S. (2005): "The Global Saving Glut and the U.S. Current Account Deficit," Speech 77, Board of Governors of the Federal Reserve System (U.S.).

BERTRAND, M. AND A. MORSE (2016): "Trickle-Down Consumption," *Review of Economics and Statistics*, forthcoming.

BURSZTYN, L., F. EDERER, B. FERMAN, AND N. YUCHTMAN (2014): "Understanding mechanisms underlying peer effects: Evidence from a field experiment on financial decisions," *Econometrica*, 82, 1273–1301.

BURSZTYN, L., B. FERMAN, S. FIORIN, M. KANZ, AND G. RAO (2017): "Status Goods: Experimental Evidence from Platinum Credit Cards," *The Quarterly Journal of Economics*, qjx048.

CAMPBELL, J. Y. AND J. H. COCHRANE (1999): "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior," *Journal of Political Economy*, 107, 205–251.

CARD, D., A. MAS, E. MORETTI, AND E. SAEZ (2012): "Inequality at Work: The Effect of Peer Salaries on Job Satisfaction," *American Economic Review*, 102, 2981–3003.

CARR, M. D. AND E. E. WIEMERS (2016): "Recent Trends in the Variability of Men's Earnings: Evidence from Administrative and Survey Data," .

——— (2018): "New evidence on earnings volatility in survey and administrative data," in *AEA Papers and Proceedings*, vol. 108, 287–91.

CHARLES, K. K., E. HURST, AND N. ROUSSANOV (2009): "Conspicuous Consumption and Race*," *The Quarterly Journal of Economics*, 124, 425–467.

CLARK, A. E. AND C. SENIK (2010): "Who Compares to Whom? The Anatomy of Income Comparisons in Europe," *Economic Journal*, 120, 573–594.

DE GIORGI, G., A. FREDERIKSEN, AND L. PISTAFERRI (2019): "Consumption Network Effects," *The Review of Economic Studies*.

DUESENBERRY, J. (1949): *Income, Saving and the Theory of Consumer Behavior*, Cambridge, MA, USA: Harvard University Press.

FAVILUKIS, J., S. C. LUDVIGSON, AND S. VAN NIEUWERBURGH (2017): "The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium," *Journal of Political Economy*, 125, 140–223.

FERRER-I-CARBONELL, A. (2005): "Income and Well-being: An Empirical Analysis of the Comparison Income Effect," *Journal of Public Economics*, 89, 997–1019.

FLAVIN, M. AND S. NAKAGAWA (2008): "A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence," *American Economic Review*, 98, 474–95.

FRANK, R. (2013): *Falling behind: How Rising Inequality Harms the Middle Class*, vol. 4, Univ of California Press.

GALI, J. (1994): "Keeping up with the Joneses: Consumption externalities, portfolio choice, and asset prices," *Journal of Money, Credit and Banking*, 26, 1–8.

GARRIGA, C. AND A. HEDLUND (2017): "Mortgage debt, consumption, and illiquid housing markets in the great recession," Working paper, Federal Reserve Bank of St. Louis.

GARRIGA, C., R. MANUELLI, AND A. PERALTA-ALVA (2019): "A macroeconomic model of price swings in the housing market," *American Economic Review*, 109, 2036–72.

GHIGLINO, C. AND S. GOYAL (2010): "Keeping up with the Neighbors: Social Interaction in a Market Economy," *Journal of the European Economic Association*, 8, 90–119.

GOURINCHAS, P.-O., H. REY, AND N. GOVILLOT (2017): "Exorbitant privilege and exorbitant duty," Working paper, University of California, Berkeley.

GREIMEL, F. AND F. ZADOW (2019): "Understanding Housing Wealth Effects: Debt, Homeownership and the Lifecycle," Working paper, University of Mannheim.

GUREN, A. M., A. MCKAY, E. NAKAMURA, AND J. STEINSSON (2018): "Housing Wealth Effects: The Long View," Tech. rep., National Bureau of Economic Research.

GUVENEN, F., G. KAPLAN, J. SONG, AND J. WEIDNER (2018): "Lifetime incomes in the United States over six decades," .

GUVENEN, F., F. KARAHAN, S. OZKAN, AND J. SONG (2019): "What Do Data on Millions of U.S. Workers Reveal About Life-Cycle Earnings Dynamics?" Tech. rep.

GUVENEN, F., S. OZKAN, AND J. SONG (2014): "The Nature of Countercyclical Income Risk," *Journal of Political Economy*, 122, 621–660.

HEATHCOTE, J., K. STORESLETTEN, AND G. L. VIOLANTE (2017): "Optimal tax progressivity: An analytical framework," *The Quarterly Journal of Economics*, 132, 1693–1754.

JUSTINIANO, A., G. E. PRIMICERI, AND A. TAMBALOTTI (2014): "The effects of the saving and banking glut on the US economy," *Journal of International Economics*, 92, S52–S67.

——— (2019): "Credit Supply and the Housing Boom," *Journal of Political Economy*, 127, 1317–1350.

KAPLAN, G., K. MITMAN, AND G. L. VIOLANTE (2019): "The housing boom and bust: Model meets evidence," *Journal of Poltical Economy.*

KAPLAN, G., B. MOLL, AND G. L. VIOLANTE (2018): "Monetary policy according to HANK," *American Economic Review*, 108, 697–743.

KAPLAN, G. AND G. L. VIOLANTE (2014): "A model of the consumption response to fiscal stimulus payments," *Econometrica*, 82, 1199–1239.

KIYOTAKI, N., A. MICHAELIDES, AND K. NIKOLOV (2011): "Winners and Losers in Housing Markets," *Journal of Money, Credit and Banking*, 43, 255–296.

KOPCZUK, W., E. SAEZ, AND J. SONG (2010): "Earnings Inequality and Mobility in the United States: Evidence from Social Security Data since 1937," *The Quarterly Journal of Economics*, 125, 91–128.

KUHN, P., P. KOOREMAN, A. SOETEVENT, AND A. KAPTEYN (2011): "The effects of lottery prizes on winners and their neighbors: Evidence from the Dutch postcode lottery," *The American Economic Review*, 101, 2226–2247.

KUMHOF, M., R. RANCIERE, A. W. RICHTER, N. A. THROCKMORTON, P. WINANT, AND E. OZSÖGÜT (2017): "Income Inequality and Current Account Imbalances," Working paper.

KUMHOF, M., R. RANCIÈRE, AND P. WINANT (2015): "Inequality, Leverage, and Crises," *American Economic Review*, 105, 1217–45.

LANDVOIGT, T. (2017): "Housing demand during the boom: The role of expectations and credit constraints," *The Review of Financial Studies*, 30, 1865–1902.

LJUNGQVIST, L. AND H. UHLIG (2000): "Tax policy and aggregate demand management under catching up with the Joneses," *American Economic Review*, 356–366.

LUTTMER, E. F. P. (2005): "Neighbors as Negatives: Relative Earnings and Well-Being," *Quarterly Journal of Economics*, 120, 963–1002.

OGAKI, M. AND C. M. REINHART (1998): "Measuring intertemporal substitution: The role of durable goods," *Journal of political Economy*, 106, 1078–1098.

PEREZ-TRUGLIA, R. (2019): "The Effects of Income Transparency on Well-Being: Evidence from a Natural Experiment," Working Paper 25622, National Bureau of Economic Research.

PIAZZESI, M. AND M. SCHNEIDER (2016): "Chapter 19 - Housing and Macroeconomics ," Elsevier, vol. 2 of *Handbook of Macroeconomics*, 1547 – 1640.

PIAZZESI, M., M. SCHNEIDER, AND S. TUZEL (2007): "Housing, Consumption and Asset Pricing," *Journal of Financial Economics*, 83, 531 – 569.

PIKETTY, T., E. SAEZ, AND G. ZUCMAN (2018): "Distributional National Accounts: Methods and Estimates for the United States," *The Quarterly Journal of Economics*, qjx043.

RAJAN, R. (2010): *Fault Lines: How Hidden Fractures Still Threaten the World Economy*, Princeton, NJ, USA: Princeton University Press.

SAIZ, A. (2010): "The geographic determinants of housing supply," *The Quarterly Journal of Economics*, 125, 1253–1296.

SOLNICK, S. AND D. HEMENWAY (2005): "Are Positional Concerns Stronger in Some Domains Than in Others?" *American Economic Review*, 95, 147–151.

STIGLITZ, J. (2009): "The global crisis, social protection and jobs," *International labour review*, 148, 1–13.

VAN TREECK, T. (2014): "Did Inequality Cause the U.S. Financial Crisis?" *Journal of Economic Surveys*, 28, 421–448.

VEBLEN, T. (1899): *The Theory of the Leisure Class*, Macmillan: George Allen and Unwin.

A Data sources

Introduction

Survey of Consumer Finances We use the micro data from the Survey of Consumer Finances (SCF). We join all five imputations and treat them as one data set. This is fine since we don't do inference.

A.1 Horse race

Real house price index and real interest rate

Figure 9: Net foreign debt position of the US We use the current account and GDP series from the BEA, retrieved via FRED (`BOPBCA`, `GDP`). Following Gourinchas et al. (2017) we compute the cumulative sum of the current account

$$\text{cum CA}_t = \sum_{i=1960}^{t} \text{CA}_t$$

and show it as a fraction of GDP in that given year $\frac{\text{cum CA}_t}{\text{GDP}_t}$.

Figure 10: P95 of LTV distribution (proxy for ω) We use the micro data from the Survey of Consumer Finances (SCF). We join all five imputations and treat them as one data set. This is fine since we don't do inference. We use the definition of mortgages and house value from above. We calculate individual $\text{LTV}_{i,t} = \frac{\text{outstanding mortgages}_{i,t}}{\text{house}_{i,t}}$. For each year we report the 95% percentile of the LTV distribution.

Acronyms SCF, FRED, BEA = U.S. Bureau of Eonomic Analysis

B Proofs

B.1 Lemmas

Lemma 1. *The necessary conditions for an optimum of the households' problem are*

$$u_c\big(c_t, s(h_t, \bar{h}_t)\big) = \lambda_t \tag{4}$$

$$u_s\big(c_t, s(h_t, \bar{h}_t)\big)s_h(h_t, \bar{h}_t) = \lambda_t(r+\delta)p \tag{5}$$

$$\dot{\lambda}_t - \rho\lambda_t = -r\lambda_t \tag{6}$$

where λ is the co-state in the continuous time optimization problem.

Proof. Without adjustment costs, the two endogenous state variables a_t and h_t collapse into one state variable net worth w_t.

$$\dot{w}_t = rw_t + y_t - (r+\delta)ph_t - c_t$$

The present-value Hamiltonian is

$$H(w, h, c, \lambda) = u\big(c, s(h, \bar{h})\big) + \lambda\big(rw_t + y_t - (r+\delta)ph_t - c_t\big),$$

34

where w is the state, c and h are the controls and λ is the co-state. The necessary conditions are

$$\frac{\partial H(w_t, h_t, c_t, \lambda_t)}{\partial c} = u_c\big(c_t, s(h_t, \bar{h}_t)\big) - \lambda_t = 0$$

$$\frac{\partial H(w_t, h_t, c_t, \lambda_t)}{\partial h} = u_s\big(c_t, s(h_t, \bar{h}_t)\big) s_h(h_t, \bar{h}_t) - \lambda_t(r + \delta)p = 0$$

$$\dot{\lambda}_t - \rho\lambda_t = \frac{\partial H(w_t, h_t, c_t, \lambda_t)}{\partial w} = -r\lambda_t. \qquad \square$$

Lemma 2. *Under our assumption of CRRA-CES preferences, the optimal relation of c_t and h_t is given by*

$$\frac{\xi}{1 - \xi}\Big(\frac{s(h_t, \bar{h}_t)}{c_t}\Big)^{\varepsilon - 1} s_h(h_t, \bar{h}_t) = (r + \delta)p. \tag{7}$$

Further assuming Assumption 3 yields

$$c_t = \kappa_0 h_t - \kappa_0 \phi \bar{h}_t, \quad \text{where } \kappa_0 = \Big((r + \delta)p\frac{1 - \xi}{\xi}\Big)^{\frac{1}{1 - \varepsilon}}. \tag{8}$$

Proof. Combining conditions (4) and (5) yields

$$\frac{u_s(c_t, s_t)}{u_c(c_t, s_t)} s_h(h_t, \bar{h}_t) \overset{!}{=} (r + \delta)p.$$

For the given CRRA-CES preferences the marginal utilites are given by

$$u_c(c_t, s_t) = ((1 - \xi)c_t^{\varepsilon} + \xi s_t^{\varepsilon})^{\frac{1 - \gamma}{\varepsilon} - 1}(1 - \xi)c_t^{\varepsilon - 1}$$

$$u_s(c_t, s_t) = ((1 - \xi)c_t^{\varepsilon} + \xi s_t^{\varepsilon})^{\frac{1 - \gamma}{\varepsilon} - 1}\xi s_t^{\varepsilon - 1}. \tag{9}$$

Thus,

$$\frac{u_s(c_t, s_t)}{u_c(c_t, s_t)} = \frac{\xi}{1 - \xi}\Big(\frac{s_t}{c_t}\Big)^{\varepsilon - 1}.$$

Plugging in above yields the first statement. Using Assumption 3 we get

$$\frac{\xi}{1 - \xi}\Big(\frac{h_t - \phi\bar{h}}{c_t}\Big)^{\varepsilon - 1} = (r + \delta)p.$$

$$\Big(\frac{c_t}{h_t - \phi\bar{h}}\Big) = \Big((r + \delta)p\frac{1 - \xi}{\xi}\Big)^{\frac{1}{1 - \varepsilon}} = \kappa_0$$

$$c_t = \kappa_0 h_t - \kappa_0 \phi\bar{h}_t \qquad \square$$

Lemma 3. *Under the assumption of time-constant house prices p, and all previous assumptions of this section, individual choices c_t, h_t are constant over time.*

Proof. The costate λ is constant over time. This follows from using Assumption 1 in condition (6), which gives $\dot{\lambda}_t = 0$.

Plugging in (8) in condition (5) one gets that an decreasing function of h is constant over time, thus h_t is constant over time. Knowing that h_t constant over time, and a similar argument for condition (4) it follows that c_t is constant over time. $\qquad \square$

B.2 Proof of Proposition 1

From the lemmas above we get that

$$c = \kappa_0 s(h, \bar{h}) = \kappa_0 h - \kappa_0 \phi \bar{h}.$$

Using the lifetime budget constraint we get

$$\mathcal{Y} := ra_0 + y = ph(r + \delta) + c$$

$$= h\Big(p(r+\delta) + \kappa_0\Big) - \kappa_0 \phi \bar{h}$$

$$\implies h = \frac{\mathcal{Y} + \kappa_0 \phi \bar{h}}{p(r+\delta) + \kappa_0} = \underbrace{\frac{1}{p(r+\delta) + \kappa_0}}_{\kappa_2} \mathcal{Y} + \underbrace{\frac{\kappa_0}{p(r+\delta) + \kappa_0}}_{\kappa_1} \phi \bar{h} = \kappa_2 \mathcal{Y} + \kappa_1 \phi \bar{h} \qquad (10)$$

where

$$\kappa_1 := \frac{\kappa_0}{p(r+\delta) + \kappa_0} = \frac{1}{\frac{p(r+\delta)}{\kappa_0} + 1} \in (0, 1)$$

since

$$\frac{p(r+\delta)}{\kappa_0} = \Big(\frac{1}{(r+\delta)p}\Big)^{\frac{1}{1-\varepsilon} - 1} \Big(\frac{\xi}{1-\xi}\Big)^{\frac{1}{1-\varepsilon}} > 0.$$

Stacking equations (10) for and using $\bar{\boldsymbol{h}} = G\boldsymbol{h}$

$$\boldsymbol{h} = \kappa_2 \boldsymbol{\mathcal{Y}} + \kappa_1 \phi G \boldsymbol{h}$$

$$\boldsymbol{h} = (I - \kappa_1 \phi G)^{-1} \kappa_2 \boldsymbol{\mathcal{Y}} = \Big(\sum_{i=0}^{\infty} (\kappa_1 \phi G)^i\Big) \kappa_2 \boldsymbol{\mathcal{Y}}.$$

Moreover,

$$\bar{\boldsymbol{h}} = G\boldsymbol{h} = \frac{\kappa_1 \phi}{\kappa_1 \phi} G\Big(\sum_{i=0}^{\infty} (\kappa_1 \phi G)^i\Big) \kappa_2 \boldsymbol{\mathcal{Y}}$$

$$= \frac{1}{\kappa_1 \phi} \Big(\sum_{i=1}^{\infty} (\kappa_1 \phi G)^i\Big) \kappa_2 \boldsymbol{\mathcal{Y}}$$

$$= \frac{1}{\kappa_0 \phi} \Big(\sum_{i=1}^{\infty} (\kappa_1 \phi G)^i\Big) \boldsymbol{\mathcal{Y}}$$

$(I - \kappa_1 \phi G)^{-1}$ is a Leontief inverse. It exists if the matrix power series $\sum_{i=0}^{\infty} (\kappa_1 \phi G)^i$ converges[23]. In that case

$$(I - \kappa_1 \phi G)^{-1} = \sum_{i=0}^{\infty} (\kappa_1 \phi G)^i.$$

Now, we calculate debt.

$$-ra = y - \delta ph - c$$

---

[23]This is the case for all nilpotent matrices (there exists a power p such that $G^p = 0I$) (there are no infintely-long paths in the network) or if all eigenvalues of $\kappa_1 \phi G$ are between 0 and 1. This holds whenever G can be interpreted as a Markov Chain.

using B.2,

$$
\begin{aligned}
&= y - \delta p h - \kappa_0 h + \kappa_0 \phi \bar{h} \\
&= y - (\delta p + \kappa_0) h + \kappa_0 \phi \bar{h} \\
-r\boldsymbol{a} &= \boldsymbol{y} - (\delta p + \kappa_0) \underbrace{\left(\sum_{i=0}^{\infty} (\kappa_1 \phi G)^i\right)}_{=I + \left(\sum_{i=1}^{\infty} (\kappa_1 \phi G)^i\right)} \kappa_2 \boldsymbol{\mathcal{Y}} + \left(\sum_{i=1}^{\infty} (\kappa_1 \phi G)^i\right) \boldsymbol{\mathcal{Y}} \\
&= \boldsymbol{y} - \kappa_3 \boldsymbol{\mathcal{Y}} + (1 - \kappa_3)\left(\sum_{i=1}^{\infty} (\kappa_1 \phi G)^i\right) \boldsymbol{\mathcal{Y}}
\end{aligned}
$$

where

$$
\kappa_3 = (\delta p + \kappa_0)\kappa_2 = \frac{\delta p + \kappa_0}{p(r + \delta) + \kappa_0} = \frac{1}{1 + \frac{pr}{\delta p + \kappa_0}} \in (0, 1).
$$

C Numerical solution for a stationary equilibrium

We first describe how we discretize the complex income process, then we show how to solve the partial equilbrium using a finite difference method from Achdou et al. (2017). Finally we present the algorithm used to compute equilibrium prices and reference measure.

The model was solved using version 1.2 of the `Julia` language. For a given parameterizaton, 200 endogenous grid points and 2000 exogenous gridpoints solving for a general equilbrium takes about 30 minutes on standard laptop using just one core.

For the calibration we ran the code in parallel (using 30 nodes with 16 cores) for 12 hours on a high performance cluster.

C.1 Discretizing the income process

Pre-tax earnings depend on four exogenous states $\theta = (\tilde{\alpha}, z, \epsilon, \nu)$,

$$
y(\theta) = (1 - \nu) \exp(\tilde{\alpha} + z + \epsilon).
$$

We first discretize the two jump-drift processes z and ϵ following the procedure of Kaplan et al. (2018). We discretize them separately, creating two continuous time Markov chains and combining them. The statespace of the combined continous time Markov Chain is given by

$$
\{z_1, \ldots, z_{N_z}\} \times \{\epsilon_1 \ldots \epsilon_{N_\epsilon}\}.
$$

Then we add non-employment states for each state, where the transition probabilities into the non-employment state are state-dependent. The statespace of the CTMC with non-employment becomes

$$
\{z_1, \ldots, z_{N_z}\} \times \{\epsilon_1 \ldots \epsilon_{N_\epsilon}\} \times \{0, 1\}.
$$

Finally we add the discretize the permanent component $\tilde{\alpha}$. We choose $N_\alpha = 10$ gridpoints, where each of those gridpoints represents a decile of $\tilde{\alpha}$'s distribution. Conditional on drawing $\tilde{\alpha}_i$, the other three components follow the same CTMC with $N_z \cdot N_\epsilon \cdot 2$ states. Denote the changing states by $\tilde{\theta} = (z, \epsilon, \nu)$

The transition between states $\tilde{\theta}$ is given by the intensities q_{ij}. For an agent at state $\tilde{\theta}_i$ the probability of jumping to a new state $\tilde{\theta}_j$ within the time short time period Δ is approximately given by $p_{ij}(\Delta) \approx q_{ij}\Delta$. More precisely, given the intensity matrix $Q = (q_{ij})$ where $q_{ij} \geq 0$ for $i \neq j$ and $q_{ii} = -\sum_{k \neq i} q_{ik}$, the matrix of transition probabilities is given by

$$P(\Delta) = \exp(-\Delta Q),$$

where exp is the matrix exponential. $P(\Delta)$ is a stochastic matrix.

C.2 Partial equilbrium given p, r, $\bar{h}$

Given prices (p, r) and reference measure $\bar{h}$ the households' problem can be characterized by a coupled system of partial differential equations: the Hamilton-Jacobi-Bellman (HJB) equation and the Kolmogorov forward (KF) equation. The HJB equation describes the optimization problem of the households and the KF equation describes the evolution of the cross-sectional distribution $\mu(\mathrm{d}a, \mathrm{d}h, \mathrm{d}y)$.

We solve these two equations using the finite difference method from Achdou et al. (2017). The discretized system can be written as

$$\rho \boldsymbol{v} = \boldsymbol{u}(\boldsymbol{v}) + A(\boldsymbol{v}; r, p, \bar{h})\boldsymbol{v}$$
$$\boldsymbol{0} = \left(A(\boldsymbol{v}; r, p, \bar{h}) + M\right)^T \boldsymbol{g},$$

where $\boldsymbol{v}$ is the discretized value function, $\boldsymbol{g}$ is the discretized cross-sectional distribution, $\boldsymbol{u}(\boldsymbol{v})$ is the discretized flow utility, $A(\boldsymbol{v}; r, p, \bar{h})$ is the discretized infinitesimal generator of the HJB equation (a very sparse matrix) and M is a matrix that corrects the intensities for births and deaths. The discretized system reveals how tightly coupled the HJB and KF equations are. The matrix $A(\boldsymbol{v}; r, p, \bar{h})$ shows up in both equation. Once it is known from the solution of the HJB equation, it can be directly used to get the distribution $\boldsymbol{g}$ from the KF equation.

C.2.1 Solving the Hamilton-Jacobi-Bellman equation

We assume that housing h can be adjusted frictionlessly. So the two states h and a collapse into one, "net worth"

$$w_t = a_t + ph_t,$$

with its law of motion

$$\dot{w}_t = rw_t + y_t - (r + \delta)ph_t - c_t.$$

The collateral constraint can be rewritten in terms of w

$$w_t = ph_t + a_t \geq ph_t - \omega ph_t$$
$$\implies ph_t \leq \frac{w_t}{1 - \omega}.$$

The households' HJB equation is

$$(\rho + m)v(w, \theta_i) = \max_{c, h \leq \frac{w}{1-\omega}} u(c, s(h, \bar{h}))$$

$$+ v_w(w, \theta_i)(rw + \theta_i - (r + \delta)ph - c)$$

$$+ \sum_{k \neq i} q_{ik}(v(w, \theta_k) - v(w, \theta_i)).$$

The intensities q_{ij} are the intensities of the continuous time Markov chain from Section C.1. In order to solve this equation, we need to replace the maximum operator with the maximized Hamiltonian. That is, we need to plug in the optimal policy functions $c^*(w, y)$, $h^*(w, y)$ which are given in Corollary 4 below. The result depends on the following lemma.

Lemma 4. *When the collateral constraint is slack, we get the optimality conditions*

$$h(w, y) = \left(\frac{1}{\tau_2}(\bar{h}^\phi(\rho + \delta)pv_w(w, y))\right)^{-\frac{1}{\gamma}} \bar{h}^\phi$$

$$c(w, y) = s(h(w, y), \bar{h})\tau_1,$$

where $\tau_1 = \left((r + \delta)p\frac{1-\xi}{\xi}\bar{h}^\phi\right)^{\frac{1}{1-\varepsilon}}$ *and* $\tau_2 = ((1-\xi)\tau_1^\varepsilon + \xi)^{\frac{1-\gamma-\varepsilon}{\varepsilon}}\xi$.

Proof. Using the optimality conditions (7) and (5) with (9) we get

$$(r + \delta)p = \frac{u_s(c, s)}{u_c(c, s)}s_h(h, \bar{h}) = \frac{\xi}{1-\xi}\left(\frac{s(h, \bar{h})}{c}\right)^{\varepsilon-1}s_h(h, \bar{h}) \tag{22}$$

$$(\rho + \delta)pv_w(w, y) = u_s(c, s)s_h = ((1-\xi)c^\varepsilon + \xi s^\varepsilon)^{\frac{1-\gamma}{\varepsilon}-1}\xi s^{\varepsilon-1}s_h. \tag{23}$$

Using (22) we express optimal c as a function of optimal s

$$c(h, \bar{h}) = s(h, \bar{h})\left((r + \delta)p\frac{1-\xi}{\xi}\frac{1}{s_h(h, \bar{h})}\right)^{\frac{1}{1-\varepsilon}}$$

using the ratio specification for s

$$= s(h, \bar{h})\left((r + \delta)p\frac{1-\xi}{\xi}\bar{h}^\phi\right)^{\frac{1}{1-\varepsilon}} =: s(h, \bar{h})\tau_1.$$

Then we can plug this expression into (23) and get

$$(\rho + \delta)pv_w(w, y) = ((1-\xi)(\tau_1 s)^\varepsilon + \xi s^\varepsilon)^{\frac{1-\gamma-\varepsilon}{\varepsilon}}\xi s^{\varepsilon-1}s_h$$

$$= \underbrace{((1-\xi)\tau_1^\varepsilon + \xi)^{\frac{1-\gamma-\varepsilon}{\varepsilon}}\xi}_{=:\tau_2} s^{1-\gamma-\varepsilon}s^{\varepsilon-1}s_h$$

$$= \tau_2 s^{-\gamma}s_h$$

Thus we get

$$s(h, \bar{h}) = \left(\frac{(\rho + \delta)pv_w(w, y)}{\tau_2 s_h}\right)^{-\frac{1}{\gamma}},$$

and using ratio-specification for s,

$$h = \left(\frac{1}{\tau_2}((\rho + \delta)pv_w(w, y)\bar{h}^\phi)\right)^{-\frac{1}{\gamma}}\bar{h}^\phi. \qquad \square$$

TABLE 5: Disentengling the effects of rising inequality and keeping up with the Joneses

	mortgage-to-income			house prices		
	growth	share	% of data	growth	share	% of data
Rising inequality	0.17	0.29	0.15	0.22	0.56	0.35
& Keeping up	+0.43	0.71	0.38	+0.17	0.44	0.27
total	0.60	1.0	0.53	0.38	1.0	0.62

Corollary 4. *The optimal policies are given by*

$$h^*(w,y) = \begin{cases} h(w,y) & \text{if } h(w,y) < \frac{w}{p(1-\omega)} \\ \frac{w}{p(1-\omega)} & \text{otherwise} \end{cases} , \quad c^*(w,y) = \begin{cases} c(w,y) & \text{if } h(w,y) < \frac{w}{p(1-\omega)} \\ \tilde{c}(w,y) & \text{otherwise} \end{cases}$$

where $h(w,y)$ and $c(w,y)$ are from Lemma 4 and $\tilde{c}(w,y)$ is the solution to the optimality condtion for c, given $h = \frac{w}{p(1-\omega)}$,

$$v_w(w,y) = ((1-\xi)c^\varepsilon + \xi s^\varepsilon)^{\frac{1-\gamma-\varepsilon}{\varepsilon}}(1-\xi)c^{\varepsilon-1},$$

which is solved numerically.

Given the optimal policies, it is straight-forward to solve the HJB using the implicit upwind scheme in Achdou et al. (2017).

C.2.2 Solving the Kolmogorov forward equation

We construct the birth and death matrix M as in Kaplan et al. (2018) and solve for the distribution using the implicit scheme from Achdou et al. (2017).

C.3 General equilibrium: Solving for r, p and $\bar{h}$

We use the following algorithm to compute general equilibria.

0. Guess r_0, p_0 and $\bar{h}_0$
1. Clear housing markets given r_{n-1} and $\bar{h}_{n-1}$

   (a) Use Newton steps until the sign of the excess demand for housing changes
   (b) Use Bisection to find the market clearing price p_n

2. Compute the excess demand on the asset market
3. Use a Newton step to update the interest rate r_n
4. Compute the implied reference measure $\bar{h}_x$ and update $\bar{h}_n = \bar{h}_{n-1} + a(\bar{h}_x - \bar{h}_{n-1})$
5. If $r_n \approx r_{n-1}$ and $\bar{h}_n \approx \bar{h}_{n-1}$, an equilibrium has been found. If not, go back to step 1.

D Additional tables

In this appendix we show tables corresponding the figures in the main text.

TABLE 6: Decomposition of the constributions of the three channels on the mortgage and house price booms.

(A) Starting from Keeping up with the Joneses

	mortgage-to-income			house prices		
	growth	share	% of data	growth	share	% of data
Inequality and keeping up	0.60	0.72	0.53	0.38	1.0	0.62
& Saving Glut	+0.17	0.21	0.15	+0.00	0.0	0.0
& Relaxed collateral constraint	+0.06	0.07	0.05	+0.00	0.0	0.0
total	0.83	1.0	0.74	0.38	1.0	0.63

(B) Starting from the Saving Glut

	mortgage-to-income			house prices		
	growth	share	% of data	growth	share	% of data
Saving Glut	0.32	0.39	0.28	0.02	0.04	0.03
& Inequality and keeping up	+0.45	0.55	0.4	+0.37	0.95	0.6
& Relaxed collateral constraint	+0.06	0.07	0.05	+0.00	0.0	0.0
total	0.83	1.0	0.74	0.38	1.0	0.63

TABLE 7: The effects of each channels on mortgages and house prices

	mortgage-to-income		house prices	
	growth	% of data	growth	% of data
Inequality and keeping up	0.6	0.53	0.38	0.62
Saving Glut	0.32	0.28	0.02	0.03
Relaxed collateral constraint	0.02	0.02	0.0	0.0