

Das House-Kapital

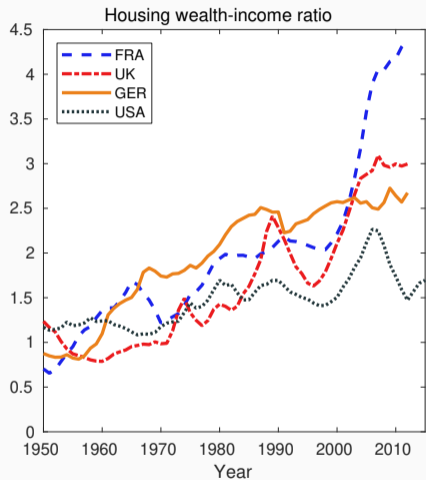
North American Summer Meeting of the Econometric Society

Volker Grossmann, **Benjamin Larin**, Thomas Steger

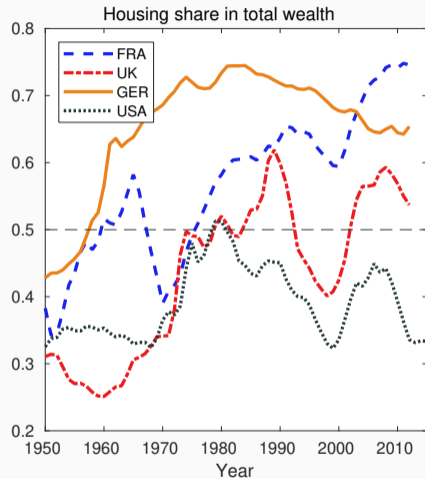
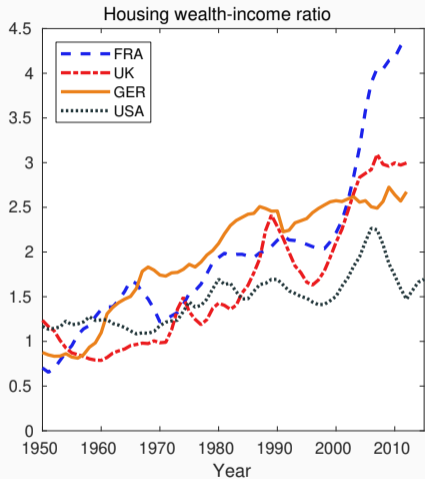
June 10, 2020

University of St.Gallen, Swiss Institute for Empirical Economic Research, Globalization of Real Estate Network

Housing has become the dominant asset class



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Paper in one slide

Research question: Why did the **housing wealth-income ratio** increase since 1950?

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 - Replicate 89% of observed increase
 - Driven by construction boom and rising demand for residential land
 - Key: elastic long-term supply of structures, inelastic long-term supply of land

Macroeconomic relevance of rising housing wealth-income ratio

- **Affordability:** representative household must devote a higher multiple of income to purchase the existing housing stock

Quigley & Raphael (2004), Albouy et al. (2016)

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 - Housing capital income share = housing yield \times housing wealth-income ratio
 - Housing yield has been stable (Jordà et al., 2019) \Rightarrow housing wealth-income ratio \uparrow

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A house is a bundle of structure and land

- We decompose housing wealth as follows

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Davis & Heathcote (2007)

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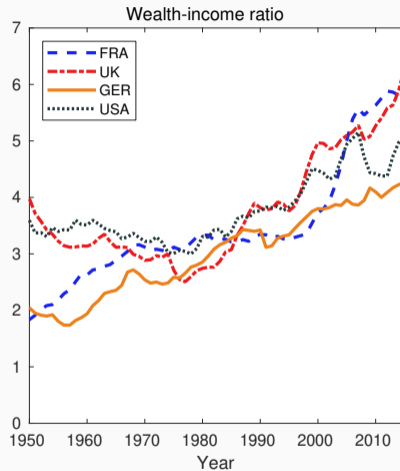
- Our data covers four developed economies: USA (1950–2015), UK (1950–2012), France (1960–2012), and Germany (1960–2012)

Stylized facts on housing & macro in the long run

1. **Wealth:** Wealth-income ratio \uparrow , housing wealth-income ratio $\uparrow\uparrow$
2. **Prices:** Real house price $\uparrow\uparrow$, construction cost \uparrow , residential land prices $\uparrow\uparrow\uparrow$
3. **Quantities:** House quantity $\uparrow\uparrow$, residential structures $\uparrow\uparrow\uparrow$, residential land \uparrow
4. **Land share:** Residential land value as share of housing wealth \uparrow
5. **Rent:** Housing rent \uparrow

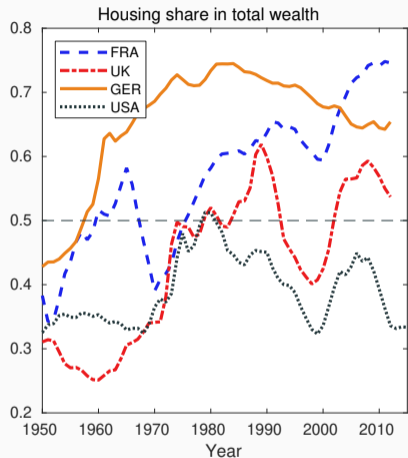
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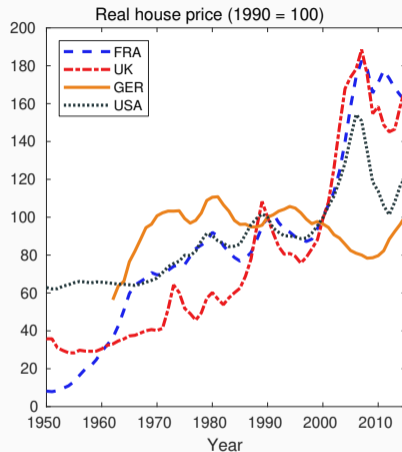
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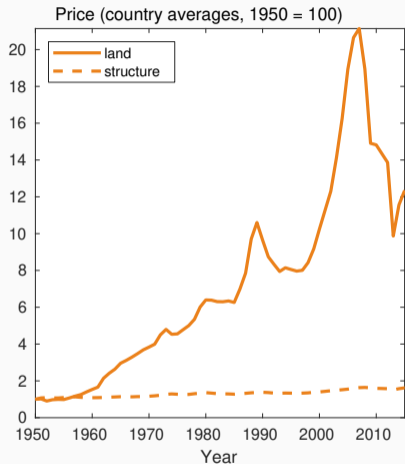
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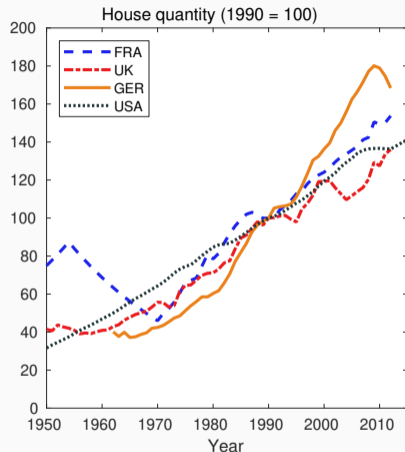
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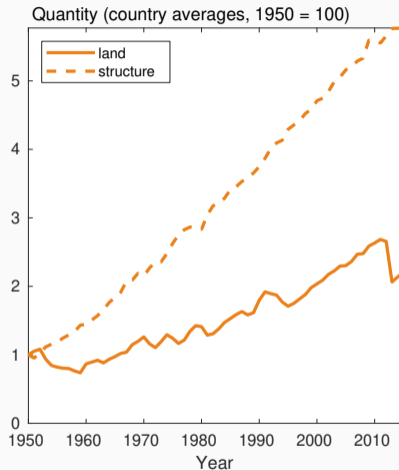
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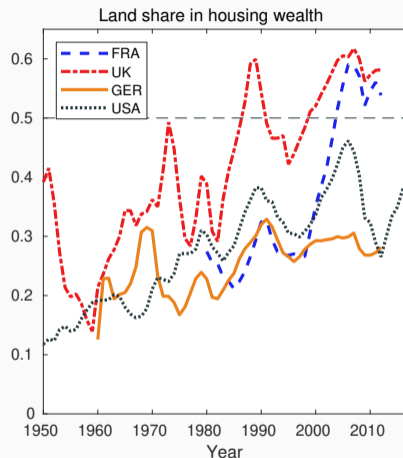
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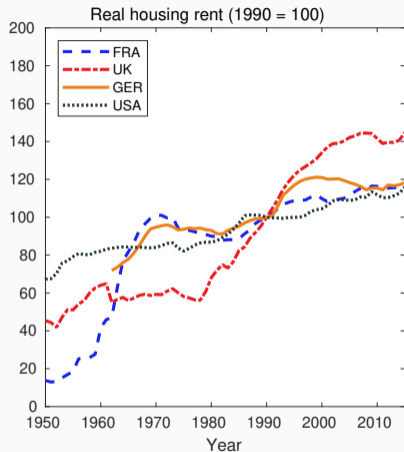
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Model: households

Representative household chooses $\{C_t\}_{t=0}^{\infty}$ and $\{S_t\}_{t=0}^{\infty}$ to maximize

$$U = \int_0^{\infty} e^{-\rho t} L_t \frac{\left[\left(\frac{C_t}{L_t} \right)^{1-\theta} \left(\frac{S_t}{L_t} \right)^{\theta} \right]^{1-\sigma} - 1}{1-\sigma} dt, \quad (1)$$

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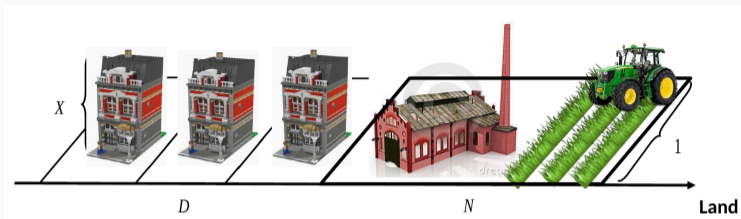
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subject to

$$\dot{W}_t + C_t + q_t S_t = r_t W_t + w_t L_t + \Pi_t^D, \quad W_0 = \text{given}, \quad NPGC. \quad (2)$$

Notes: The measure of households is normalized to one. Each household consists of measure L_t members. Each household member supplies one unit of labor inelastically such that labor supply per household is L_t . Households maximize "the sum" of per-capita utility.

Model: production sectors



Numeiraire sector

$$Y = K^\alpha (B^Y L^Y)^\beta N^{1-\alpha-\beta}$$

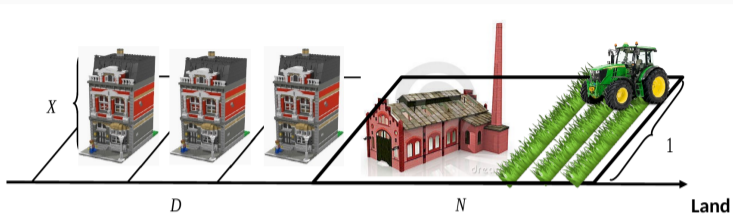
Y problem

H problem

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Model: production sectors



Housing sector

- Property management firms: demand structure X and land D to build housing H to rent out to households ($H = S$)

$$H = X^\gamma D^{1-\gamma}$$

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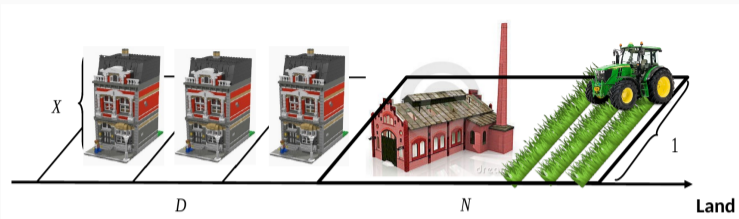
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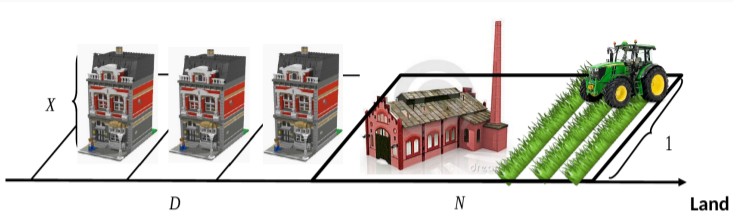
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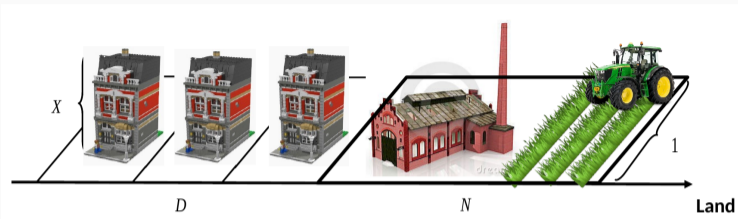
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Resource constraints

- Labor: $L^Y + L^X + L^D = L$
- Land: $D + N = Z$

Y problem

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X problem

Model: asset market

- House price

(derived from $P^D D + P^X X = P^H H$)

$$P^H = \frac{D}{H} P^D + \frac{X}{D} P^X \quad (3)$$

- Wealth consists of 3 assets

$$W = \underbrace{P^H H}_{\text{housing wealth}} + \underbrace{P^N N + K}_{\text{non-housing wealth}} \quad (4)$$

- No-arbitrage conditions hold in equilibrium

$$r = \frac{\dot{P}^H + R^H}{P^H} = \frac{\dot{P}^N + R^N}{P^N} \quad (5)$$

equilibrium

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Why do house prices grow in the long-term?

The house price grows in the long-term at the rate

$$g_{PH} = \left[1 - \eta + \eta (\psi^H - \psi^Y) \right] \frac{1 - \psi^Y}{1 - \eta\psi^Y} g^Y - (1 - \eta) \frac{1 - \psi^H}{1 - \eta\psi^Y} g^X \geq 0,$$

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- **Differential land intensities:** If $g^Y = g^X \equiv g$, growth rate simplifies to

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- **Differential technological progress:** If $\psi^Y = \psi^H \equiv \psi$, growth rate simplifies to

$$g_{PH} = \frac{(1 - \eta)(1 - \psi)}{1 - \eta\psi} (g^Y - g^X)$$

Further steady state results

- Quantitatively: differential land intensities and differential technological progress equally relevant for post 1950 US economy

back-of-the-envelope

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back-of-the-envelope

- What about house prices before 1950?

- Largely constant
- Our theory: pronounced technological growth in construction sector ($g^X \uparrow$) and high land intensity in non-housing sector ($\psi^Y \uparrow$)

Knoll, Schularick, & Steger (2017)

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Knoll, Schularick, & Steger (2017)

- Our theory: pronounced technological growth in construction sector ($g^X \uparrow$) and high land intensity in non-housing sector ($\psi^Y \uparrow$)

- Other stylized facts?

- Replicate growth rates of prices and quantities of residential land and residential structures, as well of rent

steady state growth rates

- But: Housing wealth-income ratio (and share of land in housing wealth) constant in steady state

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Calibration approach

The model is calibrated separately to the US, UK, France, and Germany over post WWII period at an annual frequency

- We do not impose that the economy is in steady state

exogenous parameters

endogenous parameters

targeted moments

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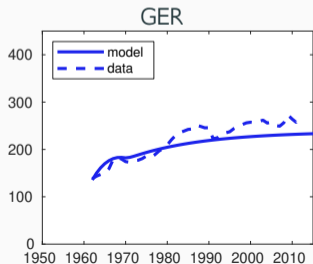
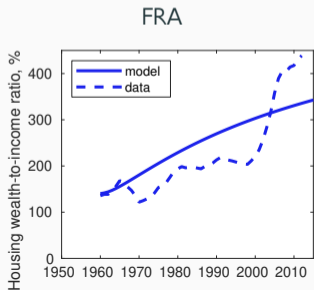
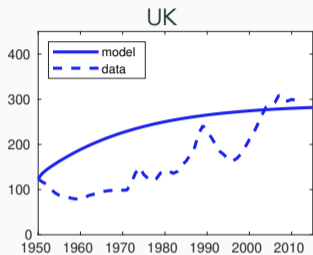
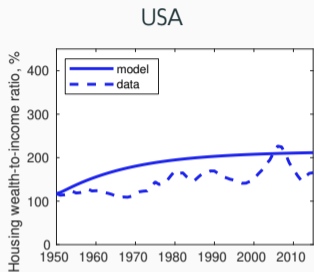
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- Transition due to initial states K_0 , X_0 , and D_0 , and exogenous transitory population growth L_t
- Some parameters are calibrated outside the model and 10 parameters are calibrated jointly inside the model by matching 10 moments along transition

exogenous parameters

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1) Replication: housing wealth-income ratios



- Replicate 80, 67, and 76 % of the increase in housing wealth-income ratio for UK, France, and Germany
- Over-predict increase by 38 % in USA (but: USA has not fully recovered from bust in 2015)

2) Why has the housing wealth-income ratio been increasing?

USA

	(1) baseline	(2) investment $K_0 = \tilde{K}$	(3) land development $D_0 = \tilde{D}$	(4) construction $X_0 = \tilde{X}$
$\frac{P^H H}{NNP}$	1.8 (0.00)	1.7 (0.03)	1.7 (0.08)	0.8 (1.01)
$P^H H$	9.7 (0.00)	6.5 (3.19)	9.3 (0.41)	4.9 (4.80)
NNP	5.9 (0.00)	4.1 (1.87)	5.9 (-0.01)	6.9 (-0.97)
$\frac{P^D D}{NNP}$	1.8 (0.00)	1.1 (0.70)	1.3 (0.49)	1.3 (0.48)
$P^D D$	4.7 (0.00)	2.0 (2.75)	8.1 (-3.41)	4.0 (0.72)
D	2.3 (0.00)	2.3 (-0.02)	1.0 (1.31)	2.3 (-0.03)
$\frac{P^X X}{NNP}$	1.8 (0.00)	1.9 (-0.11)	1.8 (0.00)	0.7 (1.04)
$P^X X$	2.4 (0.00)	1.7 (0.70)	2.4 (-0.01)	5.9 (-3.47)
X	4.3 (0.00)	4.4 (-0.10)	4.3 (0.01)	0.9 (3.46)

Notes: Initial states K_0 , D_0 , and X_0 start 77, 60, and 81 percent below their respective steady state values.

2) Why has the housing wealth-income ratio been increasing?

USA

	(1) baseline	(2) investment $K_0 = \tilde{K}$	(3) land development $D_0 = \tilde{D}$	(4) construction $X_0 = \tilde{X}$
$\frac{P^H H}{NNP}$	1.8 (0.00)	1.7 (0.03)	1.7 (0.08)	0.8 (1.01)
$P^H H$	9.7 (0.00)	6.5 (3.19)	9.3 (0.41)	4.9 (4.80)
NNP	5.9 (0.00)	4.1 (1.87)	5.9 (-0.01)	6.9 (-0.97)
$\frac{P^D D}{NNP}$	1.8 (0.00)	1.1 (0.70)	1.3 (0.49)	1.3 (0.48)
$P^D D$	4.7 (0.00)	2.0 (2.75)	8.1 (-3.41)	4.0 (0.72)
D	2.3 (0.00)	2.3 (-0.02)	1.0 (1.31)	2.3 (-0.03)
$\frac{P^X X}{NNP}$	1.8 (0.00)	1.9 (-0.11)	1.8 (0.00)	0.7 (1.04)
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- Construction boom contributes to rising housing wealth-income ratio through direct effect on X

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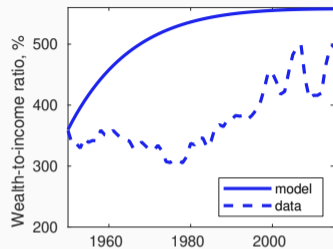
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- Construction boom contributes to rising housing wealth-income ratio through direct effect on X
- Capital accumulation raises residential land prices through housing demand effect and inelastic land supply

Notes: Initial states K_0 , D_0 , and X_0 start 77, 60, and 81 percent below their respective steady state values.

3) Other stylized facts

USA



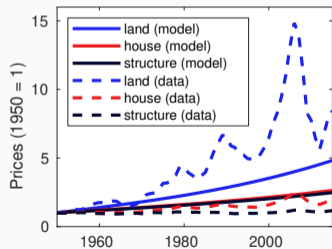
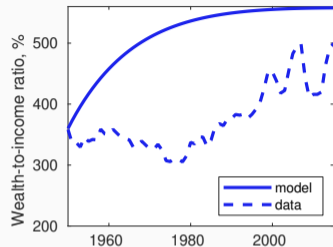
residential investment and savings

discussion

price-rent ratios

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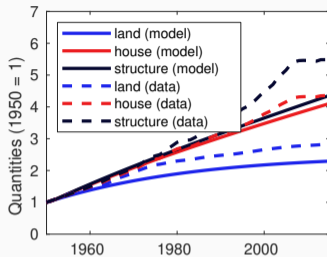
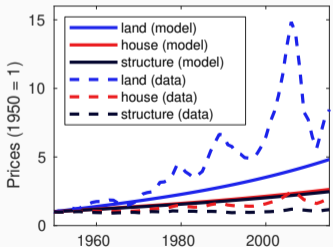
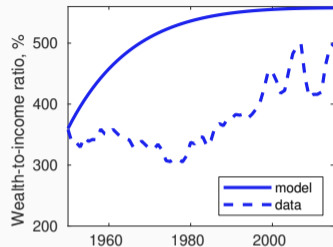


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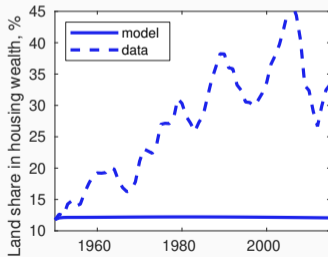
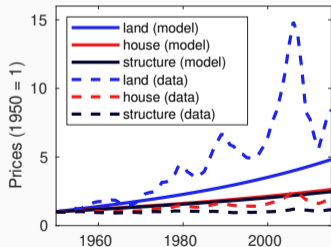
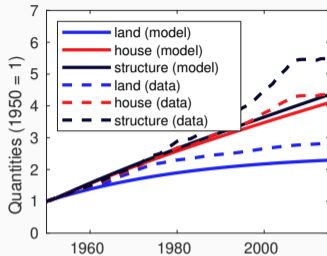
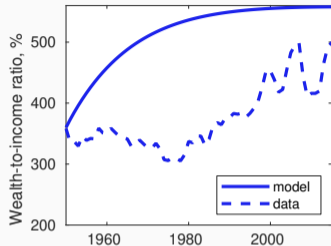


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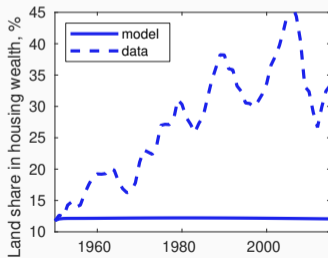
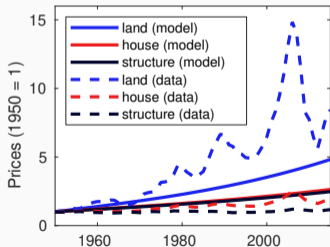
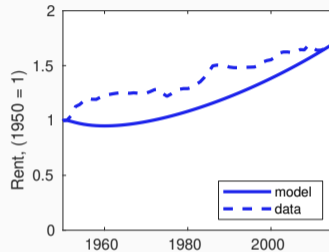
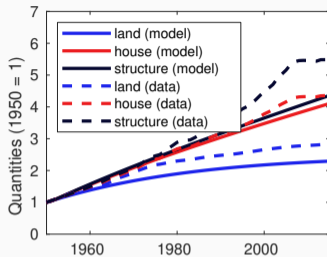
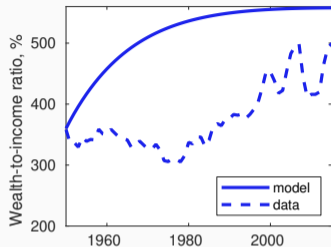
3) Other stylized facts



- residential investment and savings
- discussion
- price-rent ratios

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USA



residential investment and savings

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Summary

- We provide a theory to explain the observed increase in housing wealth relative to income in the US, the UK, France, and Germany since 1950.

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 - Driven by post-war construction boom and capital accumulation
 - Consistent with: declining share of residential investment in GDP and declining saving rates

Appendix

Related literature

- **Early literature:** Ricardo (1817); Nichols (1970)
- **Housing wealth, house and land prices:** Davis & Heathcote (2007); Piketty & Zucman (2014); Rognlie (2015); Stiglitz (2015); Knoll, Schularick, & Steger (2016)
- **Short term:** Davis & Heathcote (2005); Hornstein (2009); Iacoviello & Neri (2010); Favilukis et al. (2017); Kaplan et al. (2019); Greenwald & Guren (2019); ...
- **Long term:** Hansen & Prescott (2002); Borri & Reichlin (2018); Herkenhoff et al. (2018); Miles & Sefton (2018); Bonnet et al. (2019)
 - + Fixed quantity of overall land and endogenous land allocation
 - + Three stocks: capital, residential structure, and fixed land (residential land and non-residential land)
 - + Housing stock: two-dimensional object (reproducible structures and non-reproducible land)

Datasources

- Total wealth: Piketty & Zucman (2014), updated, from `www.wid.world`
- US nominal housing wealth and residential structure wealth: updated online appendix of Davis & Heathcote (2007)
- Nominal housing wealth and residential structure wealth for UK, FR, and DE: from Moritz Schularick, Luis Bauluz, and Filip Novokmet
- Non-housing wealth and land wealth: residual
- NNP: `www.wid.world`
- House, land, and structure price data, US: Davis & Heathcote (2007)
- House, land, and structure price data, FR, UK, DE: Knoll, Schularick, & Steger (2017), online appendix
- Quantity indices: $\text{quantity index} = \frac{\text{value index}}{\text{price index}}$
- Housing rent and interest rate: Jordá et al. (2019), downloaded at <http://www.macrohistory.net/>

Stylized facts: numbers

Fact #	Variable	US	UK	FR	DE
		1950–2015	1950–2012	1960–2012	1962–2012
1	wealth-to-income ratio	1.39	1.4	2.2	1.88
	housing wealth-income ratio	1.42	2.4	3.2	1.93
	non-housing wealth-income ratio	1.38	0.9	1.2	1.79
2	house price	1.9	4.0	6.0	1.6
	residential land price	8.4	9.6	32.2	2.3
	residential structure price	1.2	2.1	1.1	1.4
3	house quantity	4.4	3.3	2.2	4.2
	residential land quantity	2.8	2.1	1.6	3.5
	residential structure quantity	5.5	4.3	6.3	4.3
4	land's share in housing wealth	2.8	1.5	3.8	1.2
5	housing rent	1.7	3.1	2.8	1.6

Firm problem: numeraire

Mass one of identical firms that act under perfect competition and maximize

$$\max_{K, L^Y, N} K^\alpha \left(B^Y L^Y \right)^\beta D^{1-\alpha-\beta} - (r + \delta^K)K - wL^Y - R^N N \quad (6)$$

FOC

$$r = \alpha \frac{Y}{K} - \delta^K, \quad w = \beta \frac{Y}{L^Y}, \quad \text{and} \quad R^N = (1 - \alpha - \beta) \frac{Y}{N}$$

Aggregate capital stock evolves according to

$$\dot{K}_t = I_t^K - \delta^K K_t$$

Firm problem: property management

Mass one of identical firms that act under perfect competition and maximize

$$\begin{aligned} \max_{\{I_t^D, I_t^X\}_{t=0}^{\infty}} & \int_0^{\infty} e^{-\hat{r}_t} CF_t dt \\ \text{s.t.} & \dot{X}_t = I_t^X - \delta^X X_t \\ & \dot{D}_t = I_t^D, \end{aligned} \tag{7}$$

where

$$CF_t \equiv q_t X_t^\gamma D_t^{1-\gamma} - P_t^X I_t^X - P_t^D I_t^D \quad \text{and} \quad \hat{r}_t \equiv \int_0^t r_\tau d\tau$$

Firm problem: real estate development (I/II)

Mass one of identical firms take prices as given and face the production function

$$I^D = f(Z^D, L^D) = \begin{cases} \min \left\{ Z^D, \sqrt{\frac{2}{\xi} L^D} \right\} & \text{if } Z^D \geq 0 \\ \max \left\{ Z^D, -\sqrt{\frac{2}{\xi} L^D} \right\} & \text{if } Z^D < 0 \end{cases}$$

Cost minimization

$$\min_{Z^D, L^D} P^N Z^D + w L^D$$

subject to

$$f(Z^D, L^D) = I^D$$

yields the cost function

$$C(I^D; P^N, w) = P^N I^D + w \underbrace{\frac{\xi}{2} (I^D)^2}_{=\mathcal{L}^D(I^D)} \quad (8)$$

Firm problem: real estate development (II/II)

Profit maximization

$$\max_{I^D} P^D I^D - C(I^D; P^D, P^N, w) \quad (9)$$

FOC

$$I^D = Z^D = \frac{P^D - P^N}{\xi w} \quad \text{and} \quad L^D = \frac{(P^D - P^N)^2}{2\xi w^2}$$

Profits

$$\Pi^D = \frac{(P^D - P^N)^2}{2\xi w} = wL^D$$

back

Firm problem: construction sector

Mass one of identical firms that act under perfect competition and maximize

$$\max_{M, L^X} P^X \underbrace{M^\eta (B^X L^X)^{1-\eta}}_{=I^X} - M - wL^X \quad (10)$$

FOC (interior solution)

$$w = (1 - \eta) \frac{P^X I^X}{L^X} \quad \text{and} \quad 1 = \eta \frac{P^X I^X}{M}$$

back

Equilibrium

A competitive equilibrium of the model are sequences

$\{C_t, S_t, W_t, q_t, w_t, r_t, \Pi_t^D, Y_t, K_t, L_t^Y, N_t, R_t^N, H_t, R_t^H, X_t, D_t, P_t^X, CF_t, I_t^D, L_t^D, P_t^D, P_t^N, P_t^H, I_t^X, M_t, L_t^X\}_{t=0}^{\infty}$ for given initial capital, residential land, and residential structures $\{K_0, D_0, X_0\}$ and a population sequence $\{L_t > 0\}_{t=0}^{\infty}$ such that

- households maximize eq. (1) subject to eq. (2) and a no-Ponzi game condition;
- firms in the construction sector and the numeraire sector, land developers, and property management firms maximize profits as given by eqs. (6), (7), (9) and (10), taking eq. (8) and prices as given;
- rental market clears: $H_t = S_t$;
- labor market clears: $L_t^X + L_t^Y + L_t^D = L_t$;
- land market clears: $D_t + N_t = Z$;
- asset markets clear eq. (4);
- the house price is given by eq. (3);
- there are no arbitrage opportunities between assets, as described by eq. (5);

The market for the numeraire good clears by Walras' law.

Back-of-the-envelope calculation on determinants of rising house prices

- Assume US has been growing along its steady state path over 1950–2015
 - Growth rate of house prices depends on five parameters: g^Y , g^X , ψ^Y , ψ^H , and η
 - Take $\eta = 0.556$ and $\psi^Y = 0.15$ from the main calibration
 - Set g^Y , g^X , and ψ^H such that we match the average annual growth rates of 2.8, 1, and 0.3 percent for NNP, the house price, and the price of residential structures
 - First, we shut down the differences in long-run land intensities by setting elasticity $\psi^H = \psi^Y \Rightarrow$ House price growth reduces to 0.52 instead of previously 1.00 %
 - Second, we additionally shut down the differences in technological progress by setting $g^X = g^Y \Rightarrow$ House price growth rate drops to 0
- \Rightarrow Differences in long-run land intensities capture 52 % of long-term increase in house prices, differences in sector specific technological change 48 %

Steady state growth rates

Variables	Growth rate
$r, \frac{P^H H}{NNP}, \frac{W}{NNP}, \frac{P^D D}{P^H H}, L^D, L^X, L^Y, N, D$	0
$Y, K, M, w, R^N, P^N, P^D, C, NNP, W$	$\frac{\beta}{1-\alpha} g^Y$
X, I^X	$\eta \frac{\beta}{1-\alpha} g^Y + (1-\eta) g^X$
P^X	$(1-\eta) \left(\frac{\beta}{1-\alpha} g^Y - g^X \right)$
S, H	$\gamma \eta \frac{\beta}{1-\alpha} g^Y + \gamma(1-\eta) g^X$
q, P^H	$(1-\gamma \eta) \frac{\beta}{1-\alpha} g^Y - \gamma(1-\eta) g^X$

Stylized facts in steady state

In the economy's steady state equilibrium

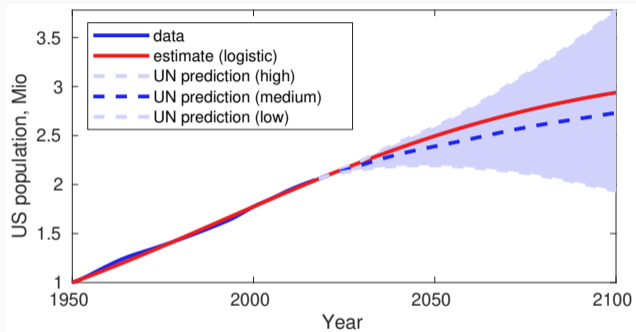
1. the wealth-income ratio, the housing wealth-income ratio, and the non-housing wealth-income ratio are constant,
2. the price of residential land, the house price, and the price of residential structures grow at strictly positive rates, and the price of residential land grows at a higher rate than the house price, which in turn grows at a higher rate than the price of residential structures iff $g^Y > 0$ and $-\frac{\eta}{1-\eta} (1 - \psi^Y) g^Y < g^X < (1 - \psi^Y) g^Y$,
3. quantities of residential structures grow at a strictly positive rate which is larger than the growth rate of residential land iff $g^X > -\frac{\eta}{1-\eta} (1 - \psi^Y) g^Y$,
4. the share of land wealth in housing wealth, given by $\frac{P^D D}{P^H H}$, is constant, and
5. rents grow at a strictly positive rate if and only if $g^X < \frac{1-\psi^Y}{1-\psi^H} \frac{1-\eta+\eta(\psi^H-\psi^Y)}{1-\eta} g^Y$ or if $g^X < (1 - \psi^Y) g^Y$.

Calibrated outside the model (US)

Parameter	Value	Explanation/Target
θ	0.18	housing expenditure share
σ	10/3	intertemporal elasticity of substitution
δ^K	$\ln(1 + 0.056)$	capital depreciation rate
δ^X	$\ln(1 + 0.015)$	structure depreciation rate
β	0.613	labor income share in Y sector
$\{L_t\}_{t=0}^{\infty}$	logistic difference equation	population dynamics

back

Population dynamics



back

Endogenously calibrated parameters (US)

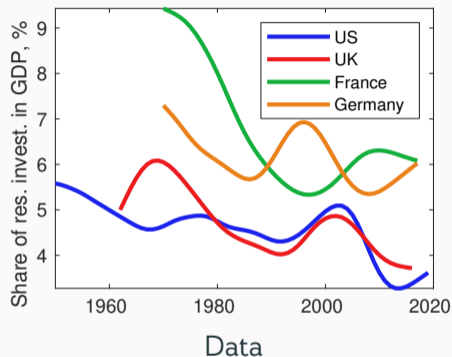
#	Parameter	Explanation	Value
1	ρ	time preference rate	0.040
2	g^Y	labor efficiency growth in numeraire sector	0.020
3	K_0/K^*	initial capital stock	0.227
4	γ	structures' elasticity in H	0.906
5	η	materials' elasticity in I^X	0.556
6	g^X	labor efficiency growth in construction sector	-0.014
7	X_0/X^*	initial stock of residential structures	0.191
8	α	capital elasticity in Y	0.275
9	ξ	intensity of convex adjustment cost in land development	759.05
10	D_0/D^*	initial stock of residential land	0.403

Notes: Initial states, K_0 , D_0 , X_0 , are expressed relative to their respective final steady state values (normalized).

Targeted moments (US)

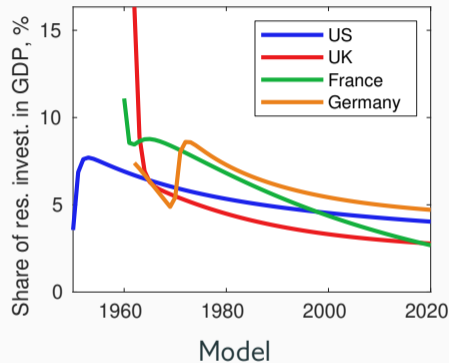
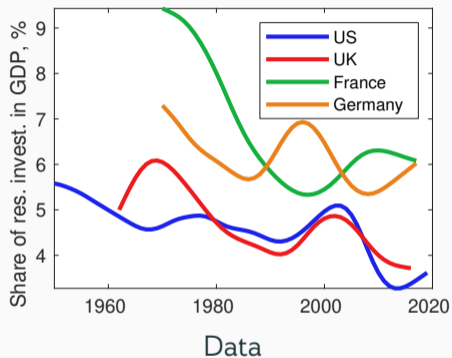
	Moment	Data	Model
1	$\frac{W}{NNP}$, in 1950	3.6	3.6
2	$\frac{NNP_{2015}}{NNP_{1950}}$	6.0	6.0
3	$\frac{P^H H}{NNP}$, in 1950	1.2	1.2
4	$\frac{P^D D}{P^H H} \times 100$, in 1950	11.8	11.8
5	$\frac{L^X}{L} \times 100$, long run	2.5	2.5
6	$\frac{q_{2015}}{q_{1950}}$	1.7	1.7
7	$\frac{I^H}{GDP} \times 100$, in 1950	5.6	5.6
8	$\frac{R^N N}{NNP} \times 100$, in 1950	10.0	10.0
9	Half-life of D , in years	22.6	22.6
10	$\frac{X_{2015}/D_{2015}}{X_{1950}/D_{1950}}$	1.9	1.9

Is the construction boom plausible? Residential investment over time



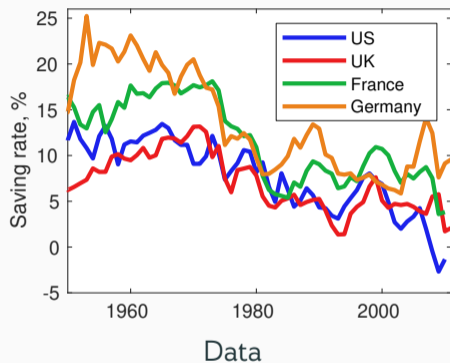
Notes: Empirical data for the USA cover the period 1950–2019, while it is 1960–2016 for the UK, and 1970–2017 for France and Germany. Since residential investment is very volatile in the short run we have HP-filtered the empirical series with a smoothness parameter of 100.

Is the construction boom plausible? Residential investment over time



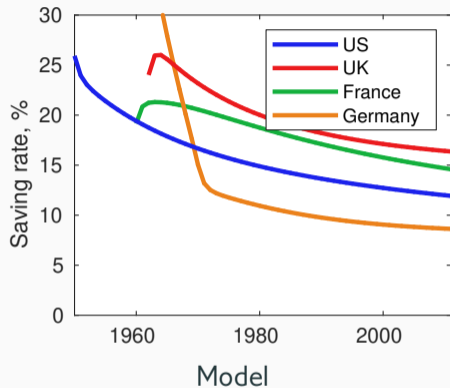
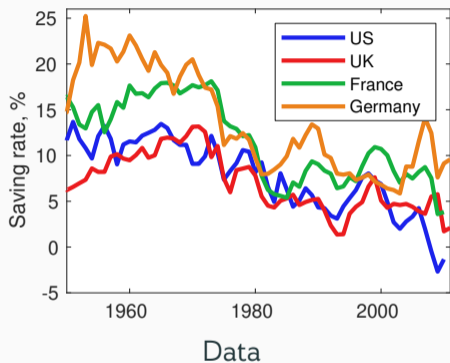
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Is capital accumulation plausible? Saving rates over time



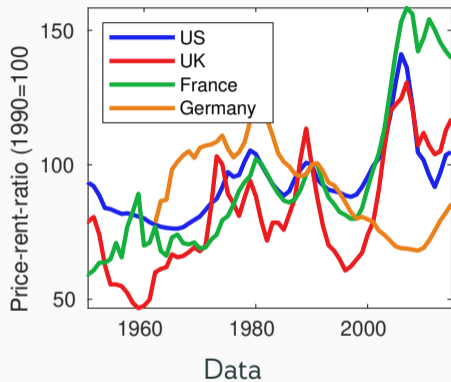
Notes: Data on saving rates is from Piketty & Zucman (2014, online appendix).

Is capital accumulation plausible? Saving rates over time

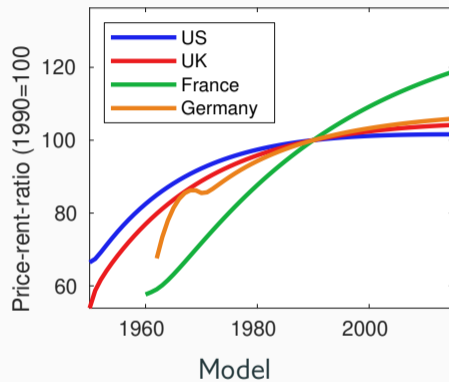
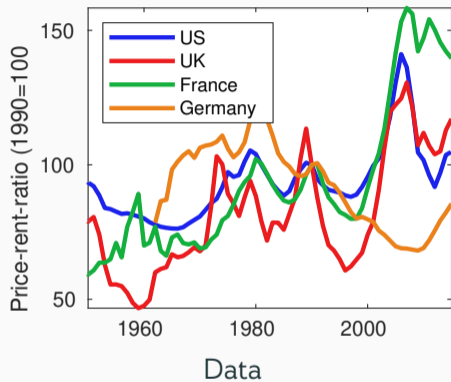


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House price-rent ratios over time



House price-rent ratios over time



[back](#)

Discussion: extensions and alternative explanations

CES technology in housing production

- Generalize: $H(X, D) = \left[\gamma X^{\frac{\chi-1}{\chi}} + (1-\gamma) D^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}$
- Knife-edge restriction:
 $g^X = -\frac{\eta}{1-\eta} \frac{1-\alpha}{\beta} g^Y$
- Set $\chi \rightarrow 0.25$: better fit regarding land and structure

Discussion: extensions and alternative explanations

CES technology in housing production

- Generalize: $H(X, D) = \left[\gamma X^{\frac{\chi-1}{\chi}} + (1-\gamma) D^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}$
- Knife-edge restriction: $g^X = -\frac{\eta}{1-\eta} \frac{1-\alpha}{\beta} g^Y$
- Set $\chi \rightarrow 0.25$: better fit regarding land and structure

Homeownership revolution

- Homeownership rate has increased post 1950
- Might have contributed to increasing house prices
- Our theory: rising housing demand ($\theta \uparrow$), but supply-side necessary

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Declining real interest rate

- Increase house price if rents do not change
- Interest rate is endogenous
- Interest declines monotonously along transition

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