Das House-Kapital:
A Long Term Housing & Macro Model

Volker Grossmann (University of Fribourg, CESifo, IZA, CReAM)

Thomas Steger (Leipzig University, IWH, CESifo)

European Summer Symposium in International Macroeconomics (ESSIM) 2017

1. Introduction – Motivation

- **Long-Term, Time-Series Data**
  - ➡ Housing wealth (Piketty & Zucman, *QJE* 2014) (data)
    - Largest private wealth component
    - As share of private wealth: US 44%, UK 57% (in 2010)
    - Growing over time more than income (housing wealth-income ratio)
  - ➡ House and land prices (Knoll, Schularick & Steger, *AER* 2017) (data)
    - On average in major OECD countries, house prices tripled since 1950
    - Even larger increases of land prices

- **Long-Term Research Questions**
  - ➡ Future evolution of housing wealth-income ratio, house prices and land prices?
  - ➡ How does secular increase in housing demand affect distribution of wealth?
  - ➡ Dynamic consequences of rent control for inequality and welfare?
  - ➡ Dynamic consequences of housing property taxation?
  - ➡ Macroeconomic effects of zoning regulations and building restrictions?

1. Introduction – Model Features

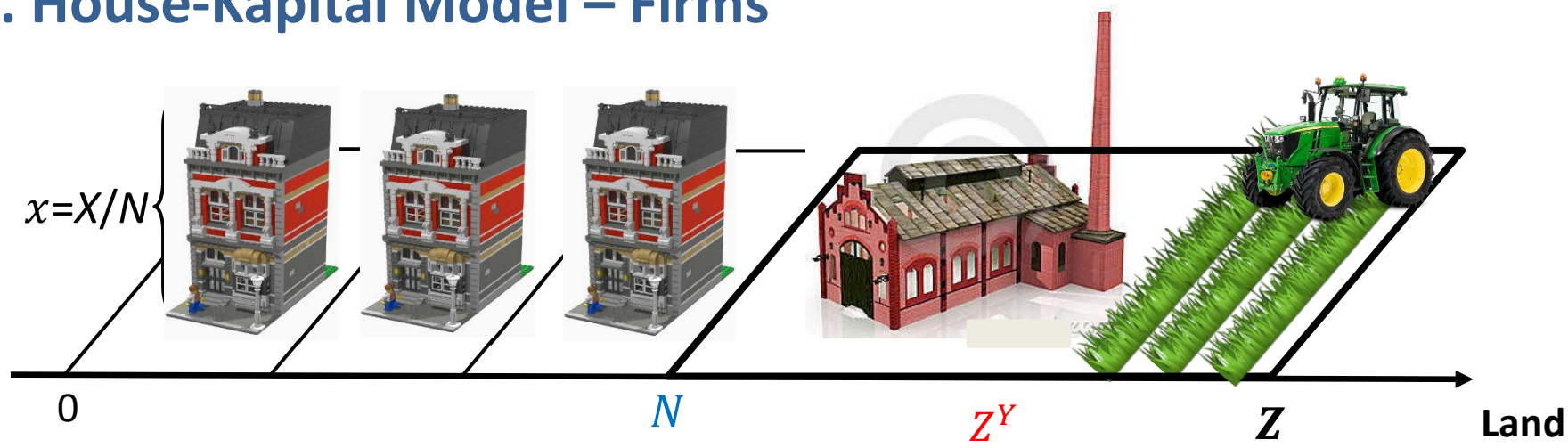
- **Two-sector Ramsey Growth Model**
  - ❖ Non-residential sector
  - ❖ Housing sector

- **Three Premises**
  - ➡ **Premise 1: Fixed Land Endowment (Stock)**
    - ❖ Overall amount of land that can be used economically is fixed in the long run
    - ❖ Mark Twain: “Buy land, they're not making it anymore.”
  - ➡ **Premise 2: Land Rivalry**
    - ❖ Land used in housing production is permanently withdrawn from alternative use (in non-residential sector)
  - ➡ **Premise 3: Land in Housing Production**
    a) Setting up new housing projects (real estate development) requires land
    b) Investment in residential structures does not require land (e.g. building higher houses or fix broken windows)

1. Introduction – Related Literature

- Knoll, Schularick & Steger (2017): *long term evolution of real house prices and land prices in 14 countries*
- Piketty & Zucman (2014, 2015): *data on wealth to income (house-capital and non-residential wealth)*
- Ronglie (2015): *housing sector drives rise in capital income share*
- Stiglitz (2015): *land prices important for rising wealth-to-income ratios and rising inequality of wealth and income*
- Davis & Heathcote (2005), Hornstein (2009), Iacoviello & Neri (2010), Favilukis, Ludvigson & Van Nieuwerburgh (2017), Borri & Reichlin (2016): *canonical housing-macro model*
  - ➡ Suitable for business cycle phenomena
  - ➡ Less suited to think long term
    - ❖ Limited land scarcity (land is a fixed flow used for residential investment)
    - ❖ No land rivalry
    - ❖ Doesn't fit SNA concepts: missing wealth component (non-residential land)

2. House-Kapital Model – Firms



- **Housing Sector**
  - ➡ Firm type 1: Real estate development

$$\dot{N}_t = \underbrace{\tilde{I}_t^N}_{\text{control}}, \quad Cost = \underbrace{P_t^Z \tilde{I}_t^N}_{\text{land cost}} + \underbrace{\frac{\xi}{2}\left(\tilde{I}_t^N\right)^2}_{\text{transformation cost}}$$

  - ➡ Firm type 2: Construction

$$\dot{X}_t = I_t^X - \delta^X X_t, \quad I_t^X = B_t^X \left(M_t\right)^{\eta} \left(L_t^X\right)^{1-\eta}$$

  - ➡ Firm type 3: Housing services (decreasing returns)

$$h_t = (x_t)^{\gamma}$$

- **Numeraire Sector**
  - ➡ Technology

$$Y_t = B_t^Y \left(K_t\right)^{\alpha} \left(L_t^Y\right)^{\beta} \left(Z_t^Y\right)^{1-\alpha-\beta}$$

- **Market Clearing**
  - ➡ Numeraire Sector

$$Y_t = C_t + M_t + \underbrace{I_t^K}_{\dot{K}_t + \delta^K K_t} + \underbrace{I_t^N}_{\frac{\xi}{2}\left(\tilde{I}_t^N\right)^2}$$

  - ➡ Housing Sector

$$N_t h_t = S_t$$

2. House-Kapital Model – Households

- **Household Optimization**

$$\max_{\{C_t, S_t\}_{t=0}^{\infty}} \int_0^{\infty} (\log C_t + \theta \log S_t) e^{-\rho t} dt$$

$$\text{s.t.} \quad \dot{W}_t = (1-\tau_r) r_t W_t + (1-\tau_w) w_t L_t - C_t - p_t S_t + T_t$$

$$W(0) = \text{given} \qquad \lim_{t\to\infty} W_t \exp\left(-\int_0^t (1-\tau_r) r_s ds\right) \geq 0$$

- **Private Wealth**

$$W_t \equiv \overbrace{\underbrace{q_t^N N_t + q_t^X X_t}_{A_t} + K_t}^{P_t^H N_t} + \underbrace{P_t^Z Z_t^Y}_{\text{non-residential land}} = \underbrace{P_t^H N_t}_{\text{housing wealth}} + \underbrace{K_t + P_t^Z Z_t^Y}_{\text{non-residential wealth}}$$

A_t: total financial asset holding

2. House-Kapital Model – Dynamic System

- **7 dynamic equations…**

$$\dot{X} = B^X M^{\eta} \left(L^X\right)^{1-\eta} - \delta^X X$$

$$\dot{N} = \frac{q^N - P^Z}{\xi}$$

$$\dot{W} = rW + wL - C - pS$$

$$\dot{C} = C\left[(1-\tau_r)r - \rho\right]$$

$$\dot{q}^N = rq^N - \pi$$

$$\dot{P}^Z = rP^Z - R^Z$$

$$\dot{q}^X = \left(r + \delta^X\right)q^X - R^X$$

- **plus a set of static equations…**

$$Z^Y + N = Z$$

$$L^X + L^Y = L$$

$$W = K + q^N N + q^X X + P^Z Z^Y$$

$$x = \frac{X}{N}$$

$$S = \underbrace{N}_{\substack{\text{\# housing} \\ \text{projects}}} \quad \underbrace{x^{\gamma}}_{\substack{\text{housing} \\ \text{services} \\ \text{per firm}}}$$

$$w = (1-\eta)\eta^{\frac{\eta}{1-\eta}} \left(B^X q^X\right)^{\frac{1}{1-\eta}}$$

$$R^Z = B^Y (1-\alpha-\beta)\left(\frac{\alpha}{\beta}\frac{w}{r+\delta^K}\right)^{\alpha}\left(\frac{L^Y}{Z^Y}\right)^{\alpha+\beta}$$

$$R^X = p\gamma x^{\gamma-1}$$

$$\pi = (1-\gamma)\, px^{\gamma}$$

$$\theta C = pS$$

$$K = \frac{\alpha}{\beta}\frac{w}{r+\delta^K}L^Y$$

$$\frac{L^X}{M} = \left(\frac{1}{q^X \eta B^X}\right)^{\frac{1}{1-\eta}}$$

$$\left(\frac{r+\delta^K}{\alpha}\right)^{\alpha}\left(\frac{w}{\beta}\right)^{1-\alpha} = B^Y\left(\frac{Z^Y}{L^Y}\right)^{1-\alpha-\beta}$$

➡ **Analytical steady states** ➡ **Transitional dynamics**

3. Thinking Long Term – Steady States

- **Land price & house price** $P^{Z*} = a\left(\underset{-}{r^*}\right)(B^Y)^{\frac{1}{1-\alpha}} D^{\frac{\beta}{1-\alpha}}$ $\quad P^{H*} = b\left(\underset{-}{r^*}\right)(B^Y)^{\frac{1}{1-\alpha}} D^{\frac{\beta}{1-\alpha}}$

  ➡ P^{Z*} and P^{H*} depend positively on B^Y and $D := L/Z$ (not on B^X)

  ➡ Ricardo's (1817) principle of scarcity.

- **Housing wealth-to-income ratio** $\frac{P^{H*}H^*}{NDP^*}$

  ➡ Does not depend on B^X, B^Y or D

  ➡ Same for other ratios, such as

  - non-residential wealth-to-income ratio $\frac{K^*+P^{Z*}Z^{Y*}}{NDP^*}$
  - House price-to-rent ratio $\frac{P^{H*}}{p^*h^*}$.

- **Number of houses** per unit of land, N^*/Z

  ➡ Does not depend on B^X, B^Y or D

  ➡ Increases in housing demand do not affect long land allocation

- **Residential structures** per unit of land, X^*/Z, are increasing in B^X, B^Y and D

3. Thinking Long Term – Calibration

➡ Initial conditions

- ❖ Initial housing stock (N_0, X_0) set to match empirical $\frac{P_0^H N_0}{NDP_0}$ in 1955
- ❖ Initial capital (K_0) set to match empirical $\frac{K_0 + P_0^Z Z_0^Y}{NDP_0}$ in 1955

➡ Growth in TFP (B_t^X, B_t^Y)

- ❖ Matches GDP growth between 1955 and 2010
- ❖ Given observed growth in population size (L_t)

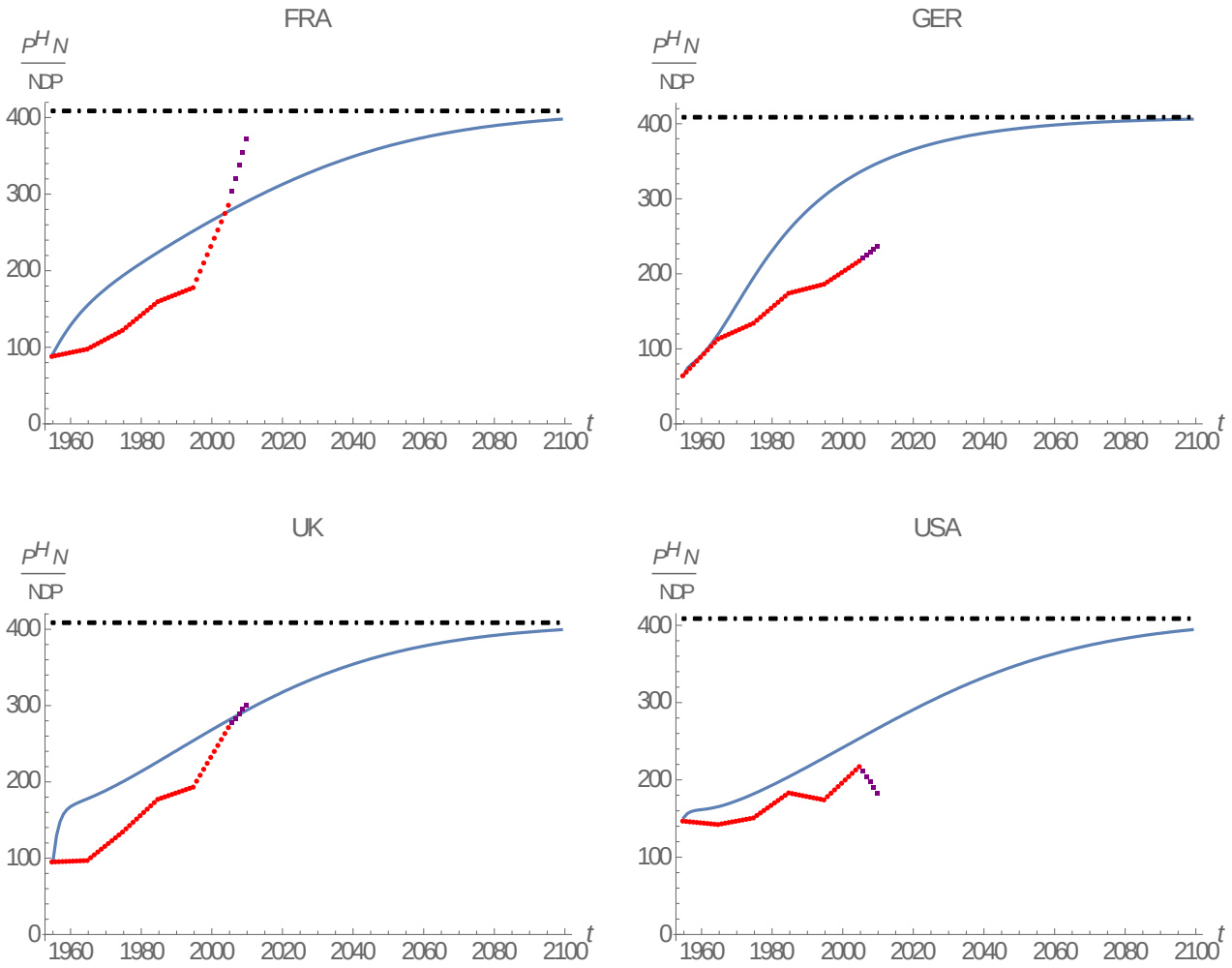
➡ Directly observable

- ❖ Depreciation rates δ^K, δ^X
- ❖ Capital income tax rate τ_r

➡ Other observables set to match

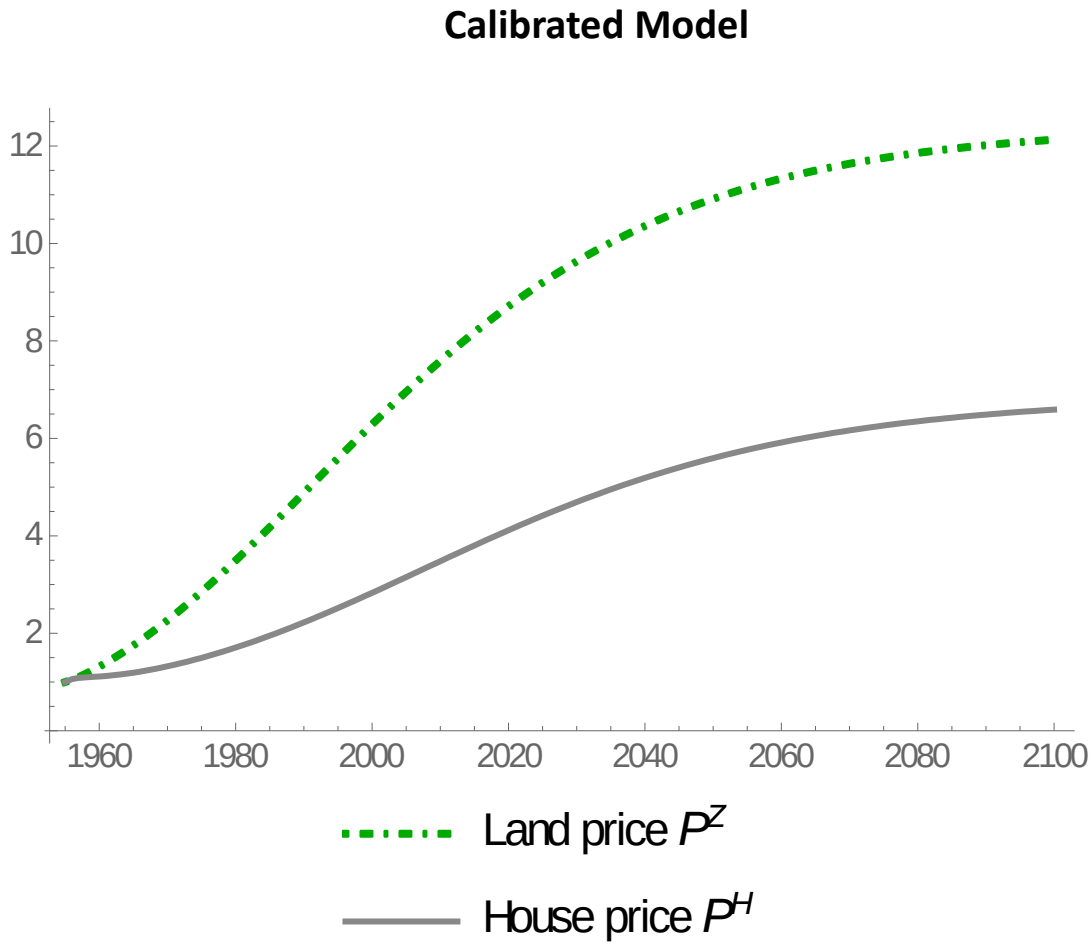
- ❖ Expenditure share for housing services
- ❖ Labor income share
- ❖ Value-added of residential construction
- ❖ Sectorial employment shares
- ❖ Sectorial investment rates

3. Thinking Long Term – Housing Wealth-to-NDP Ratio



Data Source: Piketty & Zucman (2014).

3. Thinking Long Term – House Price & Land Price



➡ Land price (1955 – 2010): Model: factor 7.5; Data: factor 5.2 (France, UK, USA)

➡ House price (1955 – 2010): Model: factor 3.4; Data: factor 3.2 (France, UK, USA)

4. Dynamics of Wealth Inequality – Households

Grossmann, Larin, Loefflad & Steger (2017)

$$\max_{\{c_j, s_j\}_{t=0}^{\infty}} \int_0^{\infty} \frac{\left[\left(c_j \right)^{1-\theta} \left(s_j - \phi \bar{s} \right)^{\theta} \right]^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt$$

$$\text{s.t.} \quad \dot{W}_j = (1-\tau_r) r W_j + (1-\tau_w) w L_j - c_j - p s_j + T$$

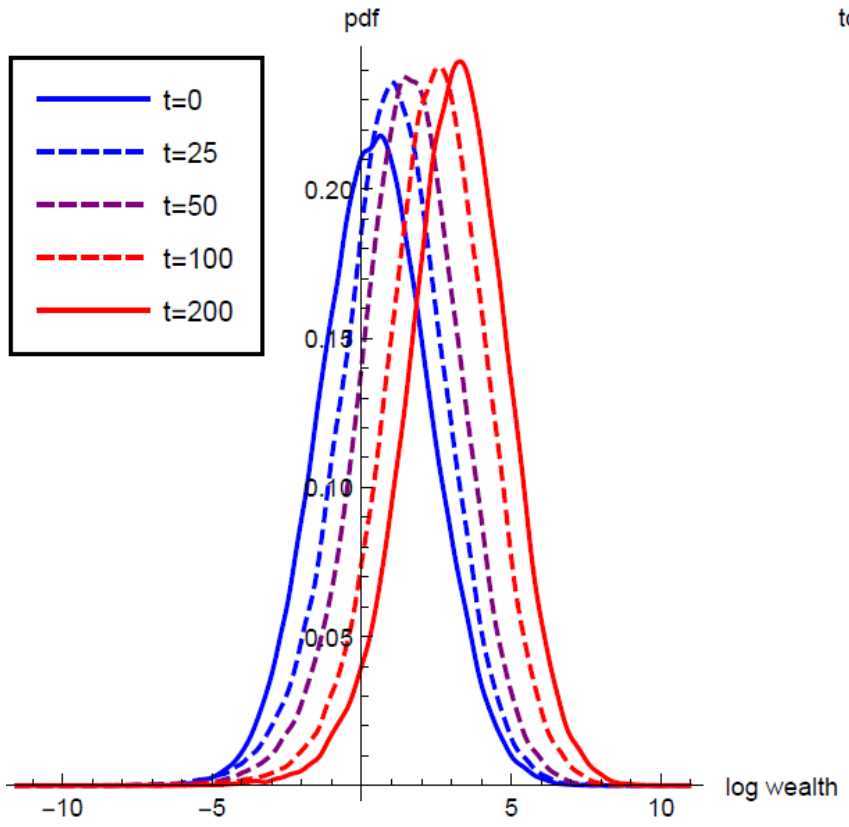
$$W_j := \underbrace{K_j}_{\text{capital}} + \underbrace{P^Z Z_j^Y}_{\text{non-residential land}} + \underbrace{P^H N_j}_{\text{houses}}$$

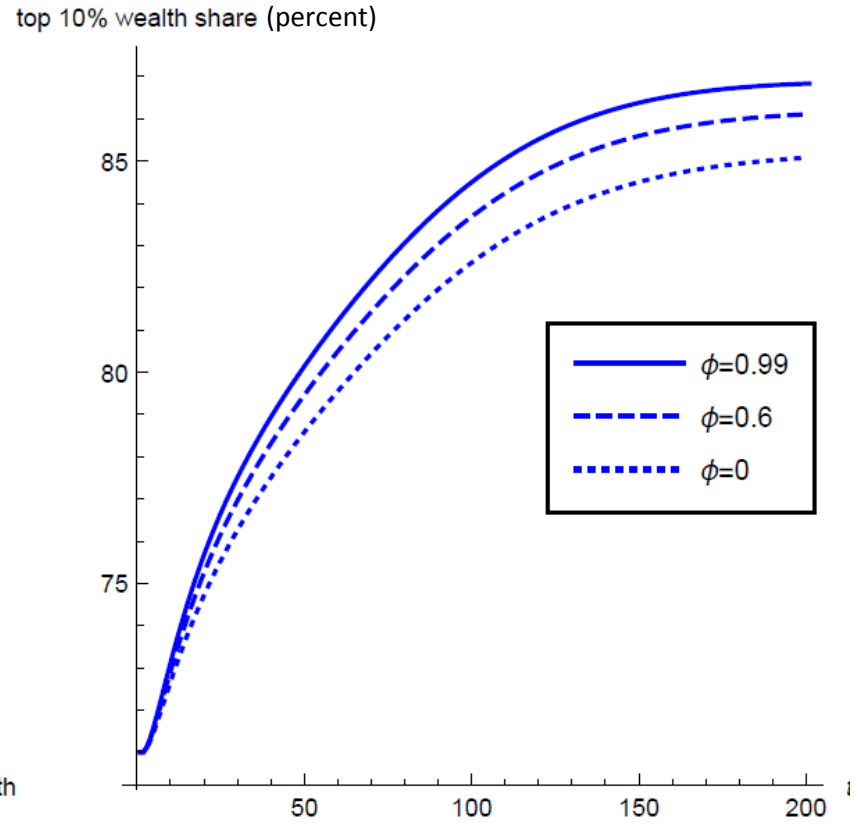
$$W_j(0) = \text{given}, \quad \text{NPGC holds}$$

- Caselli-Ventura (AER 2000) structure with J groups of HH.
- Heterogeneity in initial wealth holding (percentiles, US): $W_j(0)$ with $j \in \{1, \ldots, J\}$.
- Representative consumer, despite non-homothetic preferences.
- If $\phi > 0$, poorer HH has higher housing expenditure share $e_j := \frac{p s_j}{c_j + p s_j} = \frac{\theta}{1 - (1-\theta) \frac{\phi}{s_j / \bar{s}}}$
- Two-stage numerical solution procedure.

4. Dynamics of Wealth Inequality – Results (1)

- **How does economic growth affect the distribution of wealth?**





- **Experiment / calibration strategy**
  - ➡ Exogenous TFP growth and endogenous capital accumulation (population constant).
  - ➡ State variables such that wealth-to-income ratios (2010) are matched.
  - ➡ Portfolio structure of HH equals aggregate portfolio structure.
  - ➡ Initial wealth distribution (percentiles) from *World Wealth and Income Database*.

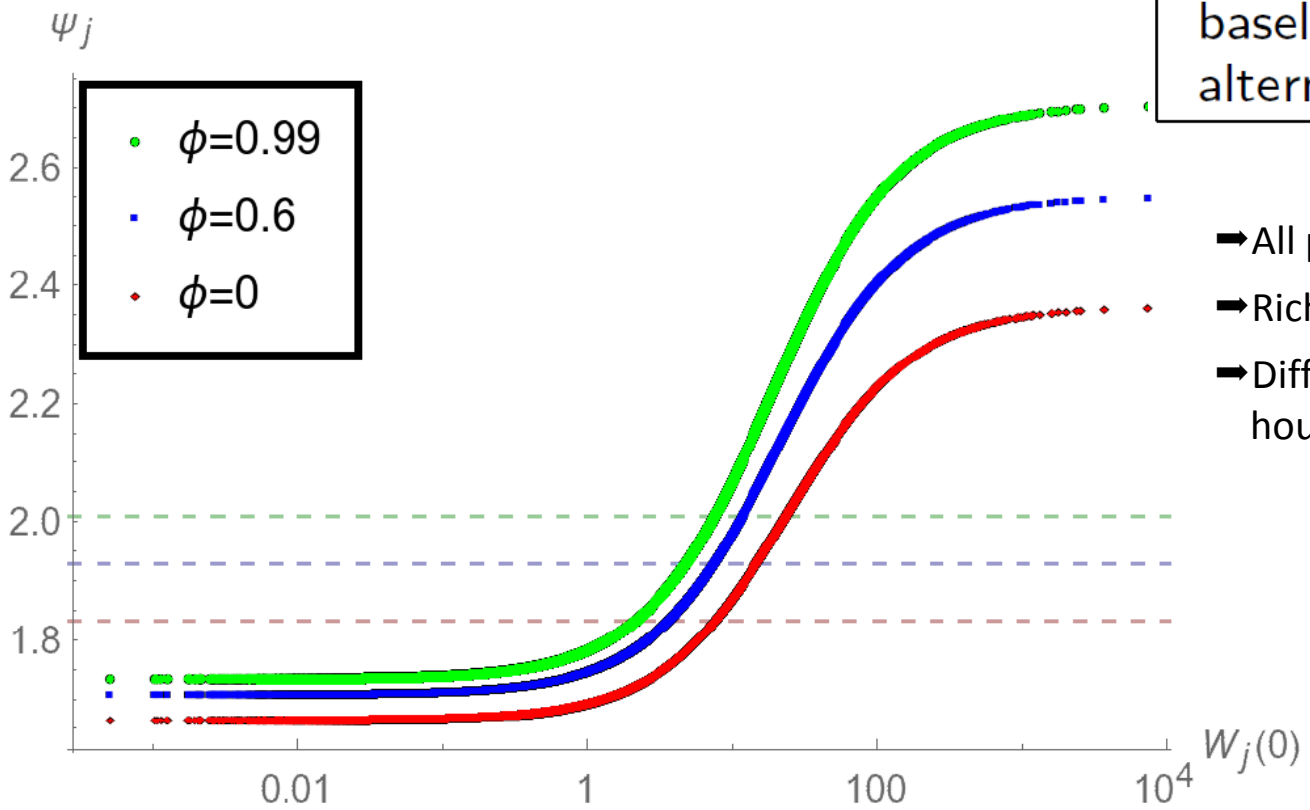
- ➡ Amplification of increase in wealth inequality if expenditure shares differ.
- ➡ Rent increase affects the poor more, suppresses their ability to accumulate wealth.

4. Dynamics of Wealth Inequality – Welfare

- **How does economic growth affect the HH-specific welfare?**

EV measure: ψ_j is factor of the ideal consumption index each period in baseline scenario (0) such that HH *j* is indifferent to alternative scenario (1).

scenario	TFP
baseline (0)	constant
alternative (1)	grows



➡All prefer the growth scenario

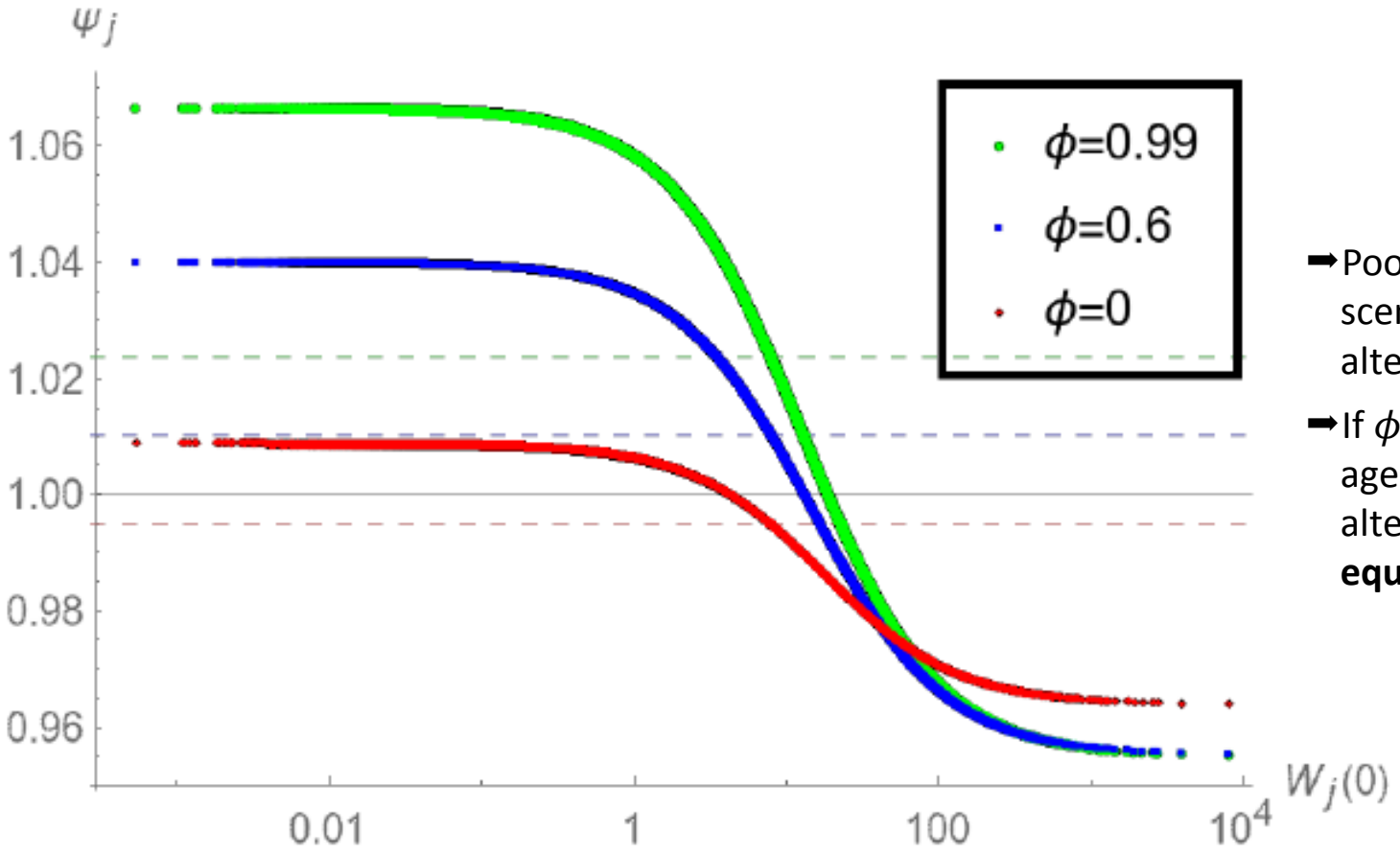
➡Rich prefer it more than the poor

➡Difference more pronounced if housing expenditure shares differ!

4. Dynamics of Wealth Inequality – Rent Control

- **Effect of rent control in growing economy on HH-specific welfare:** $p \leq p^{max}$

scenario	TFP	rent regulation?
baseline (0)	grows	no
alternative (1)	grows	yes



➡ Poor prefer alternative scenario, rich dislike alternative scenario!

➡ If $\phi > 0$, representative agent may prefer alternative scenario: **No equity-efficiency trade-off**

5. Summary & Conclusions

- **New Housing & Macro Model: Think Long Term**
  - ➡ Real estate development (extensive margin) withdraws land from alternative uses
  - ➡ Investment in structures (intensive margin) does not require land
  - ➡ Consistent with evidence that 80 percent of house price increase since WWII is associated with rising land prices (Knoll et al., 2017)
  - ➡ Rising wealth-to-income ratio over time (housing vs. non-residential wealth)
    - In long run (for baseline calibration): $\mathbf{410 + 320 = 730}$ (percent)
    - Sensitive w.r.t. long run interest rate
    - But independent of TFP and population size

- **Wealth inequality and welfare**
  - ➡ Secular increase in housing demand associated with rising wealth inequality
  - ➡ Amplified by endogenous heterogeneity in housing expenditure shares
  - ➡ Poor prefer rent ceiling, while rich dislike rent ceiling
  - ➡ Rent control possibly efficiency-enhancing

Supplement – Wealth-to-NDP ratios: Long Run Implications

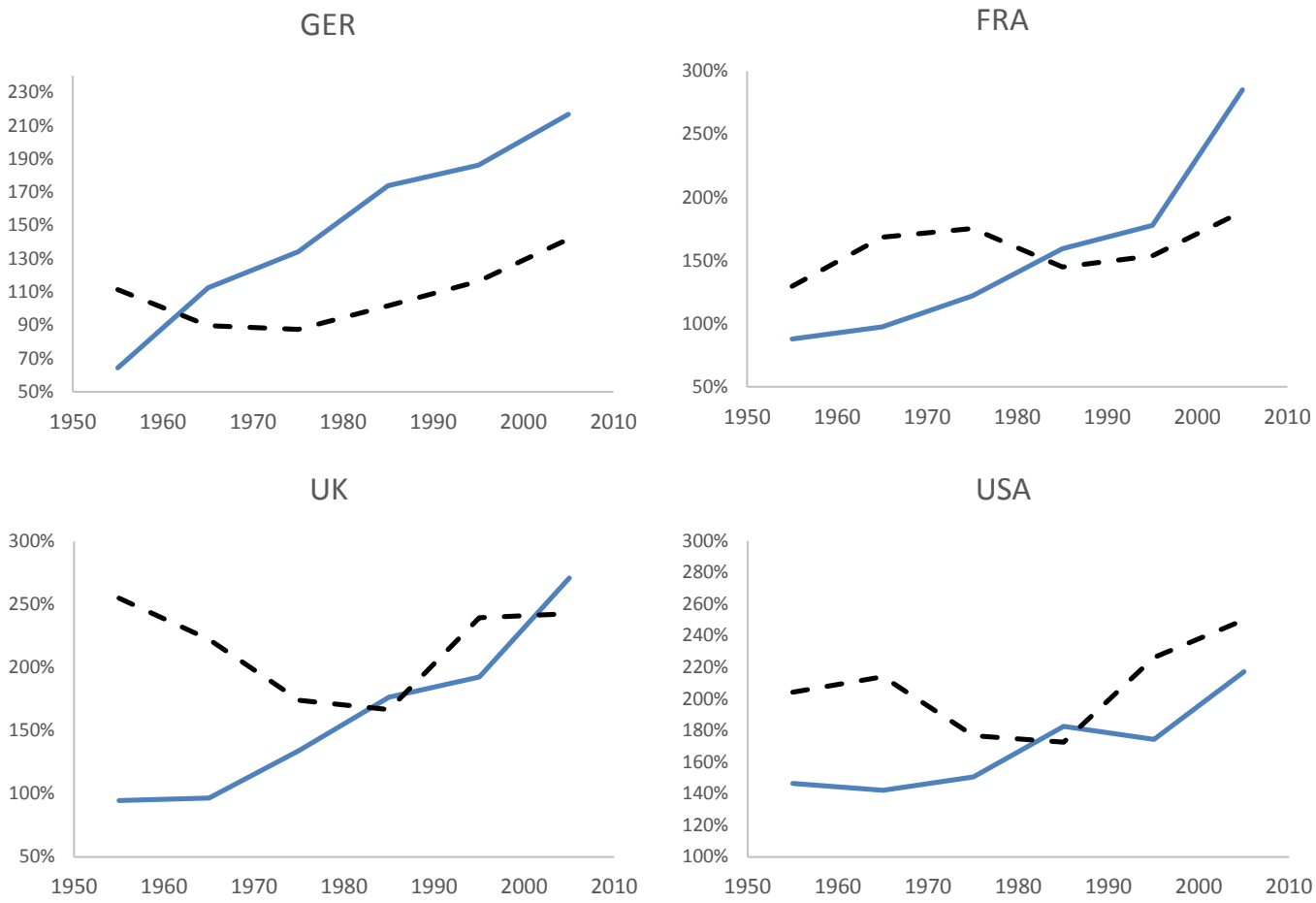
410 + 320 = 730

ρ	τ_r	$\mathfrak{H}^{NDP*}$	$\mathfrak{K}^{NDP*}$	$\mathfrak{Z}^{NDP*}$	$\bar{\mathfrak{Z}}^{NDP*}$	$\mathfrak{N}^{NDP*}$	$\bar{\mathfrak{N}}^{NDP*}$	$\mathfrak{W}^{NDP*}$	$\bar{\mathfrak{W}}^{NDP*}$
0.02	0.15	498	320	136	42	456	362	954	860
0.03	0.15	374	274	88	27	361	301	735	675
0.02	0.2	478	313	127	40	440	353	918	830
0.03	0.2	357	267	82	25	349	292	706	650
0.02	0.25	457	306	119	37	425	343	882	800
0.03	0.25	340	259	76	24	335	283	676	623

Table 1. Long run implications for wealth-to-NDP ratios.

Notes: All values are expressed in percent. Results are based on the following set of parameters: $\alpha = 0.28$, $\beta = 0.69$, $\gamma = 0.9$, $\eta = 0.38$, $\theta = 0.22$, $\delta^X = 0.015$, $\delta^K = 0.07$. Recall $\mathfrak{H}^{NDP*} = \frac{P^{H*}N^*}{NDP^*}$, $\mathfrak{K}^{NDP*} = \frac{K^*}{NDP^*}$, $\mathfrak{Z}^{NDP*} = \frac{P^{Z*}Z^{Y*}}{NDP^*}$, $\mathfrak{N}^{NDP*} = \mathfrak{K}^{NDP*} + \mathfrak{Z}^{NDP*}$, $\mathfrak{W}^{NDP*} = \frac{W^*}{NDP^*} = \mathfrak{H}^{NDP*} + \mathfrak{N}^{NDP*}$, $\bar{\mathfrak{Z}}^{NDP*} = \kappa\mathfrak{Z}^{NDP*}$, $\bar{\mathfrak{N}}^{NDP*} = \mathfrak{K}^{NDP*} + \bar{\mathfrak{Z}}^{NDP*}$, and $\bar{\mathfrak{W}}^{NDP*} \equiv \mathfrak{H}^{NDP*} + \bar{\mathfrak{N}}^{NDP*}$ with land price correction factor $\kappa = 0.31$, as explained in Online-Appendix A.5.

Supplement – Private Wealth



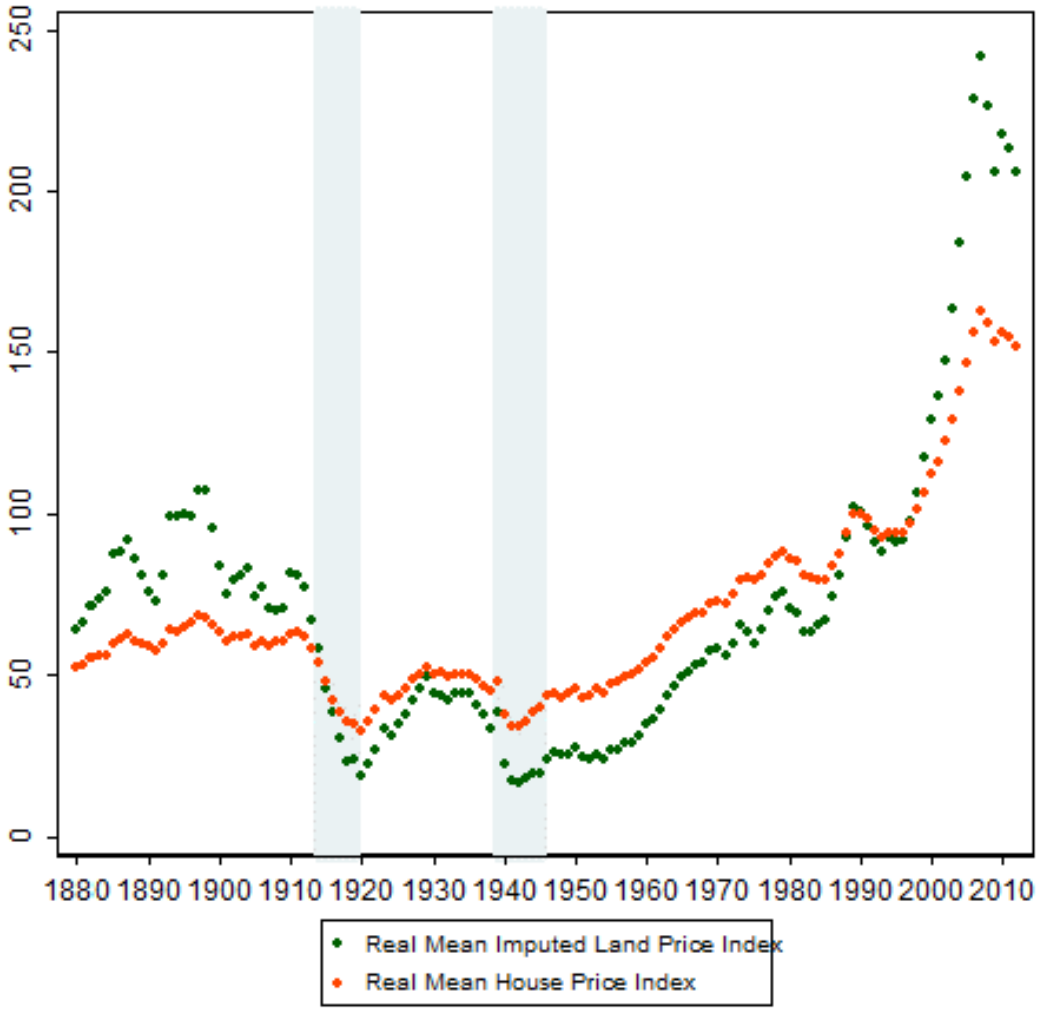
Source: Piketty & Zucman (2014). *Note:* Time series smoothed over decades.

Non-residential wealth: private wealth ./. housing wealth ./. net foreign assets.

Housing wealth: gross housing assets (not reduced by mortgages and other financial liabilities).

back

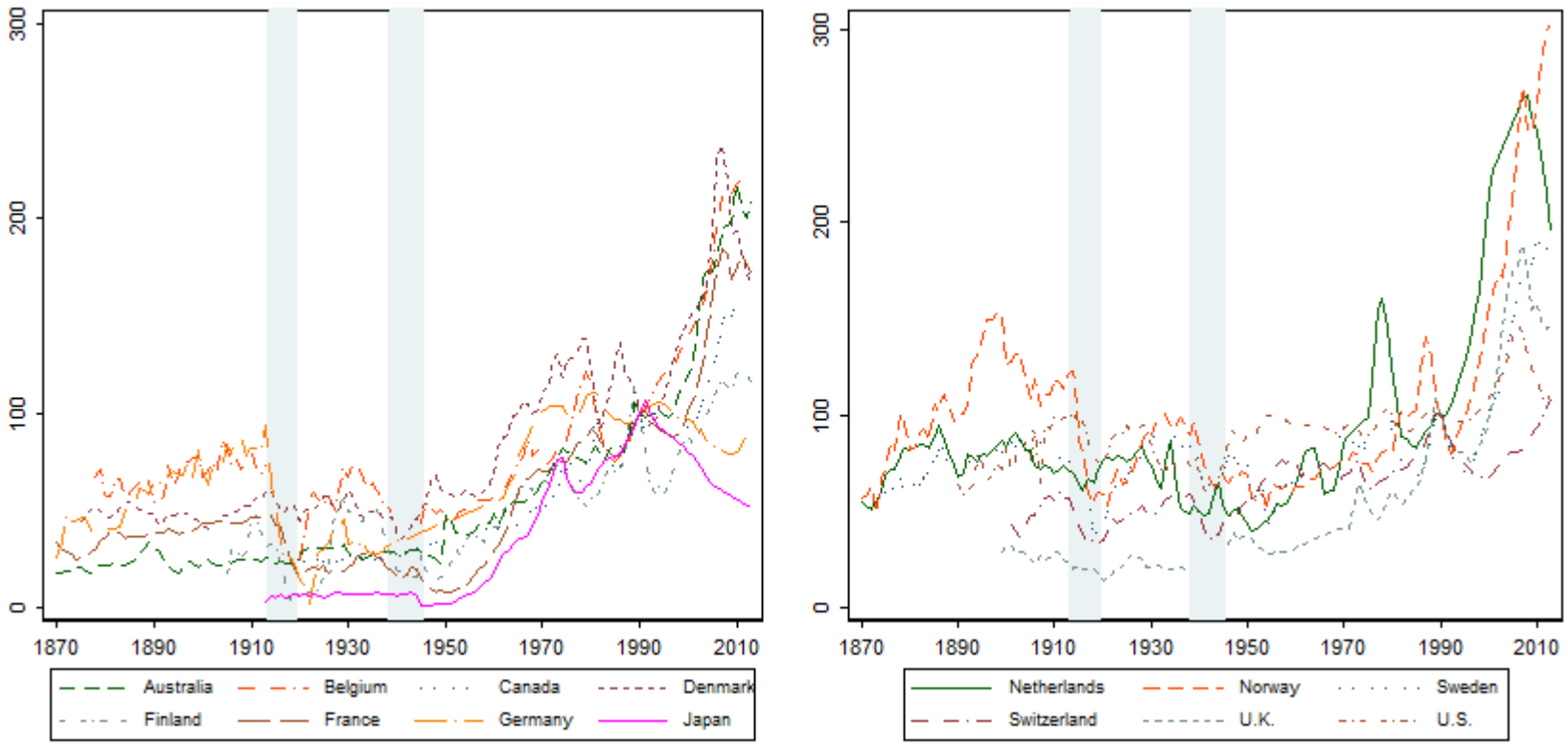
Supplement – House Prices & Land Prices



Source: Knoll et al. (2017)

back

Supplement – House Prices (country by country)



Source: Knoll et al. (2017)

back

Supplement: Canonical Model

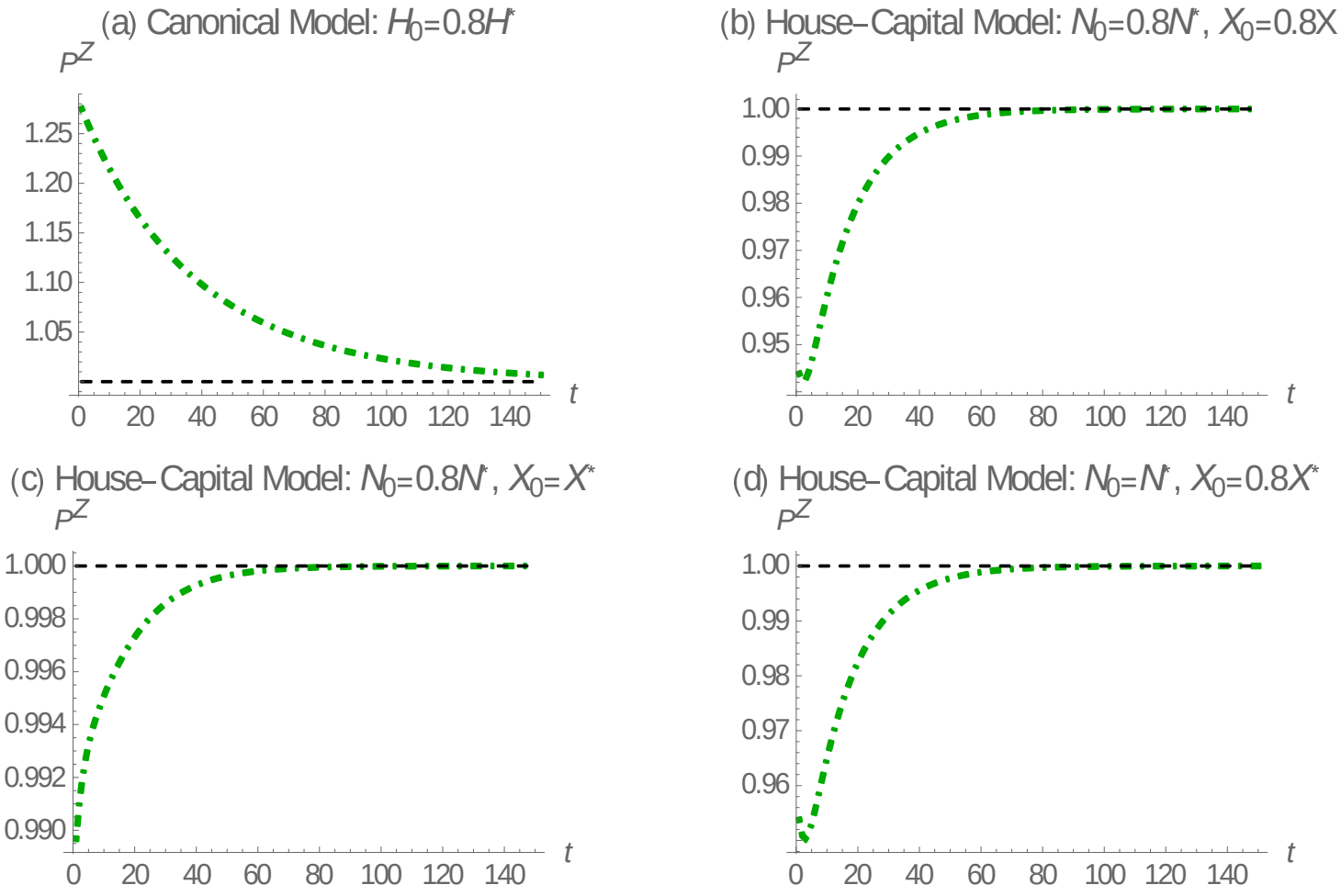
- **Merits & Features**
  - ➡ Suitable for business cycle phenomena
  - ➡ Limited land scarcity / No land rivalry
  - ➡ Long-run inconsistency: Replacement investment require land: $\int_0^\infty \bar{Z} dt = \infty$!

Numeraire good	$Y_t = B_t^Y (K_t^Y)^\alpha (L_t^Y)^{1-\alpha}$	**non-residential land missing**
Construction	$X_t = B_t^X (K_t^X)^\gamma (L_t^X)^{1-\gamma}$	intermediate input
Housing services	$\underbrace{B_t^H X_t^\beta \bar{Z}^{1-\beta}}_{\text{gross investment}} = \underbrace{\dot{H}_t}_{\text{net investment}} + \underbrace{\delta^H H_t}_{\text{replacement investment}}$	**$\bar{Z}$ is (time-invariant) flow variable**
Housing market clearing	$S_t = p_t H_t$	housing consumption
Capital market clearing	$K_t^X + K_t^Y = K_t$	
Labor market clearing	$L_t^X + L_t^Y = L_t$	

Davis and Heathcote (2005), Hornstein (2009), Iacoviello and Neri (2010), Favilukis et al. (2015), and Borri and Reichlin (2016)

Supplement – Comparison of Models

Land Price in Response to Housing Stock Destruction



- ➡ Two models differ on isolated impact of housing stock destruction on P^Z dynamics.
- ➡ The reason is that the land price determination is different!

Supplement: General Equilibrium

A **general equilibrium** consists of sequences of quantities, prices, and operating profits of housing services producers

for initial conditions $(K_0, N_0, X_0) > 0$ and $\left\{B_t^Y, B_t^X, B_t^h, L_t\right\}_{t=0}^{\infty}$ such that

1. representative household maximizes lifetime utility;
2. representative firm in X sector and Y sector, representative real estate developer, and housing services producer maximize PDV of infinite profit stream, taking prices as given;
3. land market, labor market, bond market and market for structures clear: $Z_t^Y + N_t = Z$, $L_t^X + L_t^Y = L_t$, $K_t^Y = K_t$, $X_t = N_t x_t$;
4. land price is the PDV of rental rates per unit of land in Y sector;
5. financial asset market clears: $K_t + q_t^N N_t + q_t^X X_t + P_t^Z Z_t^Y = W_t$;
6. market for housing services clears: $S_t = N_t h_t$;
7. market for Y good clears: $Y_t = C_t + I_t^K + I_t^N + M_t$ (redundant due to Walras' law)

Supplement – Notation

Symbol	Meaning
Y	final output of numeraire good
$K^Y = K$	physical capital
L^X, L^Y	labor in X and Y production
Z^Y	land in Y sector
X, $x = X/N$	residential buildings (aggregate and per house)
M	materials (in terms of numeraire)
δ^K, δ^X	depreciation rates (physical capital and buildings)
N	number of housing projects
$q^{N,}$, q^X	shadow price of N and X
R^Z, P^Z	rental rate and price of land
h	housing services (per housing project)
$S = Nh$	total housing services‘ demand and supply
τ_r , τ_w , T	policy parameters