Credit Frictions and Household Debt in the U.S. Business Cycle: A Bayesian Approach

Alessandro Notarpietro
Università Bocconi

Bank of Finland
Helsinki, 15–16 May, 2008

Objective

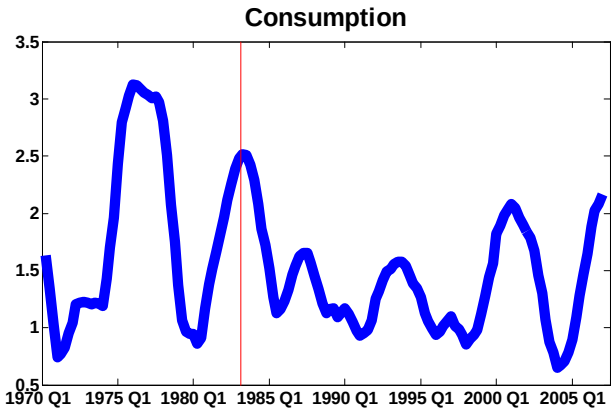
- Quantify importance of **household credit frictions (collateral channel)** and **financial** markets **liberalization** in modifying transmission of **monetary** shocks
- Focus on **reduced volatility** of consumption, residential investment and household debt in US business cycle
- Analyze role of **credit-constrained** households in the business cycle

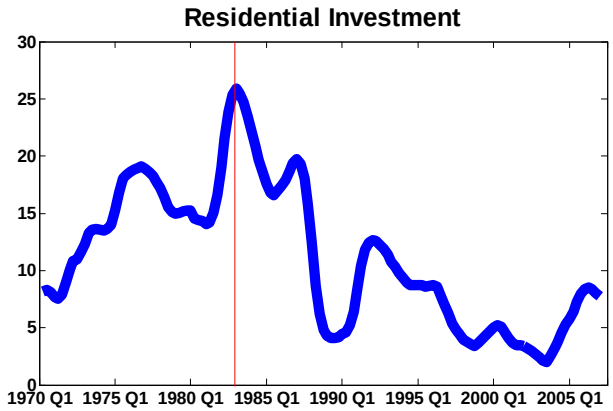
Plan of the talk

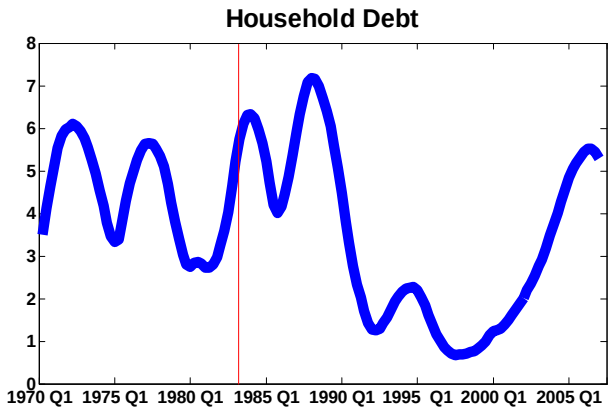
- Motivation
- Model
- Estimation
- Main results
- Conclusions

Facts (I)

Consumption, Residential Investment and **Household Debt**: reduced cyclical volatility (past 25 years)







Facts (II)

Credit Market Liberalization (past 25 years):

- **Reduced** equity requirement
- Significant deregulation in Savings & Loans Associations:

  1980: Monetary Control Act

  1982: Garn-St.Germain Act (remove interest rate ceilings)

- example: **Car Loans** (from Campbell and Hercowitz (2006))

	Down Payment	Repayment Period
1920s	33%	12-18 months
1972-1982	30%	40 months
1995-2003	8%	54 months

Motivation

- Standard DSGE models for **monetary** policy analysis **neglect** role of asset prices on **households'** balance sheets
- Concern in **policy** circles:

"...*over the years, institutional changes in U.S.* **housing** *and* **mortgage** *markets have significantly influenced both the transmission of* **monetary policy** *and the economy's* **cyclical dynamics**. *As our system of housing finance continues to evolve,* **understanding** *these* **linkages** *not only provides useful insights into the past but also holds the promise of helping us better cope with the implications of* **future** *developments*".
(Speech by Chairman Ben S. Bernanke at the Federal Reserve Bank of Kansas City's Economic Symposium "Housing, Housing Finance, and Monetary Policy", Jackson Hole, Wyoming, August 31, 2007)

Existing Literature

- Traditional **macro-monetary** models: *representative agent* hypothesis $\Longrightarrow$ *no equilibrium debt*.
- Credit frictions: usually related to *firms*:

  Kiyotaki and Moore (1997) : credit cycles

  Bernanke et al. (1996, 1999): financial accelerator, credit channel (monetary policy transmission)

- Financial accelerator applied to household credit frictions (Aoki et al. (2004))
- Recently: **borrowing constraints** introduced in DSGE models (Iacoviello (2005), Campbell and Hercowitz (2006), Monacelli (2006), Calza, Monacelli and Stracca (2007))

  Only a **handful** of **estimated** DSGE models with household credit frictions (Iacoviello and Neri (2008), Finocchiaro and Queijo (2008), Christensen et al. (2008)).

This paper in a nutshell:

- **Heterogeneity** in thrifts (Kyotaki and Moore (1997)) $\Longrightarrow$ private **debt** in equilibrium
- **Collateral constraints** (credit frictions)
- **DSGE** framework
- Bayesian **Estimation**: two samples (**pre**- and **post**-financial liberalization)

Preview of Results

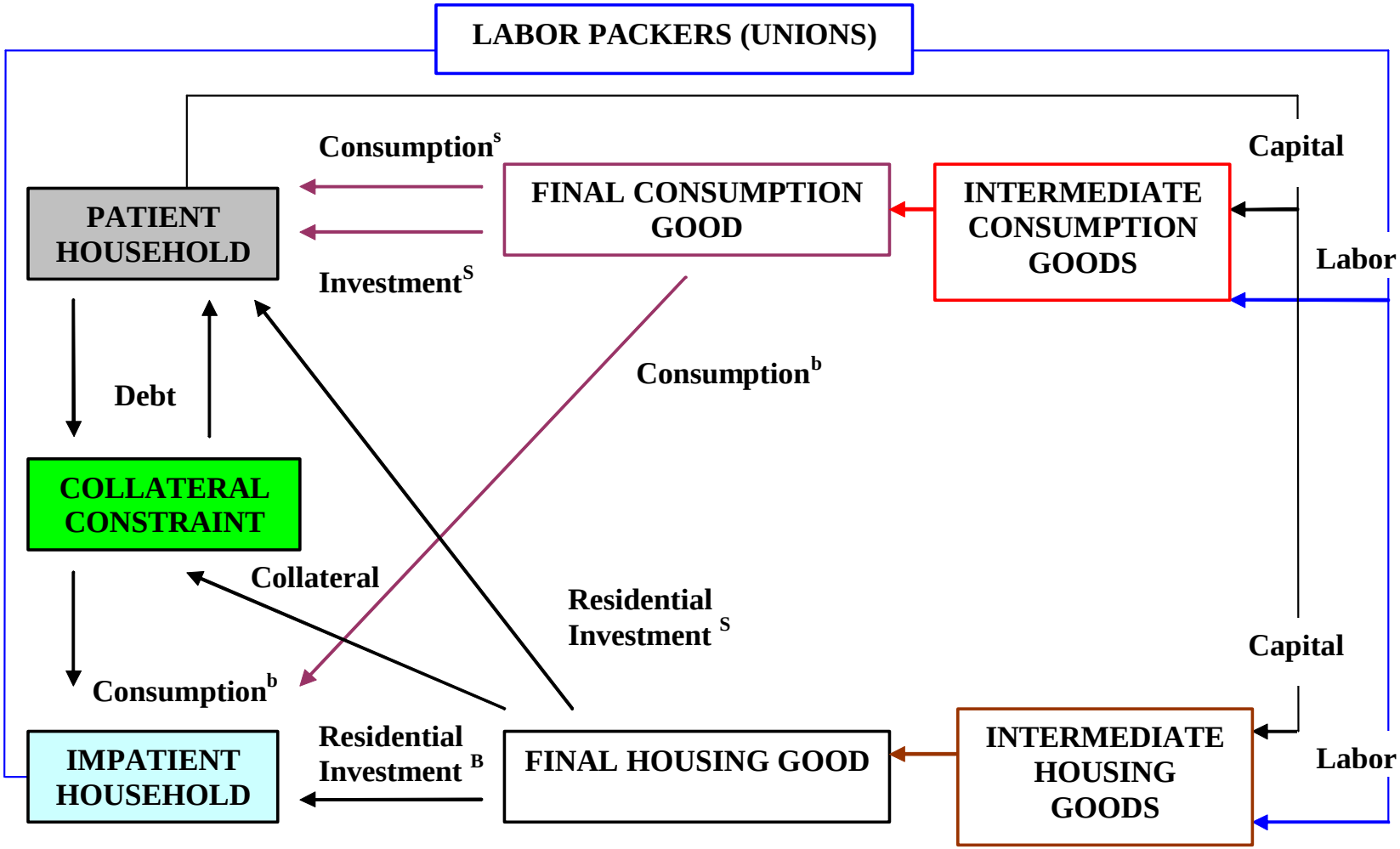
- **Housing** preference shocks explain **46%** of variation in **consumption** after 1982 but only **14%** before
- Residential investment and household debt also mainly explained by **housing** preference shocks
- Volatility of all shocks **decline** after 1982
- Estimated **asymmetry** in **price stickiness** (nondurable: sticky; housing: flexible)

The Model: Description

- General structure: Two-good, two-sector New Keynesian model
- Consumption good, residential investment
- Nonstandard feature: household structure

  Two agents, different intertemporal discount factor: $\beta < \gamma$
  Collateral constraint, always binding for impatient agents

The Model: Description



Households: Impatient agents

- Utility:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t U(X_t, N_t)$$

where

$$U(X_t, N_t) = \varepsilon_t^B \left(\log(X_t) - \frac{\upsilon \varepsilon_t^n}{1+\varphi} N_t^{1+\varphi} \right)$$

- Consume a basket of nondurable and durable goods:

$$X_t = \left[(1 - \left(\varepsilon_t^d \alpha \right))^{\frac{1}{\eta}} \left(C_t - \theta C_{t-1} \right)^{\frac{\eta-1}{\eta}} + \left(\varepsilon_t^d \alpha \right)^{\frac{1}{\eta}} D_t^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

- ε_t^d: housing preference shock

Constraints

- Budget constraint (at all t):

$$C_t + q_t(D_t - (1-\delta)D_{t-1}) - b_t = -R_{t-1}\frac{b_{t-1}}{\pi_{c,t}} + \frac{W_t}{P_{c,t}}N_t$$

  where $q_t \equiv \frac{p_{D,t}}{p_{C,t}}$ and $b_t \equiv \frac{B_t}{p_{C,t}}$

- Plus: **collateral** constraint (simplest form):

$$b_t \leq (1-\chi)q_t D_t$$

  where $\chi \in [0,1]$: share of residential good that cannot be used as a collateral, and $(1-\chi)$: proxy for **loan-to-value ratio**.

Collateral constraints

Motivation:

- **Theoretical**: needed to ensure well-defined positive consumption to both agents in equilibrium (see Becker (1980) and Becker and Foias (1987))
- **Empirical**: macro evidence on credit-constrained consumers (Jappelli and Pagano (1994), Deaton (1999)).

Summing up:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(X_t, N_t)$$

s.t.

$$C_t + q_t(D_t - (1-\delta)D_{t-1}) - b_t = -R_{t-1}\frac{b_{t-1}}{\pi_{c,t}} + \frac{W_t}{P_{c,t}}N_t$$

and

$$b_t = \varepsilon_t^{ltv}(1-\chi)q_t D_t$$

where

$$\varepsilon_t^{ltv} = \rho_{ltv}\varepsilon_{t-1}^{ltv} + \eta_t^{ltv}, \eta_t^{ltv} \sim N(0, \sigma_{ltv})$$

- Note: collateral constraint always binds in a neighborhood of the steady state.

Optimality conditions

$$q_t U_{c,t} = U_{d,t} + \beta(1-\delta)E_t\left\{U_{c,t+1}q_{t+1}\right\} + (1-\chi)\psi_t U_{c,t} q_t$$

- RHS: 3 sources of utility from housing
- Debt-generating mechanism:

$$U_{c,t} > \beta E_t\left\{U_{c,t+1}\frac{R_t}{\pi_{c,t+1}}\right\}$$

then

$$\beta = \frac{1}{1+r^b} < \frac{1}{1+r} = \gamma$$

- Repayment cost relatively cheap for the borrower ($r_t^b < r_t$)
- **Nonstandard** behavior: no consumption smoothing: any *increase* in income today $\Longrightarrow$ *higher* consumption today, financed via borrowing $\Longrightarrow$ **debt.**

Labor supply

- Only the borrowers work
- Impatient agents supply differentiated labor services:

$$N_t^i = \left(\int_0^1 N_t^i(j)^{\frac{1}{1+\lambda_W}} dj \right)^{1+\lambda_W}$$

- Labor packers (unions): combine households' hours, sell to firms
- Wage setting: nominal rigidities à la Calvo, with indexation to past and long-run inflation
- Result in a **NK(W)PC**:

$$\widehat{w}_t = \left(\frac{\beta}{1+\beta} \right) E_t \left\{ \widehat{w}_{t+1} \right\} + \left(\frac{\beta}{1+\beta} \right) E_t \left\{ \widehat{\pi}_{c,t+1} \right\} + \left(\frac{1}{1+\beta} \right) \widehat{w}_{t-1}$$
$$- \left(\frac{1+\beta\gamma_w}{1+\beta} \right) \widehat{\pi}_{c,t} + \left(\frac{\gamma_w}{1+\beta} \right) \widehat{\pi}_{c,t-1} - \left(\frac{(1-\xi_W)(1-\beta\xi_W)}{(1+\beta)\xi_W \left(1+\frac{1+\lambda_W}{\lambda_W}\varphi\right)} \right) \widehat{\mu}_t^w$$

Households: Patient agents

- Utility:

$$\max E_0 \sum_{t=0}^{\infty} \gamma^t U(\widetilde{X}_t)$$

where

$$U(\widetilde{X}_t) = \varepsilon_t^B \left(\log(\widetilde{X}_t) \right)$$

and

$$\widetilde{X}_t = \left[(1 - \varepsilon_t^d \alpha)^{\frac{1}{\eta}} \left(\widetilde{C}_t - \theta \widetilde{C}_{t-1} \right)^{\frac{\eta-1}{\eta}} + \varepsilon_t^d \alpha^{\frac{1}{\eta}} \widetilde{D}_t^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

- Note that:

$$\gamma > \beta$$

Households: Patient agents and firms

- Patient agents own capital and run firms
- Choice over: capacity utilization rate and capital accumulation
- Standard adjustment costs on capacity utilization and investment
- Standard consumption smoothing:

$$q_t = \frac{U_{\widetilde{d},t}}{U_{\widetilde{c},t}} + \gamma(1-\delta)E_t\left\{\frac{U_{\widetilde{c},t+1}}{U_{\widetilde{c},t}}q_{t+1}\right\}$$

$$U_{\widetilde{c},t} = \gamma E_t\left\{U_{\widetilde{c},t+1}R_t\frac{1}{\pi_{c,t+1}}\right\}$$

- Plus: optimality conditions for capital, investment and capacity utilization (standard)

Firms

- Each sector: perfectly competitive final-good firms:

$$Y_{j,t} = \left(\int_0^1 Y_{j,t}^{\frac{1}{1+\lambda_{pj}}} (i) di \right)^{1+\lambda_{pj}}$$

- Intermediate-good producers (monopolistic competition):

$$Y_{\iota t}(j) = \varepsilon_t^{a\iota} \left[(1-\omega) K_{\iota t}(j) \right]^{\alpha} \left[\omega N_{\iota t}(j) \right]^{1-\alpha} - \Phi_{y\iota} \overline{Y_\iota}$$

- Price setting: sticky prices à la Calvo, plus indexation
- Result in a standard (sectorial) **NKPC**:

$$\widehat{\pi}_{j,t} = \left(\frac{\gamma_{pj}}{1+\gamma_{pj}} \right) \widehat{\pi}_{j,t-1} + \left(\frac{\gamma}{1+\gamma\gamma_{pj}} \right) E_t \left\{ \widehat{\pi}_{j,t+1} \right\} + \\ + \left(\frac{\left(1-\xi_{pj}\right)\left(1-\gamma\xi_{pj}\right)}{(1+\gamma)\,\xi_{pj}} \right) \widehat{mc}_{jt}$$

Monetary Policy

- Taylor-type rule:

$$\begin{aligned}\widehat{r}_t &= \rho_r \widehat{r}_{t-1} + (1-\rho_r)\phi_\pi \widehat{\pi}_{c,t-1} \\ &\quad + \phi_{\Delta\pi}\left(\widehat{\pi}_{c,t} - \widehat{\pi}_{c,t-1}\right) + \phi_{\Delta y}\left(\widehat{y}_t - \widehat{y}_{t-1}\right) + \eta_t^r\end{aligned}$$

Market Clearing

- Goods markets:

$$Y_{c,t} = \omega \widehat{C}_t + (1-\omega)\, \widetilde{C}_t + (1-\omega)\,(I_{ct} + I_{dt})$$

and

$$Y_{d,t} = \omega \widehat{I}_{d,t} + (1-\omega)\widetilde{I}_{d,t}$$

where

$$\begin{aligned} Y_{\imath t} &\equiv \int_0^1 Y_{\imath t}(j)dj = (1-\omega)^{\alpha}\omega^{1-\alpha}\varepsilon_t^{a\imath}\int_0^1 K_{\imath t}^{\alpha}(j)N_{\imath t}^{1-\alpha}(j)dj \\ &= (1-\omega)^{\alpha}\omega^{1-\alpha}K_{\imath t}^{\alpha}N_{\imath t}^{1-\alpha} \end{aligned}$$

- Labor market:

$$N_{c,t} + N_{d,t} = N_t$$

- Bonds market:

$$\omega \widehat{B}_t + (1-\omega)\, \widetilde{B}_t = 0$$

Understanding the Mechanics: Monetary Transmission

- Traditional mechanism (nominal rigidities) is modified:

1. Debt is nominal: monetary policy decisions (short-term rate $\longrightarrow$ inflation) modify **cost** and **ex-post value** of **debt**

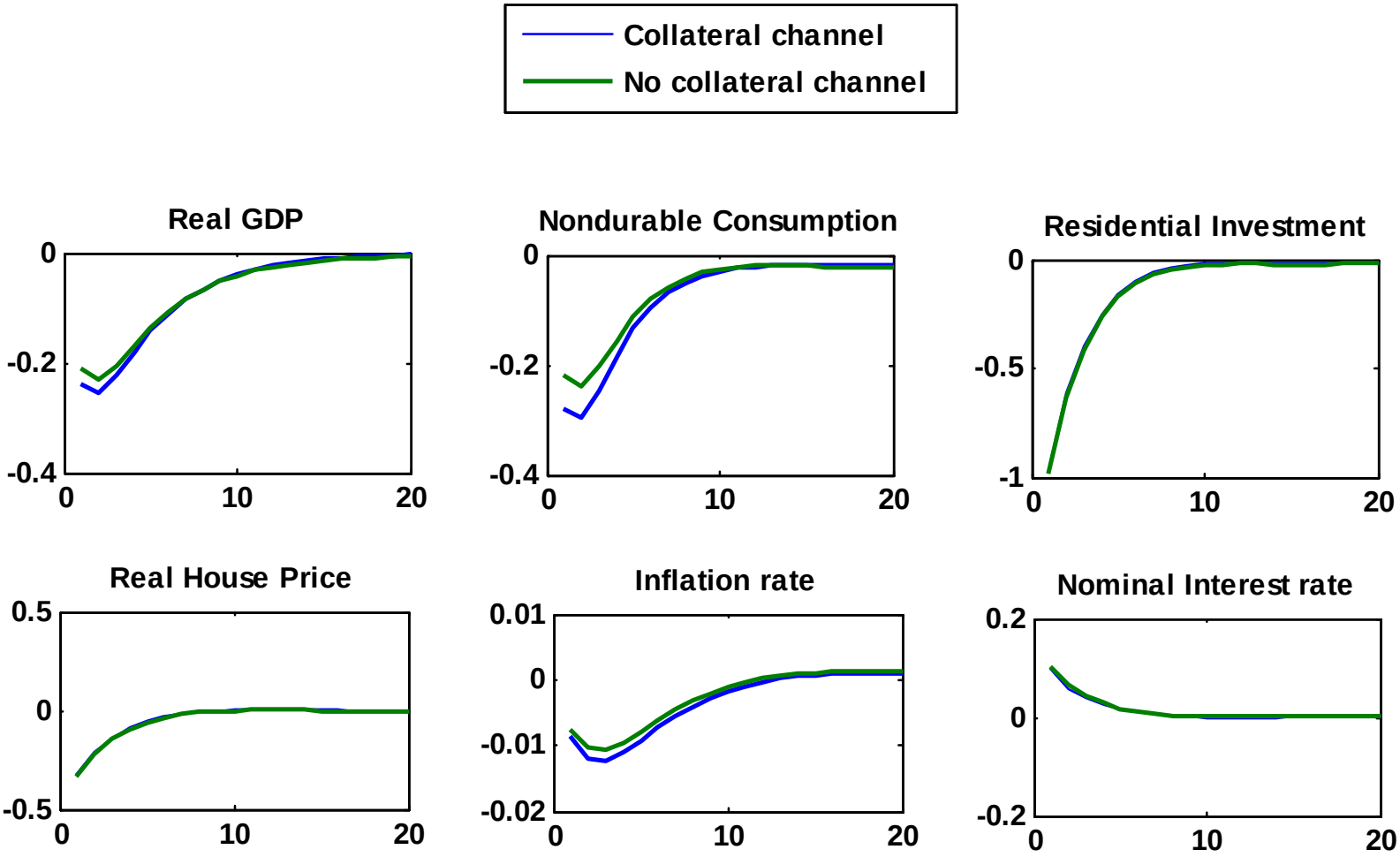
$$R_{t-1}\frac{b_{t-1}}{\pi_t}$$

2. **Collateral** constraint (I): **interaction** with m.p.: any change in $(1-\chi)$ implies **substitution effect**, ceteris paribus
3. **Collateral** constraint (II): **valuation effect** of house prices on existing collateral (e.g.housing demand shocks)

$$b_t \leq (1-\chi)q_t D_t$$

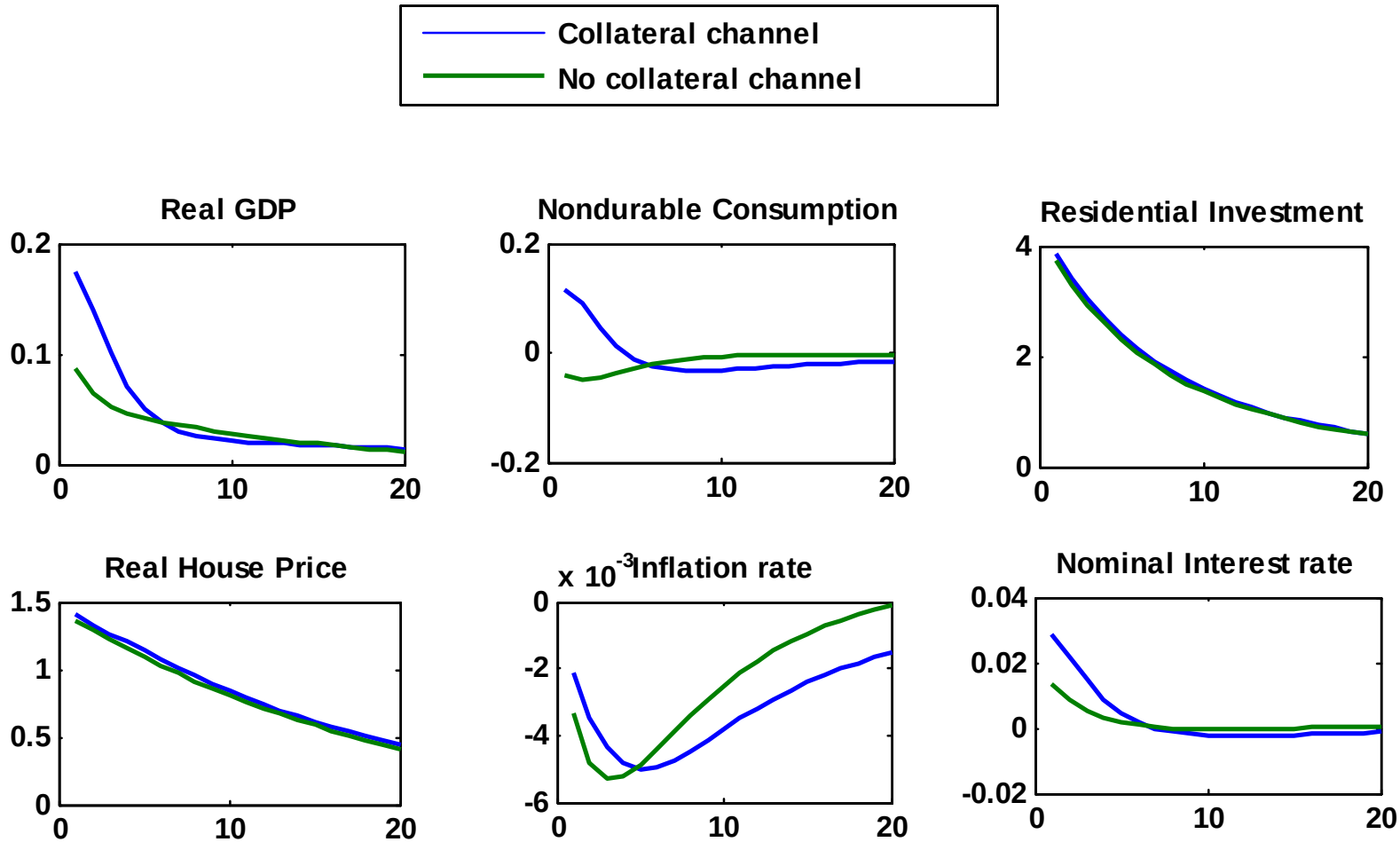
The collateral channel

Impulse responses to a Monetary Policy Shock:



The collateral channel

Impulse Responses to a Housing Preference Shock:



Estimation

- **Bayesian** Estimation of structural parameters
- Procedure:
  1. **Log-linearize** equilibrium conditions around deterministic steady state and solve
  2. Write solution in **state-space** form:

$$\mathbf{f}_t = \mathbf{C}\mathbf{s}_t$$

$$\mathbf{s}_t = \mathbf{A}\mathbf{s}_{t-1} + \mathbf{B}\varepsilon_t$$

  3. Compute **likelihood** function using **Kalman** filter
  4. Specify **prior** distributions for structural parameters and combine with likelihood (Bayes theorem)
  5. Use Monte Carlo Markov Chain (**MCMC**) methods to simulate draws from unknown posterior distribution

Shocks

- Parsimonious modelling of shocks (11 structural shocks, 9 observable variables)
- **Structural** shocks:

  1 **Preference** shock (common across agents)

  1 **Housing** preference shocks (common across agents)

  1 **Labor** supply shock

  2 **Technology** shocks (one $\forall$ sector)

  2 **Investment-specific** shocks (one $\forall$ sector)

  1 **Monetary** policy shock

  1 **Loan-to-value** ratio shock

Sample split: 1965 I-1982 IV vs 1983 I - 2006 IV

- Estimate model on two separate samples, pre and post 1982 Q4
- Motivations:

1. Garn-St.Germain Act (late 1982): start increase in LTV and development of secondary markets
2. Household debt starts increasing from 1983 Q1
3. Great Moderation in second part of sample (1984 Q1)
4. Monetary Policy stance also changes after early '80s

Data

- **Quarterly** U.S. data **1965 Q1: 2006 Q4** (168 observations)
- Nondurable consumption
- Residential Fixed Investment
- Total Household Debt
- Short-term nominal interest rate
- Consumer Price Inflation
- Real House Prices
- Nonresidential Investment
- Gross Domestic Product
- Hours worked in the consumption-good sector

Calibration and Prior Distributions

Calibrate some parameters:

- $\beta = 0.96$
- $\gamma = 0.99$
- α (share of housing in total consumption) $= 0.4$
- Deprectiation rates: $\delta = 0.0025$ (10% per year)
- $\delta_K = 0.3$
- LTV: $\chi = 0.75$ in first sub-sample, $\chi = 0.92$ in second (to reflect changes in mortgage markets and secondary markets)

Priors and Posteriors

Table 1. Prior and Posterior Distributions

		Prior			*Posterior*	
		Distr.	Mean	S.D.	Median (S1)	Median (S2)
θ	cons. habit	Beta	0.65	0.1	0.2771	0.1771
φ	inv. el.labor supply	Gamma	2	0.75	1.8579	1.7679
ϕ_i	investment adj.	Normal	4	0.5	4.0661	4.1585
ψ	adj. cost elasticity	Gamma	0.2	0.1	0.0255	0.0136
$\xi_{p,c}$	Calvo prices (nond.)	Beta	0.5	0.28	**0.8789**	**0.8811**
$\xi_{p,d}$	Calvo prices (dur.)	Beta	0.5	0.28	**0.0009**	**0.0024**
ξ_w	Calvo wages	Beta	0.5	0.28	**0.9721**	**0.9934**
$\gamma_{p,c}$	price index. (nond.)	Beta	0.5	0.28	0.7978	0.0198
$\gamma_{p,d}$	price index. (dur.)	Beta	0.5	0.28	0.4671	0.5278
γ_w	wage indexation	Beta	0.5	0.28	0.0383	0.0121

Priors and Posteriors

		Prior			*Posterior*	
		Distr.	Mean	S.D.	Median (S1)	Median (S2)
ϕ_π	Taylor rule	Normal	1.5	0.1	**1.567**	**1.5314**
$\phi_{\Delta\pi}$	Taylor rule	Gamma	0.3	0.1	0.2646	0.2633
$\phi_{\Delta y}$	Taylor rule	Gamma	0.063	0.05	**0.5455**	**0.4619**
ρ_{ξ_r}	Taylor rule	U[0,1]	0.5	0.28	0.8193	0.8588
ρ_{zc}	Tech. shock	Beta	0.5	0.28	0.9717	0.9863
ρ_{zd}	Tech. shock	Beta	0.5	0.28	0.9861	0.9903
ρ_b	Pref. shock	Beta	0.5	0.28	0.9866	0.9628
ρ_{ltv}	Ltv-shock	Beta	0.5	0.28	0.9729	0.9856
ρ_i	Inv.-specific	Beta	0.5	0.28	0.0278	0.0251
ρ_{i_d}	Inv.-specific	Beta	0.5	0.28	0.3676	0.3266
ρ_{hb}	Housing preference	Beta	0.5	0.28	0.9962	0.9972
ρ_n	Labor supply	Beta	0.5	0.28	0.7328	0.8902
ρ_{cp}	Cost-push	Beta	0.5	0.28	0.0399	0.0147
ρ_{cp_d}	Cost-push	Beta	0.5	0.28	0.5853	0.7973

Priors and Posteriors

		Prior	*Posterior*	
		Distr.	Median (S1)	Median (S2)
σ_{zc}	Tech. shock (nond.)	U[0,6]	0.0063	0.0037
σ_{zd}	Tech. shock (dur.)	U[0,6]	0.0120	0.0095
σ_{r}	Monetary policy	U[0,6]	0.0058	0.0024
σ_{ltv}	Ltv-shock (nond.)	U[0,6]	0.0124	0.0091
σ_{b}	Inv.-specific (nond.)	U[0,6]	0.0846	0.0277
σ_{i}	Inv.-specific (dur.)	U[0,6]	1.0345	0.6530
σ_{i_d}	Inv.-specific (dur.)	U[0,6]	2.2918	1.9493
σ_{hb}	Housing preference	U[0,6]	0.0436	0.0324
σ_{n}	Labor supply	U[0,6]	4.0420	3.9515
σ_{cp}	Cost-push (nond.)	U[0,6]	0.0066	0.0051
σ_{cp_d}	Cost-push(dur.)	U[0,6]	3.4427	2.0272

Variance Decomposition

Table 2. Variance Decomposition

		η_{zc}	η_{zd}	η_{hb}	η_{ltv}	η_{r}	η_{b}
C	S1	2.65	1.26	**14.25**	2.55	56.51	13.69
	S2	0.71	0.84	**45.69**	3.49	35.77	3.93
I^D	S1	3.19	6.88	76.92	1.40	1.73	2.70
	S2	1.99	9.24	73.36	5.66	0.97	0.61
$\widehat{\mathbf{B}}$	S1	0.33	1.11	90.92	2.33	2.67	1.97
	S2	0.32	1.73	85.54	4.33	5.13	0.87

- **Housing** preference shocks explain **larger** % of variance of C **after** 1982 (46% vs 14%)
- **Housing** preference shocks explain almost all variance of I^D and $\widehat{B}$

Variance Decomposition: comments

- Impact of housing demand shocks on C: evidence of **home equity withdrawal**
- Intuition: $\uparrow$ housing demand $\Rightarrow \uparrow$ house prices (supply $\sim$ fixed) $\Rightarrow$ more credit (**collateral** channel)$\Rightarrow \uparrow C$
- **Larger** effect with more **flexible** mortgage markets

Fit of the Model

- **Compare** model to a **benchmark (one-agent, no** household debt, no credit frictions):

Table 3. Marginal Likelihood				
	1965 I : 1982 IV		1983 I : 2006 IV	
	Model	Benchmark	Model	Benchmark
Laplace Approximation	1544.4	1407.8	2460.6	2267.6
Modified Harmonic Mean	1540.5	1456.6	2409	2266.8

- Model **beats** benchmark on both samples (better fit)
- **Better** fit on **second** sample
- Data ask for **credit frictions**

Main results

- **Housing** demand shocks explain larger portion of variation in C after 1982 (quantitative evidence of **home-equity withdrawal**)
- More flexible mortgage markets amplify the collateral channel
- Residential investment and household debt mainly explained by **housing** demand shocks
- **Decline** in volatility of all structural **shocks**
- **Asymmetric** price stickiness (housing sector: almost flex price)

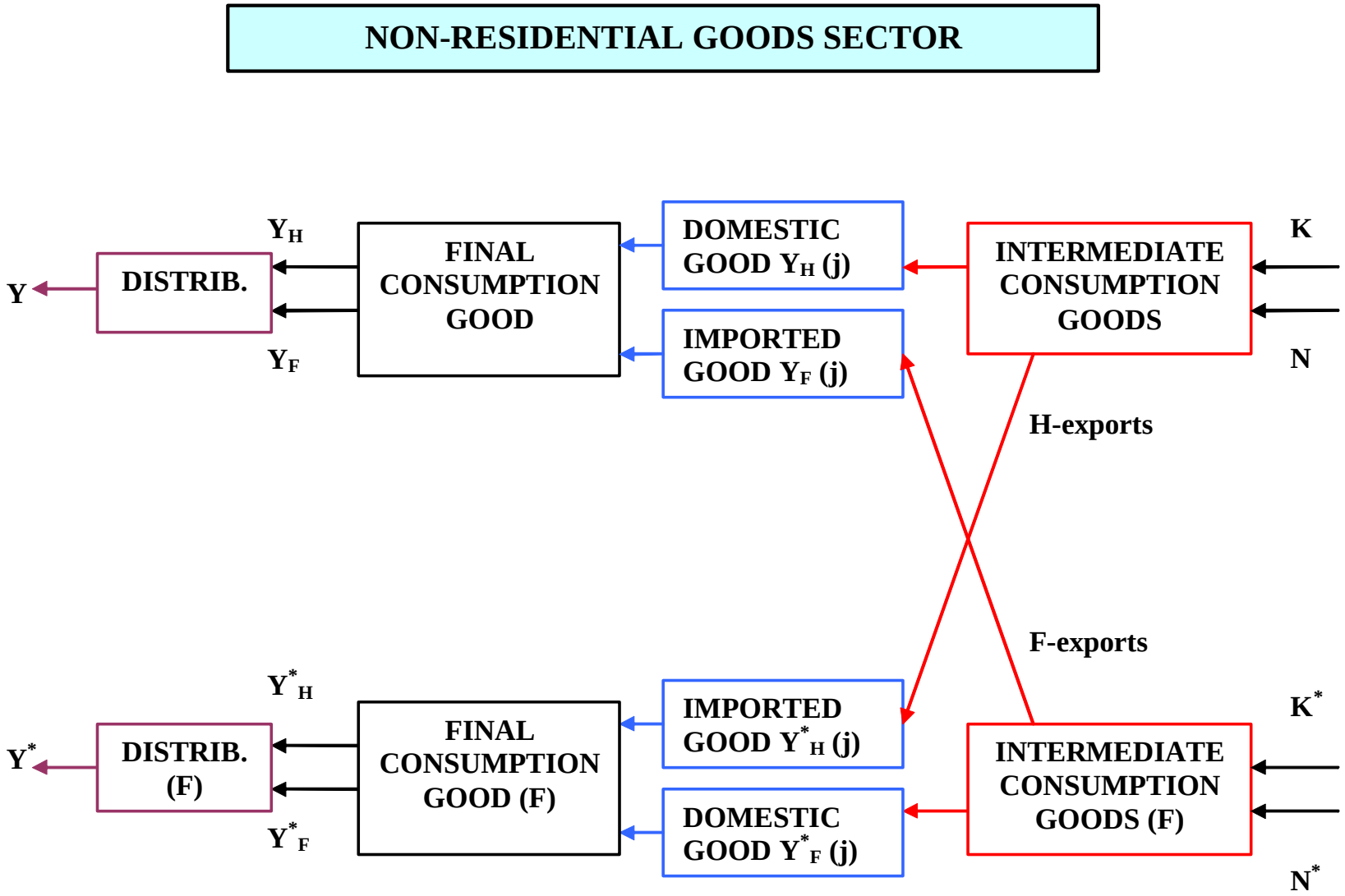
Conclusions

- Model captures existence of **collateral** channel
- Evidence of **home equity** withdrawal (impact on C)
- Financial market **liberalization** amplifies collateral channel
- **Monetary Policy** transmission crucially modified
- Extensions: open-economy setup (*in progress*)

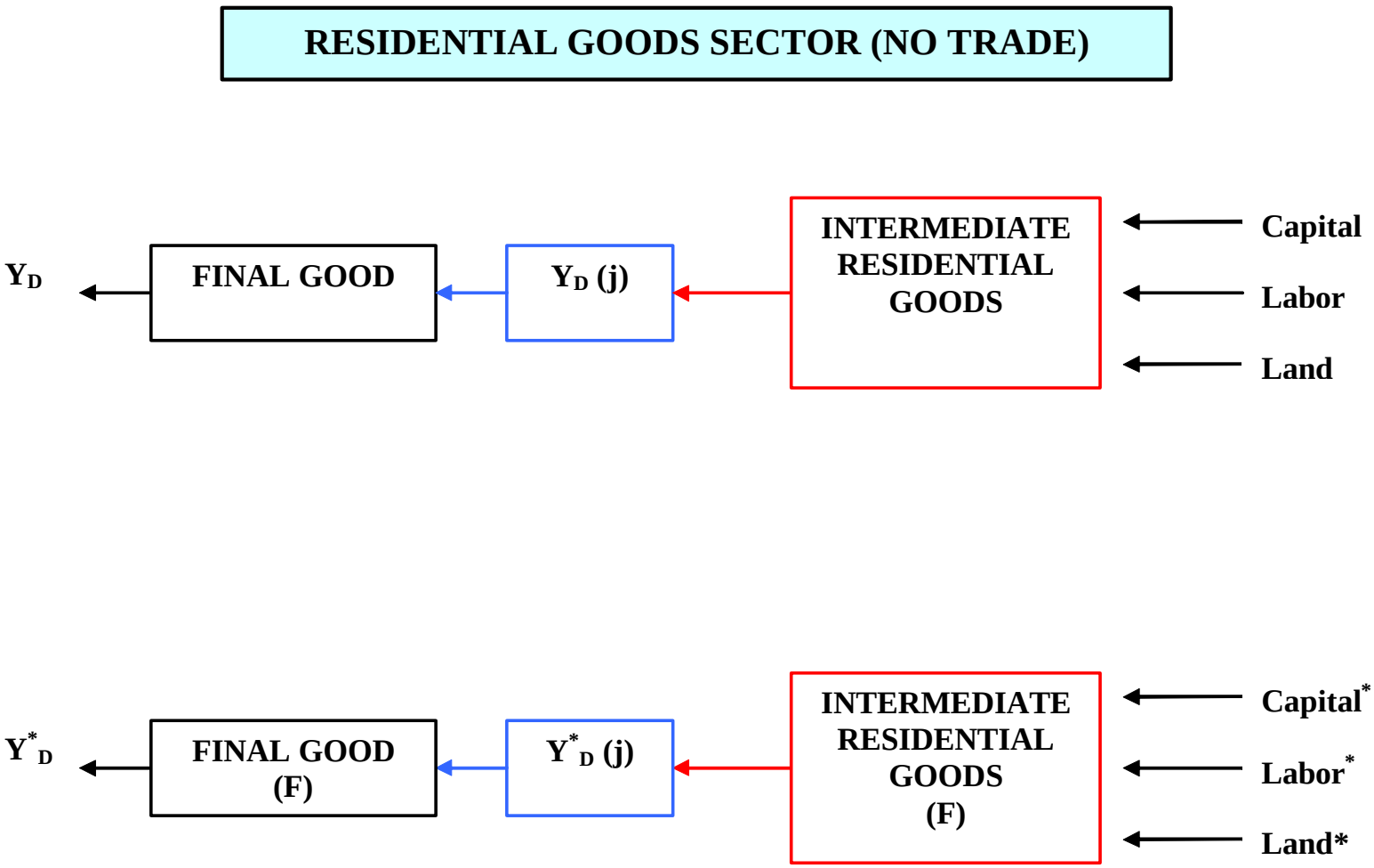
Extensions: Open Economy

- Collateral channel usually ignored in existing **NOEM** models (e.g. NAWM)
- Room for **integrating** standard open economy models with new evidence on role of credit frictions for monetary policy
- Ongoing research project (Darracq-Pariès and Notarpietro (2008)): develop and estimate a two-country DSGE model (US-EA)
- Two-country model + collateral channel
- International trade in non-residential goods (not housing) and assets (only savers)
- Role of household credit market imperfections in explaining international business cycle dynamics?
- Potential spillovers from those markets to the international economy?

The open-economy model

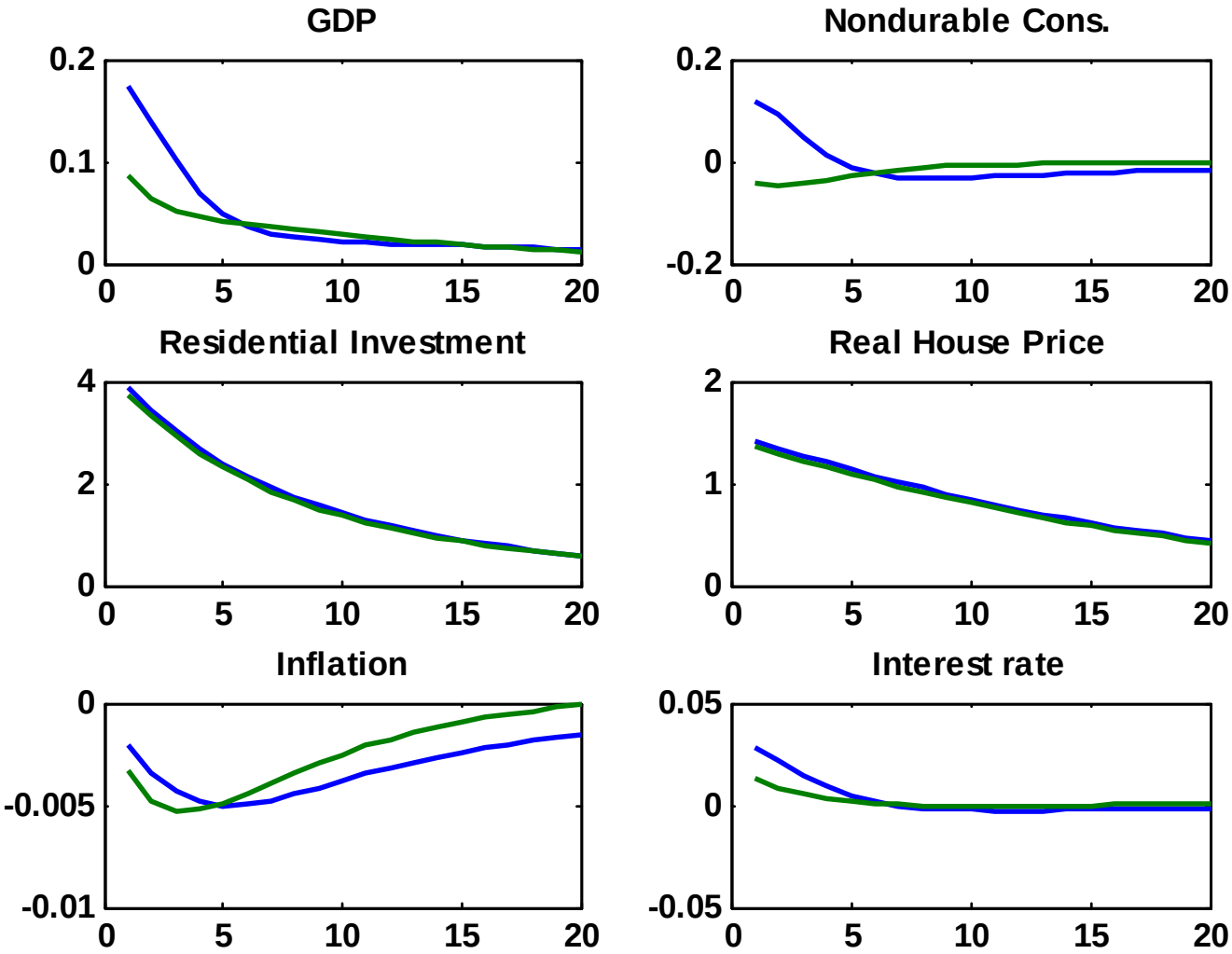


The open-economy model



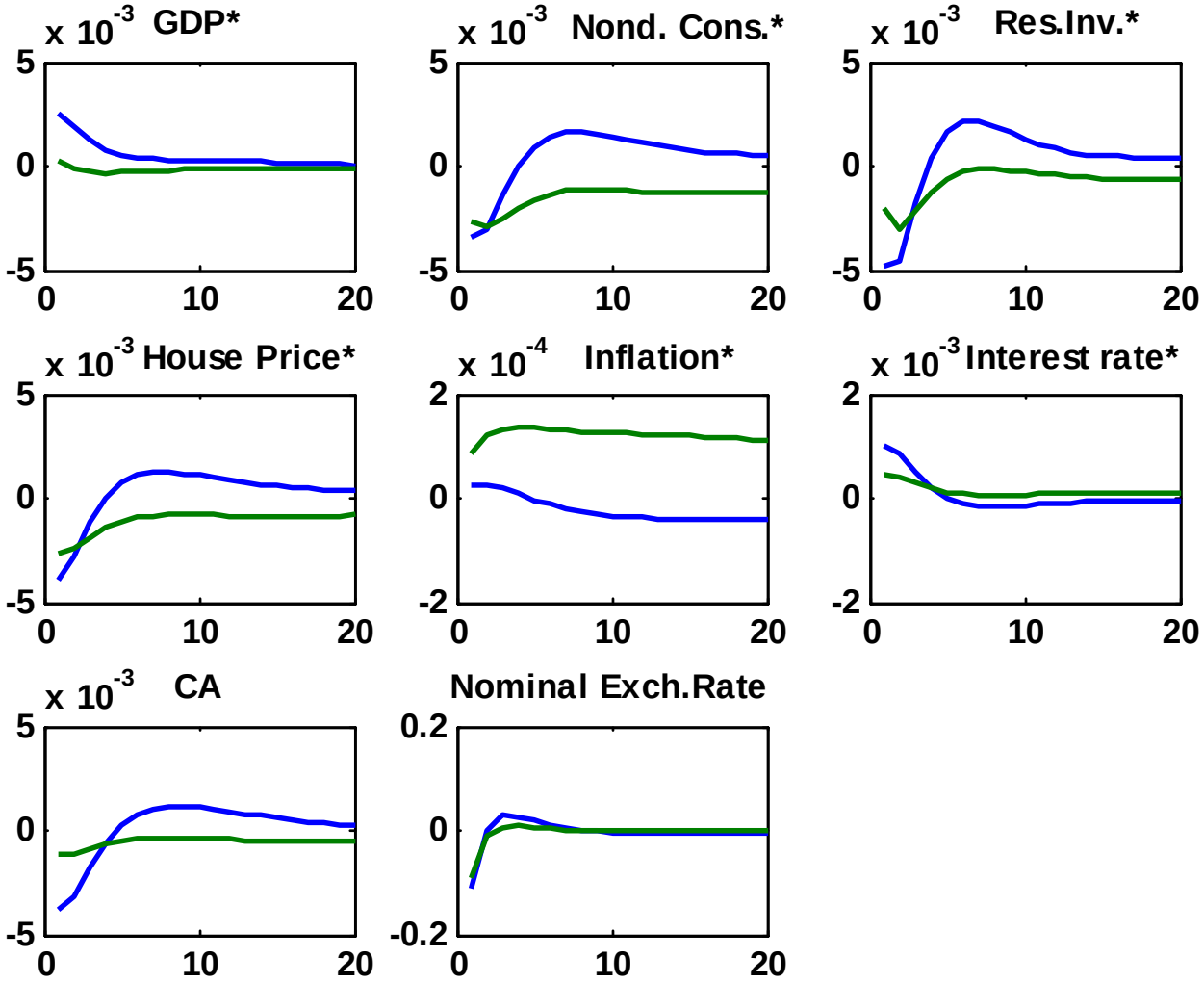
The open-economy model

Some preliminary results: housing preference shock (US)



The open-economy model

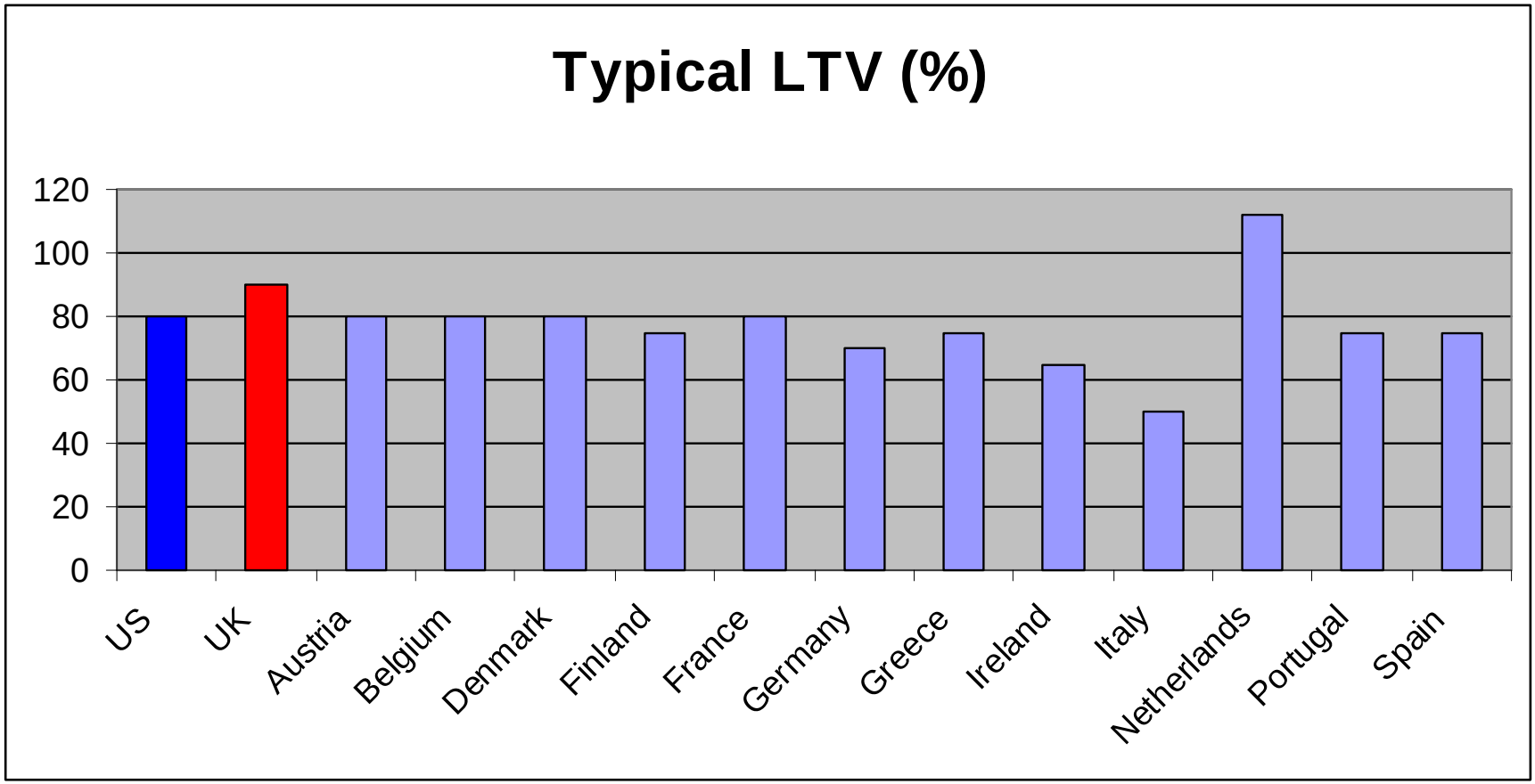
Some preliminary results: housing preference shock (US)



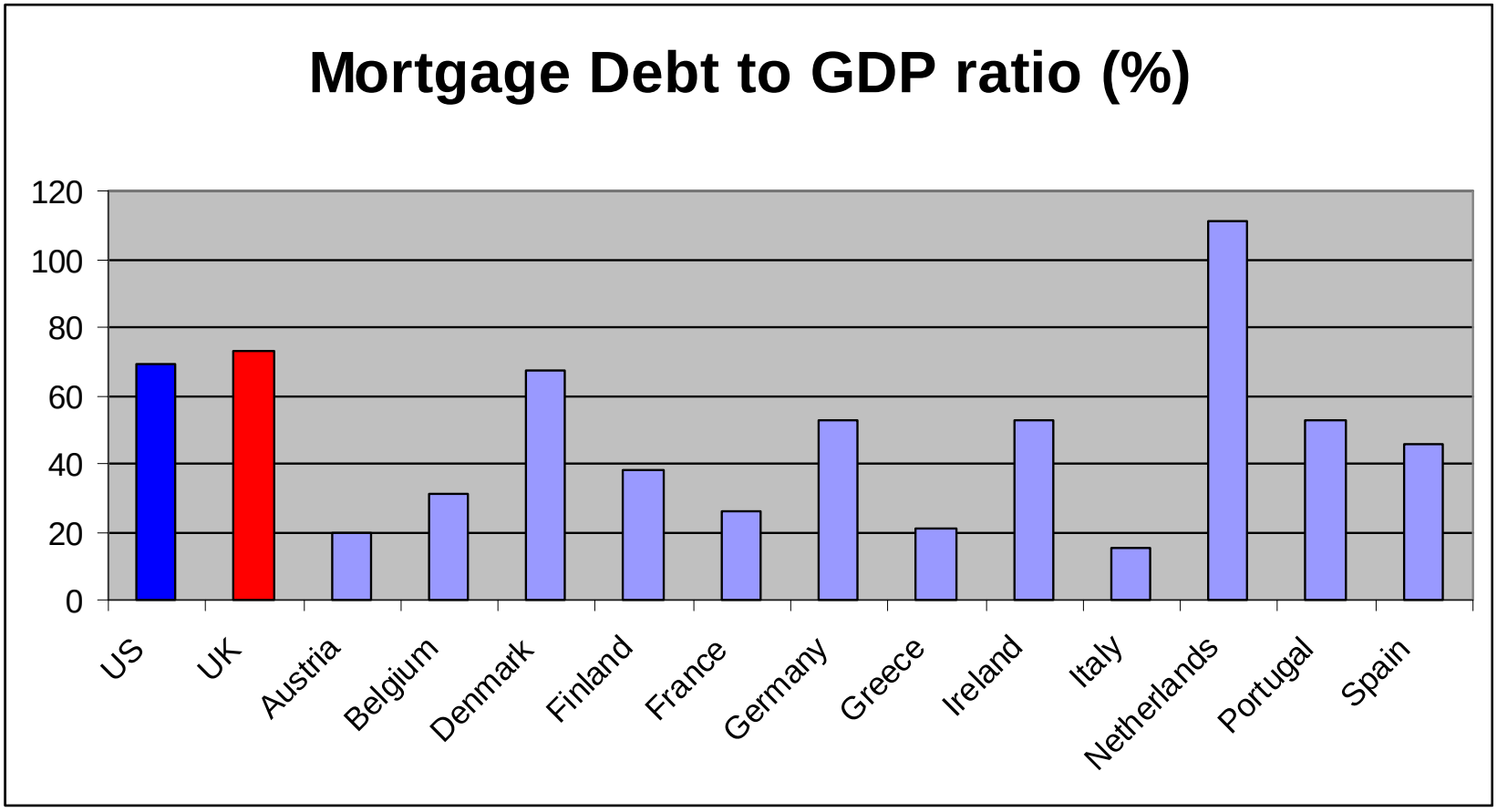
...The next step...

- Role of international **asymmetries** in housing and mortgage markets
- Housing and mortgage markets are quite heterogeneous across countries
- US: high flexibility, developed secondary markets, variety of options to borrowers
- Euro Area: high internal heterogeneity. On average: less developed markets

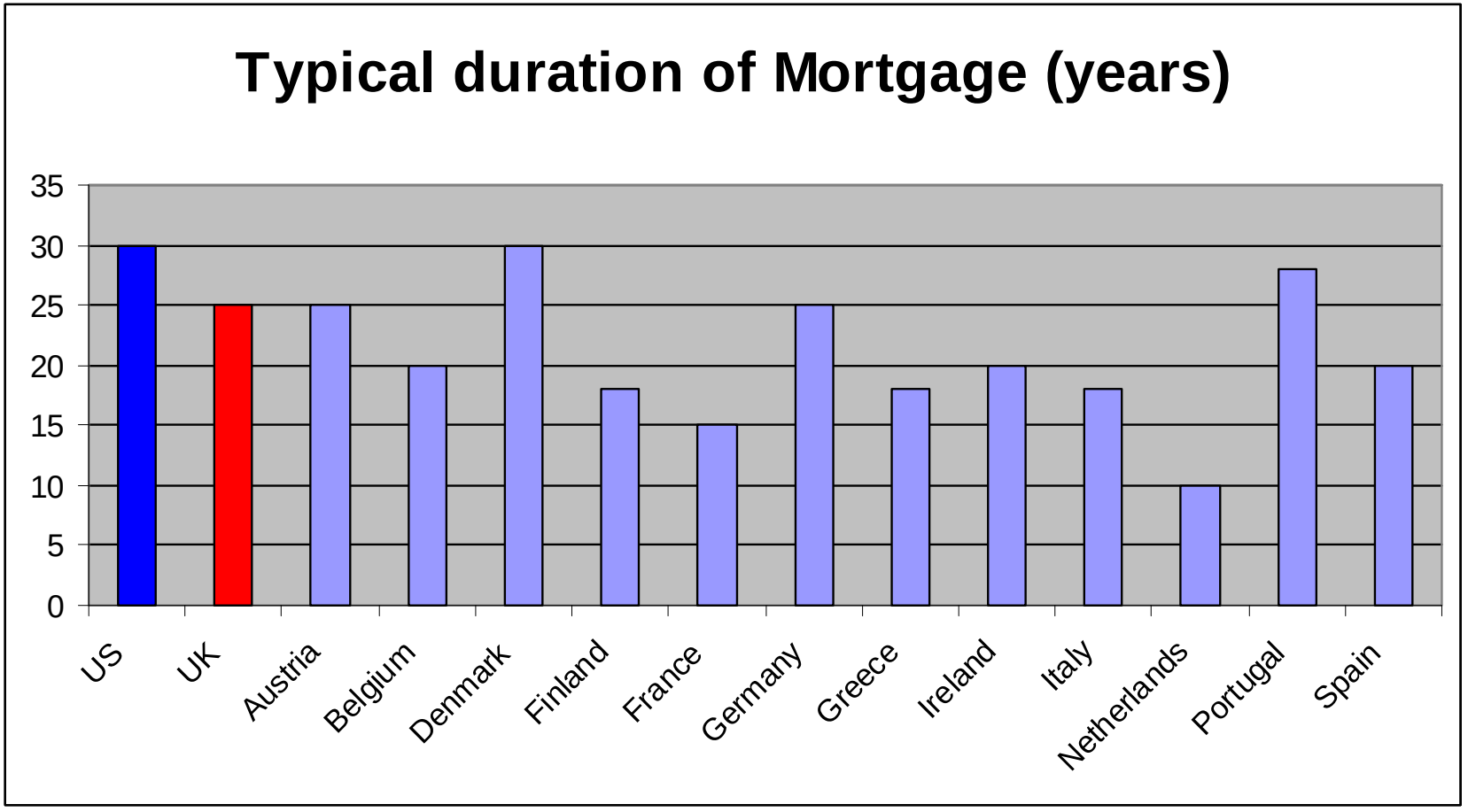
International Asymmetries



International Asymmetries



International Asymmetries



International asymmetries

- How to capture asymmetries in mortgage markets
- More sophisticated forms of collateral constraint (Campbell and Hercowitz (2006); Calza, Monacelli and Stracca (2007))
- Variable vs. Fixed-Rate Contracts:

$$R_t^m = \left(\sum_{k=0}^{m-1} \tau^k \right)^{-1} \sum_{k=0}^{m-1} \tau^k E_t \left\{ R_{t+k} \right\}$$

if $m = 1$, then $R_t^m = R_t$

- Economic depreciation of collateral $\neq$ physical depreciation:

$$B_t \leq (1 - \chi) \left[\sum_{s=0}^{\infty} (1 - \phi)^s \left(D_{t-s} - (1 - \delta) D_{t-s-1} \right) \right] P_{d,t}$$

where $\phi \geq \delta$ is the rate at which collateral looses value to creditor