Interest Rate Dynamics, Variable-Rate Loan Contracts, and the Business Cycle

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Borrowing Cost of US firms

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  (i) it is countercyclical

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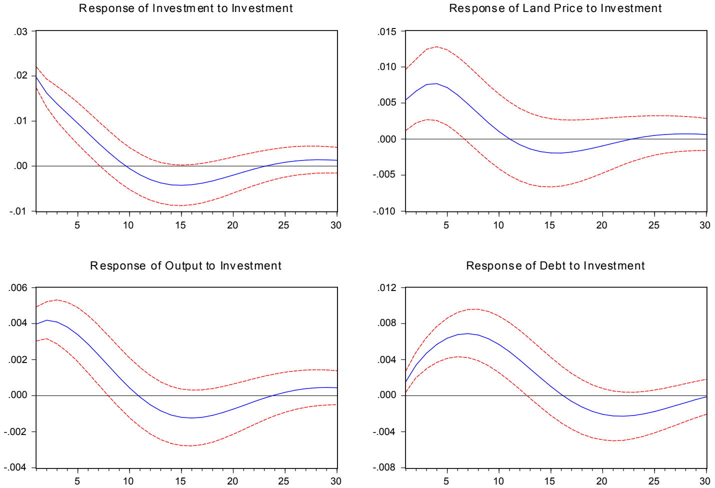
- 2-sector RBC model: Boldrin, Christiano, and Fisher (2001)

Empirical VAR

- IRFs with investment first:



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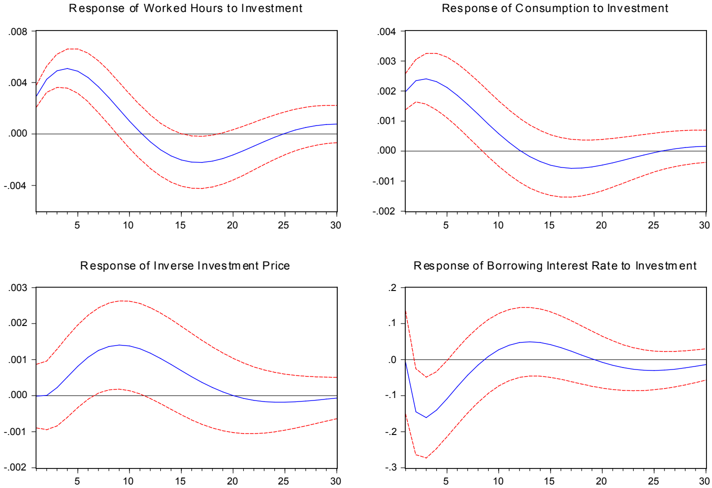
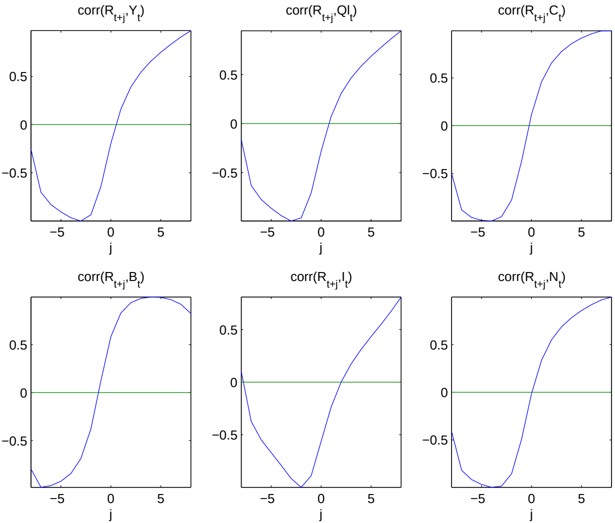


Inverted Leading Indicator

- Lead-lag correlations:



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- Key assumption: loan contract with **variable interest rate**
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- Sunspot equilibria (local and global) are very pervasive
- Sunspot shocks to investment quantitatively important

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- Sunspot equilibria (local and global) are very pervasive
- Sunspot shocks to investment quantitatively important
- Sunspot model has better fit than model with unique eqm

Related Literature

- Endogenous collateral constraints:
  Kiyotaki-Moore (1997), Iacoviello (2005), Iacoviello-Neri (2010), Pintus-Wen (2013), Liu-Wang-Zha (2013), Guerrieri-Iacoviello (2015) Justiniano-Primiceri-Tambalotti (2015a,b)
- Sunspots under collateral constraints:
  Cordoba-Ripoll (2004), Benhabib-Wang (2013), Liu-Wang (2014)
- Sentiments – unsecured credit:
  Benhabib-Wang-Wen (2015) Azariadis-Kaas-Wen (2015)
- Lead-lag correlations:
  Backus-Kehoe-Kydland (1994), Gomme-Kydland-Rupert (2001), Kydland-Rupert-Sustek (2015)

Road Map

- Motivation ✓
- Global sunspot equilibria in version of Pintus-Wen (2013)
- Quantitative model based on Liu-Wang-Zha (2013)
- Bayesian estimation results on US data 1975-2010
- Concluding remarks

Representative Lender

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$$\tilde{C}_t + Q_t(\tilde{L}_{t+1} - \tilde{L}_t) + B^l_{t+1} \leq R_t B^l_t$$

Representative Borrower

- Representative borrower solves:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \log C_t$$

subject to

$$C_t + Q_t(L_{t+1} - L_t) + R_t B_t^l \leq B_{t+1}^l + L_t$$

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- Note that interest payment $R_t B_t^l$ **responds** to shocks
- Land in fixed supply so land market clears if $L_t + \tilde{L}_t = \bar{L}$

First-Order Conditions

- From lender's: $Q_t = Q \equiv \beta/(1-\tilde{\beta})$ and $\mathbb{E}_t R_{t+1} = \tilde{\beta}^{-1}$
- Borrower's FOC and budget constraint then become:

$$\Lambda_t = \mathbb{E}_t X_{t+1} \Lambda_{t+1}$$

$$C_t + Q(1-\tilde{\beta})L_{t+1} = X_t L_t$$

where $X_t \equiv 1 + Q(1 - \tilde{\beta} R_t)$

- Closed-form solutions for borrower's choices: $C_t = (1-\beta)X_t L_t$ and $Q(1-\tilde{\beta})L_{t+1} = \beta X_t L_t$

Analytical Example of Global Sunspot Equilibria

Proposition

There exist global sunspot equilibria such that the dynamics of the land stock allocated to borrower follows

$$L_{t+1} = [1 + Q(1 - \tilde{\beta} R_t)]L_t$$

for all $t \geq 0$, given $L_0 > 0$, where $R_t = \tilde{\beta}^{-1}(1 + \varepsilon_t)$ and sunspot innovation ε_t is an i.i.d. random variable with zero mean

Predetermined Interest Rate

- Contrast this with predetermined interest rate economy:

$$C_t + Q(L_{t+1} - L_t) + R_{t-1}B^l_t \leq B^l_{t+1} + L_t$$

$$R_t B^l_{t+1} \leq QL_{t+1}$$

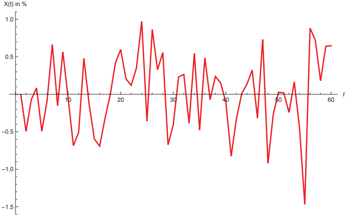
$$\tilde{C}_t + Q(\tilde{L}_{t+1} - \tilde{L}_t) + B^l_{t+1} \leq R_{t-1}B^l_t$$

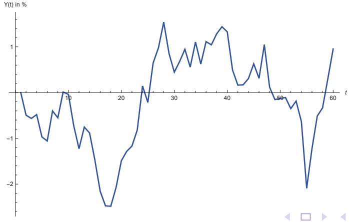
- Interest payment due in t now **predetermined**,
  interest rate entering credit constraint variable but known in t

- Such an economy is always in steady state absent fundamental shocks:
  interest rate fixed at $R_t = \tilde{\beta}^{-1}$

Variable Interest Rate

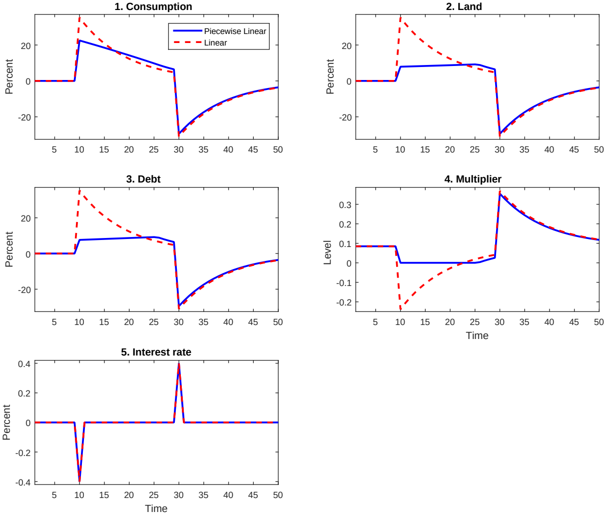
- In contrast, output growth rate and level fluctuate:





Occasionally Binding Constraint

- Sunspot equilibria with negative skewness:



Intuition

- Under variable interest rate, credit demand and supply are:

$$B^d_{t+1} = \tilde{\beta} Q L_{t+1}, \; B^s_{t+1} = Q L_{t+1} - \beta X_t L_t, \; X_t \equiv 1 + Q(1 - \tilde{\beta} R_t)$$

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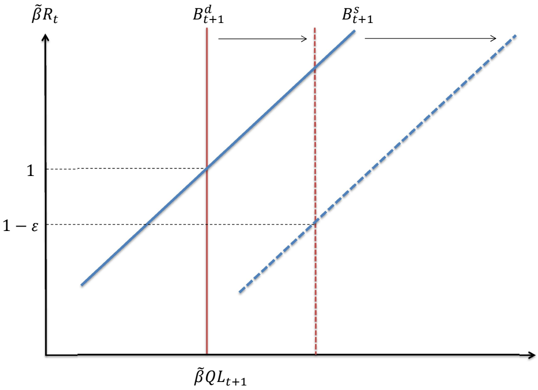

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- Related to literature on sentiments:
  Benhabib, Wang and Wen (2015)
- Sunspots even though **secured** credit,
  unlike in Azariadis, Kaas and Wen (2015)

Quantitative Model

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- Additional features typical of current DSGE models:
  - consumption habits
  - investment adjustment costs
  - productivity growth
- Shocks:
  - discount rate, land demand, labor supply
  - production technology (transitory and permanent)
  - investment technology (transitory and permanent)
  - collateral (leverage)

IRFs

Household/Lender

- Household solves:

$$\max \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t A_t (\ln(C_{ht} - \gamma_h C_{ht-1}) + \varphi_t \ln L_{ht} - \psi_t N_{ht}) \right]$$

where $A_t = A_{t-1}(1 + \lambda_{at})$,
$\ln \lambda_{at} = \rho_a \ln \lambda_{at-1} + (1 - \rho_a) \ln \bar{\lambda}_a + \sigma_a \varepsilon_{a,t}$

- subject to budget constraint:

$$C_{ht} + q_{lt}(L_{ht} - L_{ht-1}) + \frac{B_t}{R_t} \leq w_t N_{ht} + B_{t-1}$$

where $B_{t-1} = R_{t-1} B^l_{t-1}$ denotes interest payment (hence **predetermined** in original model)

Entrepreneur/Borrower

- Entrepreneur solves:

$$\max \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \ln(C_{et} - \gamma_e C_{et-1}) \right]$$

- subject to technology constraint:

$$Y_t = Z_t (L_{et-1}^{\phi} K_{t-1}^{1-\phi})^{\alpha} N_{et}^{1-\alpha}$$

where $Z_t = \nu_{zt} Z_t^p$, $Z^p = Z_{t-1}^p \lambda_{zt}$,
$\ln \lambda_{zt} = \rho_z \ln \lambda_{zt-1} + (1-\rho_z)\bar{\lambda}_z + \sigma_z \varepsilon_{zt}$,
$\ln \nu_{zt} = \rho_{\nu_z} \ln \nu_{zt-1} + \sigma_{\nu_z} \varepsilon_{\nu_z t}$

Entrepreneur/Borrower Ctnd

- capital accumulation constraint:

$$K_t = (1-\delta)K_{t-1} + \left(1 - \frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}} - \bar{\lambda}_I\right)^2\right) I_t$$

- budget constraint:

$$C_{et} + q_{lt}(L_{et} - L_{et-1}) + B_{t-1} = Y_t - \frac{I_t}{Q_t} - w_t N_{et} + \frac{B_t}{R_t}$$

where $Q_t = Q_t^p \nu_{qt}$, $Q^p = Q_{t-1}^p \lambda_{qt}$,
$\ln \lambda_{qt} = \rho_q \ln \lambda_{qt-1} + (1-\rho_q)\bar{\lambda}_q + \sigma_q \varepsilon_{qt}$,
$\ln \nu_{qt} = \rho_{\nu_q} \ln \nu_{qt-1} + \sigma_{\nu_q} \varepsilon_{\nu_q t}$

Entrepreneur/Borrower Ctnd

- collateral constraint:

$$B_t \leq \theta_t \mathbb{E}_t[q_{lt+1} L_{et} + q_{kt+1} K_t]$$

where $\ln \theta_t = \rho_\theta \ln \theta_{t-1} + (1-\rho_\theta) \ln \bar{\theta} + \sigma_\theta \varepsilon_{\theta t}$

- Variable-rate economy has instead:

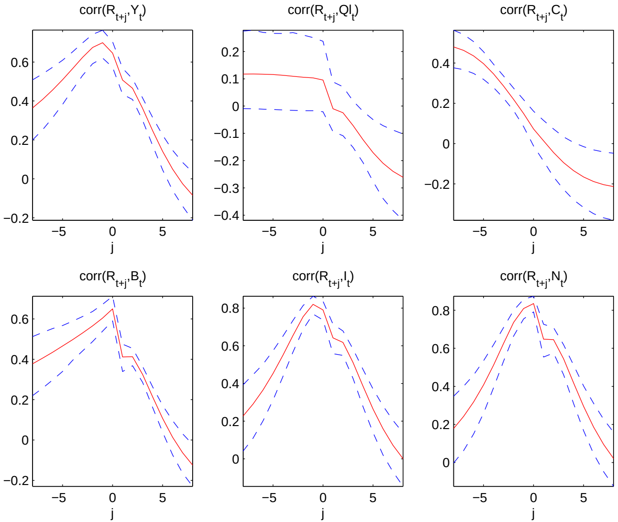
$$C_{ht} + q_{lt}(L_{ht} - L_{ht-1}) + B_t^l \leq w_t N_{ht} + R_t B_{t-1}^l$$

$$C_{et} + q_{lt}(L_{et} - L_{et-1}) + R_t B_{t-1}^l = Y_t - \frac{I_t}{Q_t} - w_t N_{et} + B_t^l$$

$$\mathbb{E}_t[R_{t+1}] B_t^l \leq \theta_t \mathbb{E}_t[q_{lt+1} L_{et} + q_{kt+1} K_t]$$

Lead-lag Correlations

- Conditional on land price shock in determinate model:



Lead-lag Correlations Ctnd

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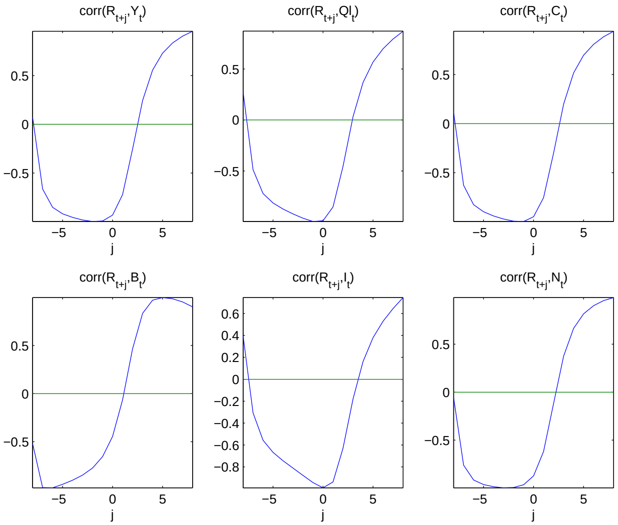
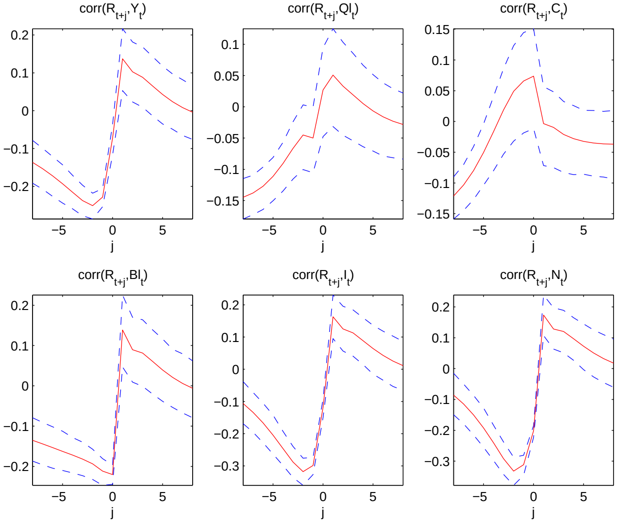


Lead-lag Correlations Ctnd

- Conditional on investment sunspot shock in indet. model:



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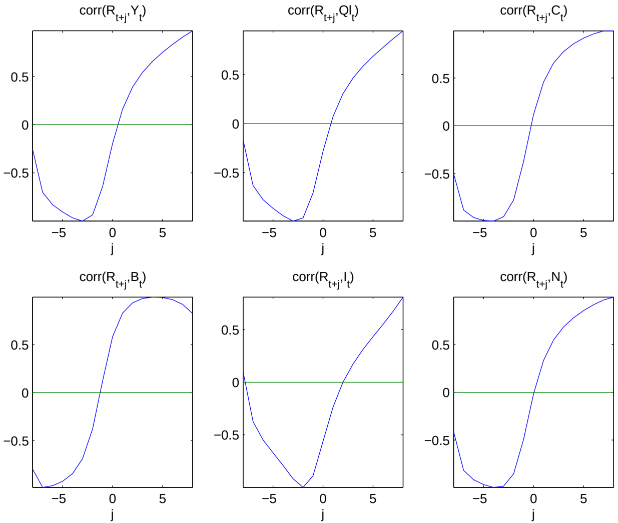

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  $\omega < 0.5$ vs $\omega > 0.5$
- We use same US 1975-2010 dataset as LWZ (2013):
  consumption, investment, land price, hours, debt, (inverse of) investment price

Estimated Parameters

- Liu-Wang-Zha (2013) with ω estimated:

More

parameters	prior			posterior			
	distribution	mean	s.d.	mode	mean	low	high
ω	beta	0.167	0.1179	**0.5**	0.4975	0.4956	0.5
ρ_a	beta	0.333	0.2357	0.9098	0.9004	0.8667	0.9367
ρ_φ	beta	0.333	0.2357	0.9997	0.9994	0.9988	1
σ_a	inv. gamma	0.01	∞	0.095	0.1358	0.0552	0.2231
σ_φ	inv. gamma	0.01	∞	0.0459	0.0488	0.0419	0.0561

- Data pushes towards highest possible value for ω (that is, 0.5)

Estimated Parameters Ctnd

- Indeterminate model: More

parameters	prior			posterior			
	distribution	mean	s.d.	mode	mean	low	high
ρ_a	beta	0.333	0.2357	**0.0215**	0.2681	0	0.5535
ρ_φ	beta	0.333	0.2357	0.9992	0.9986	0.9975	0.9999
σ_a	inv. gamma	0.01	∞	**0.0033**	0.008	0.0012	0.0159
σ_φ	inv. gamma	0.01	∞	0.0468	0.05	0.0412	0.0583
σ_{sun}	inv. gamma	0.01	∞	**0.0099**	0.01	0.0075	0.0126

- Patience shock has much smaller variance, sunspot shock has significant variance

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σ_{sun}	inv. gamma	0.01	∞	**0.0099**	0.01	0.0075	0.0126

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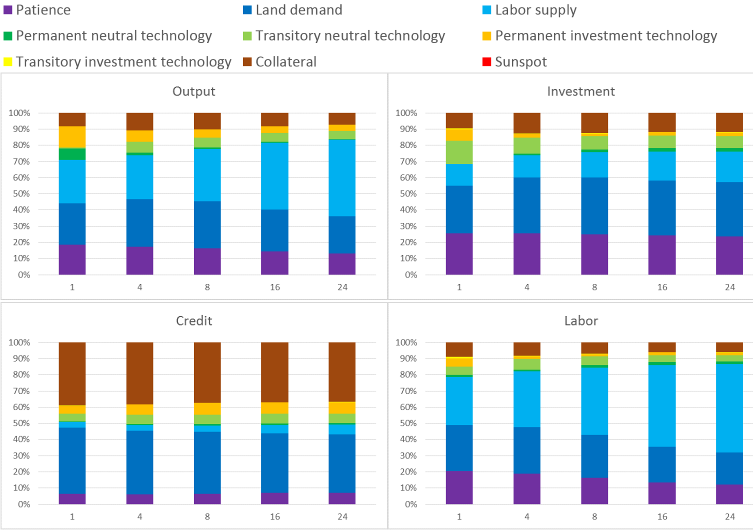
- Note that ω not identified in indeterminate model

Variance Decomposition

- Liu-Wang-Zha (2013) with ω estimated: More



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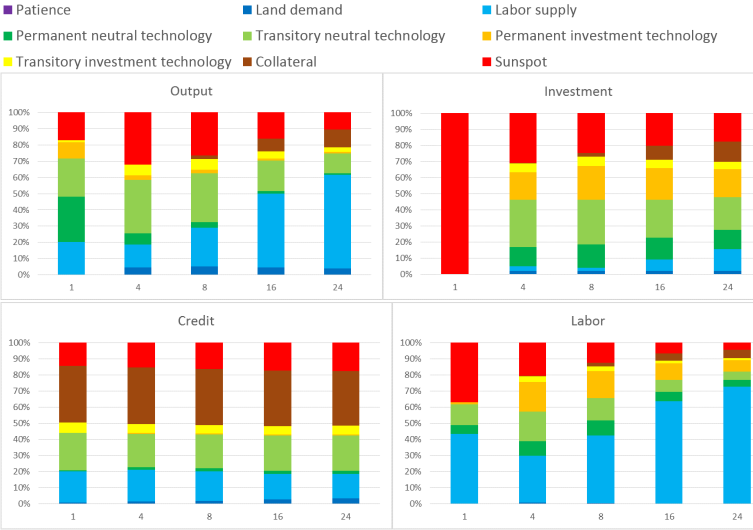

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- Land price volatility entirely driven by land demand shocks (in both models)
- Land demand shocks explain volatility of land price and interest rate only in sunspot economy

Model Fit

- Sunspot model dominates LWZ (determinate) model:

	LWZ	Hybrid LWZ	Sunspot	Hybrid Sunspot
Log marg. data density	2354.75	2359.84	2468.28	2468.59
Model posterior prob.	10^{-50}	10^{-48}	**0.42**	**0.58**

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- Pure and hybrid sunspot models not discriminated

Conclusion

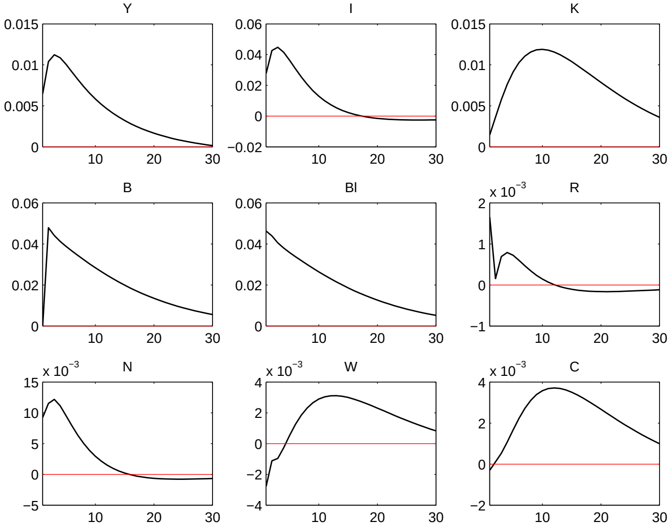
- We study versions of standard models with collateral-constrained borrowing
- We show that secured credit generates financial instability
- Business cycles driven by animal spirits pervasive under variable-rate loan contracts
- Estimation on US data 1975-2010 favors sunspot model
- Land demand shock explains entirely land price volatility

Conclusion Ctnd

- Results could be relevant for household debt
- First-order effects on monetary policy transmission
- Interbank loan market (secured + variable-rate)
- Learnability of sunspot equilibria

Impulse Responses

- land demand shock in fixed-rate (det.) economy:



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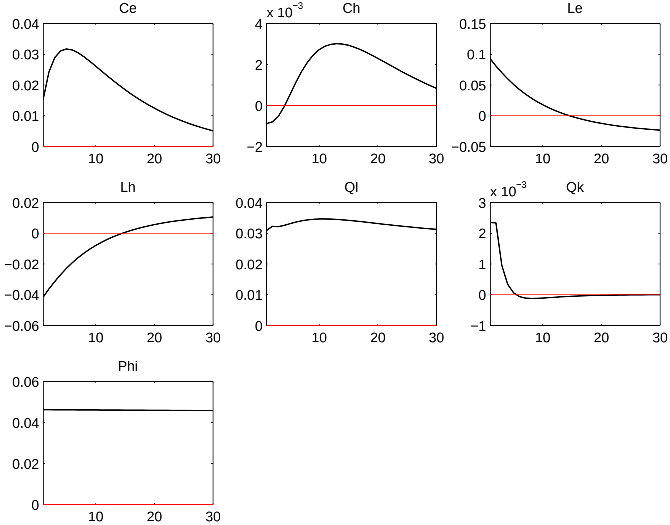

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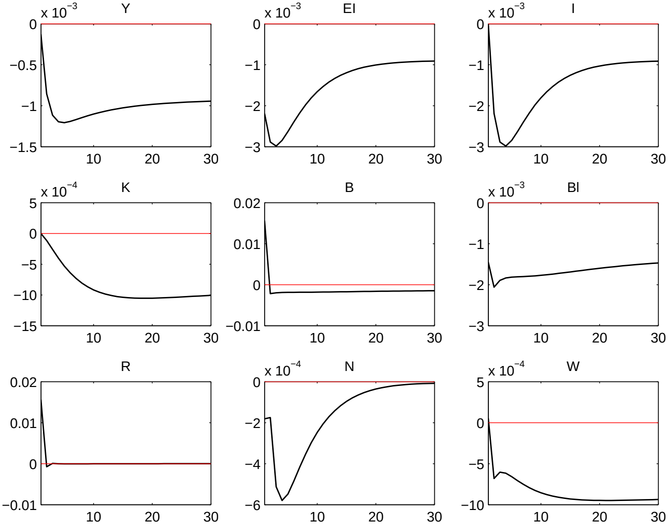

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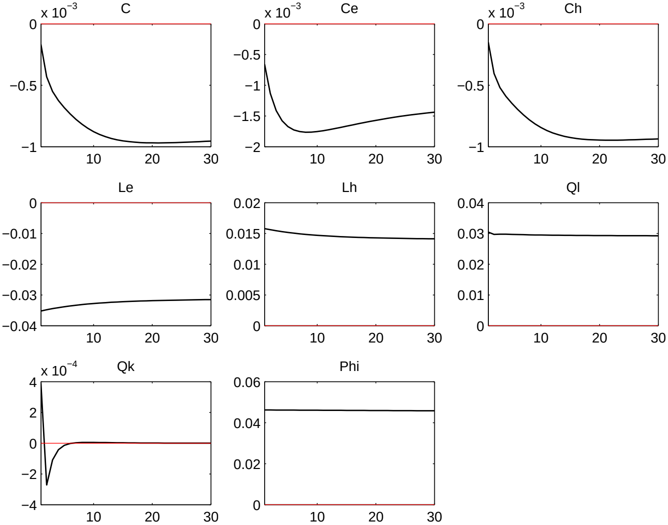
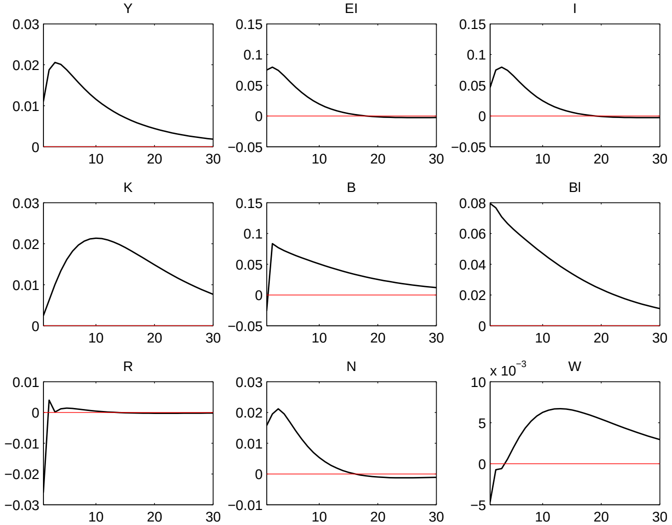


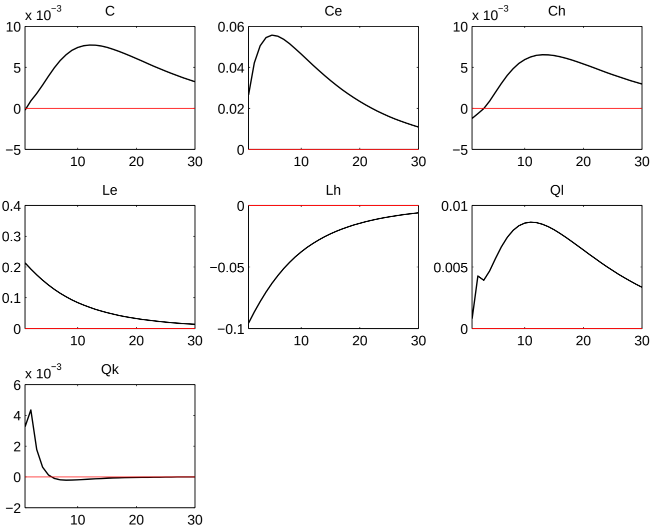
Impulse Responses Ctnd

- investment sunspot shock in variable-rate (indet.) economy:



Impulse Responses Ctnd

- investment sunspot shock in variable-rate (indet.) economy:



Estimated Parameters

parameters	prior			posterior			
	distribution	mean	s.d.	mode	mean	low	high
ω	beta	0.167	0.1179	**0.5**	0.4975	0.4956	0.5
γ_h	beta	0.333	0.2357	0.5175	0.5217	0.4673	0.5777
γ_e	beta	0.333	0.2357	0.7688	0.7241	0.5641	0.879
Ω	gamma	2	2	0.1581	0.1692	0.129	0.2108
$100(g_\gamma - 1)$	gamma	0.618	0.453	0.4174	0.3987	0.2846	0.5081
$100(\lambda_q - 1)$	gamma	0.618	0.453	1.2188	1.2147	1.078	1.3453
ρ_a	beta	0.333	0.2357	0.9098	0.9004	0.8667	0.9367
ρ_z	beta	0.333	0.2357	0.3897	0.3965	0.2836	0.5115
ρ_{ν_z}	beta	0.333	0.2357	0.2751	0.3049	0.0923	0.5167
ρ_q	beta	0.333	0.2357	0.5378	0.5349	0.4287	0.6351
ρ_{ν_q}	beta	0.333	0.2357	0.3096	0.3493	0.0555	0.6162
ρ_φ	beta	0.333	0.2357	0.9997	0.9994	0.9988	1
ρ_ψ	beta	0.333	0.2357	0.9877	0.987	0.978	0.9968
ρ_θ	beta	0.333	0.2357	0.9809	0.982	0.9757	0.9884
σ_a	inv. gamma	0.01	∞	0.095	0.1358	0.0552	0.2231
σ_z	inv. gamma	0.01	∞	0.0047	0.0047	0.0038	0.0056
σ_{ν_z}	inv. gamma	0.01	∞	0.0038	0.0039	0.0032	0.0046
σ_q	inv. gamma	0.01	∞	0.0043	0.0044	0.0036	0.0052
σ_{ν_q}	inv. gamma	0.01	∞	0.0027	0.0028	0.0021	0.0035
σ_φ	inv. gamma	0.01	∞	0.0459	0.0488	0.0419	0.0561
σ_ψ	inv. gamma	0.01	∞	0.0076	0.0078	0.0068	0.0087
σ_θ	inv. gamma	0.01	∞	0.0117	0.0119	0.0106	0.0131

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Estimated Parameters Ctnd

parameters	prior			posterior			
	distribution	mean	s.d.	mode	mean	low	high
γ_h	beta	0.333	0.2357	0.4481	0.4492	0.3904	0.506
γ_e	beta	0.333	0.2357	0.9962	0.9109	0.7401	0.9999
Ω	gamma	2	2	0.0808	0.0839	0.063	0.1037
$100(g_\gamma - 1)$	gamma	0.618	0.453	0.2574	0.1887	0.0305	0.3413
$100(\lambda_q - 1)$	gamma	0.618	0.453	1.206	1.1902	1.0618	1.3082
ρ_a	beta	0.333	0.2357	0.0215	0.2681	0	0.5535
ρ_z	beta	0.333	0.2357	0.339	0.3452	0.2424	0.4452
ρ_{ν_z}	beta	0.333	0.2357	0	0.0521	0	0.1145
ρ_q	beta	0.333	0.2357	0.3202	0.3473	0.2551	0.4469
ρ_{ν_q}	beta	0.333	0.2357	0.3182	0.2484	0.0015	0.4651
ρ_φ	beta	0.333	0.2357	0.9992	0.9986	0.9975	0.9999
ρ_ψ	beta	0.333	0.2357	0.998	0.9955	0.9911	0.9997
ρ_θ	beta	0.333	0.2357	0.9895	0.9852	0.9788	0.9923
σ_a	inv. gamma	0.01	∞	0.0033	0.008	0.0012	0.0159
σ_z	inv. gamma	0.01	∞	0.0049	0.005	0.0043	0.0058
σ_{ν_z}	inv. gamma	0.01	∞	0.0031	0.0033	0.0028	0.0039
σ_q	inv. gamma	0.01	∞	0.0054	0.0053	0.0045	0.0061
σ_{ν_q}	inv. gamma	0.01	∞	0.0018	0.002	0.0013	0.0026
σ_φ	inv. gamma	0.01	∞	0.0468	0.05	0.0412	0.0583
σ_ψ	inv. gamma	0.01	∞	0.0074	0.0075	0.0066	0.0084
σ_θ	inv. gamma	0.01	∞	0.017	0.0169	0.0148	0.019
σ_{sun}	inv. gamma	0.01	∞	0.0099	0.01	0.0075	0.0126

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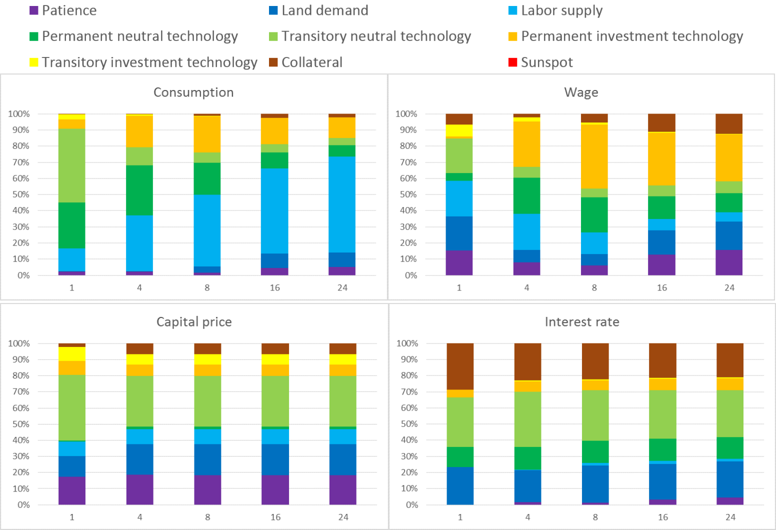
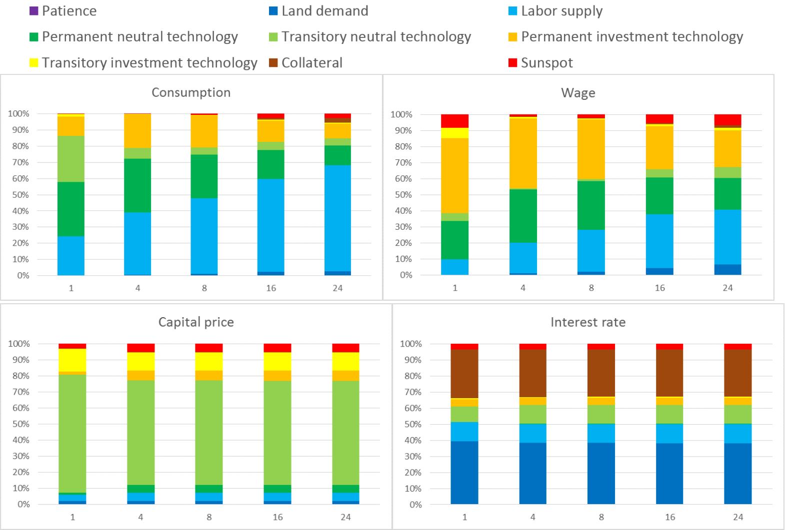
Variance Decomposition



Variance Decomposition Ctnd



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