Evaluating An Estimated New Keynesian Small Open Economy Model

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Practical Issues in DSGE Modelling at Central Banks

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Introduction

- The uncovered interest parity (UIP) condition has little empirical support
  - VAR evidence: Eichenbaum and Evans (*QJE*, 1995), Faust and Rogers (*JME*, 2003)
  - Forward discount puzzle: Fama (*JME*, 1984), Froot and Frankel (*QJE*, 1989)

- Open economy DSGE models - in which the UIP condition is typically embedded - are commonly critized for not being able to:

  1. Account for the VAR evidence (jump instead of hump-shaped response, see e.g. Adolfson et al. 2005a)

  2. Generate enough intrinsic persistence and volatility in the real exchange rates

- "Standard" specification of UIP condition in small open economy models (Adolfson et al., 2005a) features:

  – A risk premium which is a function of net foreign assets (endogenous) and exogenous disturbances

$$\widehat{R}_t - \widehat{R}_t^* = \mathsf{E}_t \Delta \widehat{S}_{t+1} - \widetilde{\phi} \widehat{a}_t + \widehat{\widetilde{\phi}}_t$$

  – If $\widetilde{\phi}$ small, this specification cannot generate a hump-shaped response in line with VAR evidence

  – In addition, this specification cannot account for the forward premium puzzle, i.e. that expected exchange rate depreciations are negatively correlated with the risk premium (Fama, 1984 and Duarte and Stockman, *JME*, 2005)

- We therefore consider a modification where the risk premium is negatively related to the expected depreciation of the nominal exchange rate

  – Modified risk premium

$$\Phi(a_t, \widehat{\widetilde{\phi}}_t, \tfrac{S_{t+1}}{S_{t-1}}) = \exp\left\{-\widetilde{\phi}_a a_t + \widehat{\widetilde{\phi}}_t - \widetilde{\phi}_s \left(\tfrac{S_{t+1}}{S_{t-1}} - 1\right)\right\}$$

  – Resulting modified UIP condition

$$\widehat{R}_t - \widehat{R}_t^* = \left(1 - \widetilde{\phi}_s\right) \mathrm{E}_t \Delta \widehat{S}_{t+1} - \widetilde{\phi}_s \Delta \widehat{S}_t - \widetilde{\phi}_a \widehat{a}_t + \widehat{\widetilde{\phi}}_t,$$

  or

$$\widehat{S}_t = \left(1 - \widetilde{\phi}_s\right) \mathrm{E}_t \widehat{S}_{t+1} + \widetilde{\phi}_s \Delta \widehat{S}_{t-1} - \left(\widehat{R}_t - \widehat{R}_t^*\right) - \widetilde{\phi}_a \widehat{a}_t + \widehat{\widetilde{\phi}}_t$$

- We explore the implications of the “standard” and the modified UIP conditions in a DSGE model for a small open economy
  - Overall empirical coherence
    - Bayesian posterior odds
    - Forecasting performance (pseudo out-of-sample)
    - Misspecification test
  - Implications for policy
    - Impulse responses
    - Actual forecasts

- The model we use is a variant of the model presented in Adolfson et al. (2005a)
  - Augment the benchmark closed economy DSGE model (Christiano, Eichenbaum and Evans, *JPE*, 2005) with open economy elements
    - Consumption and investment baskets consist of both domestic and foreign goods
    - Incomplete exchange rate pass-through by assuming sticky import and export price behavior
    - Stochastic unit-root technology shock (see e.g. Altig et al., 2003) => work with undetrended data
- Bayesian estimation following Smets and Wouters (2003)
  - Estimate a log-linearized version of the model using Bayesian techniques

- Use data for Sweden
  - Sweden went from a fixed exchange rate regime to an explicit inflation targeting regime in 1993
  - Allow for a discrete shift in the policy rule when estimating the model
  - Small open economy assumption: Adopt the approximation that foreign output, prices and interest rates are exogenous

Main findings

- Evidence for break in policy rule supported by the data (independently of UIP specification)

- Modified UIP condition strongly preferred to standard UIP specification in terms of Bayesian posterior odds

- Specification of UIP condition important for the model's forecasting performance

  - Model with modified UIP condition improves the interest rate, real exchange rate and CPI inflation forecasts substantially at longer horizons, worsens the RMSE for output and hours worked

- Forecasting performance of both DSGE specifications typically better than classical and Bayesian (Litterman prior) VARs

- Model with modified UIP condition induces hump-shaped impulse response functions and instrinsic persistence in the real exchange rate

- Applying Del Negro and Shorfheide (*IER*, 2004) and Del Negro et al. (2004) DSGE-VAR(λ) and DSGE-VECM(λ) analysis, we find that both variants of the DSGE are plagued by misspecification

  – Tightness of the DSGE prior is about the same in both variants of the model

Remainder of talk

- DSGE model overview
- Estimation results
- Identification
- Impulse responses
- Forecasting performance
- Misspecification analysis (DSGE-VAR/VECM(λ) analysis)
- Concluding remarks

DSGE model (closed economy aspects)

- Households
  - Utility from consumption, leisure and real cash balances
  - Habit persistence
  - Capital accumulation (variable capital utilization, investment adjustment costs)
  - Wage stickiness: Calvo, dynamic indexation

- Domestic goods firms
  - Cobb-Douglas (capital and labor)
  - Working capital
  - Price stickiness: Calvo, dynamic indexation

- Central bank (Taylor-type interest rate rule)

- Exogenous fiscal policy (VAR for taxes and gov. expenditures)

DSGE model (open economy aspects)

- Consumption and investment baskets
  - CES composites of domestic and imported goods

- Importing (consumption, investment) and exporting firms
  - Brand naming technology
  - Local currency price setting
  - Price stickiness: Calvo, dynamic indexation

  $\Rightarrow$ Incomplete pass-through

- Trade in foreign bonds with endogenous risk-premium

- Foreign economy exogenous (SVAR for π^*, y^*, R^*)

Estimated shocks

- Technology shocks ($\mu_{z,t}, \epsilon_t$), investment specific (Υ_t), asymmetric ($\tilde{z}_t^*$)

- Markup shocks ($\lambda_t^d, \lambda_t^{m,c}, \lambda_t^{m,i}, \lambda_t^x$) - i.i.d.

- Preference shocks (ζ_t^c, ζ_t^h)

- Risk premium shock ($\tilde{\phi}_t$)

- Monetary policy shocks ($\varepsilon_{R,t}$, $\bar{\pi}_t^c$)

Monetary policy

- Inflation targeting instrument rule (Taylor type)

$$
\begin{aligned}
\widehat{R}_t \;=\; & \rho_R \widehat{R}_{t-1} + (1-\rho_R)\left(\widehat{\bar{\pi}}_t^c + r_\pi\left(\hat{\pi}_{t-1}^c - \widehat{\bar{\pi}}_t^c\right) + r_y \hat{y}_{t-1} + r_x \hat{x}_{t-1}\right) \qquad \text{(ITpr)} \\
& + r_{\Delta\pi}\Delta\hat{\pi}_t^c + r_{\Delta y}\Delta\hat{y}_t + \varepsilon_{R,t}
\end{aligned}
$$

- But how describe policy prior to the adaption of inflation targeting regime?

  - Case 1: No break at all

  - Case 2: Fixed exchange rate rule

$$
\widehat{R}_t = r_s \Delta \hat{S}_t,\; r_s = 10^6
$$

- Case 3: Semi-fixed exchange rate rule, use structure in ITpr but apapt high prior for r_s

- Case 4: Let $\theta_{R,t}$ collect the policy parameters in period t in ITpr. Then

$$\theta_{R,t} = \begin{cases} \theta_{R,1} & \text{if} \quad t < 1993Q1 \\ \theta_{R,2} & \text{if} \quad t \geq 1993Q1 \end{cases}$$

- Model the regime shift as completely unexpected but once it has occurred it is expected to be permanent

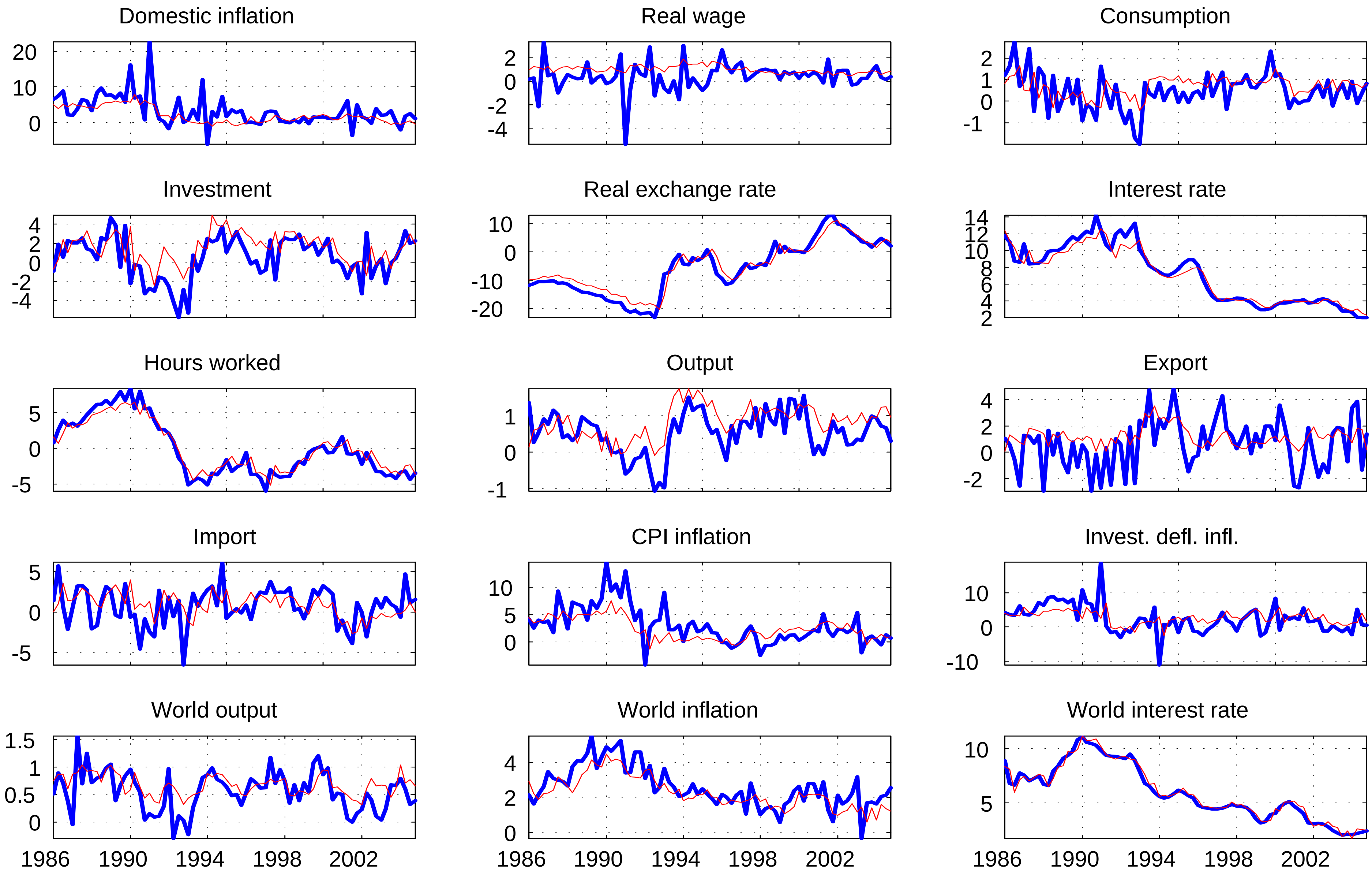
  - Exception: For Case 2 we allow the model to start adjust the states to the inflation targeting policy rule

Estimation results

- Estimate around 50 parameters
  - Price stickiness, technology growth, habit formation, policy rule, persistence and std of shocks, etc.
  - Calibrate most parameters pertaining to the steady state ("great ratios" etc.)
- Swedish data $1980Q1 - 2004Q4$
- Match large set of variables (facilitate identification of parameters)

$$\tilde{Y}_t = \begin{array}{l} [\pi_t^d \quad \Delta \ln(W_t/P_t) \quad \Delta \ln C_t \quad \Delta \ln I_t \quad \hat{x}_t \quad R_t \quad \hat{E}_t \quad \Delta \ln Y_t \ldots \\ \quad \Delta \ln \tilde{X}_t \quad \Delta \ln \tilde{M}_t \quad \pi_t^{def,c} \quad \pi_t^{def,i} \quad \Delta \ln Y_t^* \quad \pi_t^* \quad R_t^* \ ]'. \end{array}$$

- No detrending - work with raw data (except import and export)
- Plot of the data along with one sided Kalman estimates in figure


Domestic inflation
Real wage
Consumption
Investment
Real exchange rate
Interest rate
Hours worked
Output
Export
Import
CPI inflation
Invest. defl. infl.
World output
World inflation
World interest rate
1986
1990
1994
1998
2002

Bayesian inference

- Assign priors to all the parameters of the model and use the Kalman filter to compute the likelihood function
  - Model the dynamics of the unobserved state, and the mapping from the unobserved state variables to the observed variables
- Combine prior and likelihood to form the posterior
- Compute posterior distributions using Metropolis-Hastings algorithm
  - Marginal posterior densities of each parameter
  - Posterior distribution of impulse responses and variance decompositions etc.
- Compute posterior probability of the model itself
  - Examine the role of various frictions and shocks

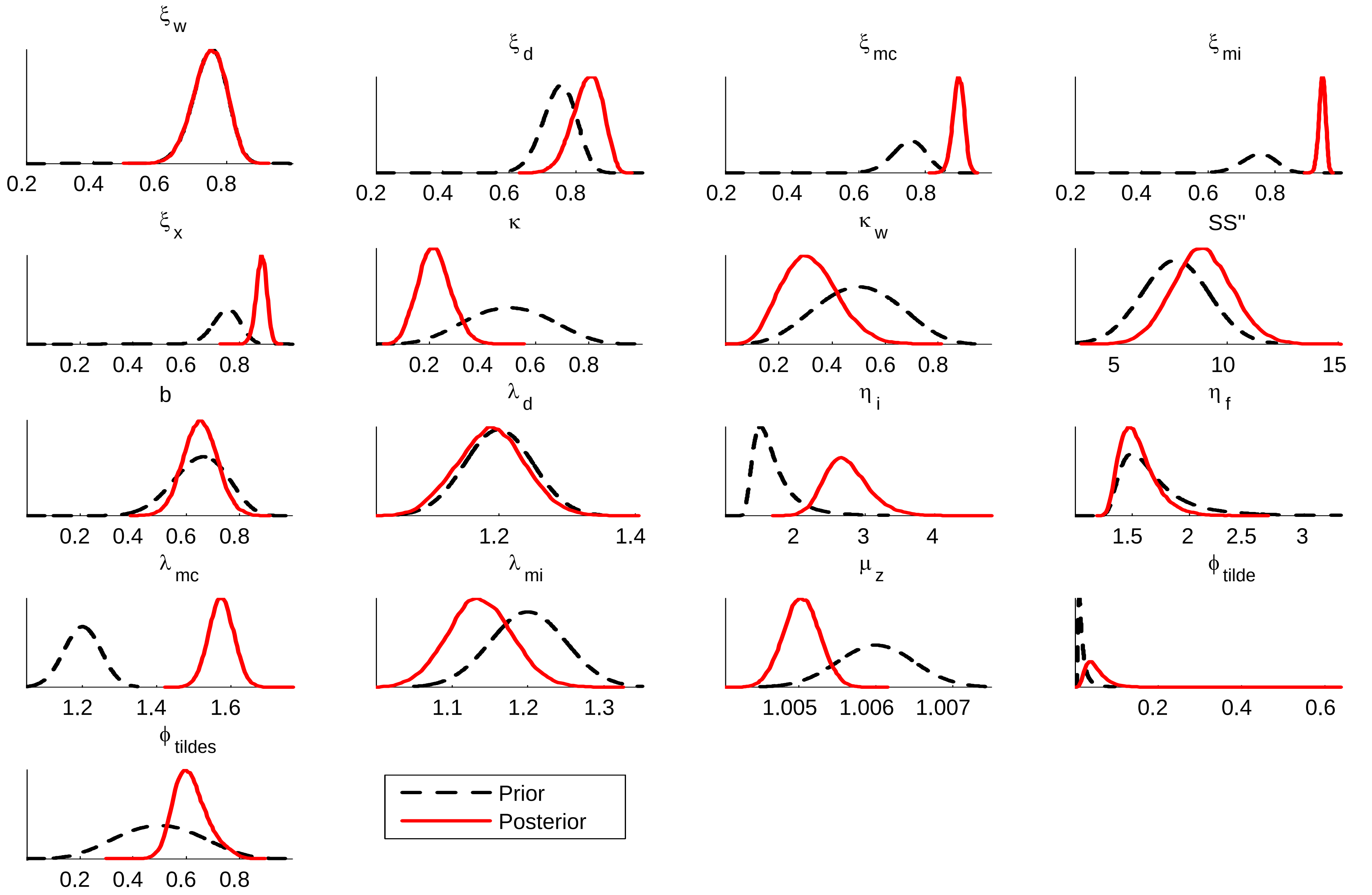
Bayesian model posterior probabilities

- Bayesian posterior odds in favor of a break (See Table 1)
  - Parameters similar except for standard deviation of policy shock (substantially lower)
- Bayesian posterior odds in favor of the modified UIP specification (See Table 1)
  - Deep parameters similar across all specifications
  - Risk premium shock estimates different

Table 1: Prior and posterior distributions

Parameter		Prior distribution			Posterior distributions									
					Instrument rule without policy break		Fixed exchange rate rule		Semi-fixed exchange rate rule		Instrument rule with policy break			
											UIP		Modified UIP	
		type	mean	std. dev. /df	med-ian	std.	med-ian	std.	med-ian	std.	med-ian	std.	med-ian	std.
Calvo wages	ξ_w	beta	0.750	0.050	0.751	0.047	0.518	0.041	0.669	0.046	0.743	0.049	0.752	0.049
Calvo domestic prices	ξ_d	beta	0.750	0.050	0.862	0.046	0.852	0.048	0.885	0.027	0.868	0.044	0.838	0.044
Calvo import cons. prices	$\xi_{m,c}$	beta	0.750	0.050	0.896	0.017	0.922	0.013	0.900	0.014	0.900	0.017	0.901	0.017
Calvo import inv. prices	$\xi_{m,i}$	beta	0.750	0.050	0.946	0.010	0.948	0.008	0.943	0.007	0.946	0.010	0.944	0.010
Calvo export prices	ξ_x	beta	0.750	0.050	0.868	0.021	0.870	0.016	0.874	0.020	0.869	0.021	0.883	0.020
Indexation wages	κ_w	beta	0.500	0.150	0.290	0.098	0.238	0.086	0.287	0.098	0.292	0.100	0.313	0.103
Indexation prices	κ	beta	0.500	0.150	0.213	0.059	0.163	0.069	0.194	0.052	0.212	0.061	0.218	0.061
Markup domestic	λ_d	truncnormal	1.200	0.050	1.196	0.050	1.197	0.049	1.200	0.050	1.189	0.048	1.189	0.049
Markup imported cons.	$\lambda_{m,c}$	truncnormal	1.200	0.050	1.585	0.033	1.782	0.031	1.580	0.032	1.578	0.033	1.574	0.034
Markup.imported invest.	$\lambda_{m,i}$	truncnormal	1.200	0.050	1.138	0.043	1.206	0.040	1.168	0.041	1.138	0.041	1.136	0.042
Investment adj. cost	$\tilde{S}''$	normal	7.694	1.500	8.593	1.306	9.193	1.290	9.335	1.337	8.706	1.307	8.884	1.318
Habit formation	b	beta	0.650	0.100	0.663	0.061	0.763	0.044	0.793	0.051	0.676	0.066	0.653	0.064
Subst. elasticity invest.	η_i	invgamma	1.500	4	2.741	0.322	2.263	0.186	2.586	0.258	2.727	0.316	2.713	0.324
Subst. elasticity foreign	η_f	invgamma	1.500	4	1.633	0.216	1.540	0.152	1.457	0.121	1.613	0.205	1.525	0.158
Technology growth	μ_z	truncnormal	1.006	0.0005	1.005	0.000	1.006	0.000	1.006	0.000	1.005	0.000	1.005	0.000
Risk premium	$\tilde{\phi}$	invgamma	0.010	2	0.033	0.018	0.035	0.015	0.034	0.015	0.031	0.017	0.046	0.029
UIP modification	$\tilde{\phi}_s$	beta	0.500	0.15									0.611	0.063
Unit root tech. shock	ρ_{μ_z}	beta	0.850	0.100	0.827	0.073	0.823	0.075	0.811	0.075	0.831	0.075	0.844	0.075
Stationary tech. shock	ρ_{ε}	beta	0.850	0.100	0.932	0.041	0.986	0.006	0.991	0.006	0.942	0.039	0.932	0.046
Invest. spec. tech shock	ρ_{Υ}	beta	0.850	0.100	0.691	0.081	0.737	0.055	0.769	0.056	0.726	0.075	0.735	0.092
Asymmetric tech. shock	$\rho_{\tilde{z}*}$	beta	0.850	0.100	0.961	0.011	0.946	0.057	0.918	0.045	0.960	0.011	0.962	0.011
Consumption pref. shock	ρ_{ζ_c}	beta	0.850	0.100	0.601	0.133	0.495	0.107	0.554	0.102	0.630	0.133	0.744	0.133
Labour supply shock	ρ_{ζ_h}	beta	0.850	0.100	0.248	0.061	0.204	0.054	0.236	0.059	0.251	0.063	0.262	0.066
Risk premium shock	$\rho_{\tilde{\phi}}$	beta	0.850	0.100	0.932	0.025	0.954	0.013	0.959	0.016	0.929	0.026	0.679	0.101
Unit root tech. shock	σ_z	invgamma	0.200	2	0.133	0.027	0.142	0.028	0.138	0.027	0.133	0.026	0.133	0.027
Stationary tech. shock	σ_{ε}	invgamma	0.700	2	0.672	0.083	0.675	0.086	0.698	0.089	0.665	0.082	0.665	0.085
Invest. spec. tech. shock	σ_{Υ}	invgamma	0.200	2	0.410	0.067	0.419	0.059	0.417	0.059	0.389	0.063	0.381	0.072
Asymmetric tech. shock	$\sigma_{\tilde{z}*}$	invgamma	0.400	2	0.190	0.027	0.194	0.029	0.194	0.029	0.192	0.028	0.189	0.028
Consumption pref. shock	σ_{ζ_c}	invgamma	0.200	2	0.292	0.048	0.278	0.041	0.266	0.041	0.287	0.049	0.246	0.048
Labour supply shock	σ_{ζ_h}	invgamma	1.000	2	0.382	0.039	0.370	0.035	0.379	0.038	0.381	0.039	0.383	0.040
Risk premium shock	$\sigma_{\tilde{\phi}}$	invgamma	0.050	2	0.372	0.079	0.319	0.035	0.297	0.036	0.376	0.079	0.805	0.221
Domestic markup shock	σ_{λ}	invgamma	1.000	2	0.774	0.078	0.796	0.075	0.753	0.071	0.769	0.078	0.799	0.084
Imp. cons. markup shock	$\sigma_{\lambda_{m,c}}$	invgamma	1.000	2	1.168	0.125	1.536	0.163	1.190	0.131	1.168	0.127	1.135	0.120
Imp. invest. markup shock	$\sigma_{\lambda_{m,i}}$	invgamma	1.000	2	1.176	0.133	1.496	0.145	1.190	0.128	1.164	0.132	1.142	0.128
Export markup shock	σ_{λ_x}	invgamma	1.000	2	0.994	0.156	1.196	0.164	1.130	0.151	1.004	0.152	1.026	0.144
Interest rate smoothing	$\rho_{R,1}$	beta	0.800	0.050	0.909	0.016			0.827	0.039	0.879	0.022	0.883	0.025
Inflation response	$r_{\pi,1}$	normal	1.700	0.100	1.664	0.099			1.710	0.098	1.679	0.100	1.679	0.100
Diff. infl response	$r_{\Delta\pi,1}$	normal	0.300	0.050	0.095	0.030			0.288	0.048	0.133	0.049	0.156	0.056
Real exch. rate response	$r_{x,1}$	normal	0.000	0.050	0.046	0.027					0.039	0.030	0.018	0.027
Nominal exch. response	r_S	normal	100	10			10^6	calib.	2.0	0.8				
Output response	$r_{y,1}$	normal	0.250	0.050	0.129	0.046			0.216	0.051	0.113	0.044	0.138	0.048
Diff. output response	$r_{\Delta y,1}$	normal	0.125	0.050	0.152	0.036			0.142	0.050	0.127	0.041	0.120	0.046
Monetary policy shock	$\sigma_{R,1}$	invgamma	0.150	2	0.249	0.024			2.335	0.778	0.398	0.060	0.398	0.066
Inflation target shock	$\sigma_{\bar{\pi}^c,1}$	invgamma	0.050	2	0.116	0.041			0.083	0.054	0.148	0.067	0.248	0.085
Interest rate smoothing	$\rho_{R,2}$	beta	0.800	0.050			0.884	0.018	0.864	0.021	0.896	0.018	0.874	0.022
Inflation response	$r_{\pi,2}$	normal	1.700	0.100			1.725	0.090	1.747	0.089	1.709	0.099	1.718	0.097
Diff. infl response	$r_{\Delta\pi,2}$	normal	0.300	0.050			0.127	0.023	0.143	0.025	0.104	0.026	0.120	0.027
Real exch. rate response	$r_{x,2}$	normal	0.000	0.050			0.022	0.019	-0.001	0.003	0.038	0.026	-0.023	0.020
Output response	$r_{y,2}$	normal	0.250	0.050			0.269	0.040	0.274	0.039	0.107	0.041	0.106	0.041
Diff. output response	$r_{\Delta y,2}$	normal	0.125	0.050			0.099	0.031	0.107	0.030	0.104	0.030	0.105	0.030
Monetary policy shock	$\sigma_{R,2}$	invgamma	0.150	2			0.102	0.013	0.094	0.011	0.104	0.013	0.103	0.013
Inflation target shock	$\sigma_{\bar{\pi}^c,2}$	invgamma	0.050	2			0.065	0.030	0.069	0.035	0.080	0.038	0.077	0.038
Log marginal likelihood					-2285.8		-2636.72		-2348.24		-2268.33		-2252.57	

- Data is generally informative about the parameters, i.e. posterior (solid red) distributions differ from the prior (black dashed) distributions
  - Results for model with standard UIP and no break in policy rules in figures



ξ_w
0.2 0.4 0.6 0.8
ξ_d
0.2 0.4 0.6 0.8
ξ_{mc}
0.2 0.4 0.6 0.8
ξ_{mi}
0.2 0.4 0.6 0.8
ξ_x
0.2 0.4 0.6 0.8
κ
0.2 0.4 0.6 0.8
κ_w
0.2 0.4 0.6 0.8
SS''
5 10 15
b
0.2 0.4 0.6 0.8
λ_d
1.2 1.4
η_i
2 3 4
η_f
1.5 2 2.5 3
λ_{mc}
1.2 1.4 1.6
λ_{mi}
1.1 1.2 1.3
μ_z
1.005 1.006 1.007
ϕ_{tilde}
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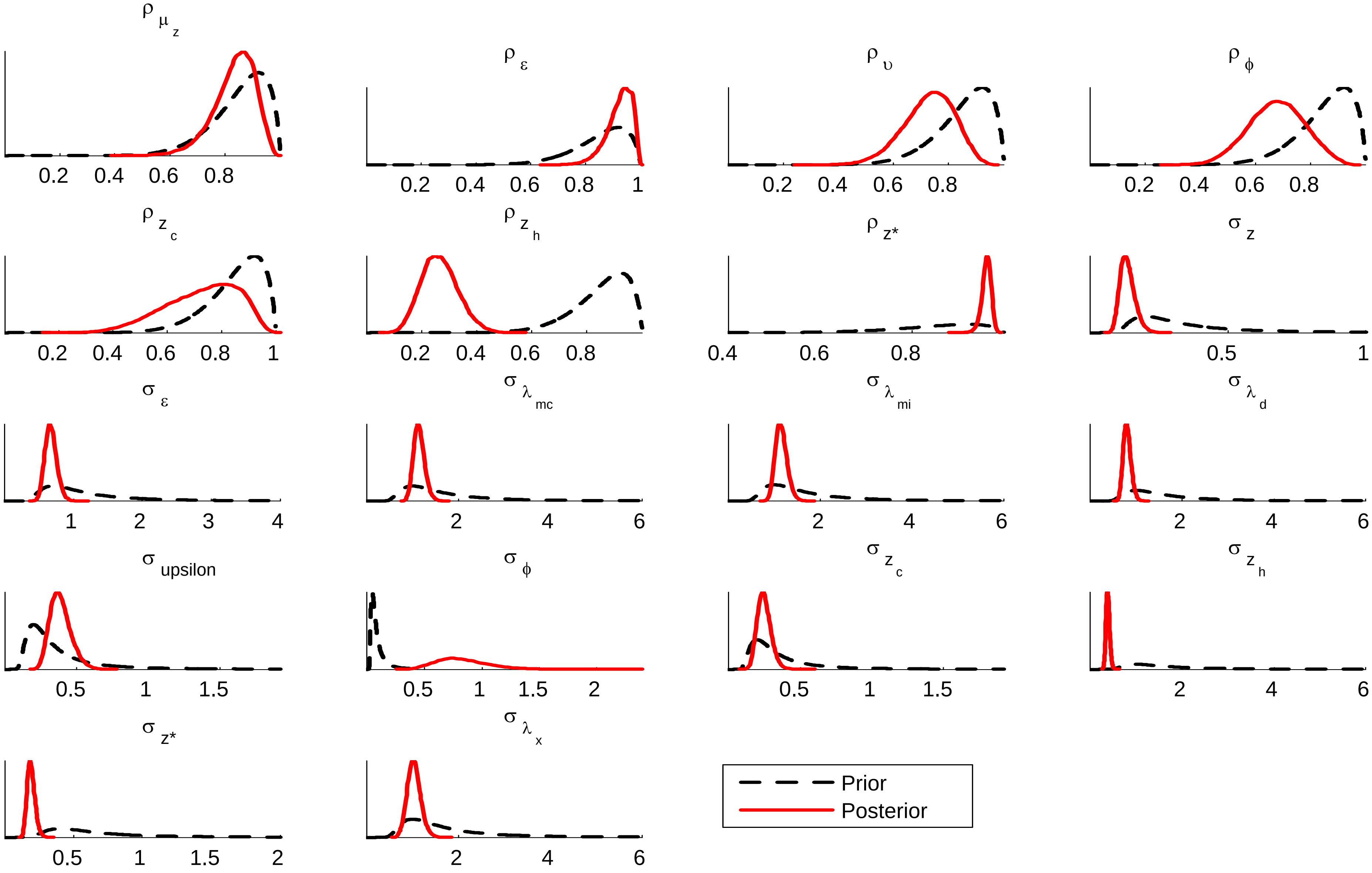
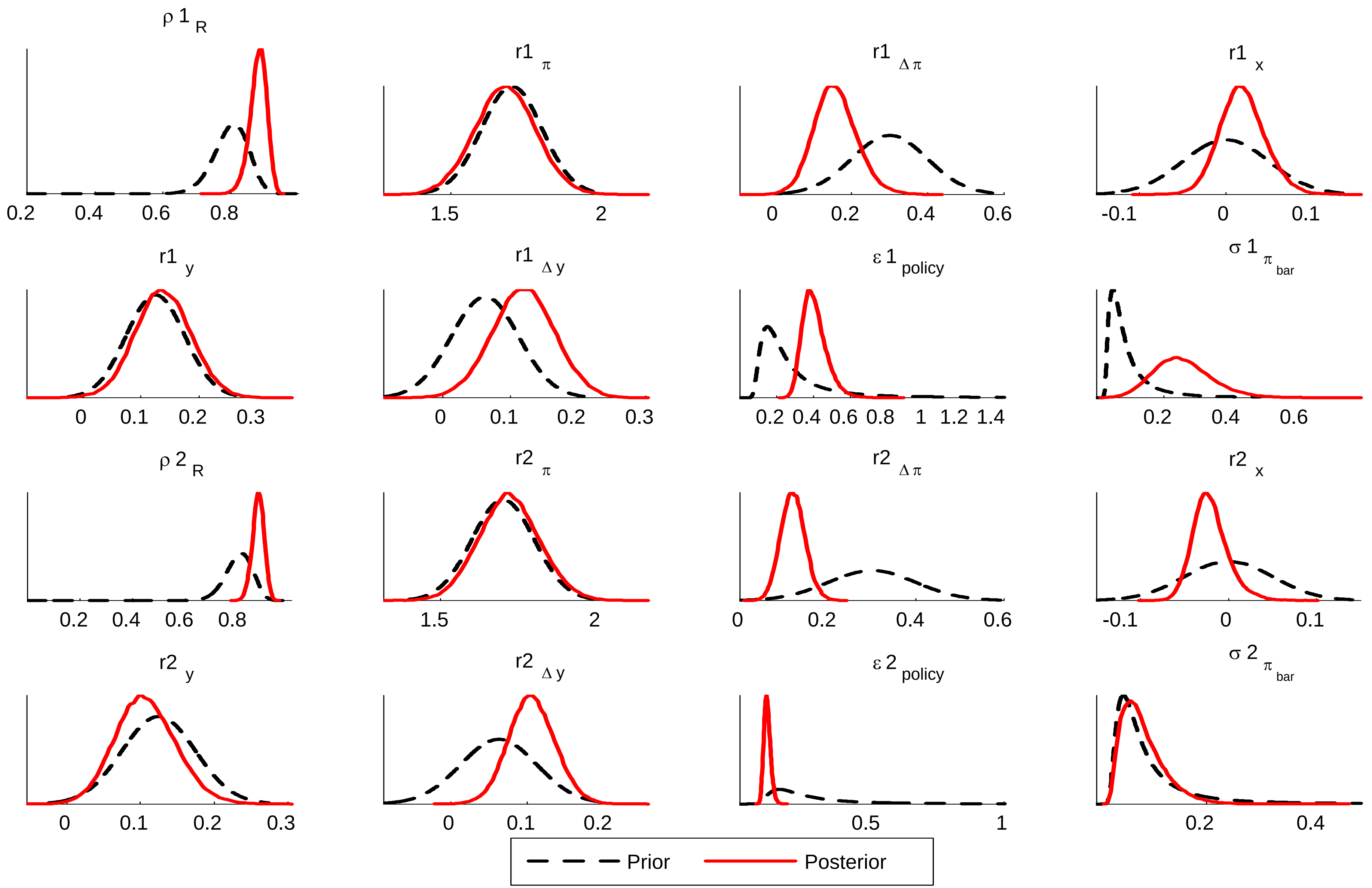
ϕ_{tildes}
0.2 0.4 0.6 0.8
Prior
Posterior


ρ μ z
ρ ε
ρ υ
ρ ϕ
0.2 0.4 0.6 0.8
0.2 0.4 0.6 0.8 1
ρ z c
ρ z h
ρ z*
σ z
0.2 0.4 0.6 0.8 1
0.4 0.6 0.8
0.5 1
σ ε
σ λ mc
σ λ mi
σ λ d
1 2 3 4
2 4 6
σ upsilon
σ ϕ
σ z c
σ z h
0.5 1 1.5
0.5 1 1.5 2
σ z*
σ λ x
0.5 1 1.5 2
Prior
Posterior


ρ 1 R
0.2 0.4 0.6 0.8
r1 π
1.5 2
r1 Δ π
0 0.2 0.4 0.6
r1 x
-0.1 0 0.1
r1 y
0 0.1 0.2 0.3
r1 Δ y
0 0.1 0.2 0.3
ε 1 policy
0.2 0.4 0.6 0.8 1 1.2 1.4
σ 1 π bar
0.2 0.4 0.6
ρ 2 R
0.2 0.4 0.6 0.8
r2 π
1.5 2
r2 Δ π
0 0.2 0.4 0.6
r2 x
-0.1 0 0.1
r2 y
0 0.1 0.2 0.3
r2 Δ y
0 0.1 0.2
ε 2 policy
0.5 1
σ 2 π bar
0.2 0.4
Prior
Posterior

Identification

- Are key model parameters well identified?
  - Consider the modified UIP condition

$$\widehat{S}_t = \left(1 - \widetilde{\phi}_s\right) \mathsf{E}_t \widehat{S}_{t+1} + \widetilde{\phi}_s \Delta \widehat{S}_{t-1} - \left(\widehat{R}_t - \widehat{R}_t^*\right) - \widetilde{\phi}_a \widehat{a}_t + \widehat{\widetilde{\phi}}_t,$$

  - Can we identify $\widetilde{\phi}_s$ while allowing for a correlated risk-premium shock ($\widehat{\widetilde{\phi}}_t$) simultaneously?

- Plot of log-likelihood surface in the $\left(\widetilde{\phi}_s, \rho_{\widehat{\widetilde{\phi}}}\right)$-space.

Figure 6a: Log likelihood contours in the $\{\widetilde{\phi}_s,\, \rho_\phi\}$-space, using all observable variables

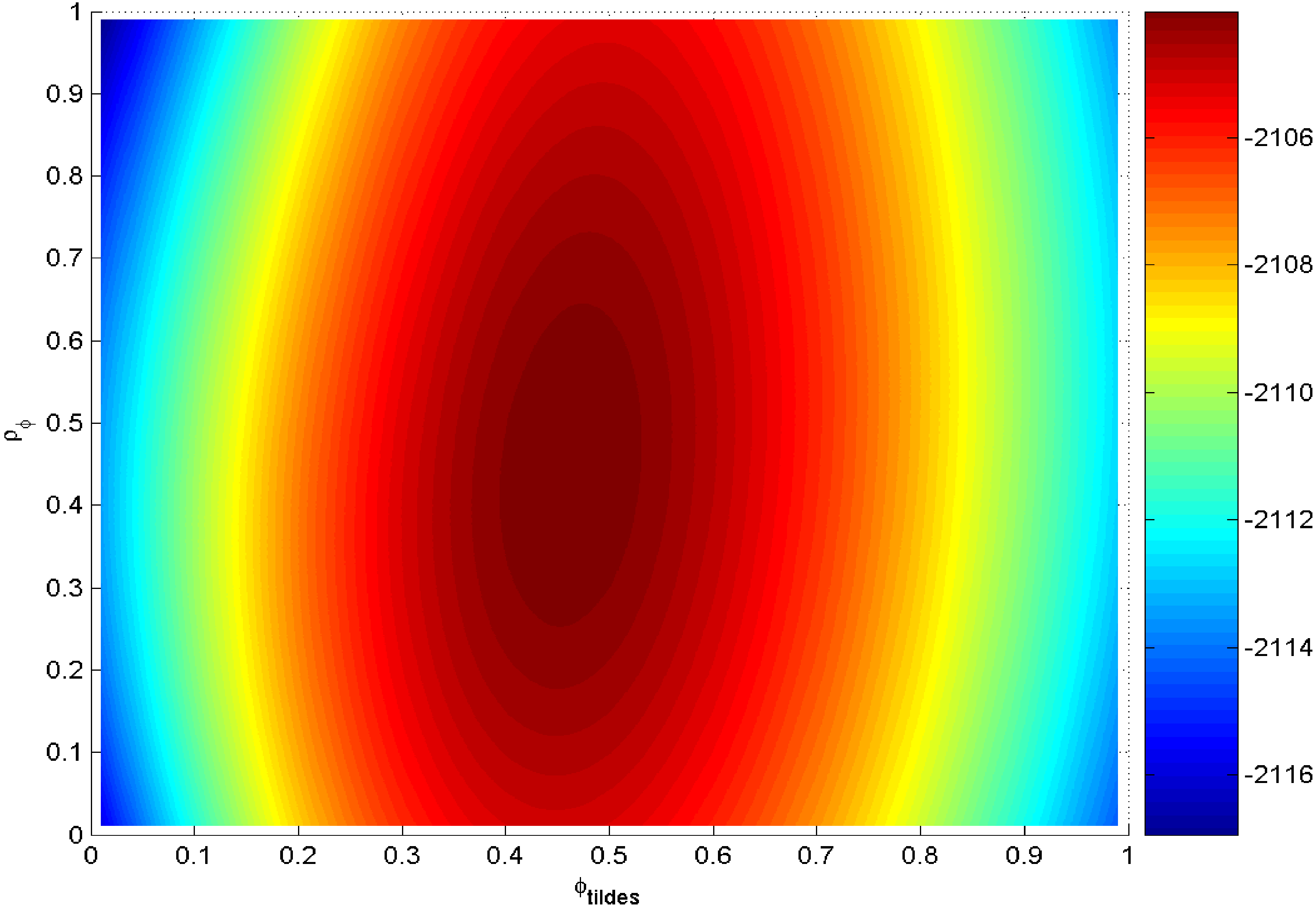
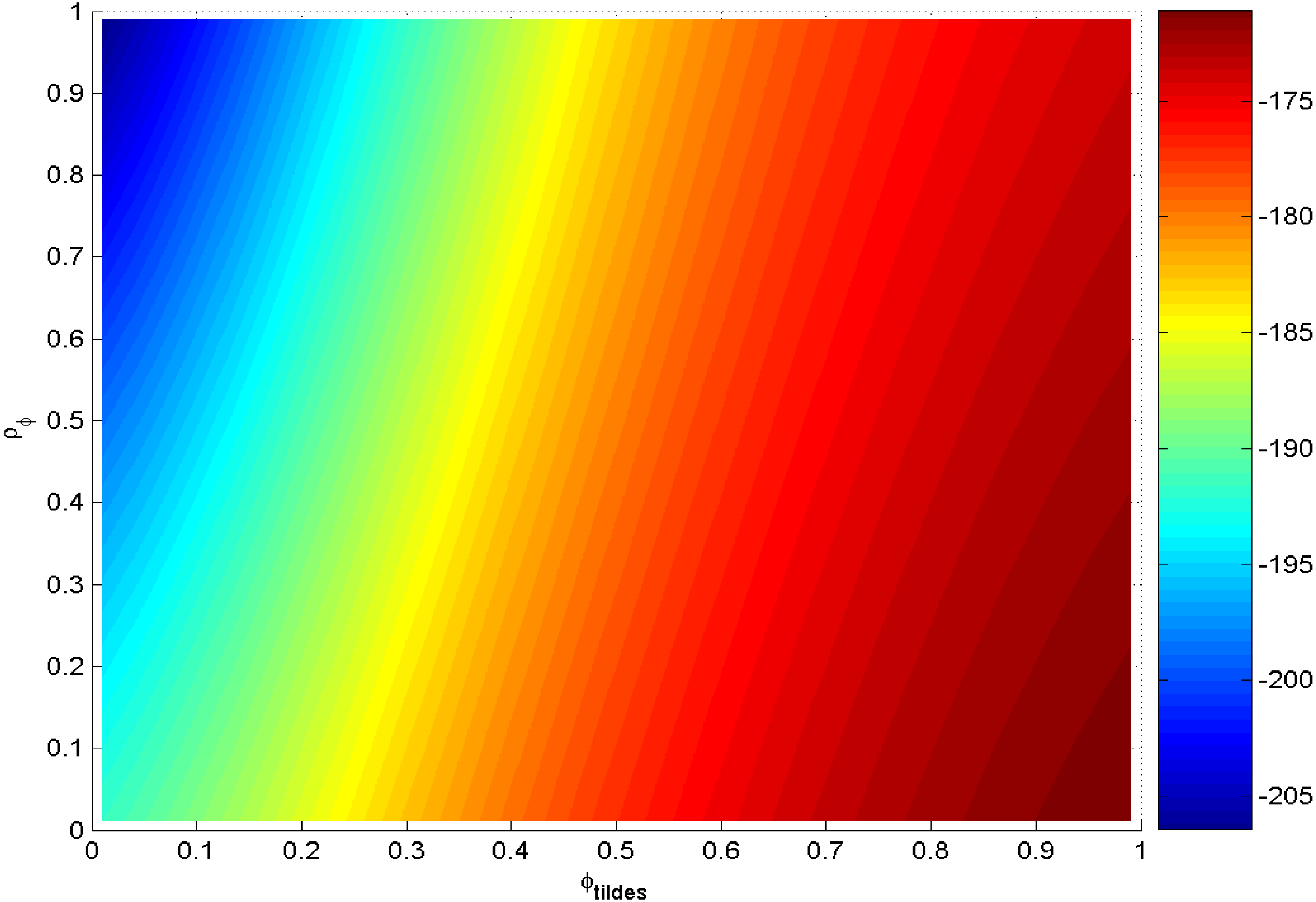


Figure 6b: Log likelihood contours in the $\{\widetilde{\phi}_s,\, \rho_\phi\}$-space, only using the real exchange rate



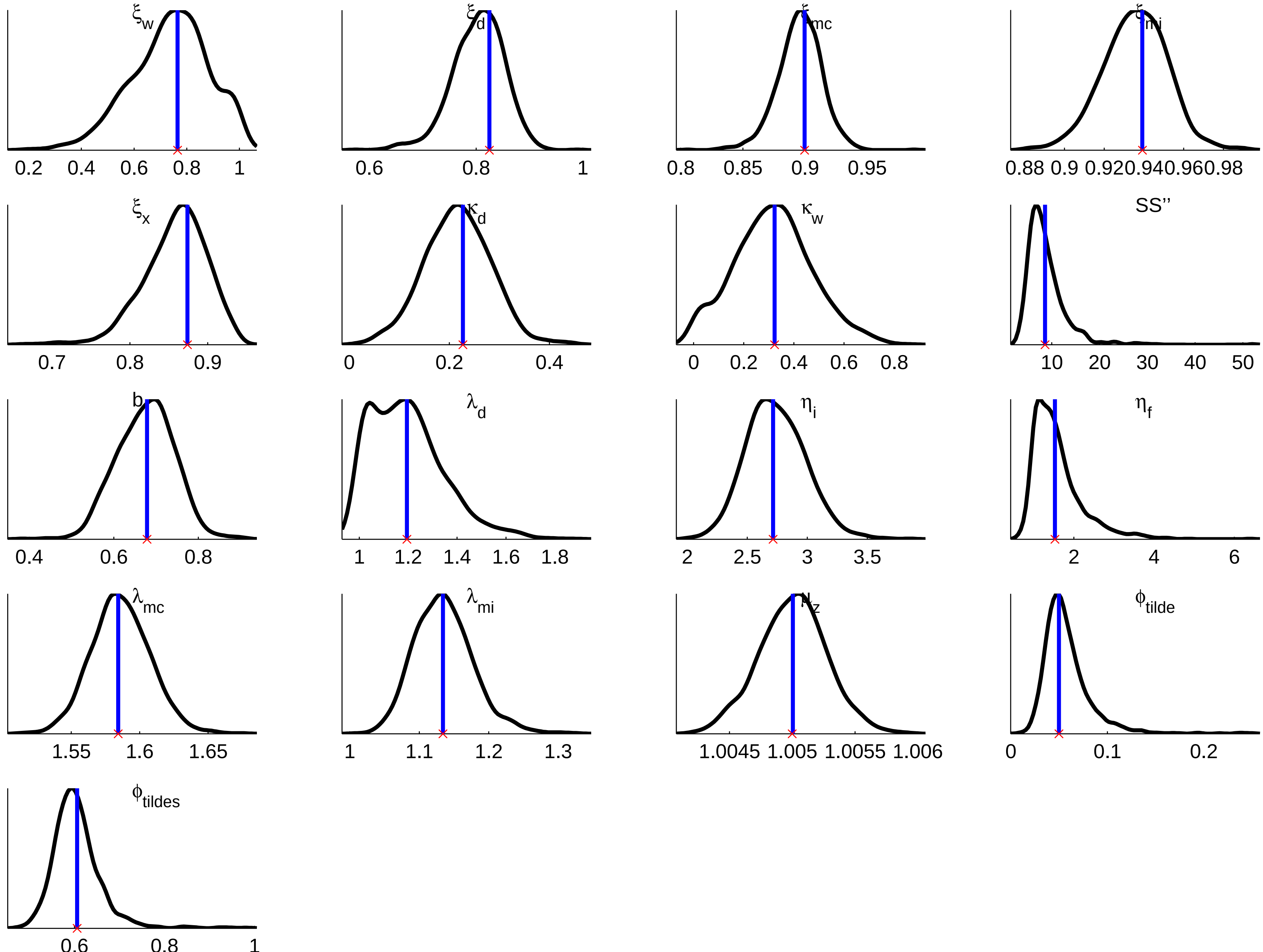
  - Both parameters well identified when all variables used to compute log-likelihood function

  - Corner solution when only real exchange rate used to compute log-likelihood function

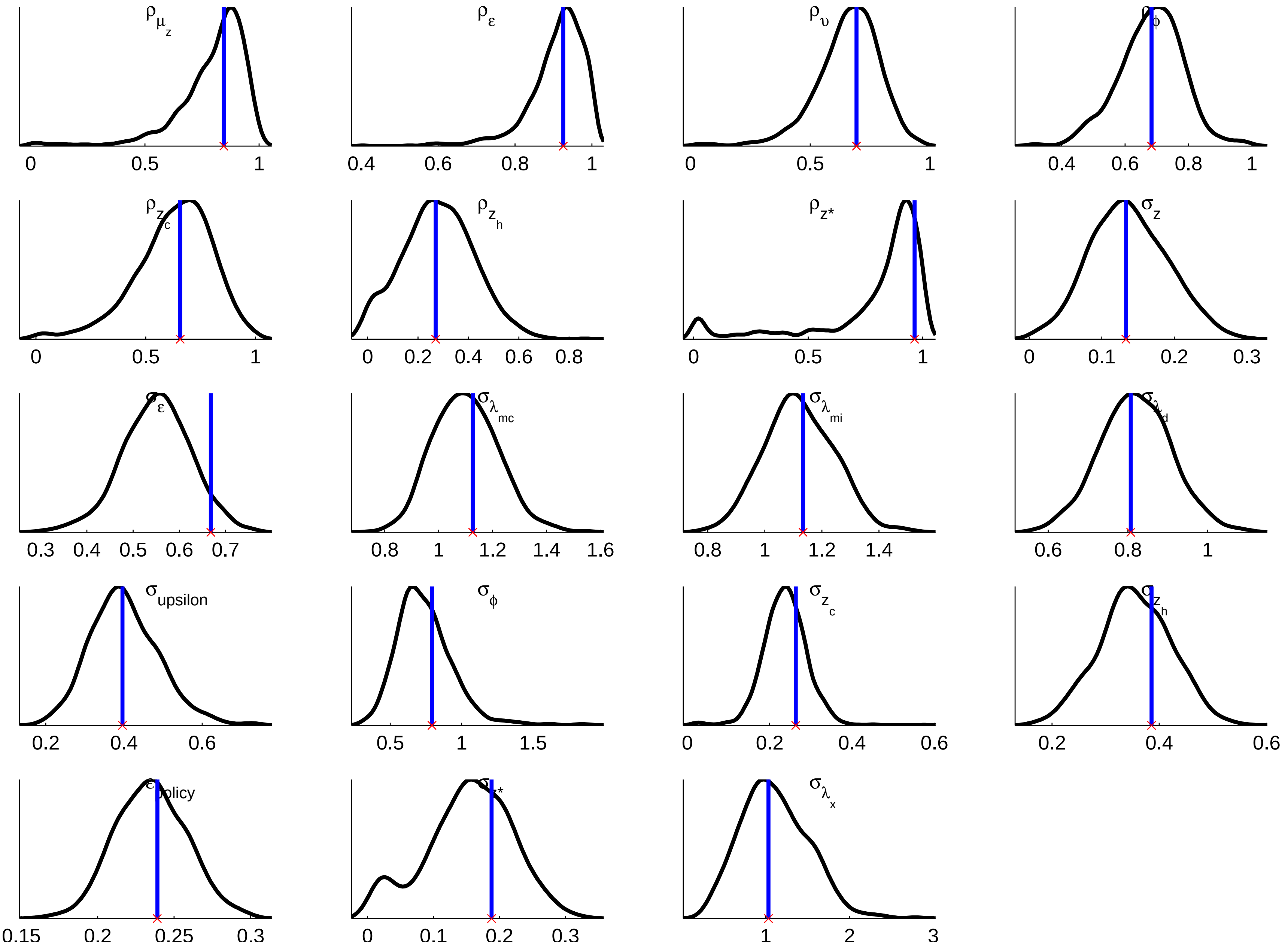
- Study small-sample properties of ML estimation on artificial samples from the model. Apply identical estimation procedure as on actual data. Preliminary results encouraging (Adolfson and Lindé, 2006, work in progress, time consuming)

  - Distribution of estimates located around the true parameters

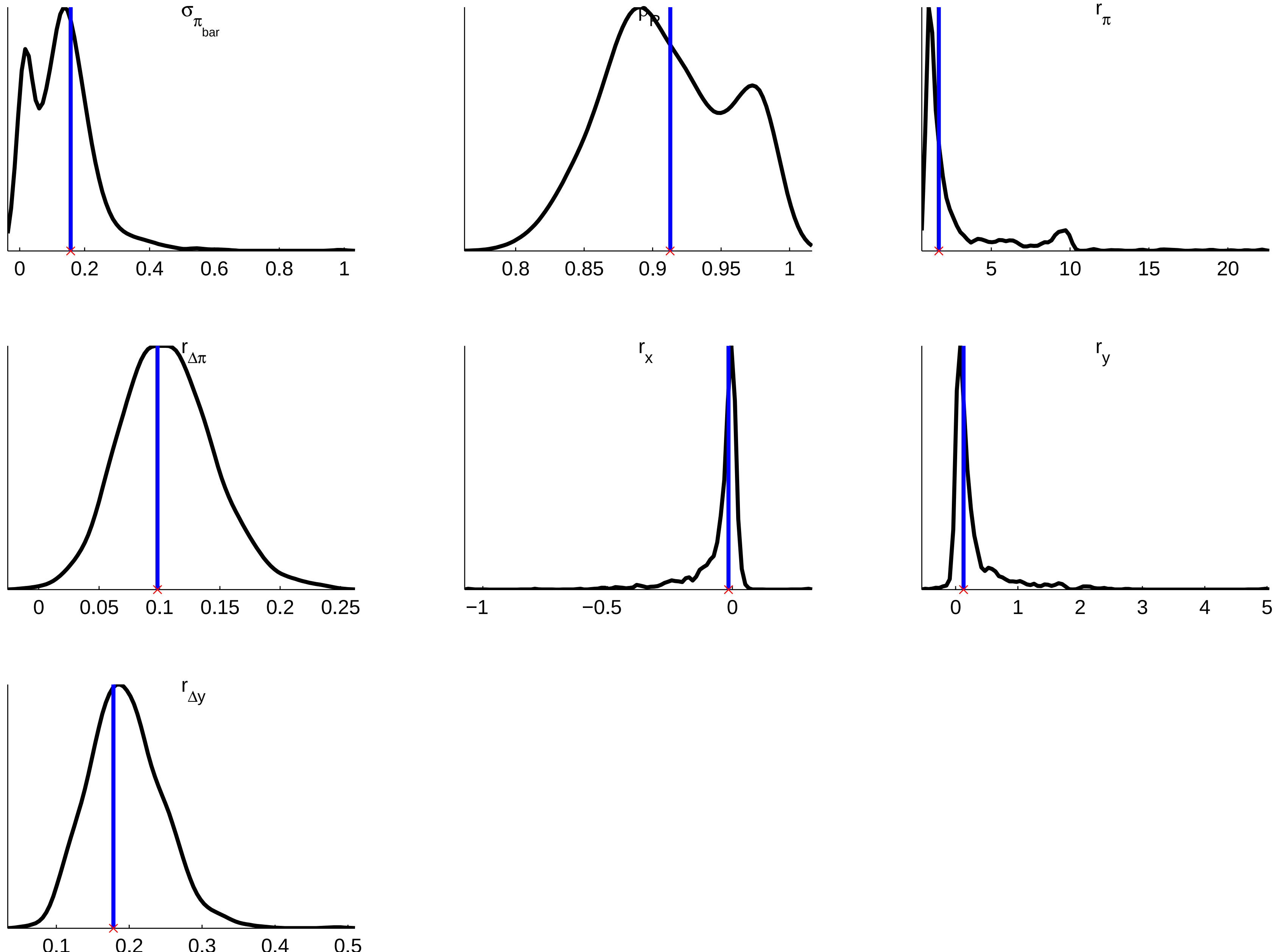
  - Convergence in distribution when sample size is increased



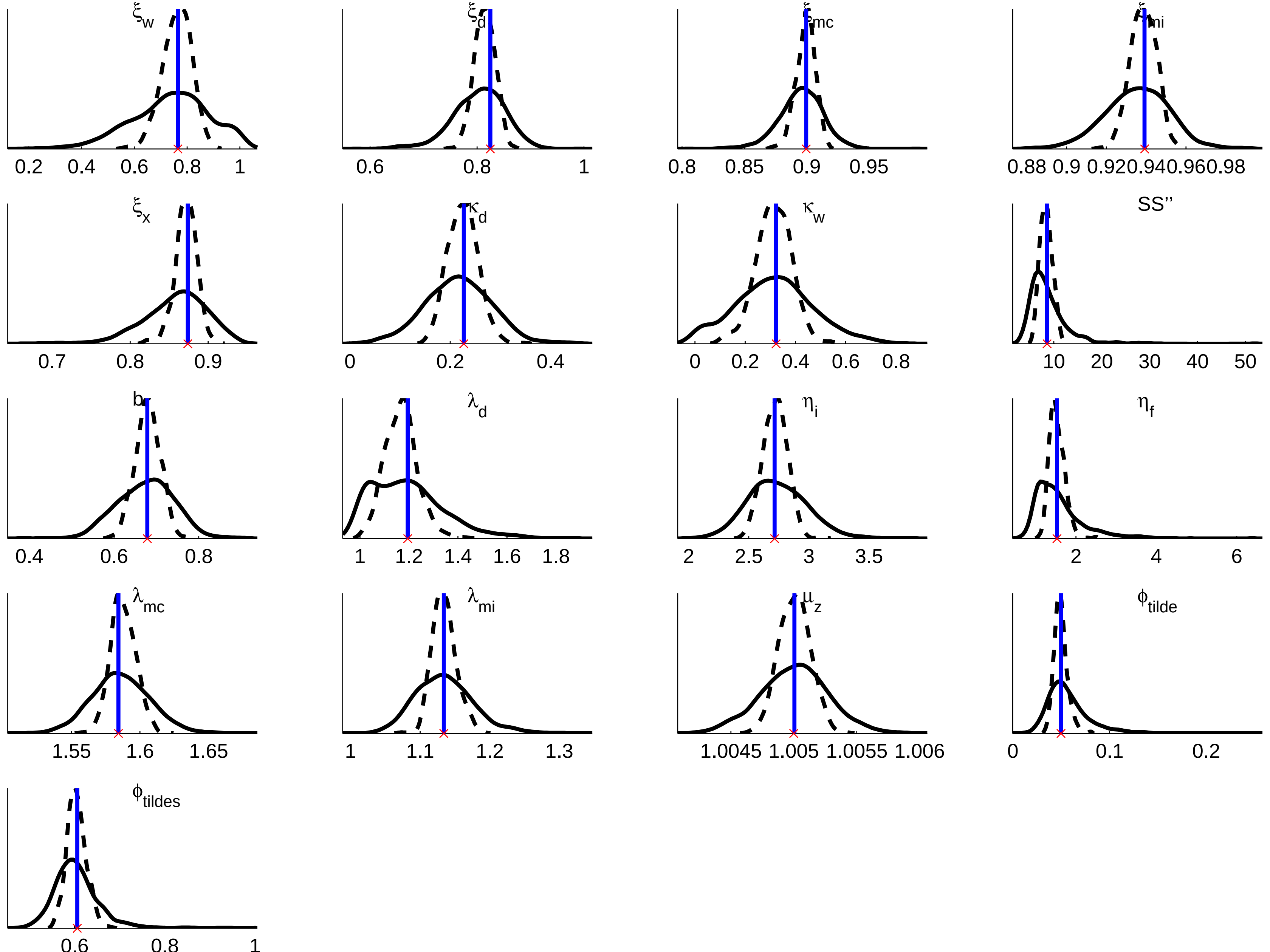
ξw
0.2 0.4 0.6 0.8 1
ξd
0.6 0.8 1
ξmc
0.8 0.85 0.9 0.95
ξmi
0.88 0.9 0.920.940.960.98
ξx
0.7 0.8 0.9
κd
0 0.2 0.4
κw
0 0.2 0.4 0.6 0.8
SS''
10 20 30 40 50
b
0.4 0.6 0.8
λd
1 1.2 1.4 1.6 1.8
ηi
2 2.5 3 3.5
ηf
2 4 6
λmc
1.55 1.6 1.65
λmi
1 1.1 1.2 1.3
μz
1.0045 1.005 1.0055 1.006
φtilde
0 0.1 0.2
φtildes
0.6 0.8 1



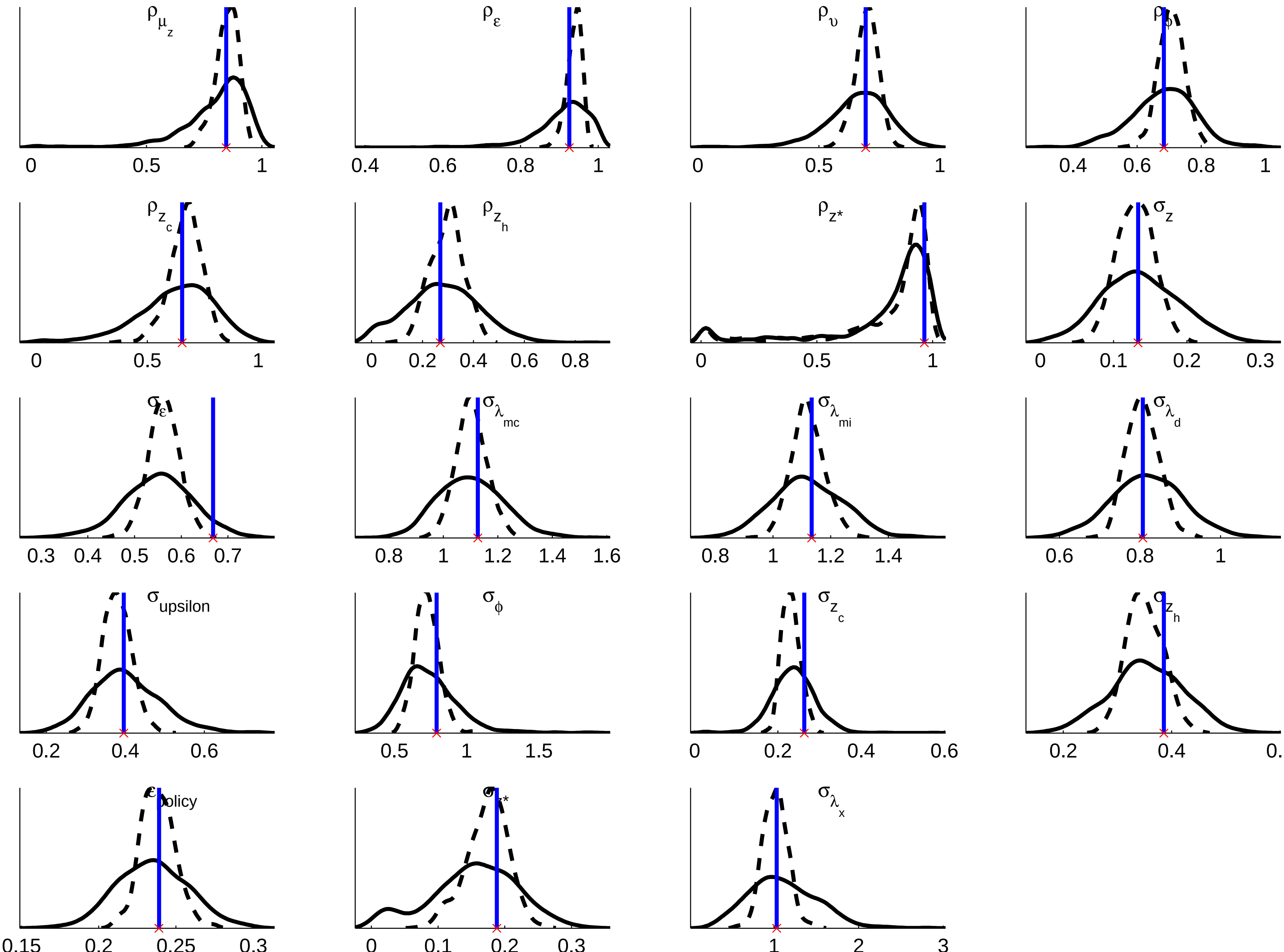
ρ_μz
ρ_ε
ρ_υ
ρ_φ
ρ_zc
ρ_zh
ρ_z*
σ_z
σ_ε
σ_λmc
σ_λmi
σ_λd
σ_upsilon
σ_φ
σ_zc
σ_zh
ε_policy
σ_z*
σ_λx



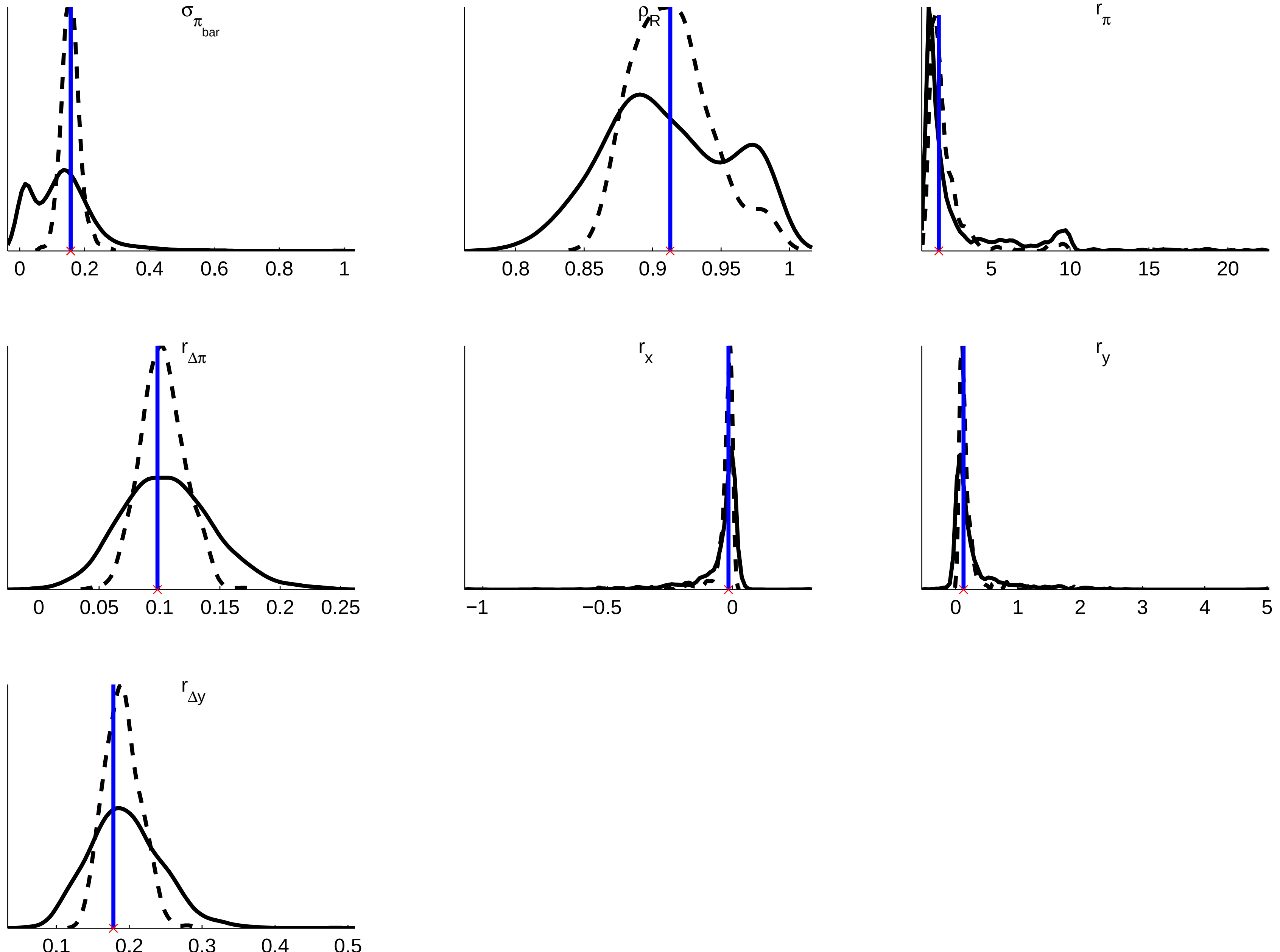
σ_π_bar
0 0.2 0.4 0.6 0.8 1
ρ_p
0.8 0.85 0.9 0.95 1
r_π
5 10 15 20
r_Δπ
0 0.05 0.1 0.15 0.2 0.25
r_x
−1 −0.5 0
r_y
0 1 2 3 4 5
r_Δy
0.1 0.2 0.3 0.4 0.5



ξw
0.2 0.4 0.6 0.8 1
ξd
0.6 0.8 1
ξmc
0.8 0.85 0.9 0.95
ξmi
0.88 0.9 0.920.940.960.98
ξx
0.7 0.8 0.9
κd
0 0.2 0.4
κw
0 0.2 0.4 0.6 0.8
SS”
10 20 30 40 50
b
0.4 0.6 0.8
λd
1 1.2 1.4 1.6 1.8
ηi
2 2.5 3 3.5
ηf
2 4 6
λmc
1.55 1.6 1.65
λmi
1 1.1 1.2 1.3
μz
1.0045 1.005 1.0055 1.006
φtilde
0 0.1 0.2
φtildes
0.6 0.8 1



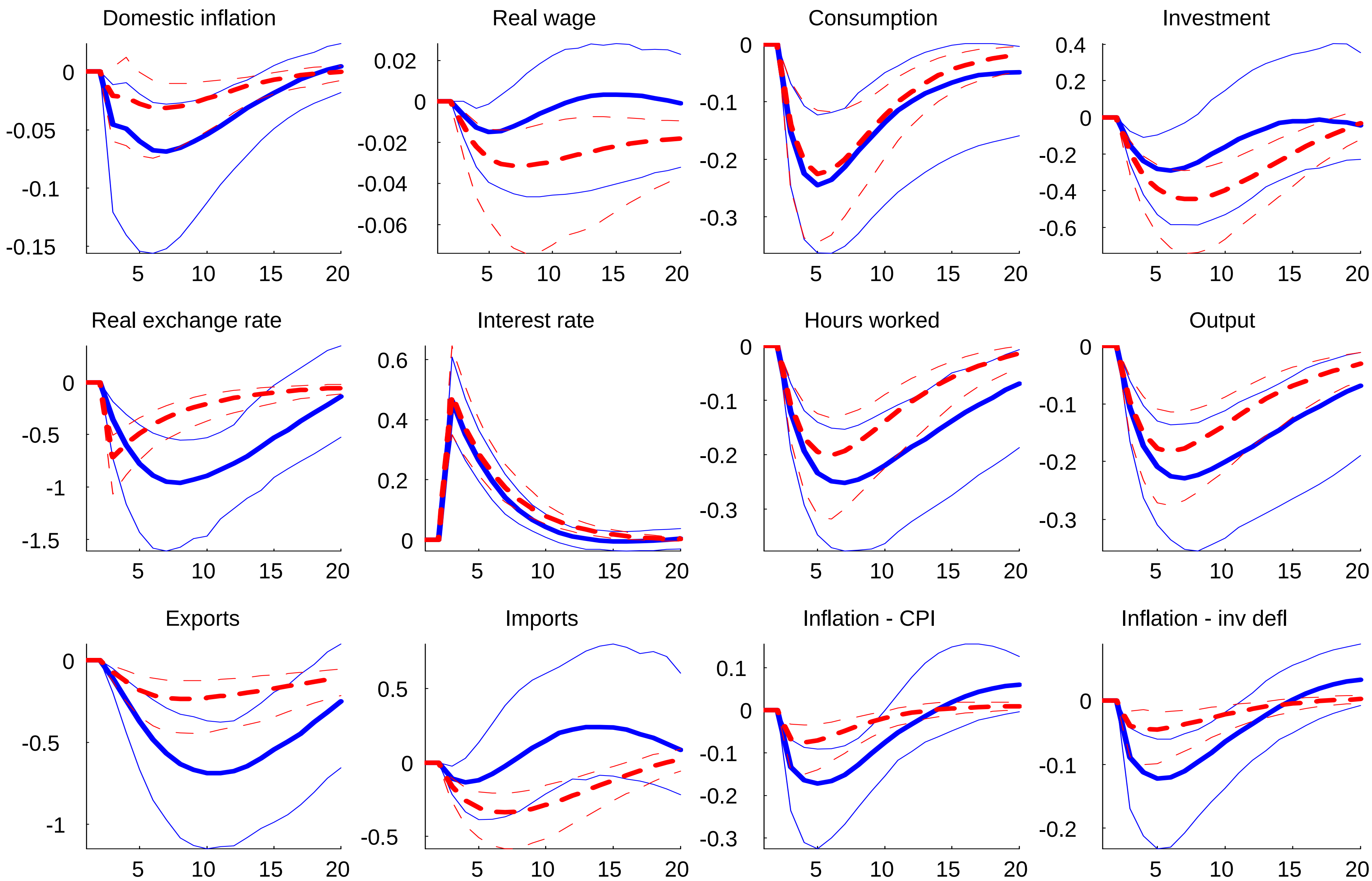
ρ_{μ_z}
ρ_ε
ρ_υ
ρ_ϕ
ρ_{z_c}
ρ_{z_h}
ρ_{z*}
σ_z
σ_ε
$\sigma_{\lambda_{mc}}$
$\sigma_{\lambda_{mi}}$
σ_{λ_d}
$\sigma_{upsilon}$
σ_ϕ
σ_{z_c}
σ_{z_h}
ε_{policy}
σ_{z*}
σ_{λ_x}



$\sigma_{\pi_{bar}}$
0 0.2 0.4 0.6 0.8 1
ρ_R
0.8 0.85 0.9 0.95 1
r_π
5 10 15 20
$r_{\Delta\pi}$
0 0.05 0.1 0.15 0.2 0.25
r_x
−1 −0.5 0
r_y
0 1 2 3 4 5
$r_{\Delta y}$
0.1 0.2 0.3 0.4 0.5

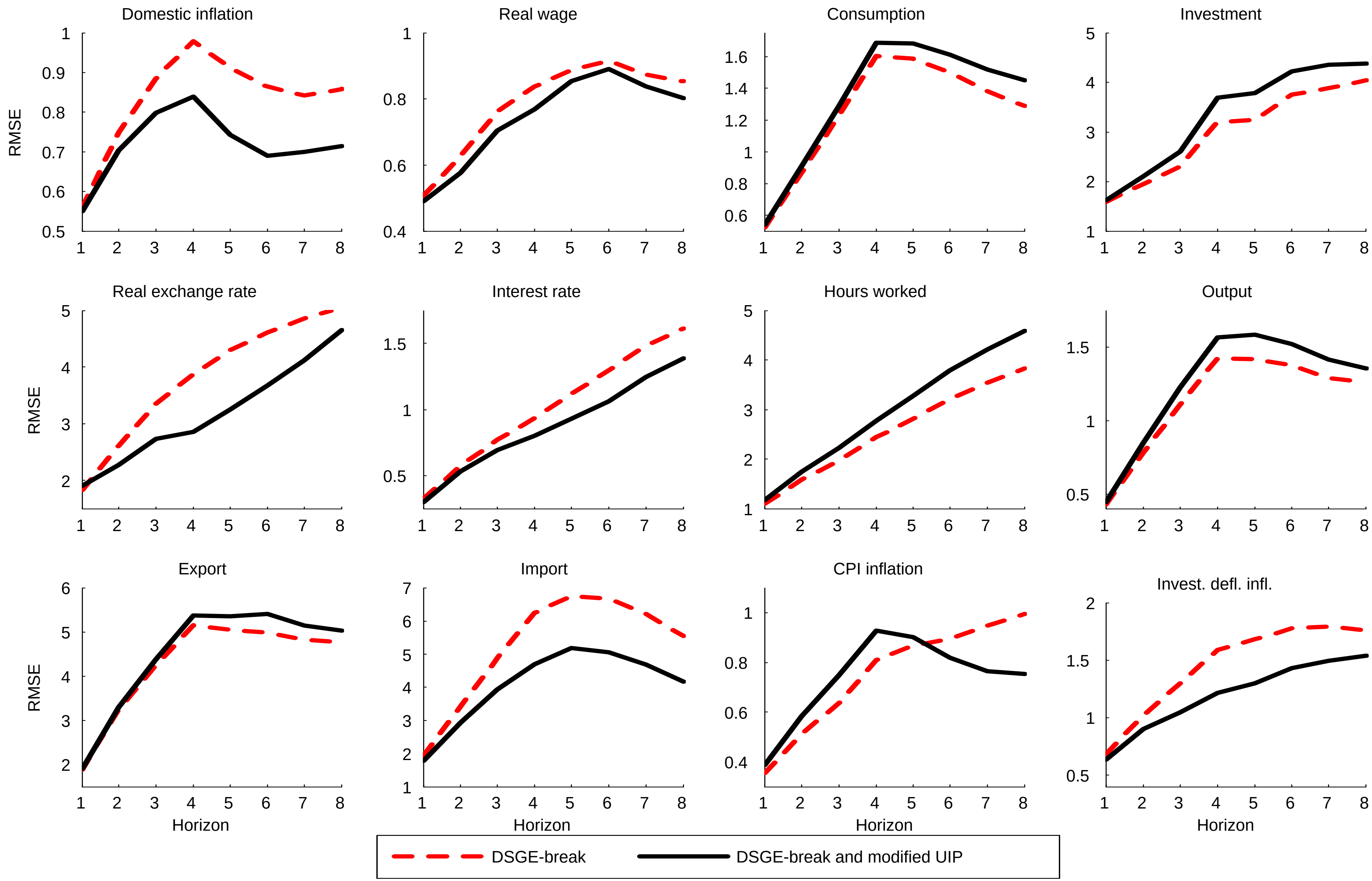
Impulse response functions

- Monetary policy shock - jump (hump-shaped) response for the real exchange rate in the model with the standard (modified) UIP condition
  - Policy parameters taken from the inflation targeting period
  - Standard UIP - red lines, Modified UIP - blue lines
  - Plot Posterior 2.5th, Median and 97.5th percentiles

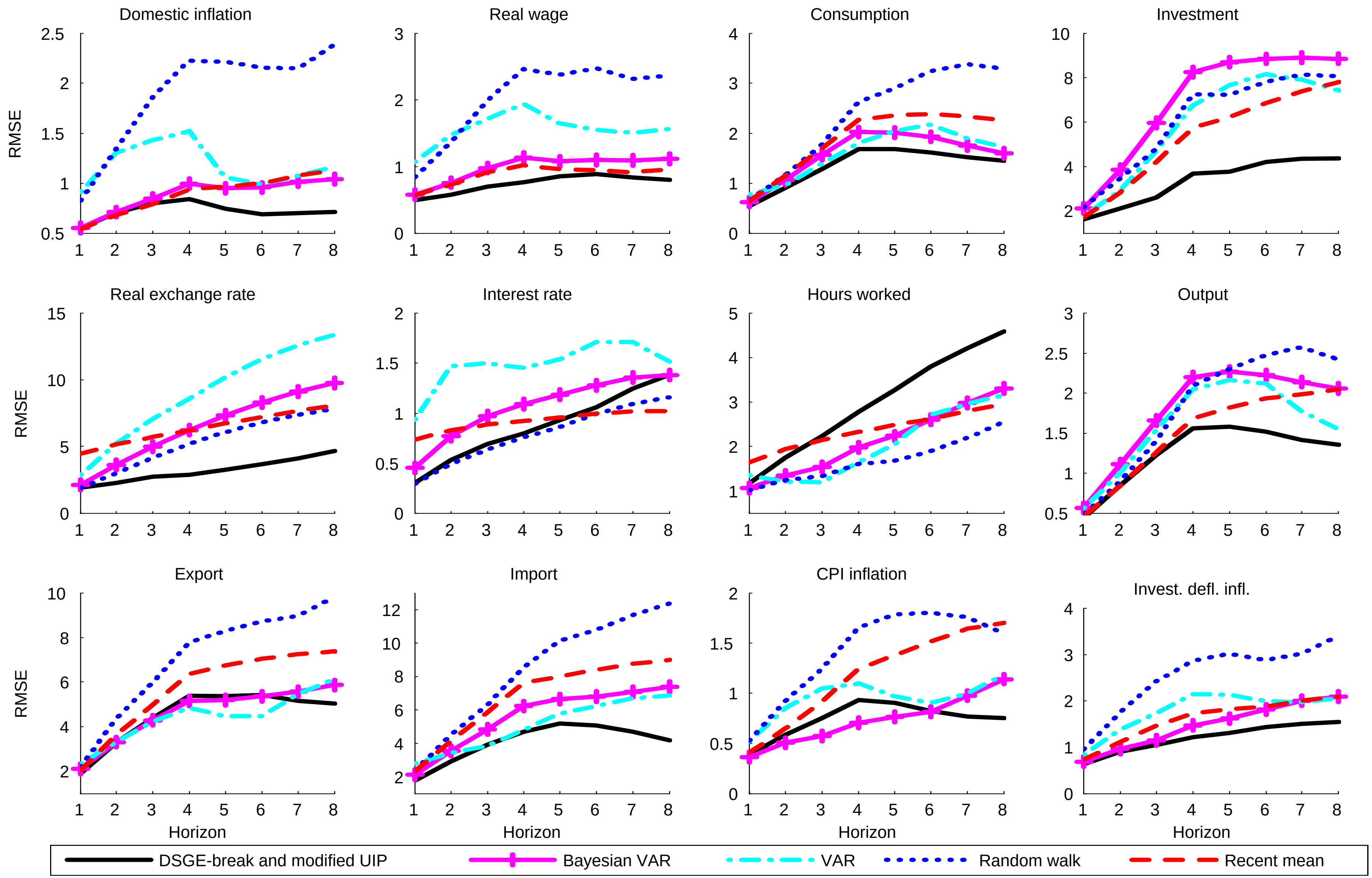

Domestic inflation
0
-0.05
-0.1
-0.15
5
10
15
20
Real wage
0.02
0
-0.02
-0.04
-0.06
Consumption
0
-0.1
-0.2
-0.3
Investment
0.4
0.2
0
-0.2
-0.4
-0.6
Real exchange rate
0
-0.5
-1
-1.5
Interest rate
0.6
0.4
0.2
0
Hours worked
0
-0.1
-0.2
-0.3
Output
0
-0.1
-0.2
-0.3
Exports
0
-0.5
-1
Imports
0.5
0
-0.5
Inflation - CPI
0.1
0
-0.1
-0.2
-0.3
Inflation - inv defl
0
-0.1
-0.2

Forecasting performance

- Report RMSEs for various models in Figures 2a and 2b.
  - Modified UIP condition outperform the standard UIP condition for the real exchange rate, nominal interest rate and the CPI, less successful for output and hours worked (Figure 2a)
  - DSGE well in line or better than alternative models (Figure 2b)

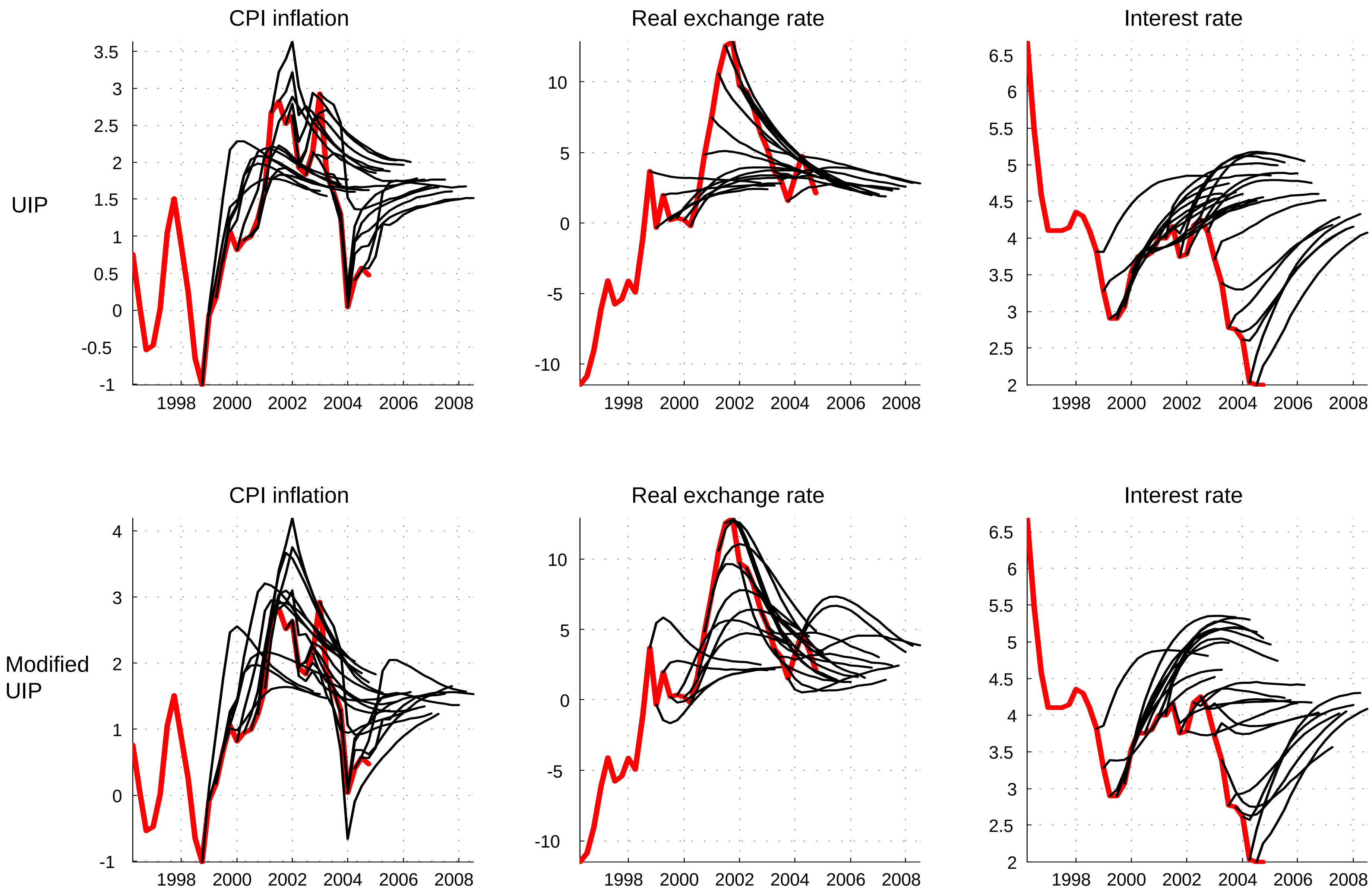


Domestic inflation
Real wage
Consumption
Investment
Real exchange rate
Interest rate
Hours worked
Output
Export
Import
CPI inflation
Invest. defl. infl.
RMSE
Horizon
DSGE-break
DSGE-break and modified UIP



Domestic inflation
Real wage
Consumption
Investment
Real exchange rate
Interest rate
Hours worked
Output
Export
Import
CPI inflation
Invest. defl. infl.
RMSE
Horizon
DSGE-break and modified UIP
Bayesian VAR
VAR
Random walk
Recent mean

- Actual forecasts with the standard UIP condition embedded into the model are sharply mean reverting, whereas the modified UIP is capable of inducing some instrinsic persistence in the model (see Figure below)


CPI inflation
Real exchange rate
Interest rate
UIP
Modified UIP
1998
2000
2002
2004
2006
2008

Misspecification analysis

- Use the DSGE as a prior for a VAR (Del Negro and Schorfheide, *IER*, 2004) to examine to what extent the cross restrictions implied by the two specifications are supported by the data
  - DSGE-VECM(λ) better approximation of the DSGE moments than the DSGE-VAR(λ) (judging from VACFs and LMLs for the DSGE and the DSGE-VAR/VECM with $\lambda = \infty$)
  - For both specifications, we find evidence of misspecification. $\hat{\lambda}$ about 7 in all cases. Compare well with DSSW (2004)

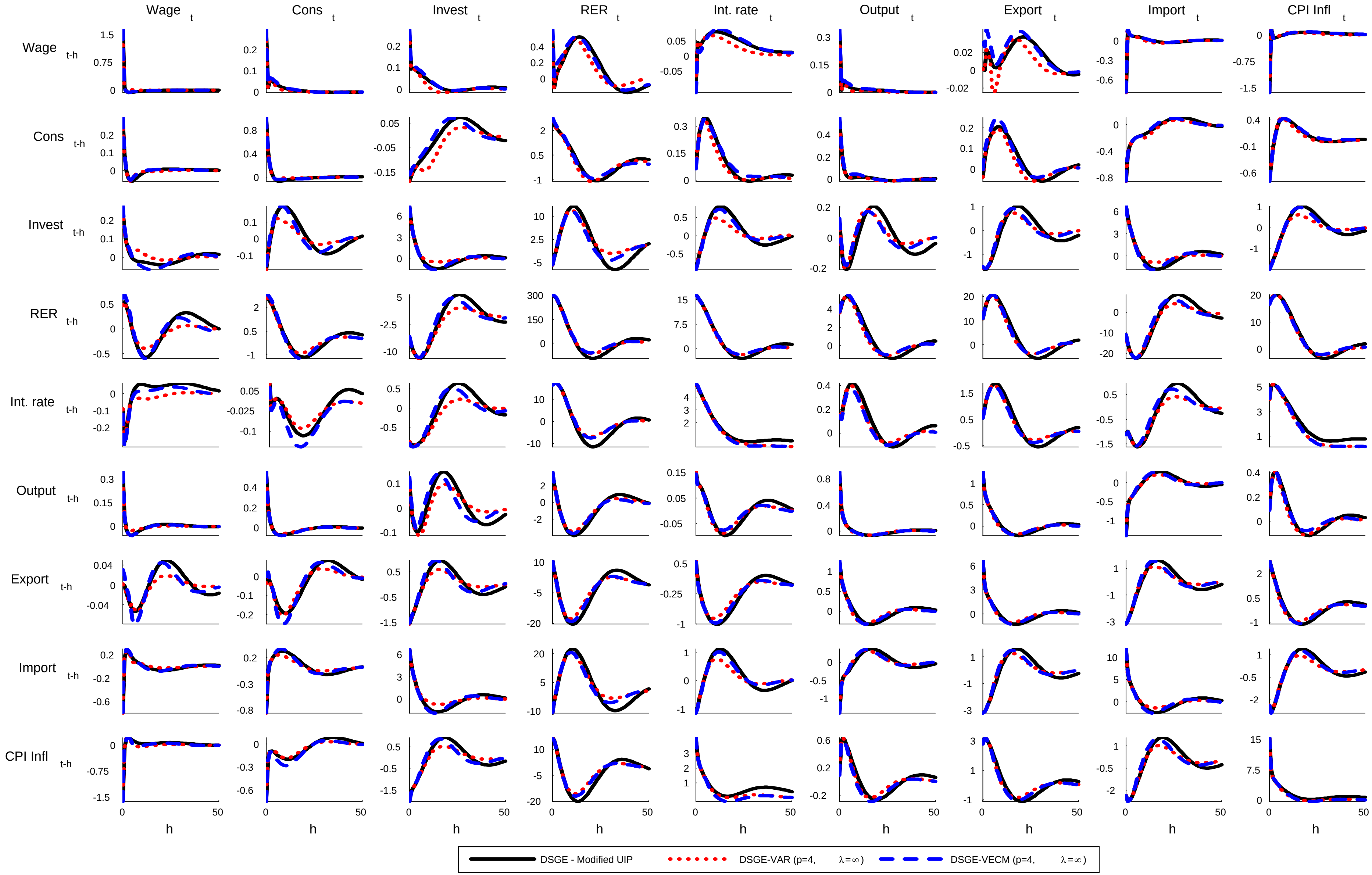
- $\hat{\lambda}$ about the same for the standard and modified UIP conditions, suggesting that the modification of the UIP condition is not an improvement once the DSGE cross-restrictions are relaxed

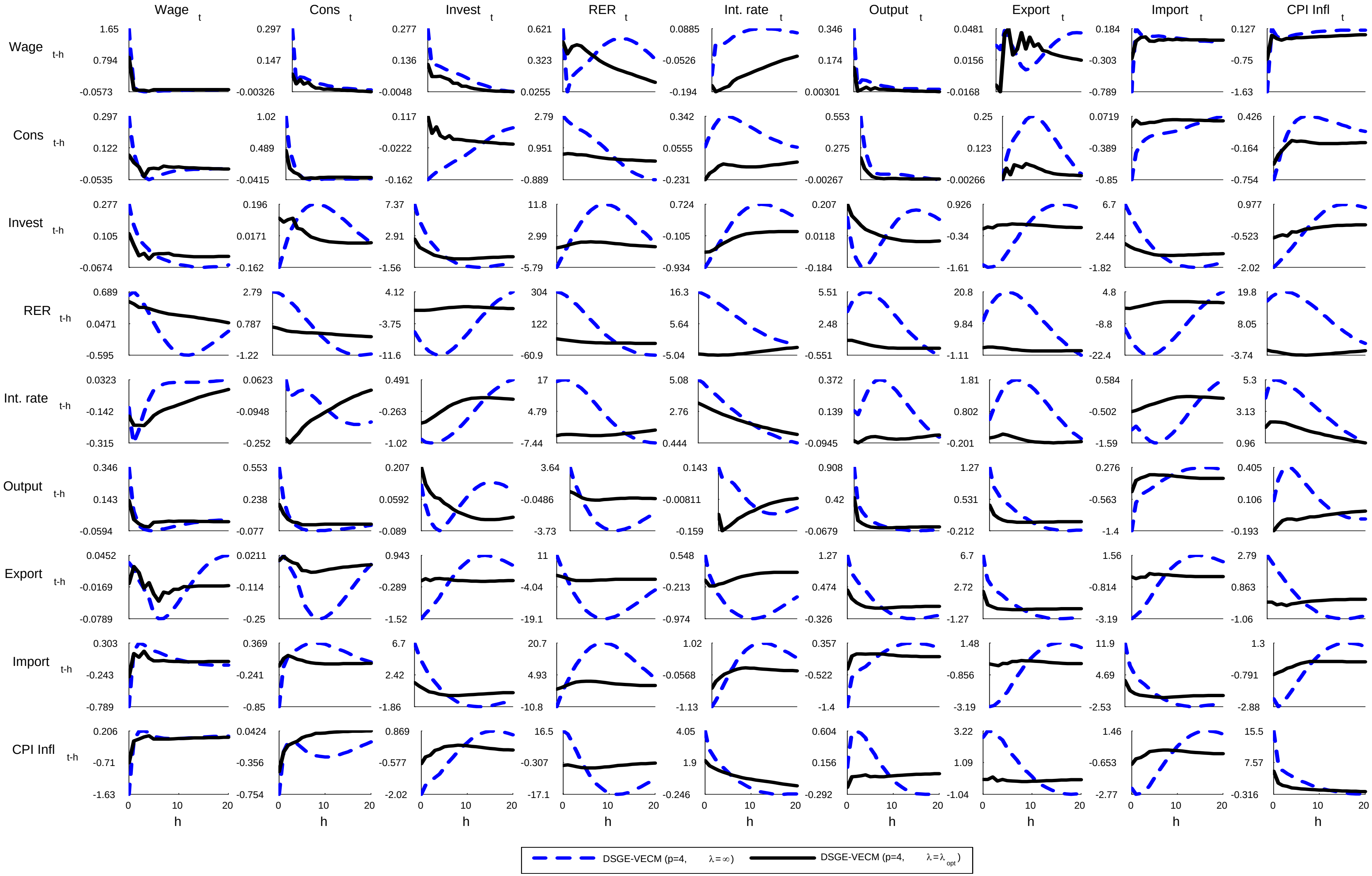
- DSGE-VECM($\hat{\lambda}$) have close to zero posterior odds compared to the DSGE-VAR($\hat{\lambda}$), so the model based cointegrating vectors are not supported by the data

Table 2: Log marginal likelihood of VAR/VECM with DSGE prior. With regime change in the Taylor-type instrument rule.

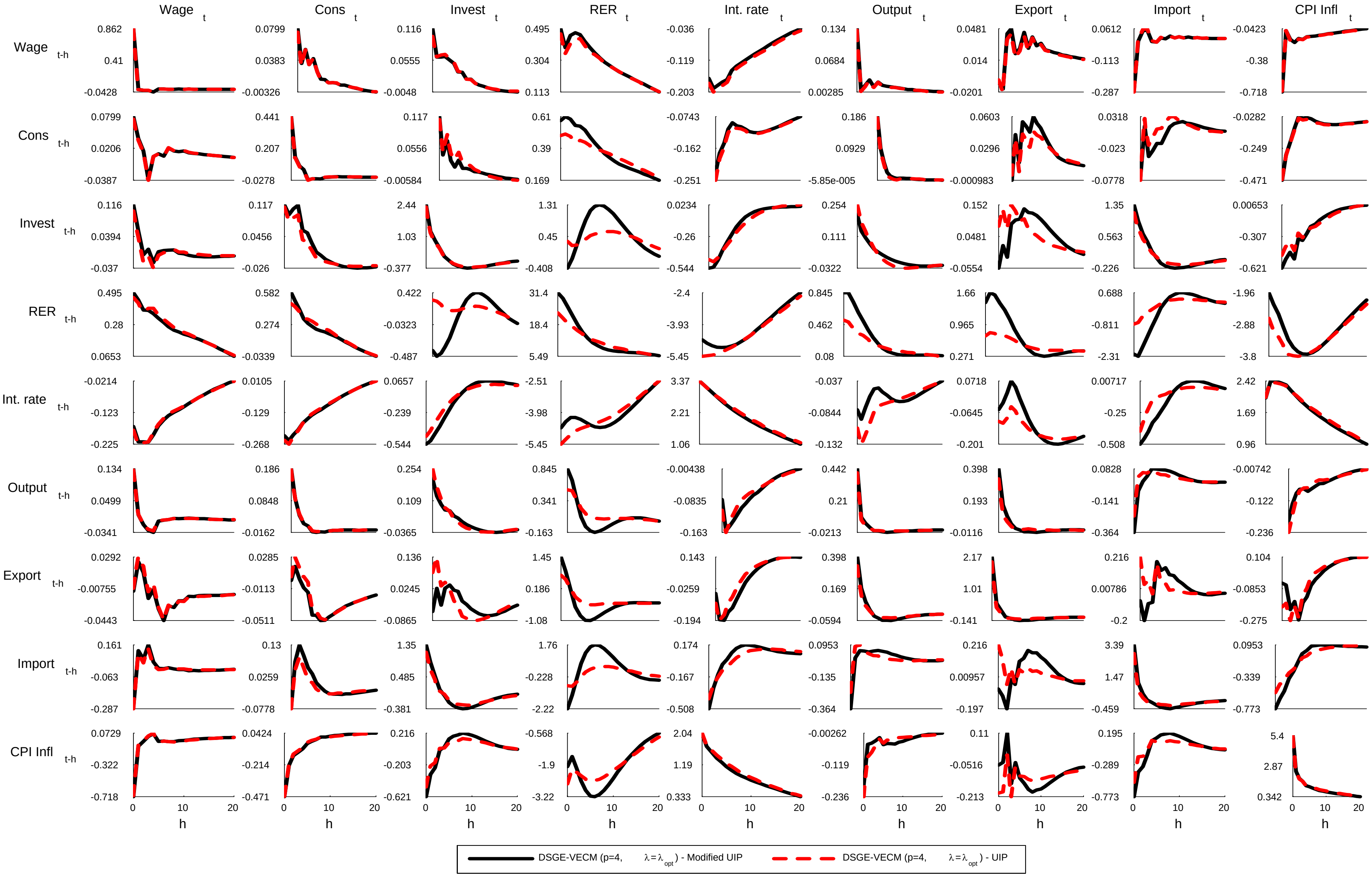
	DSGE-VAR		DSGE-VECM	
λ	UIP	Modified UIP	UIP	Modified UIP
2.714	-2164.78	-2163.19		
2.929			-2190.79	-2187.77
4	-1998.27	-1996.23	-2028.20	-2025.89
4.5	-1980.51	-1979.88	-2002.60	-2000.46
5	-1964.96	-1970.43	-1987.80	-1985.78
5.5	-1970.78	**-1965.86**	-1979.47	-1977.53
7	**-1965.98**	-1966.72	**-1974.12**	**-1972.28**
7.5	-1968.72	-1969.46	-1975.74	-1973.91
8	-1972.05	-1972.79	-1978.24	-1976.39
10	-1988.94	-1987.02	-1992.72	-1990.83
25	-2083.09	-2081.13	-2093.68	-2091.13
50	-2143.73	-2140.50	-2164.52	-2160.00
∞	-2232.06	-2227.65	-2270.78	-2265.08
DSGE	-2268.33	-2252.57	-2268.33	-2252.57

Note: The table displays laplace approximations of the log marginal likelihood. λ = 2.714 and λ = 2.929 are the minimal tightnesses for the VAR and VECM, respectively. Bold numbers indicate the λ with the maximal log marginal likelihood.


Wage t
Cons t
Invest t
RER t
Int. rate t
Output t
Export t
Import t
CPI Infl t
Wage t-h
Cons t-h
Invest t-h
RER t-h
Int. rate t-h
Output t-h
Export t-h
Import t-h
CPI Infl t-h
h
DSGE - Modified UIP
DSGE-VAR (p=4, λ=∞)
DSGE-VECM (p=4, λ=∞)



Wage t
Cons t
Invest t
RER t
Int. rate t
Output t
Export t
Import t
CPI Infl t
Wage t-h
Cons t-h
Invest t-h
RER t-h
Int. rate t-h
Output t-h
Export t-h
Import t-h
CPI Infl t-h
h
DSGE-VECM (p=4, λ=∞)
DSGE-VECM (p=4, λ=λ opt)


Wage t
Cons t
Invest t
RER t
Int. rate t
Output t
Export t
Import t
CPI Infl t
Wage t-h
Cons t-h
Invest t-h
RER t-h
Int. rate t-h
Output t-h
Export t-h
Import t-h
CPI Infl t-h
h
DSGE-VECM (p=4, λ=λ opt) - Modified UIP
DSGE-VECM (p=4, λ=λ opt) - UIP

Concluding remarks

- For a DSGE to be successful in a policy environment, it needs to be empirically coherent:
  - Comply with central bank's view of monetary transmission channel
  - In a forecast based policy environment $\Rightarrow$ forecasting performance (R and π)
- This is where the standard UIP appears to cause trouble in DSGE models
  - Poor forecasting performance for the nominal interest rate in the standard model
  - Clear improvement in the model with modified UIP condition
  - So when using the DSGE model in policy analysis, we currently use the specification with the modified UIP condition

- But, the DSGE-VAR/VECM(λ) analysis indicates that our suggested modification is not an improvement at the preferred λ, so need to think hard about additional modifications
  - Term structure of interest rates of particular interest, but many other modifications are also worthwhile considering
- The DSGE-VAR/VECM analysis also indicates that the model-based cointegrating vectors are not supported by the data
  - $*$ In particular, how should we account for the strong trends in $\tilde{X}_t/Y_t$ and $\tilde{M}_t/Y_t$

Steady state

- Pick a steady state where;
  - * $R = R^*$, $\pi = \pi^*$, $S_t = S_{t+1} = 1 \Rightarrow$
    * $\Phi(a, \widetilde{\phi}) = 1$, $B^* = A = 0$, $\widetilde{\phi} = 0$
    $\frac{SP^*}{P} = 1$