Evaluating An Estimated New Keynesian Small Open Economy Model

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Central Bank Macroeconomic Modelling Workshop,

Banco Central de Chile, Santiago

September 29, 2006

Introduction

- Open economy DSGE models often criticized for not being able to:
  - account for the transmission mechanism of monetary policy
  - generate enough intrinsic persistence and volatility in the real exchange rates

Adolfson et al. (2005); Justiniano and Preston (2005); Lubik and Schorfheide (2005); Rabanal and Tuesta (2005)

- Typically embed a UIP condition which has received little empirical support from
  - VAR evidence: Eichenbaum and Evans (1995), Faust and Rogers (2003)
  - Forward discount puzzle: Fama (1984), Froot and Frankel (1989)

What we do

- Consider a modified UIP condition in a DSGE model for a small open economy
  - Allow the risk premium to be negatively related to the expected depreciation of the nominal exchange rate
- Explore the consequences of this modification
  - Implications for policy (impulse responses and actual forecasts)
  - Overall empirical coherence (posterior marginal density, forecasting performance, misspecification)

Framework

- The model is an open economy version of CEE, 2005 (see Adolfson et al., 2005a)
  - Consumption and investment baskets (domestic and imported goods)
  - Incomplete exchange rate pass-through
  - Stochastic unit-root technology shock (Altig et al., 2003)
- Bayesian estimation following Smets and Wouters (2003)
  - Use Swedish data
  - Foreign output, inflation and interest rates are exogenous
  - From fixed exchange rate regime to explicit inflation targeting in 1993
    # Allow for a discrete shift in the policy rule

UIP condition

- "Standard" specification of UIP condition in a small open economy features:

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

  - Risk premium is a function of net foreign assets (endogenous) and exogenous disturbance

    $\Rightarrow$ cannot account for the forward premium puzzle

  - If $\widetilde{\phi}$ small, this specification cannot generate a hump-shaped response to a monetary policy shock

Modified UIP condition

- Allow risk premium to be negatively related to the expected depreciation of the nominal exchange rate

  - Modified risk premium

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

  - Resulting modified UIP condition

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

    or

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

Main findings

- Modified UIP condition strongly preferred to standard UIP specification
  - Induces hump-shaped impulse responses and intrinsic persistence in the RER
  - Important for the model's forecasting performance (in particular RER and interest rate)
- Forecasting performance of both DSGE specifications typically better than VARs and BVARs
- Both DSGEs are useful as a prior for a VAR model
  DSGE-VAR(λ) analysis; Del Negro and Schorfheide, 2004
  - But data supports relaxation of the cross-equation restrictions in both models

Structure of talk

- DSGE model overview
- Estimation results
- Effects of modifying the UIP-condition
  - Impulse responses
  - Forecasting performance
- Misspecification analysis
- Concluding remarks

DSGE model (closed economy aspects)

- Households
  - Utility from consumption, leisure and real cash balances
  - Habit persistence
  - Capital accumulation (investment adjustment costs)
  - Wage stickiness: Calvo, partial indexation
- Domestic goods firms
  - Cobb-Douglas (capital and labor)
  - Working capital
  - Price stickiness: Calvo, partial indexation
- Central bank (Taylor 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, partial indexation

  $\Rightarrow$ Incomplete pass-through

- Trade in foreign bonds with risk-premium

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

Monetary policy

- Inflation targeting instrument rule (Taylor type):

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

- Policy prior to adopting the inflation target in 1993Q1:
  - No break
  - Fixed exchange rate rule: $\widehat{R}_t = r_S \Delta \hat{S}_t, \qquad r_S = 10^6$
  - Semi-fixed exchange rate rule
  - Discrete break in the policy parameters $\theta_{R,t}$:

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

Estimated shocks

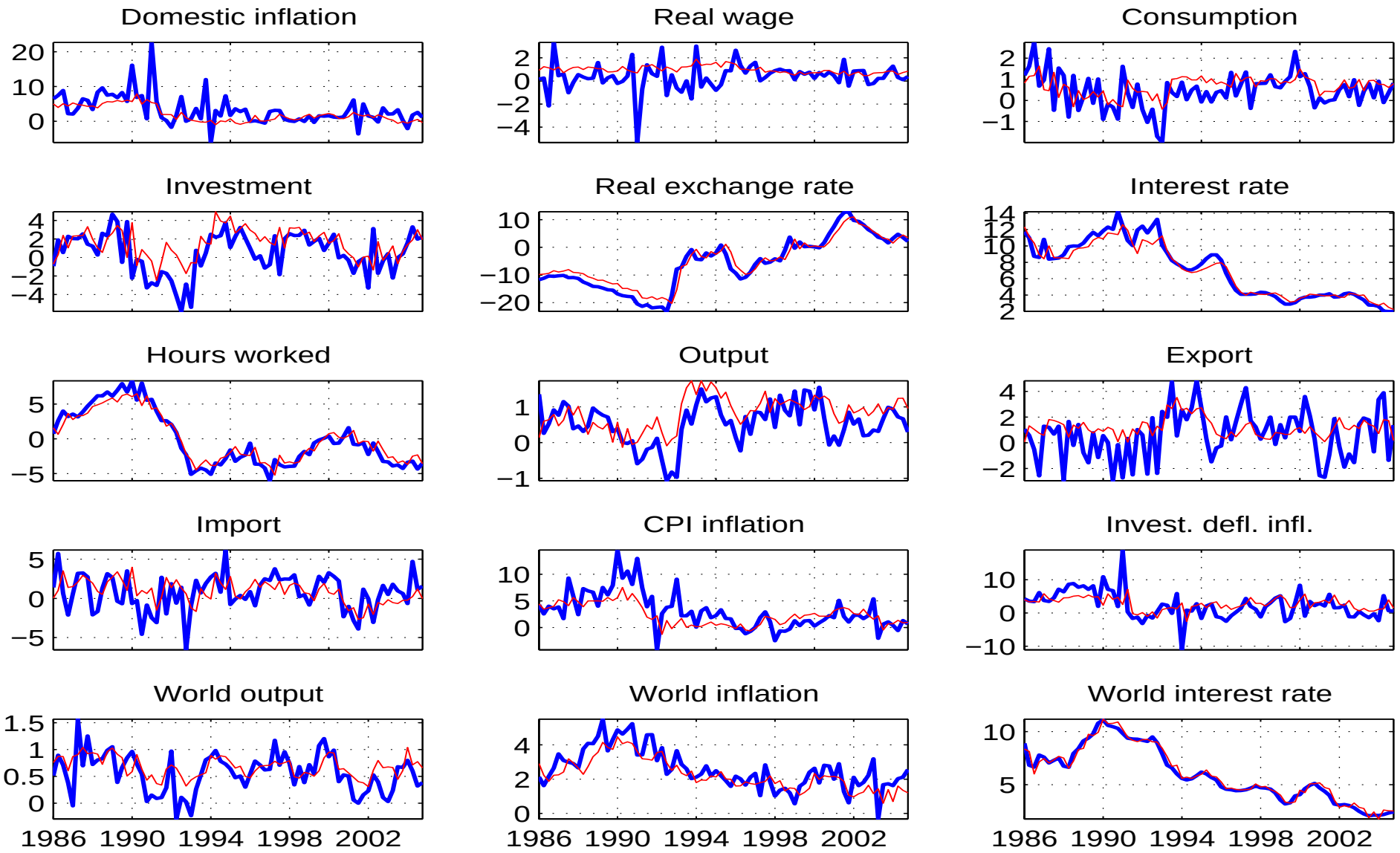
- Technology shocks ($\mu_{z,t}, \epsilon_t$), investment specific (Υ_t), asymmetric ($\widetilde{z}_t^*$)
- Markup shocks ($\lambda_t^d, \lambda_t^{m,c}, \lambda_t^{m,i}, \lambda_t^x$) - i.i.d.
- Preference shocks (ζ_t^c, ζ_t^h)
- Risk premium shock ($\widetilde{\phi}_t$)
- Monetary policy shocks ($\varepsilon_{R,t}$, $\bar{\pi}_t^c$)

Estimation

- Estimate 43 (51 with break) 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)

$$\tilde{Y}_t = [\pi_t^d \quad \Delta \ln(W_t/P_t) \quad \Delta \ln C_t \quad \Delta \ln I_t \quad \hat{x}_t \quad R_t \quad \hat{H}_t \quad \Delta \ln Y_t ... \\ \Delta \ln \tilde{X}_t \quad \Delta \ln \tilde{M}_t \quad \pi_t^{cpi} \quad \pi_t^{def,i} \quad \Delta \ln Y_t^* \quad \pi_t^* \quad R_t^* \ ]'.$$

- No detrending - work with raw data (except imports and exports)


Domestic inflation
20
10
0
Real wage
2
0
−2
−4
Consumption
2
1
0
−1
Investment
4
2
0
−2
−4
Real exchange rate
10
0
−10
−20
Interest rate
14
12
10
8
6
4
2
Hours worked
5
0
−5
Output
1
0
−1
Export
4
2
0
−2
Import
5
0
−5
CPI inflation
10
5
0
Invest. defl. infl.
10
0
−10
World output
1.5
1
0.5
0
World inflation
4
2
0
World interest rate
10
5
1986 1990 1994 1998 2002
1986 1990 1994 1998 2002
1986 1990 1994 1998 2002

Estimation results: model specification

- Bayesian posterior odds in favor of a break in policy rule
  - Parameters similar except for standard deviation of policy shock (shrinking)

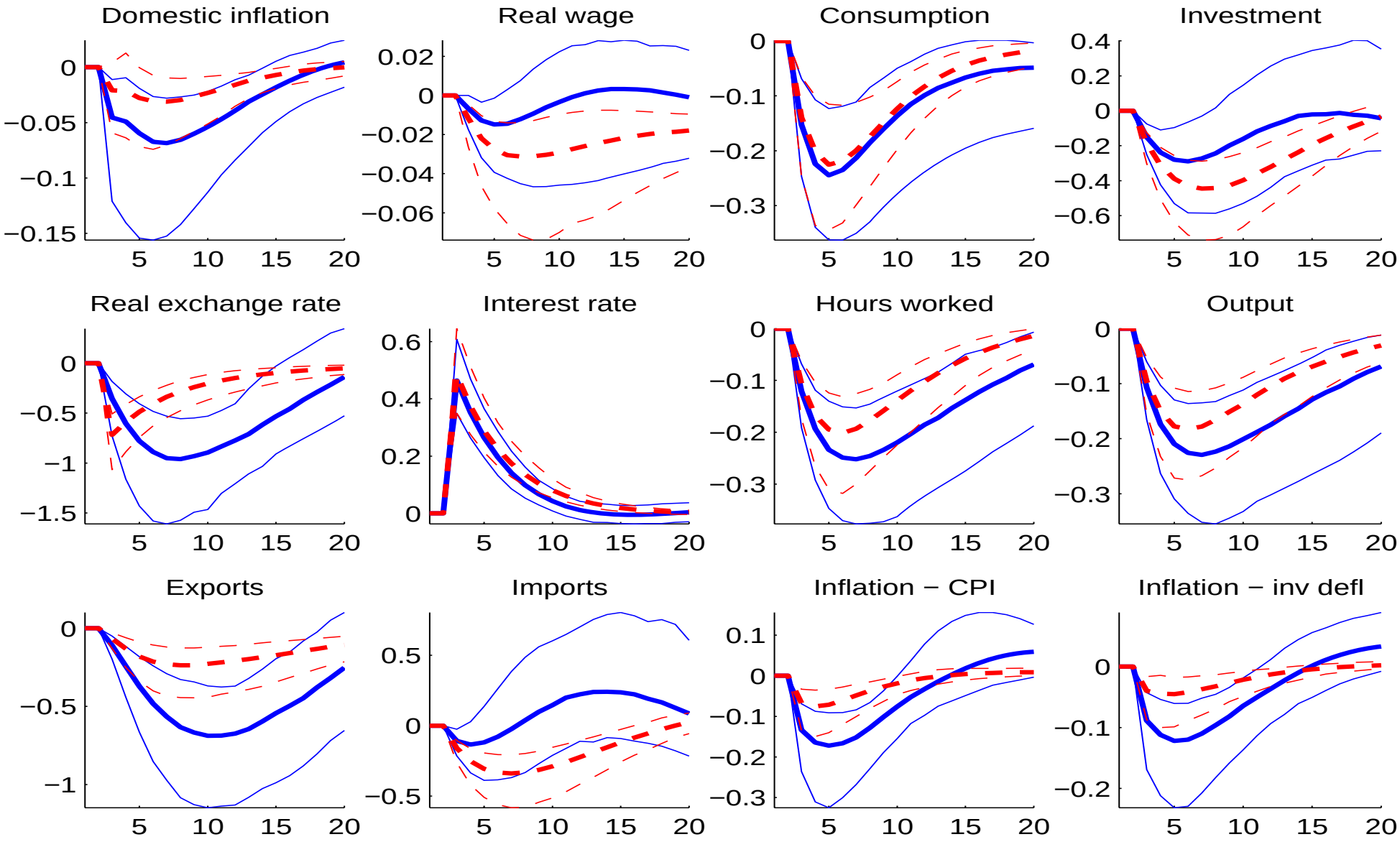
- Bayesian posterior odds in favor of the modified UIP specification
  - Deep parameters similar across all specifications
  - Risk premium shock estimates different

Exert from 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.	median	std.	median	std.	median	std.	median	std.	median	std.
UIP modification	$\tilde{\phi}_s$	beta	0.500	0.15									0.611	0.063
Risk premium shock persistence	$\rho_{\tilde{\phi}}$	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
Risk premium shock	$\sigma_{\tilde{\phi}}$	invg.	0.050	2	0.372	0.079	0.319	0.035	0.297	0.036	0.376	0.079	0.805	0.221
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 resp.	$r_{x,1}$	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	$\sigma_{R,1}$	invg.	0.150	2	0.249	0.024			2.335	0.778	0.398	0.060	0.398	0.066
Inflation target shock	$\sigma_{\bar{\pi}^c,1}$	invg.	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	$\sigma_{R,2}$	invg.	0.150	2			0.102	0.013	0.094	0.011	0.104	0.013	0.103	0.013
Inflation target shock	$\sigma_{\bar{\pi}^c,2}$	invg.	0.050	2			0.065	0.030	0.069	0.035	0.080	0.038	0.077	0.038
Log marg. likelihood					-2285.8		-2636.72		-2348.24		-2268.33		-2252.57	

Impulse response functions

- Monetary policy shock
  - From jump to hump-shaped response for the real exchange rate with modified UIP condition
  - Negative correlation between the risk premium and expected exchange rate changes $\Longrightarrow$ increased persistence in RER response


Domestic inflation
Real wage
Consumption
Investment
Real exchange rate
Interest rate
Hours worked
Output
Exports
Imports
Inflation − CPI
Inflation − inv defl

Forecasting performance

- Compare RMSEs for various models, $1999Q1 - 2004Q4$ (1-8 quarters ahead)
  - Modified UIP condition outperforms on forecasts for x_t, R_t, and π_t^{cpi}, less successful for Y_t and H_t
  - DSGE well in line or better than alternative forecasting tools

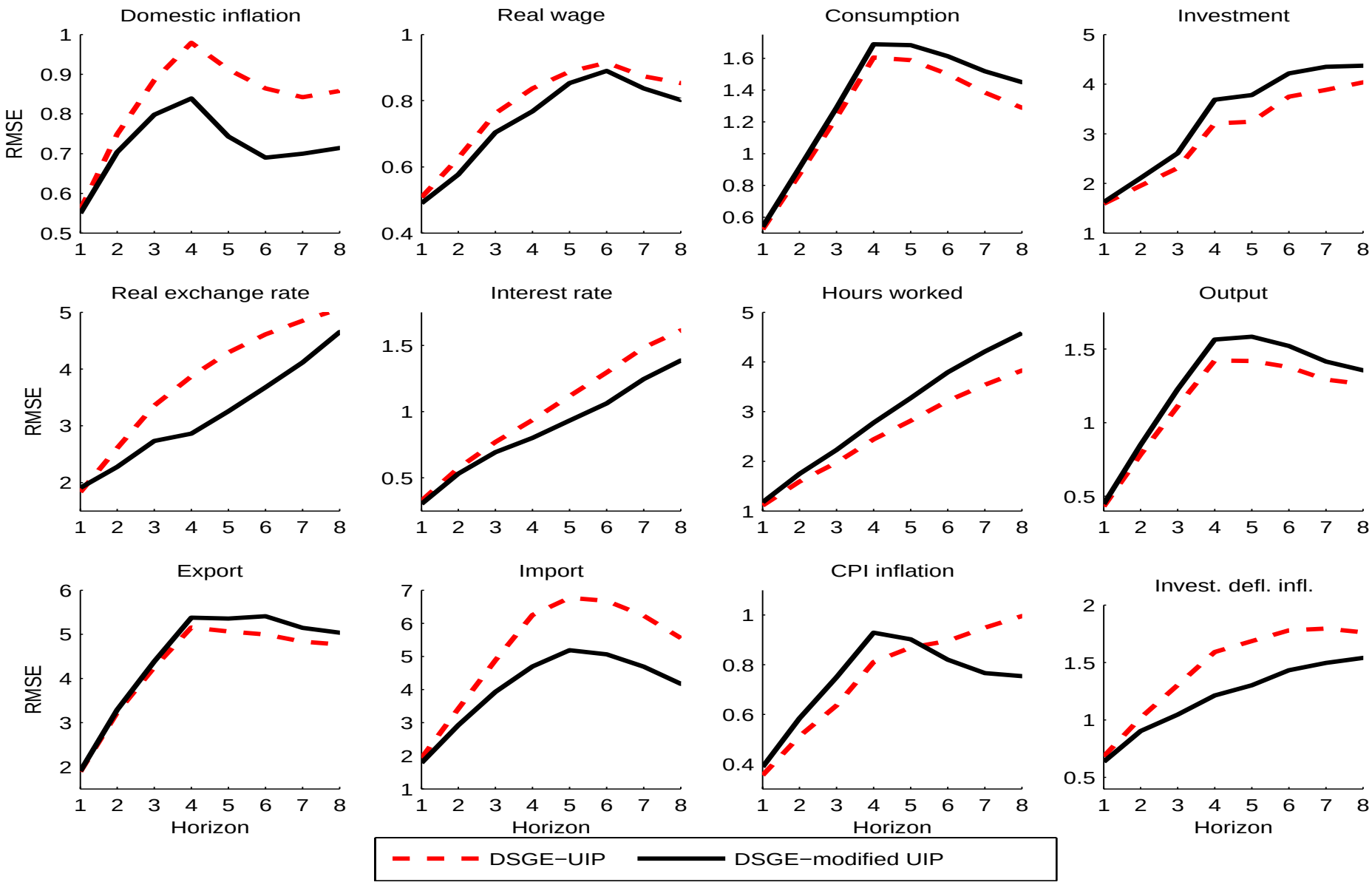
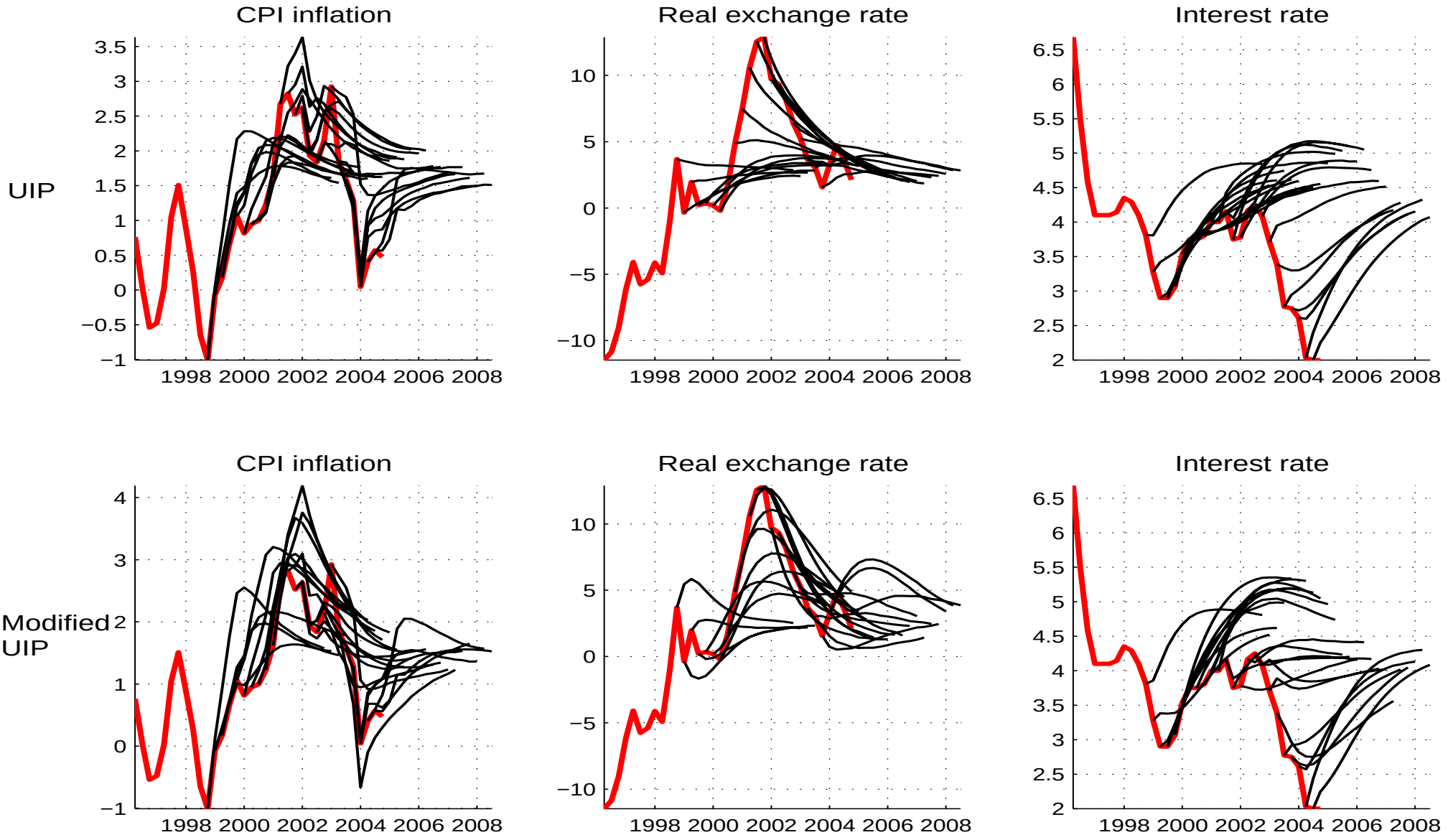

Domestic inflation
Real wage
Consumption
Investment
Real exchange rate
Interest rate
Hours worked
Output
Export
Import
CPI inflation
Invest. defl. infl.
RMSE
Horizon
DSGE−UIP
DSGE−modified UIP

Figure 1:


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

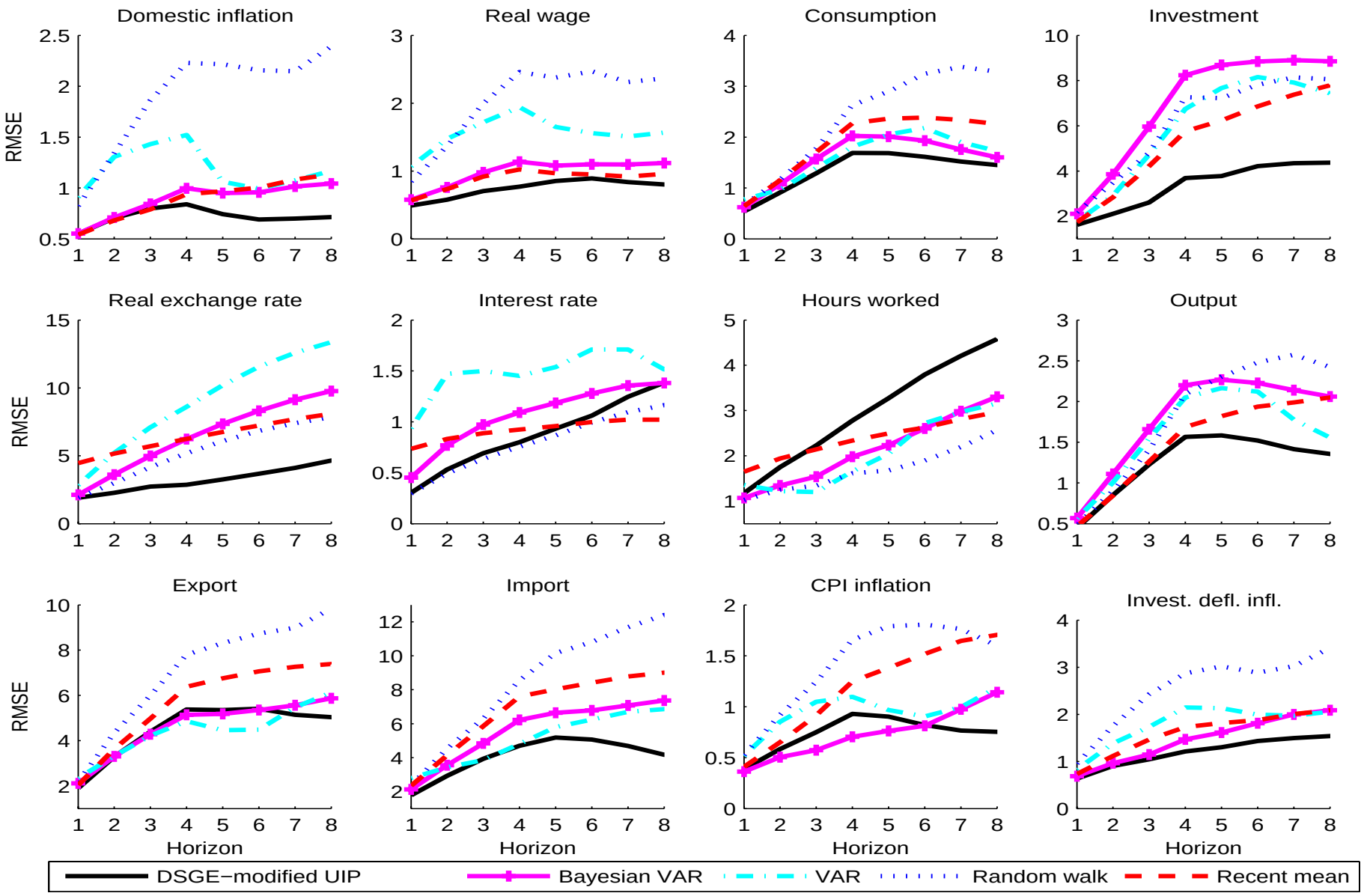

Domestic inflation
Real wage
Consumption
Investment
Real exchange rate
Interest rate
Hours worked
Output
Export
Import
CPI inflation
Invest. defl. infl.
RMSE
Horizon
DSGE−modified UIP
Bayesian VAR
VAR
Random walk
Recent mean

Figure 2:

Misspecification analysis

- Do the data support the DSGE models' cross-equation restrictions?
  - Use Del Negro and Schorfheide (2004) and Del Negro, Schorfheide, Smets and Wouters (2004) to measure the degree of misspecification
- Compare marginal likelihoods of DSGE and a VAR with prior centered on the DSGE (i.e, DSGE-VAR(λ))
  - Tightness in the prior λ from diffuse ($\approx$3) to very informative (∞) governs to what extent the cross-equation restrictions are enforced
  - Let data determine preferred relaxation ($\hat{\lambda}$)
- Check implications by comparing vector autocovariance functions in the various specifications

Misspecification - results

- How well does the DSGE-VAR/VECM(∞) approximate the DSGE?
  - DSGE-VECM better approximation than DSGE-VAR (see VACF; fig. 4a)

- Both UIP specifications show signs of misspecification
  - $\hat{\lambda} =$ 5-7 $<<$ ∞ and about the same for both specifications
  - $\hat{\lambda}$ implies substantial relaxation of the cross-equation restrictions
  - Hybrid model improves considerably in terms of marginal likelihood

- Weak support for model based cointegration
  - DSGE-VECM has zero posterior probability compared to DSGE-VAR

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

λ	DSGE-VAR		DSGE-VECM	
	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. $\lambda = 2.714$ and $\lambda = 2.929$ are the minimal tightnesses for the VAR and VECM, respectively. Bold numbers indicate the λ with the maximal log marginal likelihood.

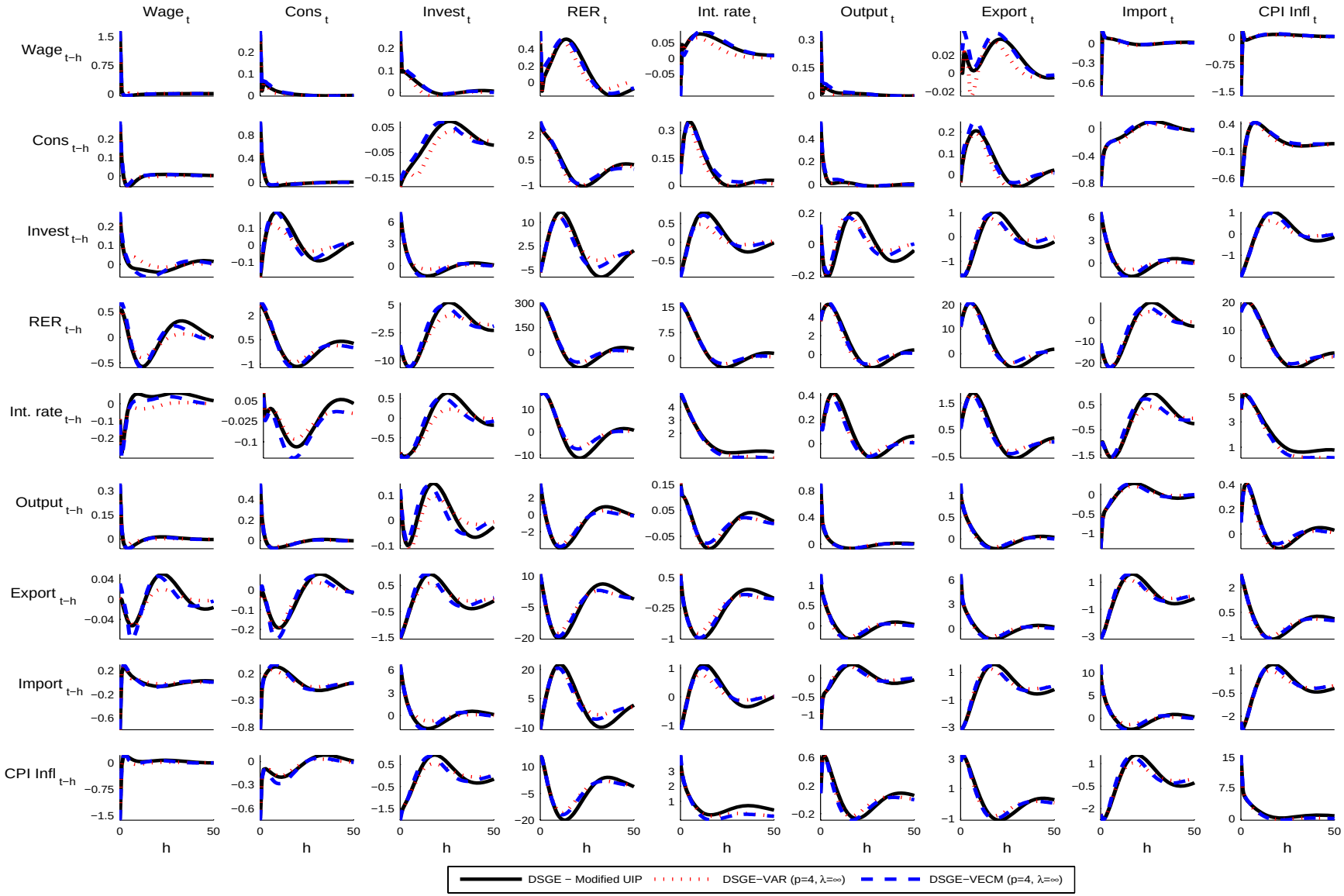

Wage t
Cons t
Invest t
RER t
Int. rate t
Output t
Export t
Import t
CPI Infl t
Wage t−h
Cons t−h
Invest t−h
RER t−h
Int. rate t−h
Output t−h
Export t−h
Import t−h
CPI Infl t−h
h
DSGE − Modified UIP
DSGE−VAR (p=4, λ=∞)
DSGE−VECM (p=4, λ=∞)

Figure 3:

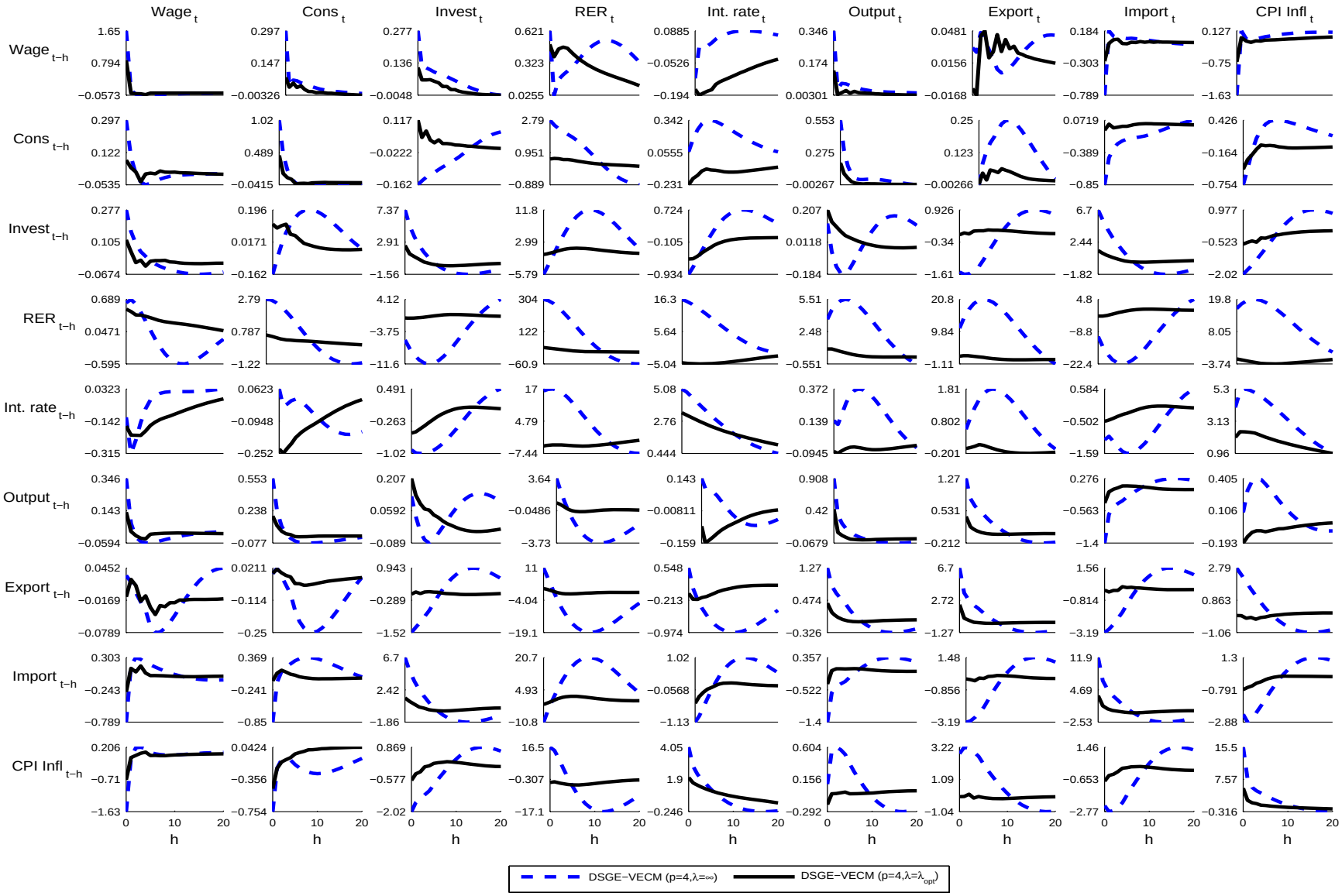

Wage t
Cons t
Invest t
RER t
Int. rate t
Output t
Export t
Import t
CPI Infl t
Wage t−h
Cons t−h
Invest t−h
RER t−h
Int. rate t−h
Output t−h
Export t−h
Import t−h
CPI Infl t−h
h
DSGE−VECM (p=4,λ=∞)
DSGE−VECM (p=4,λ=λopt)

Figure 4:

Concluding remarks

- For a DSGE to be sucessful in a policy environment, it needs to be empirically coherent:
  - Comply with the CB's view of the monetary transmission channel
  - Forecast based policy environment $\Rightarrow$ forecasting performance
- Modified UIP condition allowing for a negative correlation between the risk premium and expected exchange rate changes
  - Induces intrinsic persistence in the real exchange rate
  - Improves on the model's forecasting properties
- DSGE model is useful as a prior for a VAR model
  - DSGE misspecified in the sense that data relaxes the cross-equation restrictions

Identification

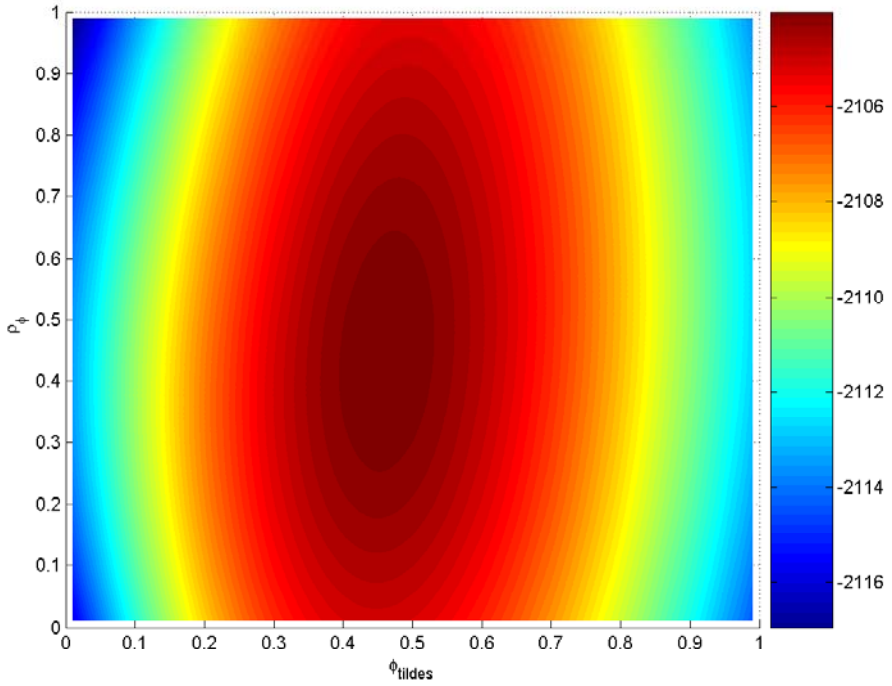
- Are key parameters identified?
  - Consider the modified UIP condition

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

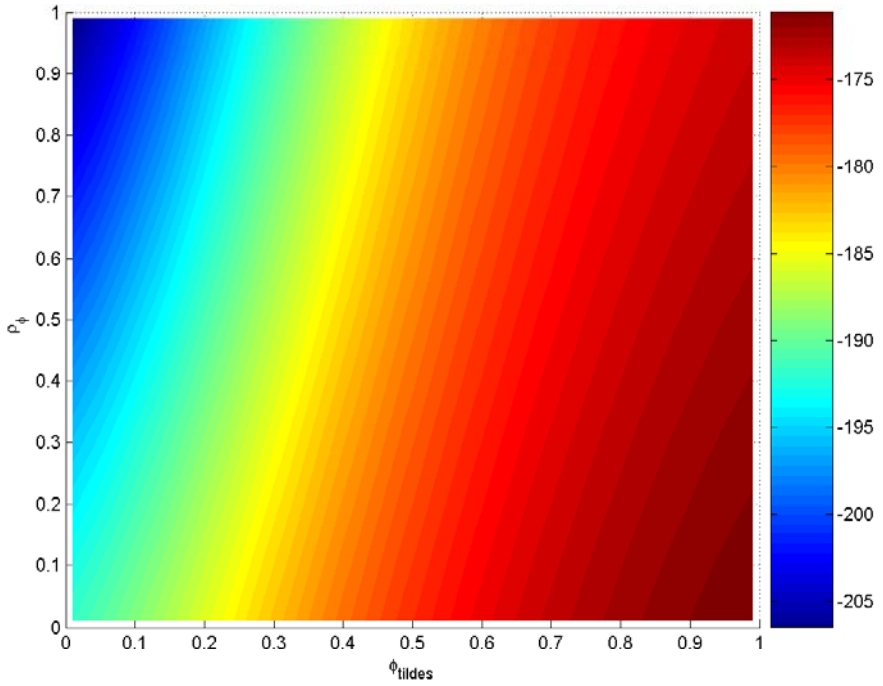
  - Can $\widetilde{\phi}_s$ be identified when simultaneously allowing for correlated risk premium shocks $\widehat{\widetilde{\phi}}_t$

- Contour plots of the log-likelihood in $\{\widetilde{\phi}_s, \rho_{\widetilde{\phi}}\}$-space
  - Both parameters well identified when using all variables to compute likelihood

15 observables

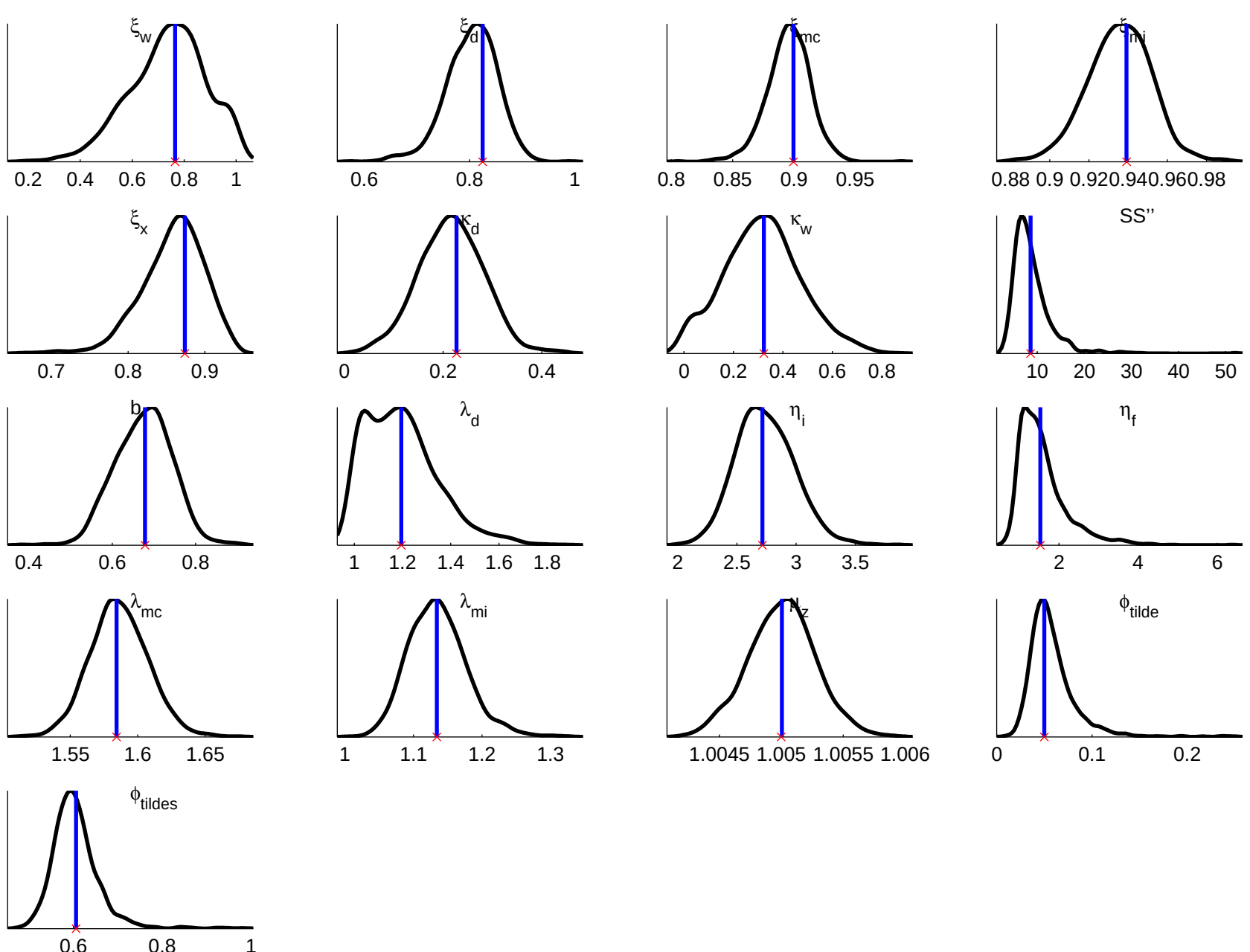


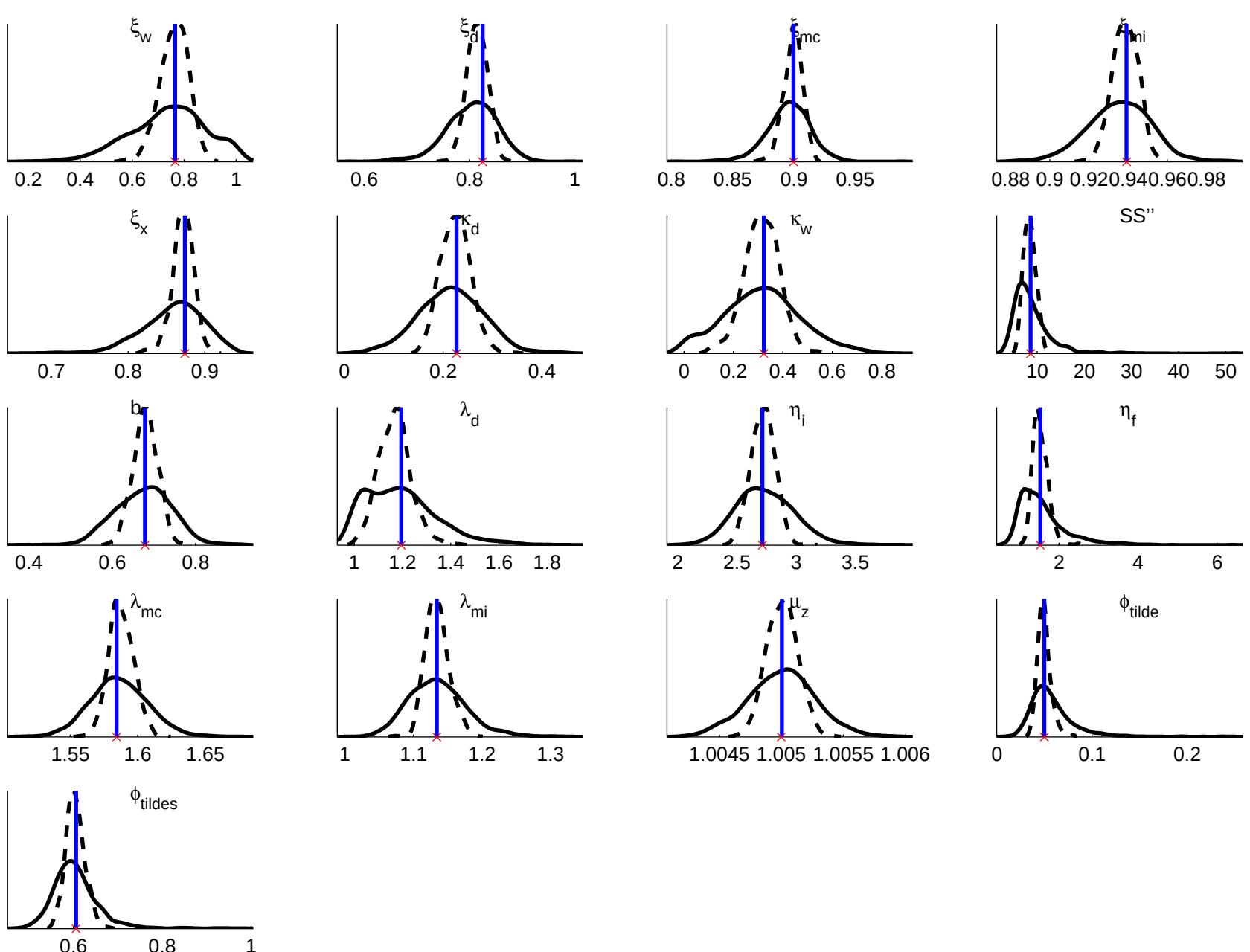
Only RER



Identification (cont.)

- Small sample properties of ML estimation using simulated data from the model (Adolfson and Lindé, 2006)
  - Distribution of estimates located around the true parameters
  - Convergence in distribution when sample size increased


ξ_w
0.2 0.4 0.6 0.8 1
ξ_d
0.6 0.8 1
ξ_{mc}
0.8 0.85 0.9 0.95
ξ_{mi}
0.88 0.9 0.92 0.94 0.96 0.98
ξ_x
0.7 0.8 0.9
κ_d
0 0.2 0.4
κ_w
0 0.2 0.4 0.6 0.8
SS''
10 20 30 40 50
b
0.4 0.6 0.8
λ_d
1 1.2 1.4 1.6 1.8
η_i
2 2.5 3 3.5
η_f
2 4 6
λ_{mc}
1.55 1.6 1.65
λ_{mi}
1 1.1 1.2 1.3
μ_z
1.0045 1.005 1.0055 1.006
ϕ_{tilde}
0 0.1 0.2
ϕ_{tildes}
0.6 0.8 1


ξ_w
0.2 0.4 0.6 0.8 1
ξ_d
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0 0.2 0.4
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SS''
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