Oil Price Shocks, Monetary Policy Rules and Welfare
(Work in Progress)

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Plan of the talk

- Motivation
- Main conclusion
- Model description
- Solution method
- Calibration
- Optimal response to oil-price shocks and welfare
- Conclusion

Motivation

- The oil-price escalation since 2003 is reminiscent of the oil-crises of the 1970s.
- "With oil shocks, policymakers are confronted with a new dilemma" (Gramlich, Sept. 2004).
- A wrong policy can make more damage than the oil-shock per se (Bernanke, Gertler and Watson 1997)
- We study what a DSGE model can tell us on this issue.
- Apply second-order solution methods to a large DSGE model.

Related work

- Policy analysis in DSGE models
  - Schmitt-Grohè and Uribe (2004,2005): medium-scale closed economy models
- Oil prices
  - Leduc and Sill (2004): role of MP in oil-induced recessions
  - Kamps and Pierdzioch (2002): what inflation-measure should the CB target (SOE)
  - de Walque, Smets and Wouters (2005): estimated DSGE model
- Second-order-approximation solution technique
  - Lombardo and Sutherland (2006)

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Main conclusion

- At present only results under complete markets
- The central bank should respond to a measure of core inflation: Oil-shocks should be partially accommodated.
- Welfare losses incurred in adopting alternative Taylor-type rules are relatively small.

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The model

- Three-country model: euro area (EA), US and oil-exporting block
- US and EA
  - same economic structure
  - produce final consumer goods, import final goods and oil
  - independent fiscal and monetary authorities
  - sticky prices and wages with indexation
  - OIL enters consumption (CES) and production (linked to aggregate capital (Kim-Loungani) and firm-specific utilization (M.Finn) and
- Oil exporting block
  - no fiscal policy, currency is pegged to the dollar
  - produce only oil, import EA and US goods
  - flexible prices and wages

EA and US

Households

- Consume a basket of domestically produced goods, imported goods and oil.

$$
\begin{aligned}
(1a) C_{e,t} &= \left[(1-o)^{\frac{1}{\xi}} C_t^{\frac{\xi-1}{\xi}} + o^{\frac{1}{\xi}} \left(e_{h,t}\right)^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}} \\
(1b)\ P_t^c &= \left[n \left(P_t^H\right)^{1-\chi} + (1-n)\left(S_t P_t^F\right)^{1-\chi}\right]^{\frac{1}{1-\chi}} \\
(1c)\ P_t &= \left[(1-o)\left[(1+\tau_{c,t})P_t^c\right]^{1-\xi} + o\left[(1+\tau_{e,t})\left(S_t P_t^e + \varpi\right)\right]^{1-\xi}\right]^{\frac{1}{1-\xi}}.
\end{aligned}
$$

- Preferences display home bias and habit persistence in consumption.

Households cont'd

- Allocate savings in
  - investment goods (with adjustment costs)
  - financial assets: domestic government debt and either internationally traded bonds or state contingent assets.

- Supply a differentiated type of labour to a union that combines the different types and offers this aggregate labour input to firms.

Firms

- Produce differentiated goods using labour and energy-loaded capital

$$y_t = \epsilon_t L_t^{1-\alpha} \left(u_t K_{e,t} \right)^{\alpha}$$

- Set prices à la Calvo (1983).

- Oil enters production in two ways:
  - Capital can only be used to produce if combined with oil

$$K_{e,t} = \left[\varphi^{\frac{1}{\eta}} K_t^{\frac{\eta-1}{\eta}} + (1-\varphi)^{\frac{1}{\eta}} e_{p,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

  - Oil is needed to vary capital utilization and hence to produce capital services

$$e_{u,t} = a\left(u_t\right) K_{e,t}$$

The fiscal authority

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- Levies taxes on labor income, final consumption and oil plus a lump-sum tax.
- Purchases the same basket of goods purchased by Households.
- Has positive net liabilities (in domestic currency): a debt-to-gdp ratio holds in steady state.

The central bank

- Monetary policy is characterized by a short-run nominal interest rate rule.

$$R_t = \lambda_R R_{t-1} + (1-\lambda_R)\left[\lambda_\pi \left(\frac{\pi_t}{\pi} - 1\right) + \lambda_Y \left(\frac{Y_t}{Y} - 1\right) + \lambda_{\Delta Y}\left(\frac{Y_t}{Y_{t-1}} - 1\right)\right.$$

$$\left. + \lambda_{\Delta Pe}\left(\frac{P_{e,t}}{P_{e,t-1}} - 1\right) + \lambda_{Pe}\left(\frac{P_{e,t}}{P_e} - 1\right) + R_0\right] + \varepsilon_t^R$$

Oil exporting country

- The price of oil is endogenous.
- There are increasing marginal costs of production of oil:

$$e_t^o = \nu_t^e \, {L_t}^{\iota}, \;\; \iota < 1$$

- Productivity in the oil-sector is modelled as a stochastic process.

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Solution method

- The calibration is based on a first-order approximation of the model (DYNARE + SYMBSOLVE).

- The welfare analysis is based on a second-order approximation of the model (SYMBSOLVE).

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Calibration

- We calibrate the model under incomplete markets (similar calibration results obtains under complete markets).

- Procedure:

1. start from parameter values estimated in empirical work;
2. modify them to match sample moments and to produce a variance decomposition in line with that obtained in related works.

Shares of oil (+ nat. gas)

	Consumption		Production	
	data	model	data	model
EA	$\sim$ 6.2%	6.03%	$\sim$ 1.5%	1.56%
US	$\sim$ 5.6 %	6.89%	EA$+ \approx 30\%$	1.96%

Variance decomposition: contribution of oil to GDP

- The existing literature: wide range . . .
- Dotsey and Reid (1992) 5 to 6% (US real GNP).
- Jimènez-Rodrìguez and Sanchèz (2004): 7.5% (EA) and 10.9% (US GDP).
- De Walque et al. (2005) report small values in the order of 1.0% (EA) and 1.5% (US)
- We have 1.9% (EA) and 4.37% (US)

Moments matching

- The standard deviations and cross-correlations of most of the macroeconomic variables described by the model are broadly in line with those observed in the data.

The effects of an exogenous oil-price shock

- We model the exogenous oil-price shock as a negative transitory shock to the level of productivity of the oil-producing sector.

  PRICES

- For the euro area a 10% increase in the dollar real price of oil would increase the GDP deflator by about 0.25% after 2 years. For the US this number is about 0.44% (twice as much for CPI).

  – in Bernanke et al. (1997) the monthly VAR yields an increase in the GDP deflator of about 0.2% two years after the oil-price shock. The quarterly VAR (Bernanke et al. (2004)) produces a milder increse (about 0.1%).

The effects of an exogenous oil-price shock cont'd

OUTPUT

- GDP at constant prices first increases then falls, reaching the trough after about 5-6 quarters at -0.14% (-0.24%) in the euro area (US)
  - Bernanke et al. (2004) (five-variable quarterly VAR): a 10% increase in the price of oil implies a change of GDP of about -0.7% (at the trough four quarters after the innovation).
  - Bernanke et al (1997) (seven-variable monthly VAR) a 10% increase in the price of oil produced a fall in GDP of around -0.25% about 24 months after the shock.

The effects of an exogenous oil-price shock cont'd

POLICY

- The nominal policy rate increases by about 28 (57) annualized basis points by the second quarter in the euro area (US).
  - Bernanke et al. (1997) estimate a value of about 63 bp after 6 months for the US

- The net foreign asset position, net-trade and the terms of trade (price of import over price of export) all worsen.

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The welfare measure

- Each central bank chooses the simple interest rate rule that maximizes the aggregate households' welfare.

- In aggregating over households we neglect the real money-balance component of welfare obtaining

(2) $$\mathbb{W}_s = E_{s-1}\sum_{t=s}^{\infty}\beta^{t-s}\varepsilon_t^C\left\{\frac{\left(C_{e,t}-hC_{e,t}\right)^{1-\gamma}}{1-\gamma}-\zeta_t\frac{\int_0^b L_{i,t}^{1+\varsigma}\mathrm{d}i}{1+\varsigma}\right\}$$

- We use a steady-state-conditional measure of welfare

Optimality criteria

Our choice of a desirable monetary policy rule satisfies four criteria (as in Schmitt-Grohè and Uribe (2004,2005)

1. The rule must be simple and operational.

2. The rule must satisfy a zero-lower-bound condition definde by $\log(R_0) > 2\sigma_R$.

3. Among the rules satisfying criteria 1. and 2., we choose the rule that maximizes welfare.

4. The choice of policy parameters must constitute either a Nash equilibrium or a cooperative equilibrium.

Results

Three shocks: government spending, technology, oil-prices

- The optimal policy parameters if respond to oil

Country	λ_R	λ_π	$\lambda_{\Delta y}$	λ_y	λ_{Pe}	$\lambda_{\Delta Pe}$
EA	0.95	27.2	0	1.98	0	$27.2 \times (-0.088)$
US	0.95	20.8	0	1.98	0	$20.8 \times (-0.12)$

- The optimal parameters if don't respond to oil

Country	λ_R	λ_π	$\lambda_{\Delta y}$	λ_y	λ_{Pe}	$\lambda_{\Delta Pe}$
EA	0.95	16.8	0	1.5	0	0
US	0.95	18.8	0	2.5	0	0

Results cont'd

Welfare losses in units of steady-state consumption:	EA	US
Optimal rule	0.128%	0.246%
Constrained Optimum	0.136%	0.252%
Benchmark rule	0.156%	0.279%
Flexible prices	0.074%	0.181%

- Some unconditional means relative to benchmark
  - Consumption increases
  - labour effort increases
  - inflation and short term interest rate fall
  - lower expected wage dispersion
  - Also, lower volatility of inflation

Results cont'd

- In summary

1. The optimal linear rule shows a very marked degree of inertia: due to zero-lower-bound condition
2. The optimal response to inflation are, in the long run, extremely large. This suggests that the cost of inflation in our model is overwhelming.
3. The optimal rule calls for a negative response to the oil-price inflation: i.e. respond to "core" inflation
4. The size of the welfare losses is relatively small

Results cont'd

- Optimal coefficients without oil-shocks and with oil-shocks only
- No oil-price shocks: While responding vigorously to headline inflation, the central bank responds positively to oil-price inflation.

Country	λ_R	λ_π	$\lambda_{\Delta y}$	λ_y	λ_{Pe}	$\lambda_{\Delta Pe}$
EA	0.95	29.7	0	1.98	0	1.23
US	0.95	27.2	0	1.98	0	2.72

Results (cont'd)

- Oil-price shocks only: Central bank would react less aggressively and would partially accommodate increases in oil-price inflation.

Country	λ_R	λ_π	$\lambda_{\Delta y}$	λ_y	λ_{Pe}	$\lambda_{\Delta Pe}$
EA	0.95	12.4	0	1.98	0	$12.4 \times (-0.081)$
US	0.95	12.4	0	1.98	0	$12.4 \times (-0.14)$

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Conclusion and future work

- We developed a three-country DSGE model with endogenous oil production which is able to replicate a number of open-economy stylized facts.

- This model suggests that under complete markets a welfare-maximizing central bank should respond to a particular measure of core inflation: i.e. it should partially accommodate oil-price increases.

- Caveat: We assume away problems of credibility and commitment

- related work in progress:

  - Study the interaction of fiscal and monetary policy (work in progress).
  - Improve the expectational channel of oil shocks: e.g. inventories .

Appendix

Price and wage setting

	Calvo probability	Degree of indexation
Prices		
EA	0.8	0.4
US	0.6	0.4
Wages		
EA	0.83	0.7
US	0.73	0.7

Taxes

- The labour income tax rate and the VAT are taken from Coenen et al. (2005).

- VAT taxes on oil are assumed to be the same as the VAT taxes on other final consumption goods: 18.3% (EA) and 7% (us).

- Excise tax are set at 70% (EA) and 20% (US) of the steady-state price of oil.

Monetary policy

We take the parameters of the interest rate rule from de Walque et al. (2005)

Country	λ_R	λ_π	$\lambda_{\Delta y}$	λ_y	λ_{Pe}	$\lambda_{\Delta Pe}$
EA	0.9	1.72	0.2	0.1	0.0	0.0
US	0.87	1.7	0.2	0.13	0.0	0.0

Monetary policy cont'd

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- Note that the rule estimated in de Walque et al. (2005) differs from ours in two important respects.
  - It responds to aggregate demand while ours responds to real gdp.
  - It responds to deviations of aggregate demand from its flexible price equilibrium while our responds to deviation from the non-stochastic steady state.

- The stochastic properties of our model remain virtually unchanged under an alternative rule as estimated by Christiano et al. (2006) in a closed economy setting for the euro area and the US.

Tables of moments

Standard deviations in ppt

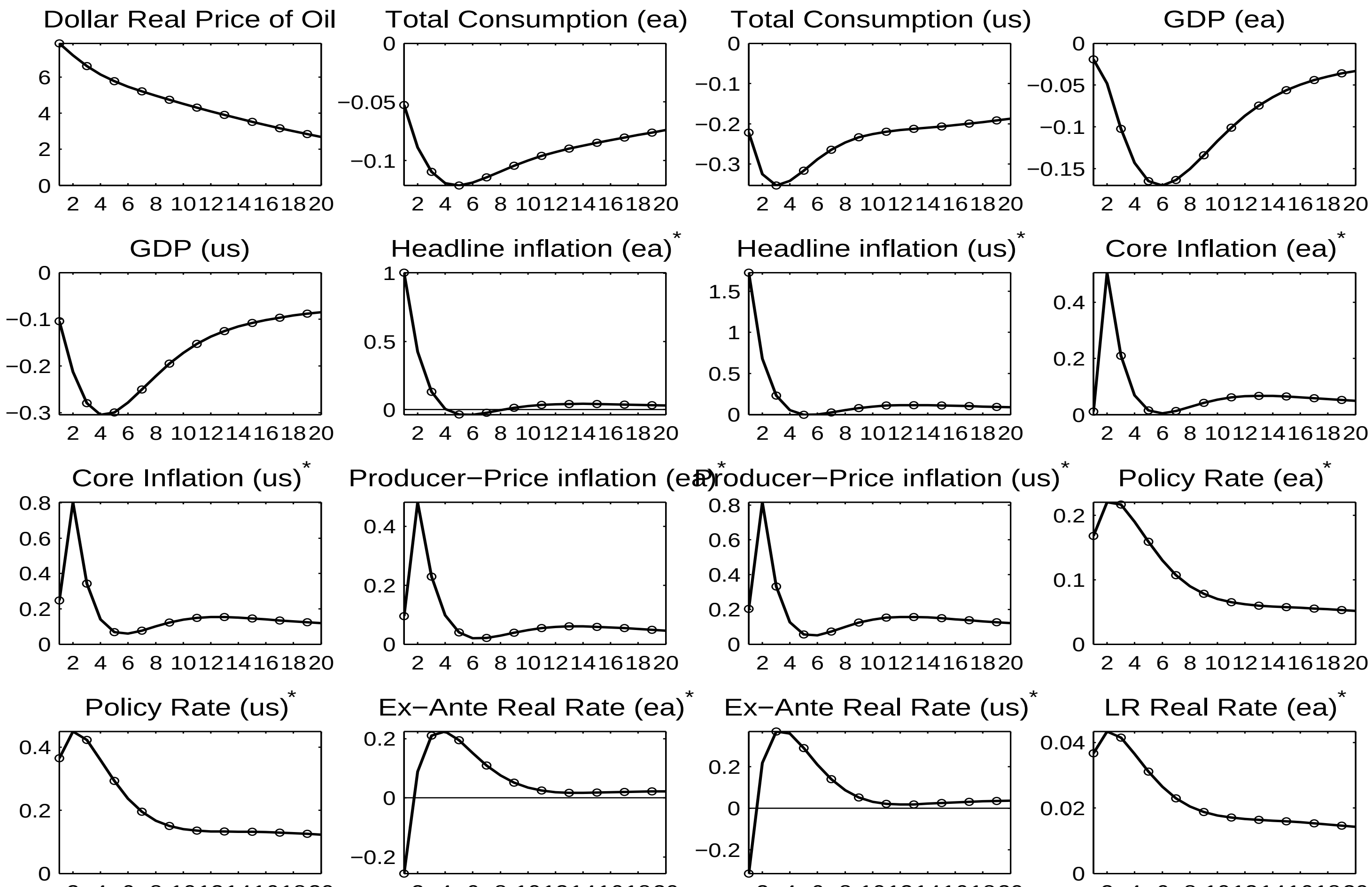
vbls	US	model	EA	model
GDP	1.02	1.42	0.93	1.22
C	.90	1.43	0.80	0.53
I	4.90	4.00	2.6	2.56
NX	0.37	0.47	0.46	0.32
tot	1.4	5.5	1.2	3.32
RER	7.0	1.44	7.0	1.44
π	1.2	3.1	1.05	2.18
R	1.16	1.32	0.99	0.87
Pe	17.1	11.34	11.5	19.0

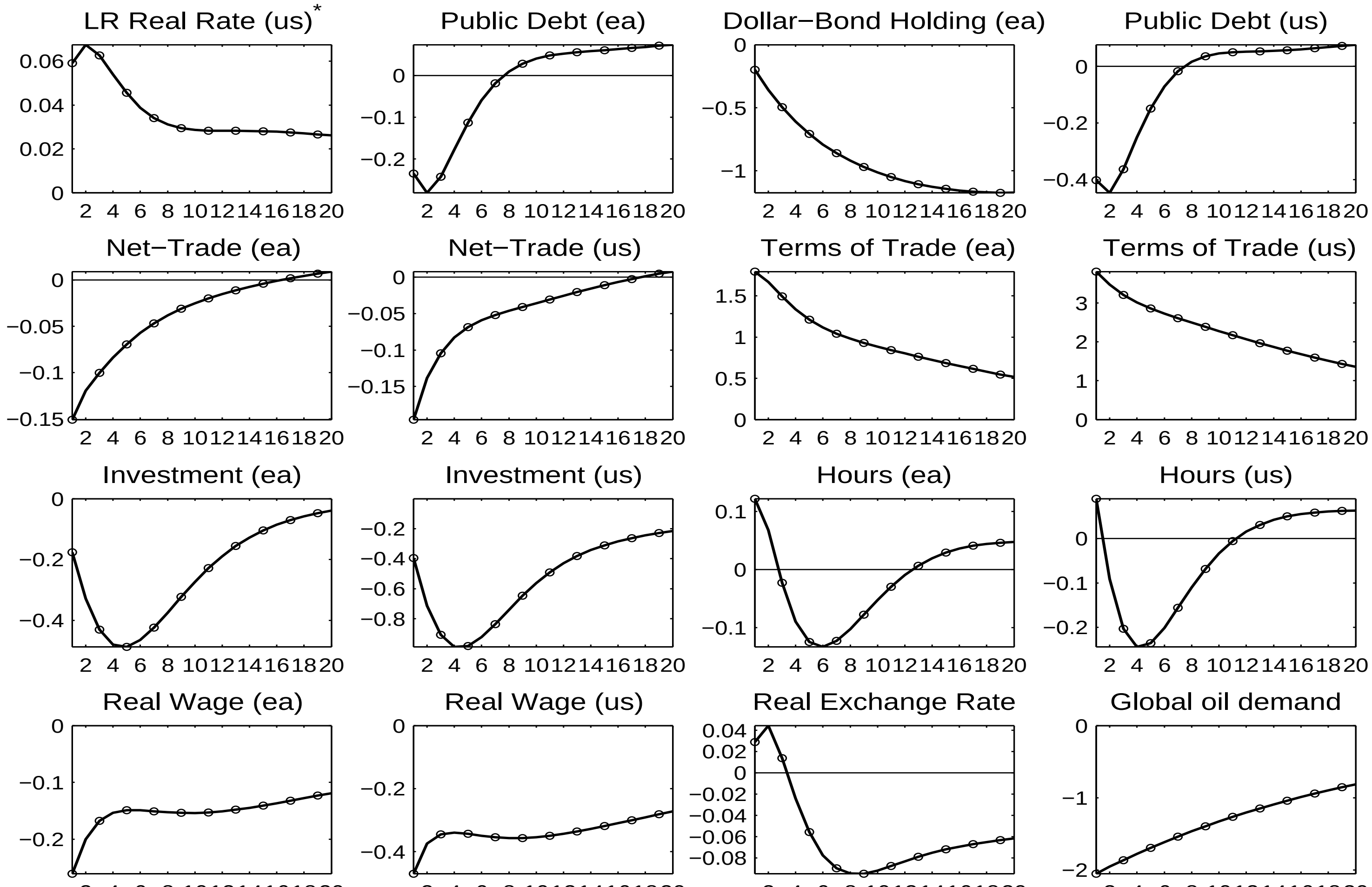
x-correlations

vbls	US	model	EA	model
(GDP, NX)	-0.39	-0.71	-0.69	-0.57
(C, NX)	-0.54	-0.20	-0.75	-0.072
(I, NX)	-0.51	0.27	-0.79	-0.11
(Pe, NX)	-0.25	-0.75	-0.41	-0.49
(tot, NX)	-0.51	-0.71	-0.38	-0.45
(Pe, tot)	0.80	0.98	0.76	0.88
(RER, NX)	0.08	-0.2	-0.15	-0.14
(REX, Pe)	0.05	0.09	0.43	0.21

Cross-country correlations

vbls	data	model
(C, C^*)	0.14	0.081
(I, I^*)	0.17	0.39
(GDP, GDP^*)	0.29	0.27
(R, R^*)	0.56	0.57
(π, π^*)	0.39	0.47
$((C - C^*), RER)$	0.007	-0.028


Dollar Real Price of Oil
Total Consumption (ea)
Total Consumption (us)
GDP (ea)
GDP (us)
Headline inflation (ea)*
Headline inflation (us)*
Core Inflation (ea)*
Core Inflation (us)*
Producer−Price inflation (ea)*
Producer−Price inflation (us)*
Policy Rate (ea)*
Policy Rate (us)*
Ex−Ante Real Rate (ea)*
Ex−Ante Real Rate (us)*
LR Real Rate (ea)*



LR Real Rate (us)*
Public Debt (ea)
Dollar−Bond Holding (ea)
Public Debt (us)
Net−Trade (ea)
Net−Trade (us)
Terms of Trade (ea)
Terms of Trade (us)
Investment (ea)
Investment (us)
Hours (ea)
Hours (us)
Real Wage (ea)
Real Wage (us)
Real Exchange Rate
Global oil demand

Results cont'd

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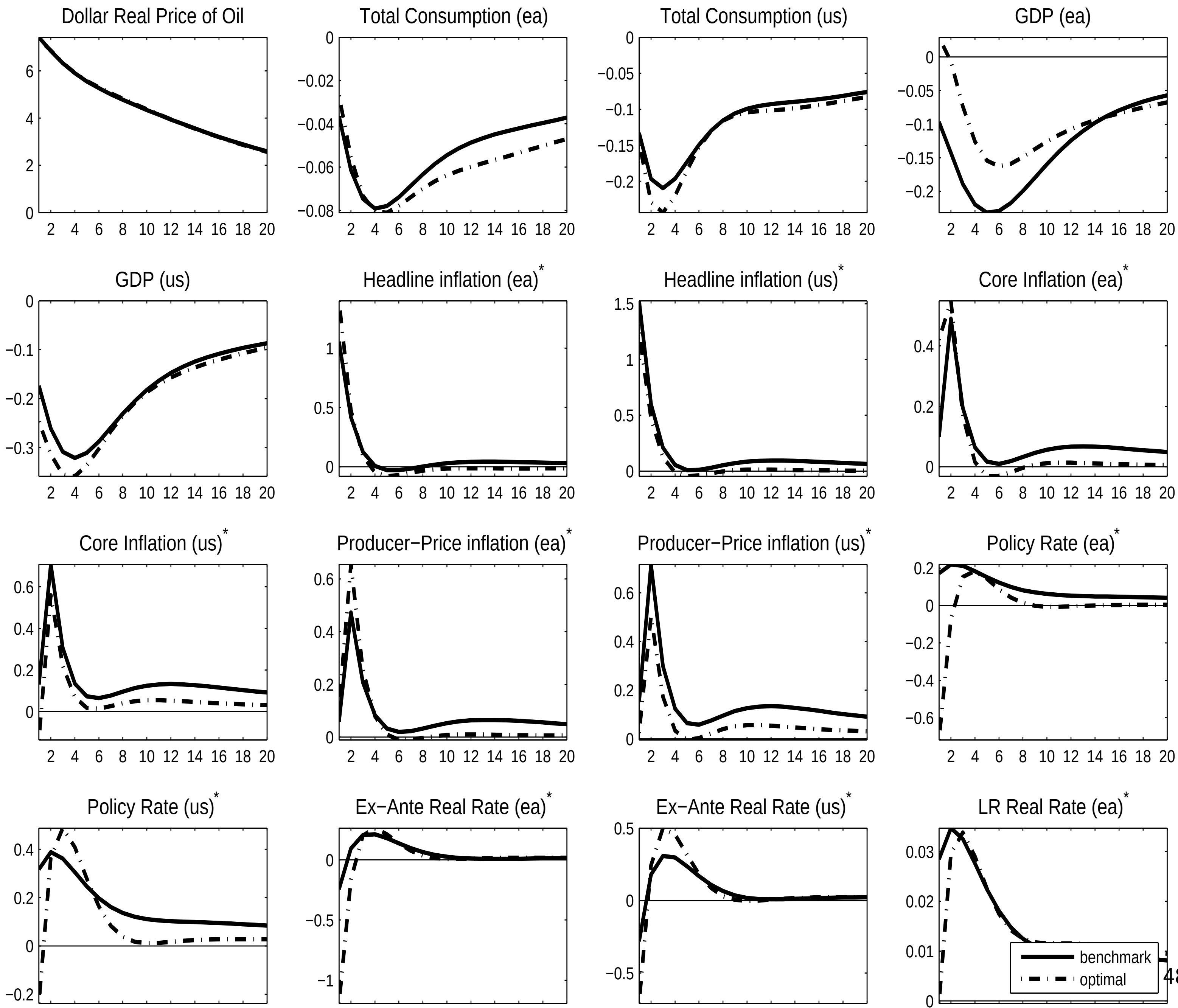
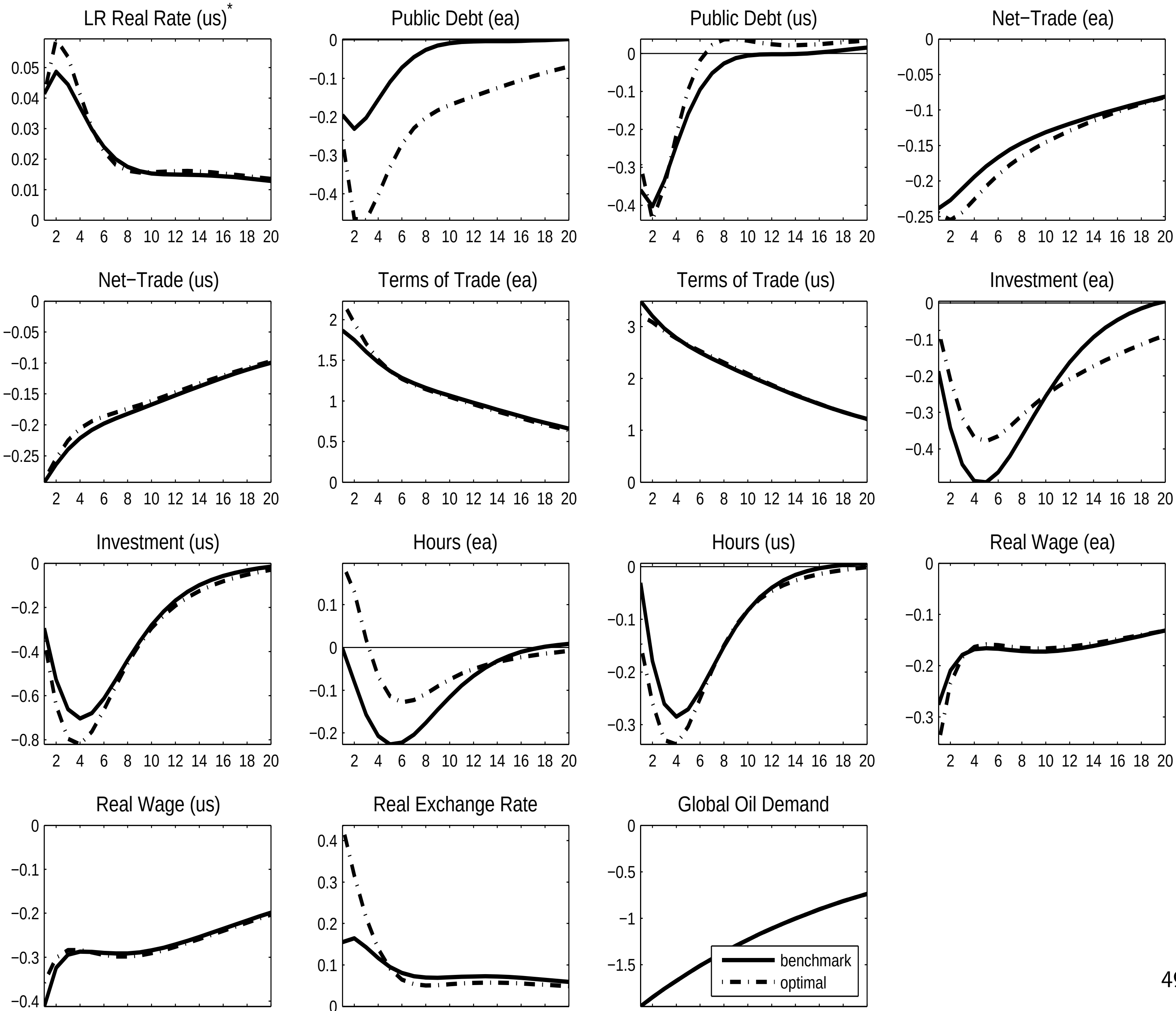
- In particular, the optimal rule under the constraint of zero response to oil-prices (inflation or level) is about 0.008% and 0.006% worse than the optimal rule, for EA and US respectively.

- These small numbers are not unusual in the related literature.
  - For example, Schmitt-Grohè and Uribe (2005) report a welfare cost of using a simple interest rate rule (relative to the Ramsey-optimal rule) of about $9.1 per US citizen per year (at 2003 prices).
  - Using the 2003 value of US GDP per capita (at PPP), our model implies that the constrained optimum costs about $2.45 more per person and per year than the unconstrained optimum.
  - The cost to the household of the unconstrained optimum relative to the flexible price equilibrium is about $24.05.

IR under the optimal rule vs. benchmark (complete markets)


Dollar Real Price of Oil
Total Consumption (ea)
Total Consumption (us)
GDP (ea)
GDP (us)
Headline inflation (ea)*
Headline inflation (us)*
Core Inflation (ea)*
Core Inflation (us)*
Producer−Price inflation (ea)*
Producer−Price inflation (us)*
Policy Rate (ea)*
Policy Rate (us)*
Ex−Ante Real Rate (ea)*
Ex−Ante Real Rate (us)*
LR Real Rate (ea)*
benchmark
optimal


LR Real Rate (us)*
Public Debt (ea)
Public Debt (us)
Net−Trade (ea)
Net−Trade (us)
Terms of Trade (ea)
Terms of Trade (us)
Investment (ea)
Investment (us)
Hours (ea)
Hours (us)
Real Wage (ea)
Real Wage (us)
Real Exchange Rate
Global Oil Demand
benchmark
optimal

Results cont'd

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- The negative coefficient on oil-price inflation implies that, on impact, the short-run nominal interest rate falls.
  - The government partially benefits from the fall in short term real rates and the households lose out.
  - Consumption and investment (to a first order of approximation) are affected by the short-run rates only to the extent that these bring about variations in the long-run real rate of interest.
  - Overall, to a first order of approximation the optimal rule does not bring about a clear pattern in the dynamics of the real variables.
- More evident is the effect on the dynamics of inflation:
  - except on impact, all measure of inflation approach the long run equilibrium more quickly under the optimal rule