The Transmission of Monetary Policy in a Multisector Economy

Hafedh Bouakez, Emanuela Cardia,

and Francisco J. Ruge-Murcia

Discussion by Fabio Ghironi

Dynamic Models and Monetary Policymaking

Federal Reserve Bank of Cleveland

September 22-24, 2004

Introduction

• This is (the start of) a very good paper.

• It contributes to a growing literature on New Keynesian, multi-sector models (Aoki, 2001; Benigno, 2004; Carlstrom, Fuerst, and Ghironi, 2002; Erceg and Levin, 2002, among others).

• Sectoral heterogeneity is an important feature of the data:

- Erceg and Levin (2002): Durables expenditure is substantially more interest-rate sensitive than non-durables (more on this later).

- Bils and Klenow (2004): Nominal rigidity varies substantially across sectors.

- Hafedh, Emanuela, and Francisco allow for several empirically relevant sources of sectoral heterogeneity: production function parameters, input composition, capital adjustment costs, depreciation rates, nominal rigidity, productivity shocks.
- This results in a quantitative business cycle model that features much richer dynamics than the basic New Keynesian setup.
- Cross-sectoral relative price dynamics matter for shock transmission.

- Hafedh, Emanuela, and Francisco estimate the model with SMM and explore the transmission of monetary policy (money growth shock).
- Example in available version of paper focuses on heterogeneity in production function parameters, input structure, and capital depreciation. No heterogeneity in capital adjustment costs or nominal rigidity.
- Results are interesting, but preliminary.
- It will be important to disentangle the role of various channels in shock propagation.

• My discussion will focus on the role of relative prices and the nature of monetary policy in a simpler, two-sector model, where I can go deeper into analytics.

• The model features heterogeneous nominal rigidity, immobile labor, endogenous interest rate setting, and sectoral productivity shocks.

• The discussion draws on work with Chuck Carlstrom, Tim Fuerst, and Kolver Hernandez.

• Paper coming soon — I hope. ☺

• Kolver on the market. Outstanding.

A Simple Multi-Sector Model

The Representative Household

- Continuum of households between 0 and 1.

- Representative household consists of two agents.

- One of these supplies labor to firms in sector 1, the other supplies labor to firms in sector 2. Labor is immobile across sectors.

- These agents jointly maximize $E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t,\ M_{t+1}/P_t,\ L_t^1,\ L_t^2\right),\ 1 > \beta > 0.$

- For simplicity, assume $U\left(C_t,\ M_{t+1}/P_t,\ L_t^1,\ L_t^2\right) = \log C_t + V\left(\frac{M_{t+1}}{P_t}\right) - \left(L_t^1\right)^2/2 - \left(L_t^2\right)^2/2$.

- Consumption basket: $C_t = \left[b^{\frac{1}{\omega}} \left(C_t^1 \right)^{\frac{\omega-1}{\omega}} + (1-b)^{\frac{1}{\omega}} \left(C_t^2 \right)^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}},\quad \omega > 0,\ 1 > b > 0.$

- Sectors 1 and 2 populated by monopolistically competitive firms.

- Sector 1: firms in the interval b/w 0 and *b*; sector 2: firms b/w *b* and 1:

$$C_t^1 = \left[\left(\frac{1}{b} \right)^{\frac{1}{\theta}} \int_0^b \left(C_t^1(z) \right)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}},\ C_t^2 = \left[\left(\frac{1}{1-b} \right)^{\frac{1}{\theta}} \int_b^1 \left(C_t^2(z) \right)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}},\ \theta > 1.$$

- Then: $P_t = \left[b \left(P_t^1 \right)^{1-\omega} + (1-b) \left(P_t^2 \right)^{1-\omega} \right]^{\frac{1}{1-\omega}},$

$$P_t^1 = \left[\frac{1}{b} \int_0^b \left(P_t^1(z) \right)^{1-\theta} dz \right]^{\frac{1}{1-\theta}},\ P_t^2 = \left[\frac{1}{1-b} \int_b^1 \left(P_t^2(z) \right)^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

• Household allocates consumption to individual brands according to:

$$C_t^j(z) = \left(\frac{P_t^j(z)}{P_t^j}\right)^{-\theta}\left(\frac{P_t^j}{P_t}\right)^{-\omega} C_t, \quad j = 1, 2.$$

• Symmetric equilibria: drop firm-specific index z and consider

representative firm in each sector $j = 1, 2$.

• BC: $M_{t+1} = M_t + X_t + R_{t-1}B_{t-1} + W_t^1 L_t^1 + W_t^2 L_t^2 + \Pi_t^1 + \Pi_t^2 - B_t - P_t C_t$.

• Fisher equation: $\frac{U_C(t)}{P_t} = R_t \beta E_t\left(\frac{U_C(t+1)}{P_{t+1}}\right)$.

• Labor supplies: $-\frac{U_{L^1}(t)}{U_C(t)} = \frac{W_t^1}{P_t}, \qquad -\frac{U_{L^2}(t)}{U_C(t)} = \frac{W_t^2}{P_t}$.

Firms

- Technology: $Y_t^j = \Phi_t^j L_t^j, \qquad j = 1, 2.$
- AR(1) sectoral productivity shocks (in logs).
- Pricing subject to nominal rigidity (Calvo-Yun-Rotemberg).
- Optimal price in sector *j*: $\frac{P_t^j}{P_t} = \frac{1}{Z_t^j}\frac{W_t^j}{P_t}\frac{1}{\Phi_t^j}, \quad j = 1, 2,$

where Z^j = marginal cost in sector *j* ($1/Z^j$ = markup).

- Sectoral New-Keynesian Phillips curve holds in log-linear model:

$\pi_t^j = \lambda_j z_t^j + \beta E_t \pi_{t+1}^j,$ λ_j: nominal rigidity in sector *j*, *j* = 1, 2.

Monetary policy

- $r_t = \tau_1 b \pi_t^1 + \tau_2 (1-b) \pi_t^2 + \tau_C c_t + \varphi_t^r$, $\varphi_t^r = \rho_r \varphi_{t-1}^r + \varepsilon_t^r$.
- If $\tau_1 = \tau_2$, central bank reacts to CPI inflation.
- Carlstrom, Fuerst, Ghironi (2002): $r_t = \tau\left[(1-\eta)\pi_t^1 + \eta \pi_t^2\right]$ with $1 \geq \eta \geq 0$.
- $\tau > 1$ necessary and sufficient for local determinacy for any value of η.

The Role of the Terms of Trade

- Define the terms of trade (TOT) across sectors as: $T_t \equiv p_t^1 - p_t^2$.

- Sectoral inflation:

$$\pi_t^j = \lambda_j\left[2c_t - (1+\omega)rp_t^j - 2\varphi_t^j\right] + \beta E_t\left(\pi_{t+1}^j\right),\ j = 1, 2,$$

where $rp_t^j \equiv p_t^j - p_t$ $\quad (rp_t^1 = (1-b)T_t,\ \ rp_t^2 = -bT_t)$.

- Fisher equation and policy:

$$E_t\left(c_{t+1}\right) - c_t = \tau_1 b\pi_t^1 + \tau_2(1-b)\pi_t^2 + \tau_C c_t + \varphi_t^r - E_t\left(\pi_{t+1}\right).$$

- Solution of log-linear model has the form:

$$\pi_t^1 = \alpha_1 T_{t-1} + \gamma_1 \varphi_t^1 + \gamma_2 \varphi_t^2 + \gamma_{r,1} \varphi_t^r,$$

$$\pi_t^2 = \alpha_2 T_{t-1} + \gamma_3 \varphi_t^1 + \gamma_4 \varphi_t^2 + \gamma_{r,2} \varphi_t^r,$$

$$c_t = \alpha_3 T_{t-1} + \gamma_5 \varphi_t^1 + \gamma_6 \varphi_t^2 + \gamma_{r,3} \varphi_t^r,$$

$$\pi_t = \alpha_4 T_{t-1} + \gamma_7 \varphi_t^1 + \gamma_8 \varphi_t^2 + \gamma_{r,4} \varphi_t^r.$$

• TOT: $T_t = \alpha_5 T_{t-1} + (\gamma_1 - \gamma_3)\varphi_t^1 + (\gamma_2 - \gamma_4)\varphi_t^2 + (\gamma_{r,1} - \gamma_{r,2})\varphi_t^r$.

• $\alpha_5 \equiv 1 + \alpha_1 - \alpha_2 \in (0,1)$: Endogenous persistence of TOT (beyond persistence of shocks).

• Persistent TOT dynamics imply persistent movements in rp^j.

• When $\lambda_1 \neq \lambda_2$ and/or when $\tau_1 \neq \tau_2$, this implies endogenous persistence in CPI inflation and aggregate output dynamics.

• Sectoral variables are affected by TOT even when aggregates are not.

- Elasticity of aggregate and sectoral variables to past TOT does not depend on exogenous shock persistence.
- It depends on nominal rigidity and the nature of monetary policy (and other structural parameters).

Identical Nominal Rigidity, Reaction to CPI Inflation

- $\lambda_1 = \lambda_2 = \lambda$ and $\tau_1 = \tau_2 = \tau$.

- Then:

$$\pi_t = 2\lambda c_t + \beta E_t(\pi_{t+1}) - 2\lambda\left[b\varphi_t^1 + (1-b)\varphi_t^2\right].$$

$$E_t(c_{t+1}) - c_t = \tau\pi_t + \tau_C c_t + \varphi_t^r - E_t(\pi_{t+1}).$$

- Sectoral relative price movements have no impact on CPI inflation and aggregate output (Benigno, 2004).

• When $\lambda_1 = \lambda_2$:

$$\beta E_t T_{t+1} - [1 + \beta + \lambda(1+\omega)]T_t + T_{t-1} = 2\lambda(\varphi_t^1 - \varphi_t^2).$$

• One eigenvalue outside the unit circle and one inside.

• TOT remain endogenously persistent:

$$\alpha_5 = e = \frac{1+\beta+\lambda(1+\omega) - \sqrt{[1+\beta+\lambda(1+\omega)]^2 - 4\beta}}{2\beta}.$$

• <u>But</u> TOT completely insulated from monetary policy when $\lambda_1 = \lambda_2$

(regardless of whether or not $\tau_1 = \tau_2$).

Identical Nominal Rigidity, Different Sectoral Inflation Reactions

- $\lambda_1 = \lambda_2 = \lambda$ but $\tau_1 \neq \tau_2$.

- CPI inflation still:

$$\pi_t = 2\lambda c_t + \beta E_t\left(\pi_{t+1}\right) - 2\lambda\left[b\varphi_t^1 + (1-b)\varphi_t^2\right].$$

- But π^1 and π^2 cannot be aggregated into π in

$$E_t\left(c_{t+1}\right) - c_t = \tau_1 b\pi_t^1 + \tau_2(1-b)\pi_t^2 + \tau_C c_t + \varphi_t^r - E_t\left(\pi_{t+1}\right).$$

- Since π^1 and π^2 depend on TOT regardless of λ_1 vs. λ_2, c and π depend on past TOT when $\lambda_1 = \lambda_2 = \lambda$ but $\tau_1 \neq \tau_2$.

• Benigno's (2004) result that c and π are insulated from TOT when nominal rigidity is identical across sectors is conditional on the central bank reacting to π.

- The AR(1) root for TOT is still $\alpha_5 = e$ as before.

- Elasticity of c to past TOT is:

$$\alpha_3 = \frac{\lambda b(1-b)(1+\omega)(\tau_1 - \tau_2)e}{(1-e+\tau_C)(1-\beta e)+2\lambda[b\tau_1 + (1-b)\tau_2 - e]}.$$

- Using this, we can find elasticities of other variables to past TOT.

• We can analyze how elasticities are affected by policy.

• For instance, α_3 decreases if the central bank reacts more aggressively to output (if τ_C rises).

• Why?

• More aggressive reaction to c dampens the effect of past TOT on current π^1 and π^2.

• This implies that π (and, in turn, c) is less responsive to past TOT.

Different Nominal Rigidity, Reaction to CPI Inflation

- $\lambda_1 \neq \lambda_2$ and $\tau_1 = \tau_2 = \tau$.

- CPI inflation obeys:

$$\pi_t = \beta E_t \pi_{t+1} + 2[b\lambda_1 + (1-b)\lambda_2]c_t - (1+\omega)b(1-b)(\lambda_1 - \lambda_2)T_t - 2[b\lambda_1\varphi_t^1 + (1-b)\lambda_2\varphi_t^2].$$

- Fisher equation: $E_t(c_{t+1}) - c_t = \tau\pi_t + \tau_C c_t + \varphi_t^r - E_t(\pi_{t+1})$.

- TOT: $\beta E_t T_{t+1} - \{1 + \beta + (1+\omega)[(1-b)\lambda_1 + b\lambda_2]\}T_t + T_{t-1} = -2(\lambda_1 - \lambda_2)c_t + 2(\lambda_1\varphi_t^1 - \lambda_2\varphi_t^2)$

- Hence, if $\lambda_1 \neq \lambda_2$, π inherits the persistence of TOT, and so does c.

• Intuition:

- Changes in relative prices redistribute demand across sectors.

- When nominal rigidity differs in the two sectors, sectoral relative prices move at different speeds.

- This introduces persistence in the aggregate economy, as aggregate adjustment must continue until all prices are "aligned."

- Importantly, $\lambda_1 \neq \lambda_2$ implies that TOT are no longer insulated from monetary policy.

- The stable AR(1) root α_5 in the TOT solution becomes a function of τ and τ_C.

- Again, we can explore how changes in policy parameters affect elasticities.

- Examples and the general case $\lambda_1 \neq \lambda_2$ and $\tau_1 \neq \tau_2$ will be in our paper.

Monetary Policy Transmission

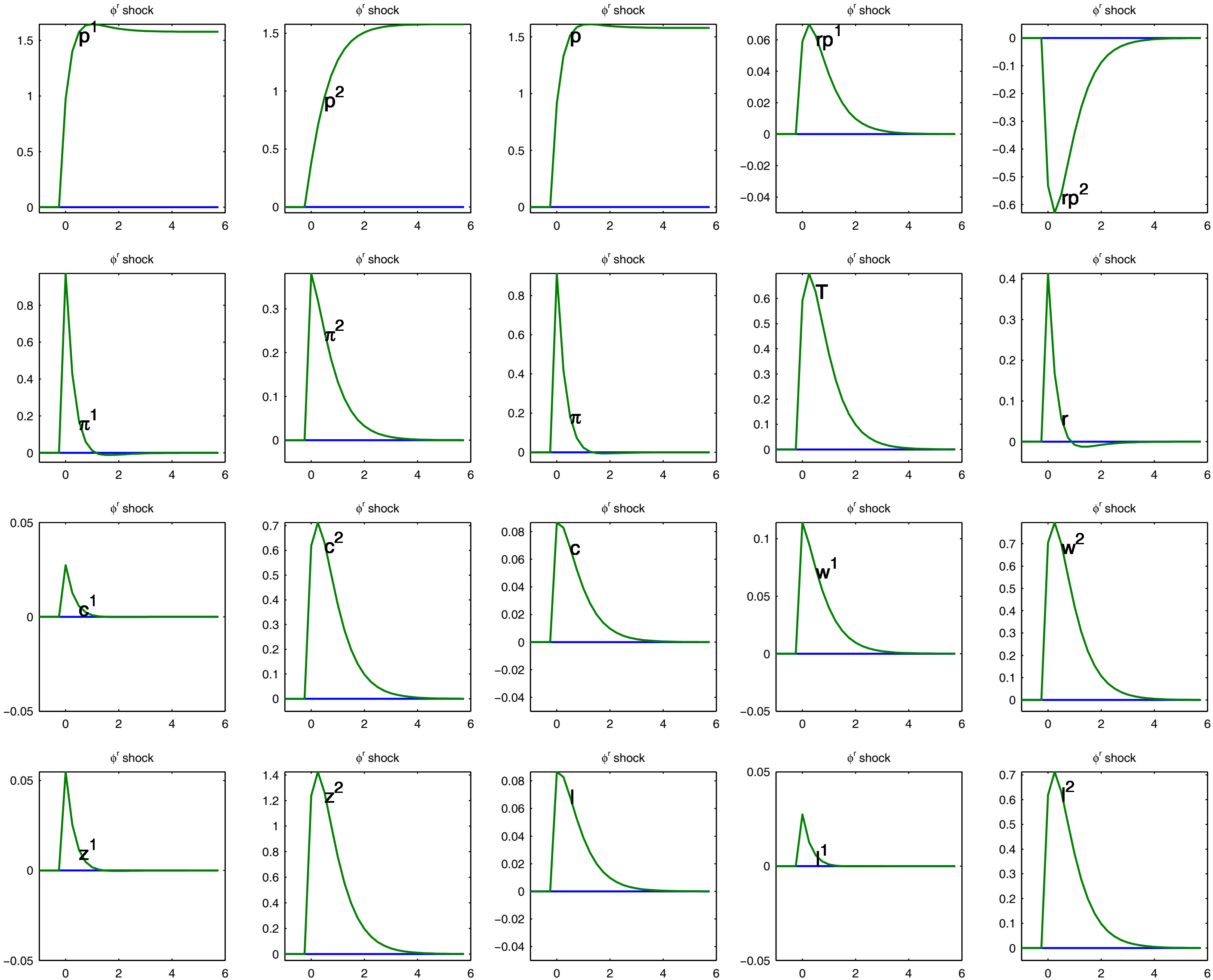
- Exogenous decrease in the interest rate.

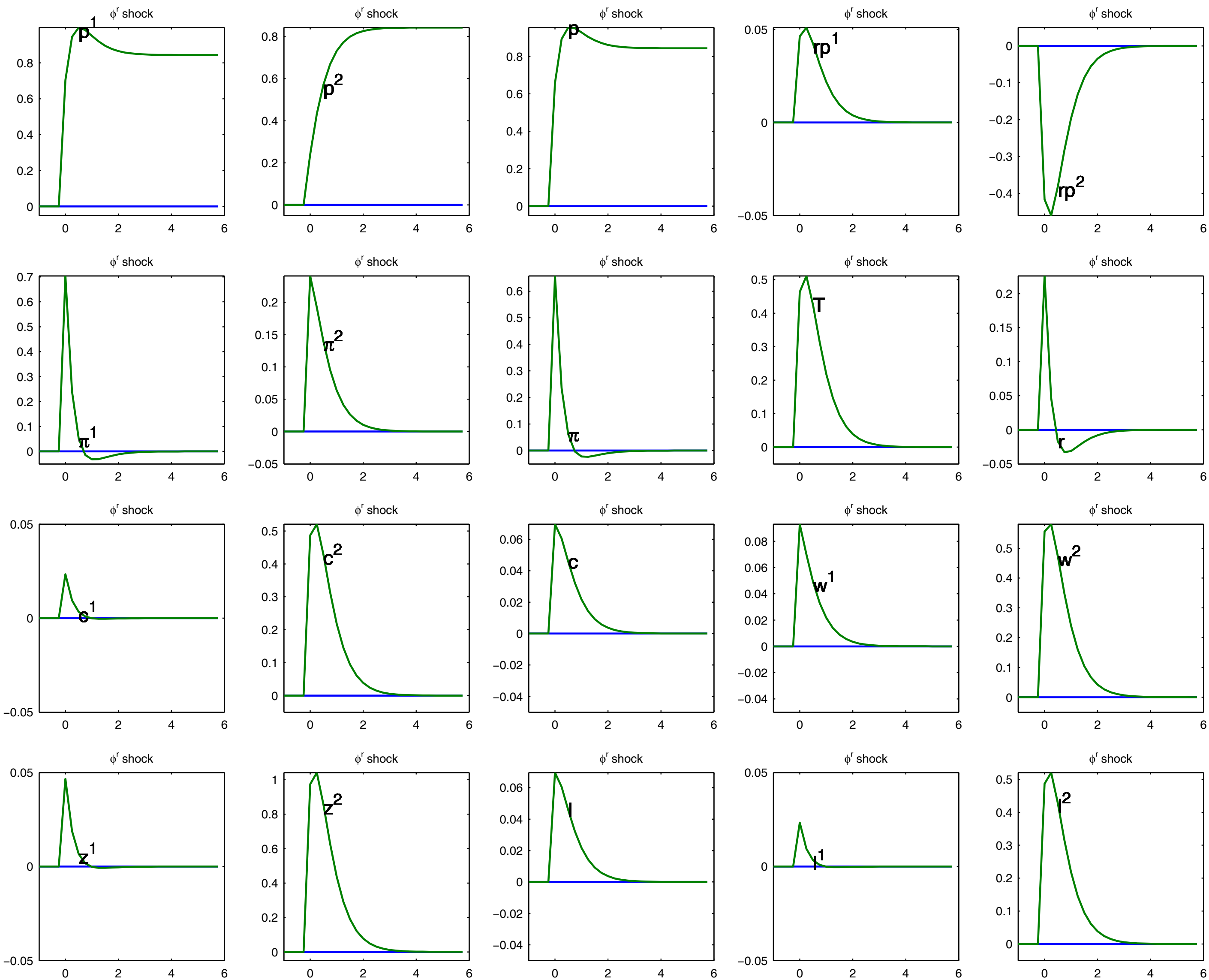
- Parameter values: $\beta = .99$, $\omega = 1$, $\rho_r = .5$, $\lambda_1 = 10$, $\lambda_2 = .052$, $b = .9$

- Bils and Klenow (2004): 90 percent of firms in the economy have essentially flexible prices within the quarter. Other firms preset prices for roughly five quarters.

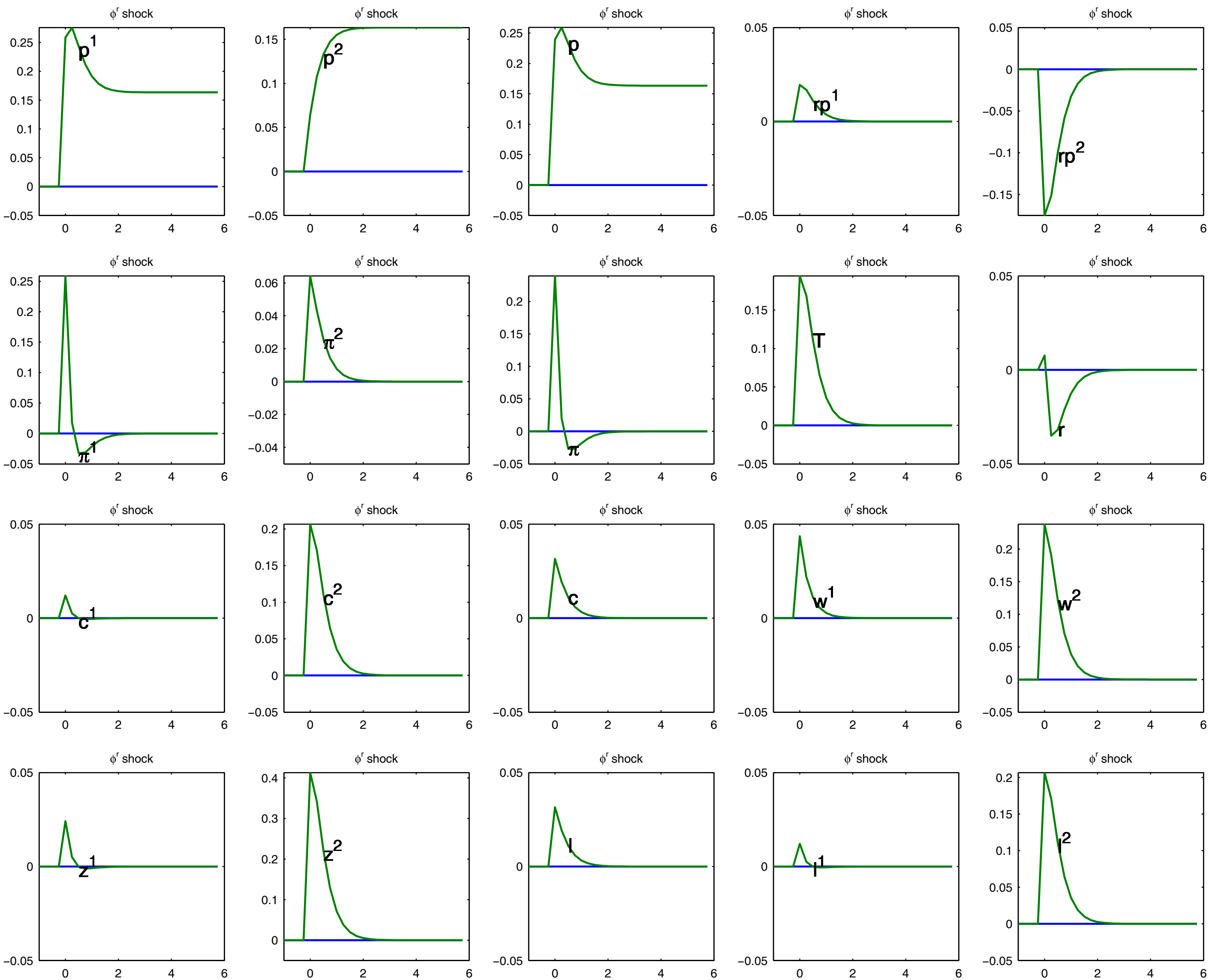
- Benchmark policy: Taylor (1993): $\tau_1 = \tau_2 = 1.5$, $\tau_C = .5$.

- Alternative: Aoki (2001)-Benigno (2004): (Much) stronger reaction to inflation in sticky sector: $\tau_1 = 1.5$; $\tau_2 = 10, 100, 1000$; $\tau_C = .5$.

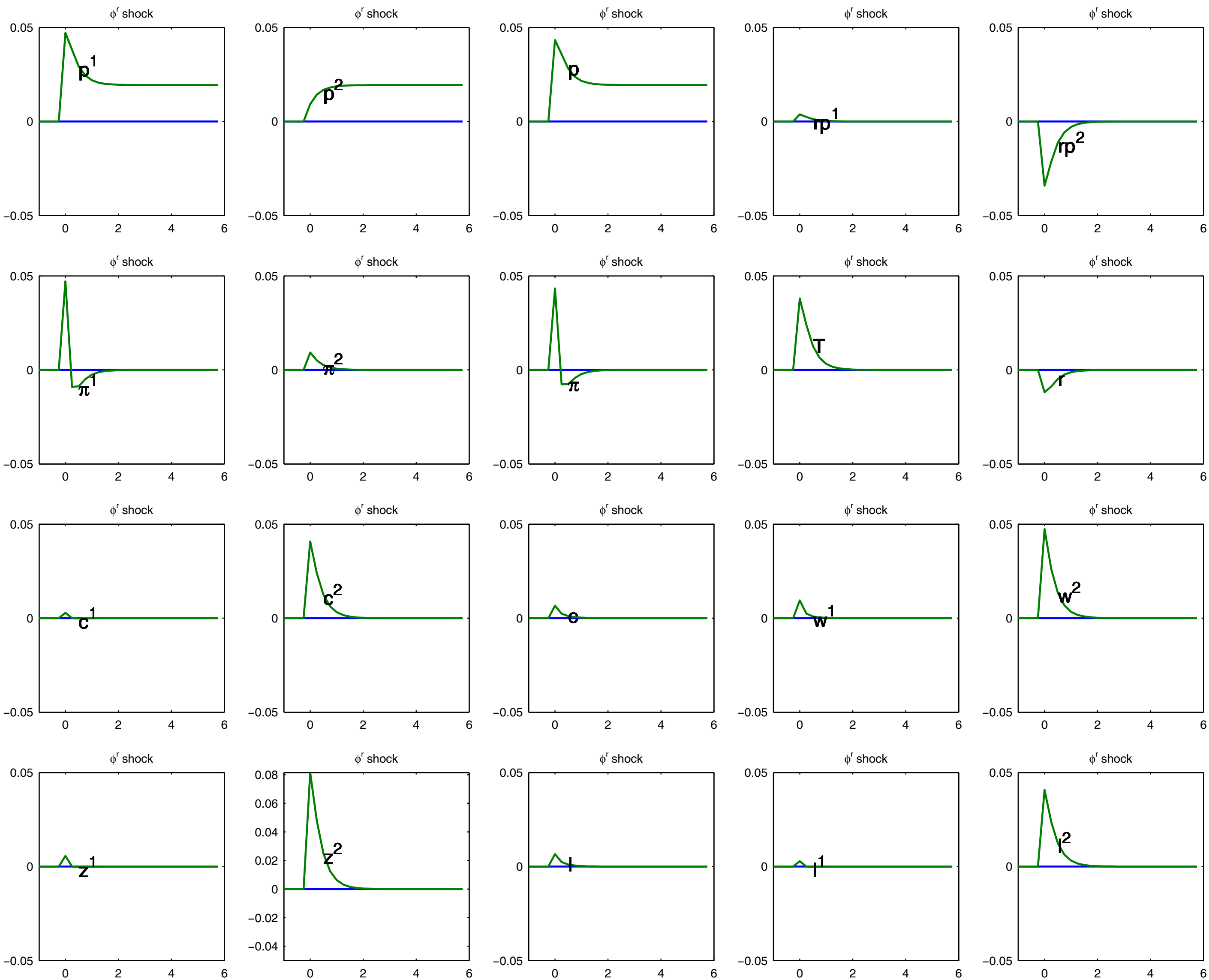

ϕr shock
p1
p2
p
rp1
rp2
π1
π2
π
T
r
c1
c2
c
w1
w2
z1
z2
l
l1
l2



ϕ^r shock
p^1
p^2
p
rp^1
rp^2
π^1
π^2
π
T
r
c^1
c^2
c
w^1
w^2
z^1
z^2
l
l^1
l^2



φ^r shock
p^1
p^2
p
rp^1
rp^2
π^1
π^2
π
T
r
c^1
c^2
c
w^1
w^2
z^1
z^2
l
l^1
l^2


ϕr shock
0.05
0
−0.05
0
2
4
6
p1
p2
p
rp1
rp2
π1
π2
π
T
r
c1
c2
c
w1
w2
z1
0.08
0.06
0.04
0.02
−0.02
−0.04
z2
l
l1
l2

Some Other Comments

Durable versus Non-Durable Goods

• Erceg and Levin (2002) document that durables expenditure is much more interest-rate sensitive than non-durables (five times).

• They build a two-sector model that reproduces this empirical feature.

• Households derive utility from consumption of non-durables (familiar C) and durable services.

• Accumulation of durables much like capital and subject to adjustment cost.

- Separating the nature of durables and non-durables more “drastically” than bundling them as differentiated goods in the same CES basket may be important for quantitative multi-sector models.
- In the available example, Hafedh, Emanuela, and Francisco’s model does not replicate the Erceg-Levin evidence on durables versus non-durables.
- Also no humps in aggregate or sectoral quantities and π, but heterogeneous nominal rigidity should help there.

• Erceg and Levin's model may omit an important feature of household behavior with respect to durables: the ability to use them as collateral for loans.

• Fernández-Villaverde and Krueger (2001) propose a (flex-price) model of durable and non-durable consumption where durables can be used as collateral for loans by households facing borrowing constraints.

• No adjustment cost in durable accumulation.

• Durable expenditure is more interest-rate sensitive than non-durables.

• Perhaps this is another promising approach.

• Iacoviello (2001) focuses on housing as the collateralizable asset in a model where households consume C and housing services, and he explores the role of house prices in the transmission of monetary policy.

Estimation

• I like SMM.

• But it would be interesting to know if estimates would be different with other methods that are now fashionable (maximum likelihood as in Ireland, 2001, or Bayesian as in Smets and Wouters' work).

• Also, would it be feasible to estimate more parameters that are not shock-process parameters with SMM?

• Finally, how do estimated innovation variances compare to evidence?

Conclusion

• Once completed, great paper!

• Rich heterogeneity lends itself naturally to empirical and quantitative work.

• Chuck, Kolver, Tim and I have been exploring a simpler multi-sector model.

• Our analytical results and intuitions can facilitate the understanding of dynamics in a richer setup.