Real Keynesian Models and Sticky Prices

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Introduction: Demand Shocks

- In most macro models...
- price stickiness = source of money non neutrality...
- ... and of demand shocks non neutrality
- There are alternative modelling choices for demand non-neutrality:
  - Demand driven fluctuations in flex. price environments (Ex: Angeletos-La’O, Angeletos-Lian, Guerrieri-Lorenzoni, Lorenzoni, Beaudry-Portier, Beaudry-Galizia-Portier,... etc ~ Real Keynesian models
- Should we care for better understanding the effect of monetary policy?
Introduction: Two Contributions, One Message
Contributions

1. Propose a new class of simple extensions of the *New Keynesian* model (the *Real Keynesian* model) that has very different implications for monetary policy
2. Propose a novel way to identify shocks in SVARs
“The theory of natural output matters to understand the impact of monetary policy on the output gap”
Roadmap

1. Theory & Estimation
2. Dissecting the results using a new SVAR approach
3. Zero Lower Bound and Missing Deflation
Roadmap

1. Theory & Estimation
2. Dissecting the results using a new SVAR approach
3. Zero Lower Bound and Missing Deflation
Extended Linearized Model

\[ l_t = \alpha_l E_t l_{t+1} - \alpha_r (i_t - E_t \pi_{t+1}) + d_t \]
\[ \pi_t = \beta E_t \pi_{t+1} + \kappa (\gamma_l l_t + \gamma_r (i_t - E_t \pi_{t+1})) \]

Euler Equation (EE)
Phillips Curve (PC)

- Two changes:
  - \( \alpha_l \leq 1 \): Add asymmetric information: some households always repay their debt, some do only if it is in their interest \( \sim \) positively sloped cost of funds \( \sim \) discounted EE
  - \( \gamma_r \geq 0 \): Firms need to borrow to pay for intermediate inputs before production \( \sim \)
- Nothing novel, except for putting them together.
- Note: standard NK model: \( \alpha_l = 1, \gamma_r = 0 \)
- Here only demand shock (news shock, \( \beta \) shock,...)
- To remember: \( \alpha \)'s for the EE, \( \gamma \)'s for the PC
Sticky & Flex Price Versions

- Sticky Prices

\[ l_t = \alpha E_t l_{t+1} - \alpha r (i_t - E_t \pi_{t+1}) + d_t \] (EE)
\[ \pi_t = \beta E_t \pi_{t+1} + \kappa (\gamma l_t + \gamma r (i_t - E_t \pi_{t+1})) \] (PC)

- Flex Prices

\[ l_t = \alpha E_t l_{t+1} - \alpha r t + d_t \] (EE)
\[ mc_t = \gamma l_t + \gamma r r_t = 0 \] Marginal Cost (MC)
The *i.i.d.* Case

- I will give some graphical interpretation in the specific case where shocks are *i.i.d.*
- In that case, for any variable $x$: $E_t x_{t+1} = 0$
The RK condition

Result 1

*With flex. prices, positive demand shocks (both current and expected future) always maintain a positive effects on $\ell$ if and only if*

$$\frac{\gamma_r}{\gamma_\ell} > \frac{\alpha_r}{(1 - \alpha_\ell)} \quad \text{(RK)}$$
The RK condition

Result 1

With flex. prices, positive demand shocks (both current and expected future) always maintain a positive effects on $\ell$ if and only if

$$\frac{\gamma_r}{\gamma_\ell} > \frac{\alpha_r}{(1 - \alpha_\ell)}$$  \hspace{1cm} (RK)

general case:

$$\ell_t = \alpha_\ell E_t \ell_{t+1} - \alpha_r r_t + d_t$$  \hspace{1cm} (EE)

$$\ell_t = -\frac{\gamma_r}{\gamma_\ell} r_t$$  \hspace{1cm} (MC)
The RK condition

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*With flex. prices, positive demand shocks (both current and expected future) always maintain a positive effects on \( \ell \) if and only if*

\[
\frac{\gamma_r}{\gamma_\ell} > \frac{\alpha_r}{(1 - \alpha_\ell)} \quad (RK)
\]

*i.i.d. case*:

\[
\ell_t = -\alpha_r r_t + d_t \quad (EE)
\]

\[
\ell_t = -\frac{\gamma_r}{\gamma_\ell} r_t \quad (MC)
\]
The RK condition

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*i.i.d. case:*

$$\ell_t = -\alpha_r r_t + d_t \quad \text{(EE)}$$

$$\ell_t = -\frac{\gamma_r}{\gamma_\ell} r_t \quad \text{(MC)}$$

**Marginal cost**

$$\ell_t = -\frac{\gamma_r}{\gamma_\ell} r_t$$

**Euler Equation**

$$\ell_t = -\alpha_r r_t + d_t$$
The RK condition

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\]

\textit{i.i.d. case :}

\[
l_t = -\alpha_r r_t + d_t \quad (EE) \\
l_t = -\frac{\gamma_r}{\gamma_\ell} r_t \quad (MC)
\]
The RK condition

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**i.i.d. case:**

\[
\ell_t = -\alpha_r r_t + d_t \quad (EE)
\]

\[
\ell_t = -\frac{\gamma_r}{\gamma_\ell} r_t \quad (MC)
\]
With Sticky Prices

\[ \ell_t = \alpha_e E_t \ell_{t+1} - \alpha_r (i_t - E_t \pi_{t+1}) + d_t \]  
(EE)

\[ \pi_t = \beta E_t \pi_{t+1} + \kappa (\gamma e \ell_t + \gamma r (i_t - E_t \pi_{t+1})) + \mu_t \]  
(PC)

\[ i_t = E_t \pi_{t+1} + \phi e \ell_t + \nu_t \]  
(Policy Rule)
With Sticky Prices

\[ \ell_t = \alpha_\ell E_t \ell_{t+1} - \alpha_r (i_t - E_t \pi_{t+1}) + d_t \]  
\[ \pi_t = \beta E_t \pi_{t+1} + \kappa (\gamma_\ell \ell_t + \gamma_r (i_t - E_t \pi_{t+1})) + \mu_t \]  
\[ i_t = E_t \pi_{t+1} + \phi_\ell \ell_t + \nu_t \]  

(EE)  
(EE)  
(Policy Rule)

Result 2

With policy rule \( \phi_\ell > 0 \), the economy is determinate for all admissible parameter values.
Irrelevance Result

Result 3

With sticky prices, RK and NK configurations are not qualitatively distinguishable for demand and markup shocks.
Irrelevance Result

Result 3

*With sticky prices, RK and NK configurations are not qualitatively distinguishable for demand and markup shocks.*

**i.i.d. case:**

\[ l_t = \alpha_r r_t + d_t \] \hspace{1cm} (EE)

\[ \pi_t = \kappa(\gamma_{\ell} l_t + \gamma_r r_t) + \mu_t \] \hspace{1cm} (PC)

\[ r_t = \phi_{\ell} l_t + \nu_t \] \hspace{1cm} (Policy Rule)
Irrelevance Result

Result 3

With sticky prices, RK and NK configurations are not qualitatively distinguishable for demand and markup shocks.

\[ \ell_t = \alpha_r r_t + d_t \]  
(EE)

\[ \pi_t = \kappa (\gamma_\ell \ell_t + \gamma_r r_t) + \mu_t \]  
(PC)

\[ r_t = \phi_\ell \ell_t + \nu_t \]  
(Policy Rule)

\[ \ell_t \]

\[ r_t = \phi_\ell \ell_t \]

Policy rule

Euler Equation

\[ \ell_t = -\alpha_r r_t + d_t \]

Phillips Curve

\[ \pi_t = \kappa (\gamma_\ell + \gamma_r \phi_\ell) \ell_t + \mu_t \]
Irrelevance Result

Result 3

*With sticky prices, RK and NK configurations are not qualitatively distinguishable for demand and markup shocks.*

**i.i.d. case:**

\[
\ell_t = \alpha_r r_t + d_t \quad \text{(EE)}
\]
\[
\pi_t = \kappa(\gamma\ell_t + \gamma r r_t) + \mu_t \quad \text{(PC)}
\]
\[
r_t = \phi\ell \ell_t + \nu_t \quad \text{(Policy Rule)}
\]
Irrelevance Result

Result 3

With sticky prices, RK and NK configurations are not qualitatively distinguishable for demand and markup shocks.

\[ \ell_t = \alpha_r r_t + d_t \]  \hspace{1cm} (EE)

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\[ r_t = \phi \ell_t + \nu_t \]  \hspace{1cm} (Policy Rule)
Irrelevance Result

Result 3

With sticky prices, RK and NK configurations are not qualitatively distinguishable for demand and markup shocks.

\[ \ell_t = \alpha_r r_t + d_t \]  \hspace{1cm}  (EE)

\[ \pi_t = \kappa(\gamma_r \ell_t + \gamma_r r_t) + \mu_t \]  \hspace{1cm}  (PC)

\[ r_t = \phi_e \ell_t + \nu_t \]  \hspace{1cm}  (Policy Rule)
RK Matters for Monetary Policy and Monetary Shocks

- Monetary Policy and Stabilization
- Determinacy under $i$ peg
- Monetary Shocks
Effects of Stabilization with Demand Shocks

\[ i_t = E_t \pi_{t+1} + \phi_{\ell} \ell_t \]

Result 4

A more aggressive policy (\( \phi_{\ell} \) larger) always decreases \( \sigma_{\ell}^2 \) at the cost of increasing \( \sigma_\pi^2 \) iff the RK condition is satisfied.
NK Configuration \( (\gamma_r = 0, \alpha_\ell = 1) \)

Policy rule
\[ r_t = \phi_\ell \ell \]

Euler Equation
\[ \ell_{t+1} = -\alpha_r r_t + d_t \]

Phillips Curve
\[ \pi_t = \kappa \gamma_\ell \ell_t \]
NK Configuration ($\gamma_r = 0, \alpha_{\ell} = 1$)

Policy rule:
$$r_t = \phi_{\ell} \ell$$

Euler Equation:
$$\ell_t = -\alpha_r r_t + d_t$$

Phillips Curve:
$$\pi_t = \kappa \gamma_{\ell} \ell_t$$
Under RK ($\gamma_r$ large enough)

Policy rule

$$r_t = \phi \ell \ell$$

Euler Equation

$$\ell_t = -\alpha_r r_t + d_t$$

Phillips Curve

$$\pi_t = \kappa (\gamma \ell + \gamma_r \phi \ell) \ell_t$$
Under RK ($\gamma_r$ large enough)

**Policy rule**

$r_t = \phi \ell$

**Euler Equation**

$\ell_t = -\alpha_r r_t + d_t$

**Phillips Curve**

$\pi_t = \kappa(\gamma_\ell + \gamma_r \phi_\ell) \ell_t$
Nominal Interest Rate Peg (ZLB)

- Suppose policy goes from
  \[ i_t = E_t \pi_{t+1} + \phi_2 \ell_t \]
  to
  \[ i_t = 0. \]

Result 5

In the NK configuration,
- indeterminacy
- in all equilibria, \( \sigma_{\ell}^2 \) and \( \sigma_{\pi}^2 \) move together (conditional on demand shocks)

In the RK configuration,
- determinacy
- \( \sigma_{\ell}^2 \) increases but \( \sigma_{\pi}^2 \) decreases (conditional on demand shocks)
Monetary Shocks

Result 6

In response to a contractionary monetary shocks,

- If the shock is not very persistent, then NK and RK cannot be distinguished.
- If shock is sufficiently persistent,
  - it increases inflation in RK case (neo-Fisherian effect)
  - it decreases inflation in the NK case

- RK favoured if we observe both (1) persistent monetary shock that (2) do not lead to a fall in inflation
Estimation

Data:
- $\pi$: GDP deflator,
- $i_t$: fed funds rate,
- $\ell_t$: minus unemployment rate.

Sample:
- long: 1954:3- 2007:4,

Maximum Likelihood estimation

Result 7

Estimation shows that the model is in the Real Keynesian region.
$l_t = .65 E_t l_{t+1} - .33^* (i_t - E_t \pi_{t+1}) - .38 \mu_t + d_t$  \hspace{1cm} (EE)

$\pi_t = .99^* \pi_{t+1} + 1^* (.05 E_t + .07 (i_t - E_t \pi_{t+1})) + \mu_t$  \hspace{1cm} (PC)

$i_t = E_t \pi_{t+1} + .33 d_t - 1.06 \mu_t + \nu_t$  \hspace{1cm} (Policy)

- RK condition is satisfied: \[ .07 \times (1 - .65) > .05 \times .33 \]
  \[ .0245 > .0165 \]
Roadmap

1. Theory & Estimation
2. Dissecting the results using a new SVAR approach
3. Zero Lower Bound and Missing Deflation
SVAR representation

- The model solution writes

\[
\begin{pmatrix}
\pi_t \\
i_t \\
\ell_t
\end{pmatrix}
\begin{pmatrix}
\pi_{t-1} \\
i_{t-1} \\
\ell_{t-1}
\end{pmatrix}
+ B(\Theta)
\begin{pmatrix}
d_t \\
\mu_t \\
\nu_t
\end{pmatrix}
\]

\[
\begin{pmatrix}
d_t \\
\mu_t \\
\nu_t
\end{pmatrix}
= \begin{pmatrix}
\rho_d & 0 & 0 \\
0 & \rho_\mu & 0 \\
0 & 0 & \rho_\mu
\end{pmatrix}
\begin{pmatrix}
d_{t-1} \\
\mu_{t-1} \\
\nu_{t-1}
\end{pmatrix}
+ \begin{pmatrix}
\varepsilon_{dt} \\
\varepsilon_{\mu t} \\
\varepsilon_{\nu t}
\end{pmatrix}
\]

- This is what we use for ML in order to obtain \( \hat{\Theta} \).
- But we can also estimate in two-steps:
  - First \( A, B \) and \( R \),
  - Second \( \Theta \).
Using The Structural Zeros

\[
Y_t = A(\Theta)Y_{t-1} + B(\Theta)S_t \\
S_t = R(\Theta)S_{t-1} + \varepsilon_t
\]

where \( \Theta \) are the structural parameters

Result 8

- Under the assumptions that we make for the ML estimation (\( Y_t \) observable, lag order is known, \( S_t \) are latent variables)
- if \( R \) is diagonal (at least triangular),
- then \( A, B \) and \( R \) can be identified, and so can be the structural shocks \( \varepsilon \)

- This uniquely defines structural shocks and IRF (but no names for the shocks)
- Then a second stage is to find the mapping from \( A, B \) and \( R \) to structural parameters \( \Theta \).
SVAR, Full Sample

\[ \varepsilon_1, \varepsilon_2, \varepsilon_3 \]
SVAR, Full Sample

\[ \varepsilon_1 \sim \varepsilon_d \]

\[ \varepsilon_2 \]

\[ \varepsilon_3 \]
SVAR, Full Sample

$\varepsilon_1 \sim \varepsilon_d$

$\varepsilon_2$

$\varepsilon_3$
SVAR, Full Sample

\[ \varepsilon_1 \rightsquigarrow \varepsilon_d \]

\[ \varepsilon_2 \rightsquigarrow \varepsilon_\mu \]

\[ \varepsilon_3 \]
SVAR, Full Sample

$\varepsilon_1 \sim \varepsilon_d$

$\varepsilon_2 \sim \varepsilon_\mu$

$\varepsilon_3$

\begin{align*}
\varepsilon_1 & \sim \varepsilon_d \\
\varepsilon_2 & \sim \varepsilon_\mu
\end{align*}
SVAR, Full Sample

$\varepsilon_1 \sim \varepsilon_d$

$\varepsilon_2 \sim \varepsilon_\mu$

$\varepsilon_3 \sim \varepsilon_\nu$
SVAR, Full Sample

\[ \varepsilon_1 \sim \varepsilon_d \]

\[ \varepsilon_2 \sim \varepsilon_\mu \]

\[ \varepsilon_3 \sim \varepsilon_\nu \]
Max Likelihood Estimation, Full Sample
Three Sub-Samples

I. Pre Volker dis-inflation period (1954:3-1979:1)

II. Post Volker dis-inflation period (1983:4-2007:1)

III. Zero Lower Bound period (2009:1-2016:3)
Three Sub-Samples

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Three Sub-Samples

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III. Zero Lower Bound period (2009:1-2016:3)
Robustness

1. Are these results robust to allowing the model to have endogenous propagation?
2. Are these results robust to allowing the model to have more shocks?
3. Yes and yes.
Can we obtain more standard effects of monetary shocks?

- Note that the RK model is not inconsistent with VAR evidence that finds temporary monetary shocks.
- But those shocks (as opposed to persistent monetary shocks) do not seem to be relevant in a simple 3-shocks framework.
1. Theory
2. Dissecting the results using a new SVAR approach
3. Zero Lower Bound and Missing Deflation
Low Variance of Inflation at the ZLB

\[
\begin{array}{c|ccc}
& \sigma_u & \sigma_\pi & \sigma_i \\
\hline
\text{Post-Volcker} & 1.3 & .9 & 2.5 \\
\text{ZLB} & 1.7 & .8 & .1 \\
\end{array}
\]

- Observation: the variance of inflation slightly decreased at lower bound.
- It should have increased in the NK configuration
- But this is consistent with the RK configuration
Zero Lower Bound and Missing Deflation

Policy rule
\[ r_t = \max \{0, \phi \ell_t\} \]

Euler Equation
\[ \ell_t = -\alpha_r r_t + d_t \]

Phillips Curve
\[ \pi_t = \kappa \gamma \ell_t \]
Zero Lower Bound and Missing Deflation

Policy rule
\[ r_t = \max \{0, \phi \ell_t\} \]

Euler Equation
\[ \ell_t = -\alpha r_t + d_t \]

Phillips Curve
\[ \pi_t = \kappa \gamma \ell_t \]
Zero Lower Bound and Missing Deflation

Policy rule: \( r_t = \max \{ 0, \phi \ell_t \} \)

Euler Equation: \( \ell_t = -\alpha r_t + d_t \)

Phillips Curve: \( \pi_t = \kappa \gamma \ell_t \)

Policy rule: \( r_t = \max \{ 0, \phi \ell_t \} \)

Euler Equation: \( \ell_t = -\alpha r_t + d_t \)

Phillips Curve: \( \pi_t = \kappa \left( \gamma \ell_t + \gamma_r \max \{ 0, \phi \ell_t \} \right) \)
Zero Lower Bound and Missing Deflation

Policy rule:
\[ r_t = \max\left\{ 0, \phi \ell_t \right\} \]

Euler Equation:
\[ \ell_t = -\alpha r_t + d_t \]

Phillips Curve:
\[ \pi_t = \kappa \gamma \ell_t \]

Policy rule:
\[ r_t = \max\left\{ 0, \phi \ell_t \right\} \]

Euler Equation:
\[ \ell_t = -\alpha r_t + d_t \]

Phillips Curve:
\[ \pi_t = \kappa \left( \gamma \ell_t + \gamma_r \max\left\{ 0, \phi \ell_t \right\} \right) \]
The ZLB Trap

- RK framework suggest that ZLB was quasi inevitable following a persistent fall in demand.
- In RK, both the fall in demand and the response of monetary authorities favours lower inflation:
  - Low inflation $\leadsto$
  - Monetary expansion stimulus $\leadsto$
  - Lower $i$ and lower inflation $\leadsto$
  - More monetary expansion
  - Even lower $i$ and inflation $\leadsto$
  - Hit the zero lower bound.
When demand matters with flexible prices (Real Keynesian models), adding sticky prices affect the way we think of monetary policy:

- trade-off between stabilising inflation and output when facing demand shocks
- Determinacy at the ZLB
- Variance of inflation and output moving in opposite direction at the ZLB

Data favours Real Keynesian configuration

Main reason is that monetary shocks are persistent and they have neo-Fisherian effect
Introducing more endogenous dynamics

- Let us think of richer dynamics
  - Habit persistence
  - Hybrid New Phillips curve
  - Gradual adjustment of $i$

- It amounts to constraining more or less columns of $A$ to be zero.

$$Y_t = AY_{t-1} + BS_t$$
$$S_t = RS_{t-1} + \varepsilon_t$$
Full Sample, “Habit Persistence”
Other configurations, Full sample

“Habit persistence, and hybrid New Phillips curve”

“Habit persistence, gradual adjustment of \( \epsilon \) and hybrid New Phillips curve”
Allowing for more shocks

- Enrich the analysis by:
  - Allowing for explicit oil shocks
  - Allowing for TFP shocks
  - Allowing for natural rate of employment shocks

- We find very consistent results
Real growth ($\Delta y$) as the Fourth Variable

“Fully Forward”, Full sample

“Habit persistence”, Full sample