OPTIMAL MONETARY POLICY: THE STICKY-PRICE CASE

APRIL 12, 2010

RELEVANT MARKET STRUCTURE(S)?

- Real business cycle (RBC) / neoclassical theory
  - All (goods) prices are determined in perfect competition
  - In both consumption-leisure and consumption-savings dimensions
  - Critical assumption: no firm is a price ***setter*** → no firm has any market power
- New Keynesian theory
  - Starting point: firms ***do*** wield (at least some) market power
  - Critical assumption: firms ***do*** set their (nominal) prices
  - Purposeful setting / re-setting of (nominal) prices may entail costs of some sort
    - "Menu costs," but soon interpret more broadly
    - Central issue in macro: how do "costs of adjusting prices" ("sticky prices") affect monetary policy insights and recommendations?
- Upcoming analysis
  - Step 1: Develop theory in which firms are purposeful price setters, not price takers
  - Step 2: Superimpose on the theory some "costs" of setting / re-setting nominal prices
  - TODAY → Step 3: Study optimal monetary policy

Basics of Optimal Policy Analysis

- Describe the demand-side environment (i.e., consumers)
  - Arguments of utility function?
  - Which assets trade in private-sector financial markets?
  - Derive consumer optimality conditions
- Describe the supply-side environment (i.e., firms)
  - Which inputs are used in production process?
  - Derive firm profit-maximizing conditions
    - So far: simple factor price = marginal product conditions (i.e., wage = mpn, etc.)
    - Soon: New Keynesian firm analysis more involved (price-setting decisions)
- Describe actions/role of government
  - How is monetary policy conducted? How is fiscal policy conducted?
  - How do government policy choices affect private sector behavior?
- Describe resource constraint
- Describe private-sector equilibrium
  - For given policy choices by government, how does market equilibrium arise?
  - How does price adjustment/setting affect market clearing?
- Optimal policy analysis best thought of as picking a government policy that induces the "best" private-sector equilibrium

"Cashless" NK Framework: Consumers

- Basic NK tenet
  - Money demand issues (i.e., medium-of-exchange role of money) not very important in modern developed economies
  - "Cashless" analysis
- Implications for formal NK analysis – monetary policy…
  - …does not operate on/through demand-side of economy (consumers)
  - …operates on/through supply-side of economy (firms)
- Recent events: monetary policy operates on/through financial sector of economy?
  - Intermediation between demand-side and supply-side…more research coming…
- Representative consumer
  - Period-*t* utility function $u(c, 1-n)$
  - Subjective discount factor β
  - Period-*t* budget constraint identical to CIA or MIU model, except no money balances

$$P_t c_t + P_t^b B_t + S_t a_t = P_t w_t n_t + B_{t-1} + (S_t + D_t) a_{t-1}$$

    …and so on for period *t*+1, *t*+2, etc.
  - No MIU component or CIA constraint

"CASHLESS" NK FRAMEWORK: CONSUMERS

- Lagrangian

λ is multiplier on budget constraint

$$u(c_t,1-n_t)+\beta u(c_{t+1},1-n_{t+1})+\beta^2 u(c_{t+2},1-n_{t+2})+...$$
$$+\lambda_t\left[P_t w_t n_t + B_{t-1} + (S_t + D_t)a_{t-1} - P_t c_t - P_t^b B_t - S_t a_t\right]$$
$$+\beta\lambda_{t+1}\left[P_{t+1} w_{t+1} n_{t+1} + B_t + (S_{t+1} + D_{t+1})a_t - P_{t+1} c_{t+1} - P_{t+1}^b B_{t+1} - S_{t+1} a_{t+1}\right]$$
$$+....$$

- FOCs

c_t:

n_t:

B_t:

a_t:

"CASHLESS" NK FRAMEWORK: CONSUMERS

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$$+....$$

- FOCs

c_t:

n_t:

B_t:

a_t:

- Combine into "MRS = price ratio" type of optimality condition

Consumption-leisure optimality condition

$$\frac{u_2(c_t,1-n_t)}{u_1(c_t,1-n_t)} = w_t$$

Unlike CIA analysis, nominal interest rate does NOT appear in consumption-leisure margin.

Cashless: nominal i.r. is not what causes distortions…

"CASHLESS" NK FRAMEWORK: CONSUMERS

- **Lagrangian**

λ is multiplier on budget constraint

$$u(c_t,1-n_t)+\beta u(c_{t+1},1-n_{t+1})+\beta^2 u(c_{t+2},1-n_{t+2})+\dots$$
$$+\lambda_t\left[P_t w_t n_t + B_{t-1} + (S_t + D_t)a_{t-1} - P_t c_t - P_t^b B_t - S_t a_t\right]$$
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$$+\dots.$$

- **FOCs**

c_t:

n_t:

B_t:

a_t:

KEY CONCEPTUAL DIFFERENCE BETWEEN NK ANALYSIS AND CIA ANALYSIS:

Instead, nom i.r. shows up only in consumption-savings optimality condition

- **Combine into "MRS = price ratio" type of optimality condition**

Consumption-leisure optimality condition

$$\frac{u_2(c_t,1-n_t)}{u_1(c_t,1-n_t)} = w_t$$

AND

$$\frac{u_1(c_t,1-n_t)}{\beta u_1(c_{t+1},1-n_{t+1})} = (1+i_t)\frac{P_t}{P_{t+1}}$$

Consumption-savings optimality condition (from bond first-order condition)

RETAIL FIRMS

- **Representative retail firm's profit-maximization problem**

$$\max_{\{y_{it}\}_{i=0..\infty}} P_t\left[\int_0^1 y_{it}^{1/\varepsilon}di\right]^{\varepsilon} - \int_0^1 P_{it}y_{it}di$$

Chooses profit-maximizing quantity of input of *each* wholesale good. Focus analysis on any arbitrary wholesale good – call it y_{jt}.

- **FOC with respect to y_{jt} (for any j)**

.
.
.

- **...after several rearrangements**

$$y_{jt} = \left(\frac{P_{jt}}{P_t}\right)^{\frac{\varepsilon}{1-\varepsilon}} y_t$$

DEMAND FUNCTION FOR GOOD j

- **IDENTICAL TO BASIC (FLEXIBLE-PRICE) DIXIT-STIGLITZ FRAMEWORK!**

WHOLESALE FIRMS

- Representative wholesale firm's profit-maximization problem

$$\max_{P_{jt}} P_{jt}y_{jt} - P_t mc_{jt} y_{jt} - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)^2 P_t + \frac{\beta}{1+\pi_{t+1}}\left[P_{jt+1}y_{jt+1} - P_{t+1}mc_{t+1}y_{jt+1} - \frac{\psi}{2}\left(\frac{P_{jt+1}}{P_{jt}} - 1\right)^2 P_{t+1}\right]$$

↓ Substitute in demand function for wholesale good *j* in both period t and t+1 (and t+2, t+3, t+4, …)

↓ In period t, firm chooses P_{jt}
So FOC with respect to P_{jt}

↓ Symmetric equilibrium

$$\frac{1}{1-\varepsilon}\left[1-\varepsilon mc_t\right]y_t - \psi\pi_t(1+\pi_t) + \beta\psi\pi_{t+1}(1+\pi_{t+1}) = 0$$

New Keynesian Phillips Curve

WHOLESALE FIRMS

- So far haven't considered (explicitly) the inputs to a wholesale firm's production process

- Very simple model of production
  - Production technology in every period (for any wholesale firm *j*)

$$y_{jt} = f(n_{jt}) = n_{jt}$$

  - Can think of Cobb-Douglas with capital share = 0

- Labor hired by wholesale firm *j* taking market wage w_t as given

- Recall: CRS production technology → marginal cost of production is independent of quantity produced

"CASHLESS" NK FRAMEWORK: GOVERNMENT

- Money is a physical object in the "background"
  - DOES exist…
  - …so there IS a budget constraint for it
  - But not of direct importance for (routine) monetary policy issues
    - (Hence doesn't appear in consumers' budget constraints….where does it go?...)
- Central bank's budget constraint – in every period *t*,

$$M_t = (1+g_t)M_{t-1} \Leftrightarrow \tau_t = g_t M_{t-1}$$

  - g_t the growth rate of money supply in period *t*
- Money-supply rule technically isomorphic to interest rate rule
- But interest rates explicitly the "policy tool" in New Keynesian analysis
- i.e., to ***implement*** an inflation target, what is the nominal interest rate the central bank should set?
  - Instead of focusing on what is the money growth rate the central bank should set?

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  - g_t the growth rate of money supply in period *t*

Even NK theory views basic monetarist quantity-theoretic link between money growth and inflation as being correct in the ***long run***

NONETHELESS: $g = \pi$ in long run (i.e., steady state)

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"CASHLESS" NK FRAMEWORK

- Resource constraint – in every period *t*,

$$c_t + \frac{\psi}{2}(\pi_t)^2 = n_t \left(= f(n_t)\right)$$

  - Total output used for private-sector consumption…
  - …and menu costs
    - Recall: menu costs are a REAL cost – hence absorb some of the economy's resources

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- Summarize private-sector equilibrium conditions

Describes demand side:

  - Consumption-leisure optimality condition $\frac{u_2(c_t,1-n_t)}{u_1(c_t,1-n_t)} = w_t$
  - Consumption-savings optimality condition $\frac{u_1(c_t,1-n_t)}{\beta u_1(c_{t+1},1-n_{t+1})} = \frac{1+i_t}{1+\pi_{t+1}}$

Describes supply side:

  - Labor-demand condition $w_t < f'(n_t) = 1$ — Note wage is LESS THAN MP of labor
  - New Keynesian Phillips Curve $\frac{1}{1-\varepsilon}[1-\varepsilon mc_t]n_t - \psi\pi_t(1+\pi_t) + \beta\psi\pi_{t+1}(1+\pi_{t+1}) = 0$

Describes market clearing:

  - Resource constraint $c_t + \frac{\psi}{2}(\pi_t)^2 = n_t$

"CASHLESS" NK FRAMEWORK

- **Resource constraint – in every period *t*,**

$$c_t + \frac{\psi}{2}(\pi_t)^2 = n_t \left(= f(n_t)\right)$$

  - **Total output used for private-sector consumption…**
  - **…and menu costs**
    - **Recall: menu costs are a REAL cost – hence absorb some of the economy's resources**

- **Summarize private-sector equilibrium conditions**

Describes demand side

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  - **Consumption-savings optimality condition** $\frac{u_1(c_t, 1-n_t)}{\beta u_1(c_{t+1}, 1-n_{t+1})} = \frac{1+i_t}{1+\pi_{t+1}}$

Describes supply side

  - **Labor-demand condition** $mc_t < f'(n_t) = 1$ — ***$mc_t = w_t$* in every period (Problem Set 6)**
  - **New Keynesian Phillips Curve** $\frac{1}{1-\varepsilon}\left[1-\varepsilon mc_t\right] n_t - \psi\pi_t(1+\pi_t) + \beta\psi\pi_{t+1}(1+\pi_{t+1}) = 0$

Describes market clearing

  - **Resource constraint** $c_t + \frac{\psi}{2}(\pi_t)^2 = n_t$

"CASHLESS" NK FRAMEWORK

- **Condense private-sector equilibrium conditions….**
  - **…by imposing *w_t* = *mc_t* and** $n_t = c_t + \frac{\psi}{2}(\pi_t)^2$ **everywhere**

Consumption-leisure optimality condition

$$\frac{u_2\left(c_t, 1-c_t-\frac{\psi}{2}(\pi_t)^2\right)}{u_1\left(c_t, 1-c_t-\frac{\psi}{2}(\pi_t)^2\right)} = mc_t$$

One final substitution to condense things….

Consumption-savings optimality condition

$$\frac{u_1\left(c_t, 1-c_t-\frac{\psi}{2}(\pi_t)^2\right)}{\beta u_1\left(c_{t+1}, 1-c_{t+1}-\frac{\psi}{2}(\pi_{t+1})^2\right)} = \frac{1+i_t}{1+\pi_{t+1}}$$

- **New Keynesian Phillips Curve**

$$\frac{1}{1-\varepsilon}\left[1-\varepsilon mc_t\right]\left(1-c_t-\frac{\psi}{2}\pi_t^2\right) - \psi\pi_t(1+\pi_t) + \beta\psi\pi_{t+1}(1+\pi_{t+1}) = 0$$

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  - New Keynesian Phillips Curve

$$\frac{1}{1-\varepsilon}\left[1-\frac{\varepsilon u_2\left(c_t, 1-c_t-\frac{\psi}{2}(\pi_t)^2\right)}{u_1\left(c_t, 1-c_t-\frac{\psi}{2}(\pi_t)^2\right)}\right]\left(1-c_t-\frac{\psi}{2}\pi_t^2\right)-\psi\pi_t(1+\pi_t)+\beta\psi\pi_{t+1}(1+\pi_{t+1})=0$$

"CASHLESS" NK FRAMEWORK

- Condense private-sector equilibrium conditions….
  - …by imposing $w_t = mc_t$ and $n_t = c_t + \frac{\psi}{2}(\pi_t)^2$ everywhere
  - Consumption-savings optimality condition

$$\frac{u_1\left(c, 1-c-\frac{\psi}{2}\pi^2\right)}{\beta u_1\left(c, 1-c-\frac{\psi}{2}\pi^2\right)} = \frac{1+i}{1+\pi}$$

  - New Keynesian Phillips Curve

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- Limit attention to steady-state (i.e., long run) policy questions

Private-Sector Equilibrium

"Cashless" NK Framework

- **Condense private-sector equilibrium conditions….**
  - **…by imposing $w_t = mc_t$ and** $n_t = c_t + \frac{\psi}{2}(\pi_t)^2$ **everywhere**
  - **Consumption-savings optimality condition**

NK view:

Monetary policy does not operate through demand side…

$$\frac{u_1\left(c, 1-c-\frac{\psi}{2}g^2\right)}{\beta u_1\left(c, 1-c-\frac{\psi}{2}g^2\right)} = \frac{1+i}{1+g}$$

  - **New Keynesian Phillips Curve**

Monetary policy operates through supply side

$$\frac{1}{1-\varepsilon}\left[1-\frac{\varepsilon u_2\left(c, 1-c-\frac{\psi}{2}g^2\right)}{u_1\left(c, 1-c-\frac{\psi}{2}g^2\right)}\right]\left(1-c-\frac{\psi}{2}g^2\right) - \psi g(1+g) + \beta\psi g(1+g) = 0$$

- **Limit attention to steady-state (i.e., long run) policy questions**
  - **And (finally!…) use long-run monetarist relationship $g = n$**

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~~$$\frac{u_1\left(c, 1-c-\frac{\psi}{2}g^2\right)}{\beta u_1\left(c, 1-c-\frac{\psi}{2}g^2\right)} = \frac{1+i}{1+g}$$~~

SO IGNORE C-S CONDITION IN ANALYSIS OF OPTIMAL POLICY PROBLEM….

ONLY TAKE INTO ACCOUNT NKPC!

  - **New Keynesian Phillips Curve**

Monetary policy operates through supply side

$$\frac{1}{1-\varepsilon}\left[1-\frac{\varepsilon u_2\left(c, 1-c-\frac{\psi}{2}g^2\right)}{u_1\left(c, 1-c-\frac{\psi}{2}g^2\right)}\right]\left(1-c-\frac{\psi}{2}g^2\right) - \psi g(1+g) + \beta\psi g(1+g) = 0$$

- **Limit attention to steady-state (i.e., long run) policy questions**
  - **And (finally!…) use long-run monetarist relationship $g = n$**

Optimal Policy Analysis

- Can express entire steady-state private-sector equilibrium as

$$\frac{1}{1-\varepsilon}\left[1-\frac{\varepsilon u_2\left(c,1-c-\frac{\psi}{2}g^2\right)}{u_1\left(c,1-c-\frac{\psi}{2}g^2\right)}\right]\left(1-c-\frac{\psi}{2}g^2\right)-\psi g(1+g)+\beta\psi g(1+g)=0$$

- Defines implicitly a reaction function $\bar{c}(g)$
  - A (potentially complicated..) summary description of how private-sector equilibrium quantities depend on any given choice of government policy ***g***

- Maintained assumption
  - Central bank knows/understand perfectly the private-sector reaction function
  - Realism? Impossible for a central bank to literally know this…
  - …but provides a starting point for analysis

- → Central bank takes into account the reaction function $\bar{c}(g)$ when setting (optimal) policy

Optimal Policy Analysis

- Goal of policy makers
  - Maximize welfare (utility) of representative consumer
  - In steady-state

$$\sum_{s=0}^{\infty}\beta^s u\left(\bar{c},1-\bar{c}-\frac{\psi}{2}g^2\right)=\frac{u\left(\bar{c},1-\bar{c}-\frac{\psi}{2}g^2\right)}{1-\beta}$$

Recall infinite summation formula

↓

$$\sum_{s=0}^{\infty}\beta^s u\left(\bar{c}(g),1-\bar{c}(g)-\frac{\psi}{2}g^2\right)=\frac{u\left(\bar{c}(g),1-\bar{c}(g)-\frac{\psi}{2}g^2\right)}{1-\beta}$$

Taking into account private-sector reaction function

- The formal policy problem
  - Choose ***g*** that maximizes private-sector welfare
  - The ***c***(***g***) function summarizes the behavior of private markets

OPTIMAL POLICY ANALYSIS

- **Optimal monetary policy problem**

$$\sum_{s=0}^{\infty}\beta^s u\left(\bar{c}(g),1-\bar{c}(g)-\frac{\psi}{2}g^2\right)=\frac{u\left(\bar{c}(g),1-\bar{c}(g)-\frac{\psi}{2}g^2\right)}{1-\beta}$$

- **FOC with respect to *g***
  - **KEY: NOW need to take into account the dependence of private-market outcomes on the policy in place**

Optimal Policy Analysis

OPTIMAL POLICY ANALYSIS

- **Optimal monetary policy problem**

$$\sum_{s=0}^{\infty}\beta^s u\left(\bar{c}(g),1-\bar{c}(g)-\frac{\psi}{2}g^2\right)=\frac{u\left(\bar{c}(g),1-\bar{c}(g)-\frac{\psi}{2}g^2\right)}{1-\beta}$$

- **FOC with respect to *g***
  - **KEY: NOW need to take into account the dependence of private-market outcomes on the policy in place**

↓ **Rearrange to MRS = ... form**

- **If policy is set optimally**

$$\frac{u_2\left(c(g),1-c(g)-\frac{\psi}{2}g^2\right)}{u_1\left(c(g),1-c(g)-\frac{\psi}{2}g^2\right)}=\frac{c'(g)}{c'(g)+\psi g}$$

NOTE: If $\psi = 0$, exactly the same optimal-policy condition as in flexible-price analysis (Chapter 17) – i.e., RHS = 1

Optimal Policy Analysis

- If policy is set optimally

$$\frac{u_2\left(c(g),1-c(g)-\frac{\psi}{2}g^2\right)}{u_1\left(c(g),1-c(g)-\frac{\psi}{2}g^2\right)}=\frac{c'(g)}{c'(g)+\psi g}$$

- Compare with private-sector equilibrium

$$\frac{1}{1-\varepsilon}\left[1-\frac{\varepsilon u_2\left(c,1-c-\frac{\psi}{2}g^2\right)}{u_1\left(c,1-c-\frac{\psi}{2}g^2\right)}\right]\left(1-c-\frac{\psi}{2}g^2\right)-\psi g(1+g)+\beta\psi g(1+g)=0$$

- QUESTION: What money growth rate ***g*** achieves this outcome?...

Optimal Policy Analysis

Optimal Policy Analysis

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Introduce ε factor here…

- QUESTION: What money growth rate ***g*** achieves this outcome?...

- Impossible to solve for ***g***!....
- …unless we slightly "modify" the condition (NKPC) describing private-sector equilibrium…
  - Interpretation: a corrective ***fiscal policy*** intervention (Problem Set 6)

Optimal Policy Analysis

- QUESTION: What money growth rate *g* aligns these two conditions?

$$\frac{u_2\left(c(g),1-c(g)-\frac{\psi}{2}g^2\right)}{u_1\left(c(g),1-c(g)-\frac{\psi}{2}g^2\right)}=\frac{c'(g)}{c'(g)+\psi g}$$

Summarizes outcome under ***optimal policy***

$$\frac{1}{1-\varepsilon}\left[1-\frac{u_2\left(c,1-c-\frac{\psi}{2}g^2\right)}{u_1\left(c,1-c-\frac{\psi}{2}g^2\right)}\right]\left(1-c-\frac{\psi}{2}g^2\right)-\psi g(1+g)+\beta\psi g(1+g)=0$$

Summarizes private-sector equilibrium for ***any arbitrary policy choice***

- By inspection…

Optimal Policy Analysis

- QUESTION: What money growth rate *g* aligns these two conditions?

$$\frac{u_2\left(c(g),1-c(g)\right)}{u_1\left(c(g),1-c(g)\right)}=1$$

$$\frac{1}{1-\varepsilon}\left[1-\frac{u_2\left(c,1-c\right)}{u_1\left(c,1-c\right)}\right]\left(1-c\right)=0 \xrightarrow{\text{Solution requires}} \frac{u_2\left(c,1-c\right)}{u_1\left(c,1-c\right)}=1$$

- By inspection… *g* = 0 aligns the private-sector outcome with the policymaker's desired outcome

ALIGNING THESE IS THE GOAL!

ZERO INFLATION POLICY

- Optimal long-run money growth rate is $g = 0$
- Money supply should remain constant in the long run!

- Optimal long-run inflation
  - Monetarist link

$$\pi = g = 0$$

A normative statement

  - Zero long-run inflation!
  - Central bank should seek to target zero inflation on average

- Optimal long-run nominal interest rate
  - $i > 0$ from Fisher relation (aka consumption-savings optimality condition)

- Quite different policy recommendation from Friedman Rule!
  - Zero inflation, not negative inflation
  - ←→ Positive nominal interest rate, not zero nominal interest rate

- Fundamental difference: sticky prices vs. flexible prices

UNDERSTANDING ZERO INFLATION POLICY

- What does $g = n = 0$ achieve?
- Eliminates the price adjustment costs in the resource constraint

$$c + \frac{\psi}{2}\pi^2 = n \quad \xrightarrow{\text{Zero inflation}} \quad c = n$$

  - Adjustment costs are a cost!...
  - There is no benefit of "sluggish" or "sticky" prices!...
  - Basic economics: an activity has positive costs but no benefits → optimally want none of that activity!
- Private-sector achieves efficiency along consumption-leisure margin

$$\frac{u_2(c, 1-c)}{u_1(c, 1-c)} = 1$$

  - Zero inflation allows policy makers to achieve economic efficiency in private markets – even though central bank is NOT a Social Planner
    - Notice very nuanced/precise statements/logic...

- HOWEVER: zero inflation only "works" if fiscal policy is also being set optimally (Problem Set 6) – raises coordination issues, etc?...

PRACTICAL RELEVANCE OF ZERO INFLATION

- A benchmark in the theory of monetary policy
- Has been a practical guide for the conduct of monetary policy in last 25 years

- Zero inflation technically only a long-run optimal policy recommendation
- But has become the intellectual guidepost for central banks worldwide even for business-cycle-frequency inflation goals

- Encapsulated in the mantra "low and stable inflation"

- No central banks target (explicitly or implicitly) EXACTLY ZERO inflation
  - Rather, positive long-run inflation targets

- What can rationalize positive long-run inflation targets?
  - WAGE (as opposed to price) rigidity
  - Financial frictions?
  - Hitting zero-lower-bound on nom i.r. during recessions the central issue
    - i.e., Blanchard suggestion

Active areas of research

- Nature of and costs (and benefits?) associated with price adjustment still not well understood