NEW KEYNESIAN THEORY: THE MODERN STICKY-PRICE MODEL

APRIL 5, 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**
  - TODAY → **Step 2: Superimpose on the theory some "costs" of setting/re-setting nominal prices**
  - **Step 3: Study optimal monetary policy**

Menu Costs

- Do firms incur "costs" in the very act of setting/re-setting nominal prices?
- If so, what is the nature and prevalence of these costs?
- A central issue in price theory
- Menu cost – any and all costs incurred directly due to the price (re-)setting process
  - Independent of any physical production costs – i.e., NOT a cost captured by standard "production functions"
- Two common views of nature of menu costs
  - Fixed menu cost: total menu cost is independent of the magnitude of the price change being considered
  - Example: cost of printing new prices on restaurant menus is probably independent of what the new prices are
  - Convex menu cost: total menu cost is convex and increasing in the magnitude of the price change being considered
  - Example: if "menu cost" includes "cost of angering customers," "managerial time," etc., convexity assumption may be more appropriate

Anderson and Simester; Zbracki et al papers

- Both fixed and convex are likely aspects of menu costs
- Formal theoretical NK model typically focuses only on convex menu costs

Modeling Convex Menu Costs

- Introduce menu costs at level of wholesale firms
  - Because they actually (re-)set prices!
  - What does it mean for a firm that is not a price-setter to incur costs of setting prices?...
- Wholesale firm *j* incurs real menu cost of nominal price adjustment

$$\frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}}-1\right)^2$$

  - REAL cost of price adjustment – denominated in goods
  - Parameter $\Psi > 0$ governs "importance" of menu costs
    - $\Psi = 0$ means no menu cost, which recovers basic Dixit-Stiglitz framework
- Convex: the larger the percentage deviation of P_{jt} from P_{jt-1}, the larger the menu cost
- Question: are downward adjustments just as costly as upward adjustments?
  - Intuition: "no" Anderson and Simester evidence: "maybe?..."

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)**

.
.
.

Analysis

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

- Focus on the activities of an arbitrary wholesale firm *j*
- Symmetry: assume that every wholesale firm makes decisions analogously
  - Consistent with the representative-agent approach
- So can speak of "the" wholesale firm
- Assume zero fixed costs of production
- Operates a constant-returns-to-scale (CRS) production technology in order to produce its unique, differentiated output
  - CRS: if all inputs are scaled up by the factor *x*, total output is scaled up by the factor *x*
  - Implementation of theory requires specifying neither the factors of production (i.e., labor, capital, etc) nor a production function (*f*(.))
- Marginal cost of production
  - = average cost of production
  - is invariant to the quantity produced
    - i.e., mc is NOT a function mc(quantity)
- AND ALSO INCUR QUADRATIC MENU COSTS $\frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}}-1\right)^2$

Together, these imply a simple description of production

The basis for "sticky" or "sluggish" nominal price adjustment

WHOLESALE FIRMS

- Representative wholesale firm's period-*t* profit function

Total revenue depends on firm's production and its *own* product price.

mc is NOT a function of quantity produced – CRS assumption. FC = 0 → *mc* = *ac* OF PRODUCTION!

$$P_{jt}y_{jt} - P_t mc_{jt} y_{jt} - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}}-1\right)^2 P_t$$

Conversion of production costs into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

Period-t menu costs, conversion of which into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

Wholesale Firms

- Representative wholesale firm's **period-*t* profit function**

Total revenue depends on firm's production and its *own* product price.

mc is NOT a function of quantity produced – CRS assumption. FC = 0 → *mc* = *ac* OF PRODUCTION!

$$P_{jt}y_{jt} - P_t mc_{jt}y_{jt} - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)^2 P_t$$

Conversion of production costs into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

Period-t menu costs, conversion of which into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

- Presence of menu cost makes wholesale firm's profit-maximization problem a DYNAMIC one
  - Because any nominal price chosen in a given period has consequences for profits in the subsequent period through menu costs
  - Firm pricing problem is forward-looking

- Dynamic (two-period) profit function

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

Wholesale Firms

- Representative wholesale firm's **period-*t* profit function**

Total revenue depends on firm's production and its *own* product price.

mc is NOT a function of quantity produced – CRS assumption. FC = 0 → *mc* = *ac* OF PRODUCTION!

$$P_{jt}y_{jt} - P_t mc_{jt}y_{jt} - \frac{\psi}{2}\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)^2 P_t$$

Conversion of production costs into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

Period-t menu costs, conversion of which into nominal terms requires factor P_t, NOT P_{jt}. Because costs are not denominated in the firm's *own* prices.

- Presence of menu cost makes wholesale firm's profit-maximization problem a DYNAMIC one
  - Because any nominal price chosen in a given period has consequences for profits in the subsequent period through menu costs
  - Firm pricing problem is forward-looking

Discount factor is a NOMINAL discount factor (β is a REAL discount factor).

And background assumption: no agency problem.

- Dynamic (two-period) profit function

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

Analysis

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, …)

The critical point of analysis of monopoly: the firm *understands* and *internalizes* the effect of *its* price on the quantity that it sells.

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

In period t, firm chooses P_{jt}.

So FOC with respect to P_{jt}…

Analysis

Wholesale Firms

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

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

- **FOC with respect to P_{jt} (see p. 277)**

$$\frac{1}{1-\varepsilon} P_{jt}^{\frac{\varepsilon}{1-\varepsilon}} P_t^{\frac{\varepsilon}{\varepsilon-1}} y_t - \frac{\varepsilon}{1-\varepsilon} P_{jt}^{\frac{2\varepsilon-1}{1-\varepsilon}} P_t^{\frac{2\varepsilon-1}{\varepsilon-1}} mc_t y_t - \psi\left(\frac{P_{jt}}{P_{jt-1}} - 1\right)\frac{P_t}{P_{jt-1}} + \frac{\beta\psi}{1+\pi_{t+1}}\left(\frac{P_{jt+1}}{P_{jt}} - 1\right)\frac{P_{t+1}}{P_{jt}}\frac{P_{jt+1}}{P_{jt}} = 0$$

Analysis

Wholesale Firms

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

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

- **FOC with respect to P_{jt}** **(see p. 277)**

$$\frac{1}{1-\varepsilon} P_{jt}^{\frac{\varepsilon}{1-\varepsilon}} P_t^{\frac{\varepsilon}{\varepsilon-1}} y_t - \frac{\varepsilon}{1-\varepsilon} P_{jt}^{\frac{2\varepsilon-1}{1-\varepsilon}} P_t^{\frac{2\varepsilon-1}{\varepsilon-1}} mc_t y_t - \psi\left(\frac{P_{jt}}{P_{jt-1}}-1\right)\frac{P_t}{P_{jt-1}} + \frac{\beta\psi}{1+\pi_{t+1}}\left(\frac{P_{jt+1}}{P_{jt}}-1\right)\frac{P_{t+1}}{P_{jt}}\frac{P_{jt+1}}{P_{jt}} = 0$$

- **If ψ = 0, collapses to**

$$\frac{P_{jt}}{P_t} = \varepsilon mc_t$$

Exactly the flexible-price Dixit-Stiglitz pricing rule

- **Existence of menu costs (ψ > 0) complicates pricing rule**

Analysis

Symmetric Equilibrium

- **Now drop the distinction between "retail goods" and "wholesale goods"**
  - **Suppose "goods" are all identical**

- **A macro perspective**
  - **The "representative good"…**
  - **…since macro analysis is most concerned with aggregates**

- **Impose symmetry by now dropping *j* indexes – i.e., now suppose $P_{jt} = P_t$**

$$\frac{1}{1-\varepsilon} P_t^{\frac{\varepsilon}{1-\varepsilon}} P_t^{\frac{\varepsilon}{\varepsilon-1}} y_t - \frac{\varepsilon}{1-\varepsilon} P_t^{\frac{2\varepsilon-1}{1-\varepsilon}} P_t^{\frac{2\varepsilon-1}{\varepsilon-1}} mc_t y_t - \psi\left(\frac{P_t}{P_{t-1}}-1\right)\frac{P_t}{P_{t-1}} + \frac{\beta\psi}{1+\pi_{t+1}}\left(\frac{P_{t+1}}{P_t}-1\right)\frac{P_{t+1}}{P_t}\frac{P_{t+1}}{P_t} = 0$$

↓ **Lots of terms cancel…**

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

↓ **…and use definition of inflation $P_t/P_{t-1} = 1 + \pi_t$**

NEW KEYNESIAN PHILLIPS CURVE

- **The New Keynesian Phillips Curve (NKPC)**

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

- **Links period-t inflation to period-t marginal costs of production and period-(t+1) inflation**

- **"Classical" Phillips Curve**
  - **A link between period-t inflation and one component of period-t marginal costs of production (employment)**
  - **No "forward-looking" elements in it**

- **Forward-looking pricing/inflation behavior the key idea articulated by NKPC**
  - **Pricing decisions are inherently dynamic**

- **NKPC the cornerstone idea in New Keynesian theory**

- **Here derived from Rotemberg framework…can derive off alternative theories**