Monopolistic Competition and Sticky Prices

Johannes Wieland
jfwieland@ucsd.edu

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Outline

Monopolistic Competition and Markups

- Goal: Add nominal rigidity for non-neutrality.
- Problem: How does nominal rigidity work with CRS and perfect competition?
  - Older literature: Rationing with output determined as minimum of supply and demand at given price.
  - Newer Literature: Get rid of CRS and perfect competition and replace with IRS and imperfect competition $\Rightarrow$ firms set prices.
- But how do we have features of oligopoly without modeling the industrial organization, which is a mess in GE?
- Blanchard and Kiyotaki (1987) and subsequent literature: Use monopolistic competition.
  - Idea going back to Chamberlain (1933), but popularized by tractable setup of Dixit and Stiglitz (1977).
  - Monopolistic competition is widely used in GE modeling (macro, trade, labor, etc.) and is something you should know.

Outline

Monopolistic Competition

- Continuum of goods ("varieties") $i \in [0,1]$ with a monopolist for each good.
- Each monopolist faces a downward-sloping demand curve.
  - Substitution between goods imperfect due to "love of variety."
- Each monopolist's optimal choice has an infinitesimal effect on economy-wide aggregates.
  - Industrial organization in GE is simple.
  - Imperfect competition without game theory.
- Today: demand curve from consumer preferences.
- Can equivalently do firm optimization problem.

Household Problem: Setup and Notation

- Idea: CES over a continuum of goods:

$$E_t\left\{\sum_{s=0}^{\infty}\beta^s\left(\frac{C_{t+s}^{1-\gamma}}{1-\gamma}+\zeta\frac{(M_{t+s}/P_{t+s})^{1-\nu}}{1-\nu}-\chi\frac{N_{t+s}^{1+\varphi}}{1+\varphi}\right)\right\}$$

  where

$$C_t=\left[\int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}}di\right]^{\frac{\varepsilon}{\varepsilon-1}} \text{ with } \varepsilon>0$$

- Budget constraint:

$$\int_0^1 P_t(i)C_t(i)di+B_t+M_t\leq Q_{t-1}B_{t-1}+M_{t-1}+W_tN_t+P_t(TR_t+PR_t)$$

- Ct is sometimes called a “Dixit-Stiglitz aggregate.”

Solving Dixit-Stiglitz: Two-Stage Budgeting

- Two-Stage Budgeting Theorem (Deaton and Muellbauer):
    - If upper stage is separable and lower stage is homothetic, can use two-stage budgeting with nested preferences.

  $\Rightarrow$ Solve the inner nest taking expenditure as given and outer nest by standard utility maximization given inner nest optimization to determine expenditure on bundle purchased in inner nest.

- We can use two-stage budgeting here.

Dixit-Stiglitz: Inner Nest Maximization

$$\max\left[\int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}}di\right]^{\frac{\varepsilon}{\varepsilon-1}}-\lambda\left(\int_0^1 P_t(i)C_t(i)di-X_t\right)$$

- Xt is expenditure on Dixit-Stiglitz goods.
- FOC

$$C_t(i)^{-\frac{1}{\varepsilon}}C_t^{\frac{1}{\varepsilon}}=\lambda P_t(i)$$

- For any two goods i and j,

$$C_t(i)=C_t(j)\left(\frac{P_t(i)}{P_t(j)}\right)^{-\varepsilon}=\frac{P_t(i)^{-\varepsilon}}{P_t(j)^{1-\varepsilon}}P_t(j)C_t(j)$$

- Bring the denominator over and integrate wrt j:

$$C_t(i)\int_0^1 P_t(j)^{1-\varepsilon}dj=P_t(i)^{-\varepsilon}\int_0^1 P_t(j)C_t(j)dj$$

$$C_t(i)=\frac{P_t(i)^{-\varepsilon}}{\int_0^1 P_t(j)^{1-\varepsilon}dj}X_t$$

Dixit-Stiglitz: Price Index

- Indirect utility is:

$$v(P_t(k)|_{k=0}^{1}, X_t) = \left[\int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}$$
$$= \frac{X_t}{\left[\int_0^1 P_t(j)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}}}$$

- The cost of buying one unit of utility (=one unit of consumption) is:

$$P_t = \left[\int_0^1 P_t(j)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}}$$

  - Index is geometric weighted average of individual good prices.

Dixit-Stiglitz: Demand Function

- $X_t = P_t C_t$, so plugging in price index gives

$$
\begin{aligned}
C_t(i) &= \frac{P_t(i)^{-\varepsilon}}{P_t^{1-\varepsilon}} X_t \\
&= \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} C_t
\end{aligned}
$$

- CES structure delivers *constant elasticity demand function*.
  - Elasticity of demand is elasticity of substitution ε.
  - As $\varepsilon \to \infty$, perfect substitutes and demand perfectly elastic.
  - As $\varepsilon \to 1$, less perfect substitutes and demand more inelastic (but still elastic as $\varepsilon > 1$).
- Each firm has infinitesimal impact on C_t and P_t and treats them as exogenous.

Solving Dixit-Stiglitz: Upper Stage

- With this budget constraint can be written as:

$$P_t C_t + B_t + M_t \leq Q_{t-1} B_{t-1} + M_{t-1} + W_t N_t + P_t (TR_t + PR_t)$$

- Solve upper stage as normal with C_t as Dixit-Stiglitz aggregate:

$$\begin{aligned}
\frac{W_t}{P_t} &= \frac{\chi N_t^{\varphi}}{C_t^{-\gamma}} \\
1 &= \beta E_t \left\{ Q_t \frac{P_t}{P_{t+1}} \frac{C_{t+1}^{-\gamma}}{C_t^{-\gamma}} \right\} = E_t \{ \Lambda_{t,t+1} R_{t+1} \} \\
1 &= \beta E_t \left\{ \frac{P_t}{P_{t+1}} \frac{C_{t+1}^{-\gamma}}{C_t^{-\gamma}} \right\} + \zeta \frac{(M_t / P_t)^{-\nu}}{C_t^{-\gamma}}
\end{aligned}$$

Uses of Dixit-Stiglitz

- Dixit-Stiglitz is frequently used in GE modeling both in macro and other subfields.
  - Often along with free entry margin that drives profits to zero and endogenously determines number of products.
- Noteworthy Examples:
  - "New" Trade Theory (Krugman, 1980): Love of variety explains high volume of intra-industry trade, e.g. Japan exports Lexus to Germany and Germany exports Mercedes to Japan.
  - New Economic Geography (Krugman, 1990): Urbanization determined by balance between dispersion forces (e.g., housing supply) and agglomeration forces created by increasing returns. As trade costs fall, cities should develop.
  - Endogenous Growth Theory (Romer, 1990): Profits give entrepreneurs incentives to invest in creating new products. Growth through endogenously expanding product variety.

Dixit-Stiglitz Production

- Dixit-Stiglitz is used two ways:
  - Preferences: Households consume each good i, CES preferences over continuum of goods.
  - Production: Households consume final good assembled from intermediates i, CES production fn over continuum of goods.
- These are essentially equivalent.
  - We used utility maximization given to expenditure X_t, but same as cost minimization (duality theory).
  - Cost min s.t. D-S utility level C_t mathematically equivalent to profit max s.t. CES production is C_t (up to sign change).
  - Intuition: Does not matter where continuum is as long as it as CES structure.
- Gali book presents model using Dixit-Stiglitz preferences. I will follow this convention here.

Outline

Intermediate Good Producers

- From the household problem, each monopolist faces a downward-sloping demand curve:

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} C_t$$

- Produce variety CRS with labor:

$$Y_t(i) = A_t N_t(i)$$

  - See Gali for DRS.

- Market clearing implies $C_t(i) = Y_t(i)$ and $C_t = Y_t$.

Profit Maximization with Flexible Prices

- Profits for the monopolist are

$$
\begin{aligned}
PR_t(i) &= \frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t}{P_t} N_t(i) \\
&= \left(\frac{P_t(i)}{P_t}\right)^{1-\varepsilon} Y_t - \frac{W_t}{P_t} \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} \frac{Y_t}{A_t}
\end{aligned}
$$

- FOC for $P_t(i)$:

$$
(1-\varepsilon)\left(\frac{P_t^*(i)}{P_t}\right)^{-\varepsilon} Y_t + \varepsilon \frac{W_t}{P_t} \left(\frac{P_t^*(i)}{P_t}\right)^{-\varepsilon-1} \frac{Y_t}{A_t} = 0
$$

- The optimal real price is:

$$
\frac{P_t^*(i)}{P_t} = \underbrace{\mu}_{\text{Mark-up}} \times \underbrace{\frac{W_t}{P_t} \frac{1}{A_t}}_{\text{Real MC}}, \qquad \mu = \frac{\varepsilon}{\varepsilon - 1}
$$

  - Real price is a multiplicative markup over real marginal cost.

Classical Dichotomy

- Monopolistic competition by itself does not deliver monetary non-neutrality.
- Labor demand equation becomes

$$\frac{W_t}{P_t} = \underbrace{\frac{1}{\mu}}_{\text{Inverse of Mark-up}} \times \underbrace{A_t}_{MPL_t}$$

- This is the only change $\Rightarrow$ Classical Dichotomy holds.
- To get non-neutrality of money need nominal rigidity.
  - Monopolistic competition gives an identity to the price setter. We can study what happens when firms keep prices fixed.

Intermediate Good Producers: Calvo Assumption

- Calvo (1983) pricing assumption: Each firm resets price each period with iid probability $1-\theta$.
  - By LLN, fraction that reset is $1-\theta$ and fraction constant is θ.
  - Average price duration follows geometric dist with mean duration $\frac{1}{1-\theta}$.
- Firms that adjust prices choose $P_t(i), Y_t(i), N_t(i)$ to maximize expected discounted profits and demand.
- Firms that do not adjust prices set output to meet demand.

Intermediate Good Producers: Calvo Assumption

- Calvo is a strong assumption!
- Is the world Calvo?
  - Literally, no.
  - But it could be a decent approximation.
- Literature on "menu cost" models where there is an inaction region due to fixed cost of changing price.
  - Initial literature: Much more flexible than Calvo, since firms that have price furthest from MC change price.
  - Recent literature: To match micro-pricing facts, need large and infrequent firm-level MC shocks, which looks close to Calvo.

Price Dynamics With Calvo

- A fraction $1-\theta$ of firms adjust to P_t^* and fraction θ keep $P_{t-1}(i)$:

$$
\begin{aligned}
P_t &= \left[\int_0^1 P_t(i)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \\
&= \left[\theta \int_0^1 P_{t-1}(i)^{1-\varepsilon} di + (1-\theta)\int_0^1 P_t^{*1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \\
&= \left[\theta \left(\int_0^1 P_{t-1}(i)^{1-\varepsilon} di\right)^{\frac{1-\varepsilon}{1-\varepsilon}} + (1-\theta)\int_0^1 P_t^{*1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \\
&= \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta) P_t^{*1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}
\end{aligned}
$$

- Price index P_t is geometric average of P_{t-1} and P_t^*.
- Calvo is tractable because we do not need to keep track of distribution of prices.

Inflation Dynamics With Calvo

- Divide by P_{t-1} to get inflation between $t-1$ and t, Π_t

$$\Pi_t = \frac{P_t}{P_{t-1}} = \left[\theta + (1-\theta)\left(\frac{P_t^*}{P_{t-1}}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

- From this, we can see that Calvo price setting implies a partial adjustment mechanism:
  - If $P_t^* = P_{t-1}$, then $\Pi_t = 1$.
  - If $P_t^* > P_{t-1}$, then $\Pi_t > 1$ and $P_t^* > P_t > P_{t-1}$.

Optimal Intermediate Reset Price Setting

$$\max_{P_t^*, \{Y_{t+s|t}\}_{s=0}^{\infty}} E_t \left\{ \sum_{s=0}^{\infty} \theta^s \Lambda_{t,t+s} \left(\frac{P_t^* Y_{t+s|t}}{P_{t+s}} - TC_{t+s}(Y_{t+s|t}) \right) \right\}$$

$$Y_{t+s|t} = \left(\frac{P_t^*}{P_{t+s}} \right)^{-\varepsilon} Y_{t+s}$$

- The intermediate producer maximizes real discounted profits.
  - Also discounting by prob they keep price same θ.
- Real Profits are:
  - Nominal revenue deflated by the price level, $\frac{P_t^* Y_{t+s|t}}{P_{t+s}}$, minus total real cost $TC_{t+s}(Y_{t+s|t})$.
  - Output at time $t+s$, $Y_{t+s|t}$ is determined by the demand curve at time $t+s$ and the price chosen at time t.

Optimal Intermediate Reset Price Setting

$$E_t \left\{ \sum_{s=0}^{\infty} \theta^s \Lambda_{t,t+s} Y_{t+s|t} \left(\frac{P_t^*}{P_{t+s}} - (1+\mu) MC_{t+s}(Y_{t+s|t}) \right) \right\} = 0$$

- If $\theta = 0$, no stickiness and this collapses to flex price model:

$$P_t^* = (1+\mu) P_t MC_t$$

- If $\theta > 0$, then the optimal reset price is a markup over a weighted average of expected future marginal costs:

$$P_t^* = (1+\mu) E_t \left\{ \sum_{s=0}^{\infty} \omega_{t,t+s} P_{t+s} MC_{t+s|t} \right\}$$

$$\text{where } \omega_{t,t+s} = \frac{\theta^s \Lambda_{t,t+s} Y_{t+s} P_{t+s}^{\varepsilon-1}}{\sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} Y_{t+k} P_{t+k}^{\varepsilon-1}}$$

Completing the Model

- Because of CRS, real marginal cost is:

$$MC_{t+s|t} = \frac{W_{t+s}/P_{t+s}}{Y_{t+s|t}/N_{t+s|t}} = \frac{W_{t+s}/P_{t+s}}{A_{t+s}} = MC_{t+s}$$

- Aggregate output is:

$$Y_t = \left[\int_0^1 [A_t N_t(i)]^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} = A_t N_t \left[\int_0^1 \left(\frac{N_t(i)}{N_t}\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

  - Term in brackets is loss in output due to misallocation caused by price dispersion.
  - Creates welfare costs of inflation, but it is second order and drops out of log-linearization.

Outline

1. Introduction
2. Dixit-Stiglitz
3. Monopolistic Competition and Sticky Prices
4. Next Steps

Completing the Model

- Combine price setting "block" with household "block" and monetary policy "block" to arrive at the new Keynesian model.