Duopolistic Competition and Monetary Policy

Kozo Ueda

Waseda University

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Research Question

- How do implications for monetary policy change when we incorporate strategic pricing behaviors?
  - Why do firms not raise prices in Japan? Strategic motive?
  - Standard NK model is based on monopolistic competition developed by Dixit and Stiglitz (1977)
    - ★ Goods produced by firms are perfectly differentiated.
    - ★ Consumers have strong preferences for diversity.
    - ★ The number of rival firms is sufficiently large.

- We construct a macroeconomic model with
  - Calvo-type price stickiness and
  - Hotelling (1929) duopolistic competition (also Armstrong 2006)
  - while maintaining model simplicity.
    - Model simplicity enables us to make an interesting extension.

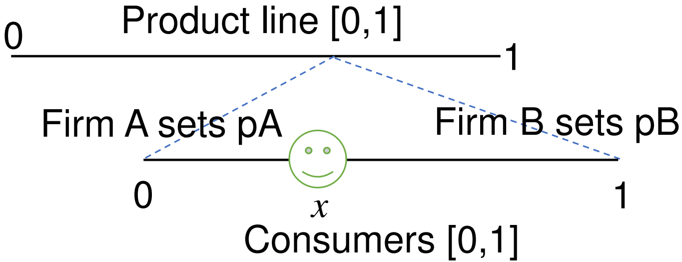
Main Results

- Dynamic strategic complementarity exists.
  - An increase in a firm's reset price increases the optimal price set by the rival firm in future, which influences its optimal price today.
- Then,
  - the steady-state price level depends on price stickiness;
  - the real effect of monetary policy is larger; and
  - a duopoly model with heterogeneous transport costs can explain temporary sales, which decreases the real effect of monetary policy considerably.
- These results show the importance of understanding the competitive environment when considering the effects of monetary policy.

Related Literature

- Relations between strategic pricing and sticky prices: Fershtman and Kamien (1987), Maskin and Tirole (1988), Slade (1999), Bhaskar (2002), Fehr and Tyran (2008), and Chen, Korpeoglu, and Spear (2017)
  - They are not macro studies.
- In NK models, the importance of strategic complementarities: Ball and Romber 1990, Kimball 1995, Woodford 2003, Christiano, Eichenbaum, and Evans 2005, Levin, Lopez-Salido, and Yun 2007, Angeletos and La'o 2009, Aoki, Ichiue, and Okuda 2019, L'Huillier 2020
  - Our study provides a new insight on the source of strategic complementarities, from the perspective of an oligopoly.
- Monetary policy under oligopolistic competition: Faia (2012) and Mongey (2017)
  - They maintain the monopolistic competition framework. By contrast, our model is based on Hotelling's (1929) location model.
- Role of temporary sales for monetary policy: Guimaraes and Sheedy (GS, 2011), Sudo et al. (2018), and Kryvtsov and Vincent (forthcoming)
  - Sales are a source of strategic complementarity, whereas they are a strategic substitute in the GS model. This decreases the real effect of monetary policy considerably.

Setup



- Two firms A and B
  - Produce one unit of product using one unit of labor, which costs nominal wage W_t.
- A household
  - is comprised of an infinite number of consumers.
  - They go shopping, consume, and supply labor.
- Monetary authority supplies money.

A head of household maximizes

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log C_t - (L_t + \tau D_t) \right],$$

where aggregate consumption C_t and shopping distance D_t are given by

$$\log C = \int_0^1 \log c^j dj \quad \text{and} \quad D = \int_0^1 d^j dj. \tag{1}$$

Parameter τ is the transport cost incurred per unit of distance.
The budget constraint:

$$M_t + B_t + P_t C_t \leq M_{t-1} + R_{t-1} B_{t-1} + W_t L_t + \Pi_t + T_t, \tag{2}$$

Nominal spending must be equal to the money supply:

$$P_t C_t = M_t \Rightarrow M_t = W_t. \tag{3}$$

- A consumer located at $x \in [0, 1]$ is a distance x from firm A and $1 - x$ from firm B.
- Because of the unit elasticity, a consumer spends M in a nominal term. Thus, $c = M/p^i$ if the consumer buys from firm $i = A, B$.
- The consumer's net surplus:

$$u^i = \log c^i - \tau d^i = \log M - \log p^i - \tau d^i, \tag{4}$$

  where d^i represents the distance the consumer travels to firm i.
- Although we call τ the transport cost, it also represents a consumer's choosiness.
  - How much he/she dislikes buying from his/her less preferred firm.
  - When τ is high, the consumer is loyal to his/her preferred firm. When τ is low, the consumer cares about the prices sold in the two firms, acting as a bargain hunter.

Goods market clearing:

$$Y_t (= L_t) = C_t.$$

Money supply exogenous:

$$\begin{aligned} \log(M_t / M_{t-1}) &= \varepsilon_t \\ &= \rho \varepsilon_{t-1} + \mu_t, \end{aligned} \tag{5}$$

where μ_t is an i.i.d. shock to money supply.

Steady State without Price Stickiness

A consumer will buy from firm A if

$$\log p^A + \tau x \leq \log p^B + \tau(1 - x). \tag{6}$$

Firm A's profit:

$$\Pi(p^A, p^B) = \begin{cases} 0 & \text{if } \frac{\log p^A - \log p^B}{\tau} \geq 1/2 \\ (p^A - W)\left(\frac{1}{2} - \frac{\log p^A - \log p^B}{\tau}\right)\frac{M}{p^A} & \text{if } -1/2 < \frac{\log p^A - \log p^B}{\tau} < 1/2 \\ (p^A - W)\frac{M}{p^A} & \text{if } \frac{\log p^A - \log p^B}{\tau} \leq -1/2. \end{cases} \tag{7}$$

The best response of p^A given p^B, $p^A(p^B)$, increases as p^B increases, showing the static strategic complementarity.
Steady-state price:

$$p = (1 + \tau/2)\, W. \tag{8}$$

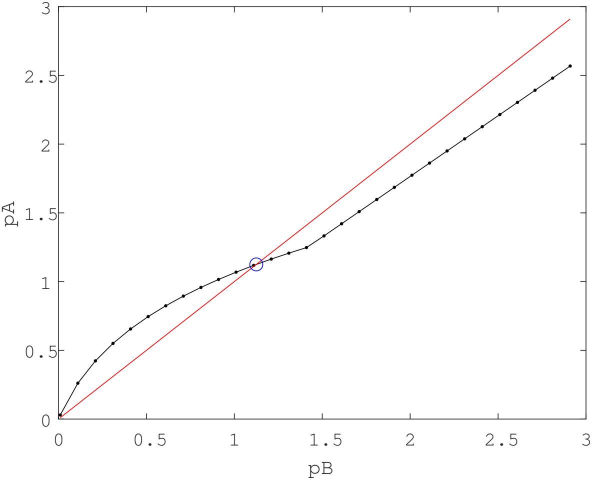


Figure: Best Response

Pricing under Price Stickiness

- Calvo-type stickiness
  - Both firms A and B can reset their prices with a probability of $1 - \theta \in (0, 1)$.
  - Specifically, with the probability of $1 - \theta$, an old firm exits the market and a new firm enters in its place and sets its price. Thus, only a new firm can optimize price.
  - $\rightarrow$ We consider the dynamic effects of price setting only to the extent that a firm's reset price today influences the rival firm's reset price in the following periods.
- Assume that the Markov perfect equilibrium concept applies.
  - Each firm's price setting depends on a state consisting only of p^A_{t-1}, p^B_{t-1}, and ε_t.
  - Exclude collusive pricing

When firm A has a chance to set its price at t, it sets $\bar{p}_t^A$ to maximize

$$\max \sum_{k=0}^{\infty} \theta^k \beta^k \mathbb{E}_t \left[\left(1 - \frac{M_{t+k}}{\bar{p}_t^A}\right) \theta^{k+1} \left(\frac{1}{2} - \frac{\log \bar{p}_t^A - \log p_{t-1}^B}{\tau} \right) \right] \cdot \frac{\Lambda_{t+k}}{\Lambda_t} \frac{P_t}{P_{t+k}} \frac{M_{t+k}}{M_t}$$
$$+ \sum_{k=0}^{\infty} \theta^k \beta^k \mathbb{E}_t \left[\left(1 - \frac{M_{t+k}}{\bar{p}_t^A}\right) \sum_{k'=0}^{k} (1-\theta)\theta^{k-k'} \left(\frac{1}{2} - \frac{\log \bar{p}_t^A - \log \bar{p}_{t+k'}^B}{\tau} \right) \right] \cdot \frac{\Lambda_{t+k}}{\Lambda_t} \frac{P_t}{P_{t+k}} \frac{M_{t+}}{M_t} \tag{9}$$

Firm A has to take account of how its reset price at t influences the rival firm B's reset price at $t + k^{'}$, which is given by $\partial \log \bar{p}_{t+k'}^B / \partial \log \bar{p}_t^A$.

Log-linearization around the Steady State

Denote $\bar{p}_t^A \equiv pM_t e^{p_t^{A*}}$, $p_t^B \equiv pM_t e^{\hat{p}_t^B}$.
The optimal reset prices are expressed in the following forms:

$$p_t^{A*} = \Gamma \hat{p}_{t-1}^A + \Gamma^* \hat{p}_{t-1}^B + \Gamma^\varepsilon \varepsilon_t \tag{10}$$

$$p_t^{B*} = \Gamma \hat{p}_{t-1}^B + \Gamma^* \hat{p}_{t-1}^A + \Gamma^\varepsilon \varepsilon_t, \tag{11}$$

$$\partial \log \bar{p}_{t+k}^B / \partial \log \bar{p}_t^A = \partial p_{t+k}^{B*} / \partial p_t^{A*} = \Gamma^*, \tag{12}$$

where Γ, Γ^*, and Γ^ε can be calculated numerically from the first-order condition.

Steady-State Price

- It is given by

$$p = 1 + \frac{1}{2}\tau \left(1 - \frac{(1-\theta)(1+\theta-\theta^2\beta)}{1-\theta^2\beta}\theta\beta\Gamma^*\right)^{-1}. \tag{13}$$

- Different from that without nominal rigidity.
- Firms take account of the effect of their price on the rival firm's price in the following periods.
- Specifically, if Γ^* is positive, there is a dynamic strategic complementarity.
  - An increase in firm A's price increases firm B's price in the following periods. This effect increases the steady-state price level.

Comparison with a DS Monopolistic Competition Model

Consumption is aggregated following the Dixit-Stiglitz form of aggregation:

$$C_t = \left\{ \int_0^1 C_t(j)^{\frac{\sigma-1}{\sigma}} dj \right\}^{\frac{\sigma}{\sigma-1}} . \tag{14}$$

	Duopoly	Monopoly
Steady-state price markup (p/W)	$1 + \frac{1}{2}\tau \left(1 - \frac{(1-\theta)(1+\theta-\theta^2\beta)}{1-\theta^2\beta}\theta\beta\Gamma^*\right)^{-1}$	$\sigma/(\sigma-1)$
Demand elasticity	$1 + 2/\tau$	σ
Degree of strategic complementarity	$1/(2+\tau/2)$	0
Dependence on demand elasticity for inflation dynamics	Yes	No

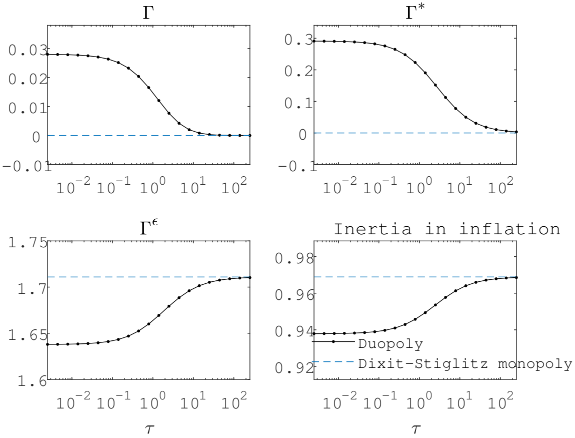
In the absence of price stickiness, the duopoly model with $\tau = 0.25$ yields the same price markup and demand elasticity as the monopoly model with $\sigma = 9$, which is assumed in Gali (2015).

Parameterization

- A time unit is a quarter.
- Normalize $W = 1$.
- Transport cost $\tau = 0.25$, consistent with $\sigma = 9$ in Gali (2015).
- Price stickiness $\theta = 0.75$: price revisions once per year.
- $\rho = 0.85$ and $\beta = 0.99$.

Policy Function

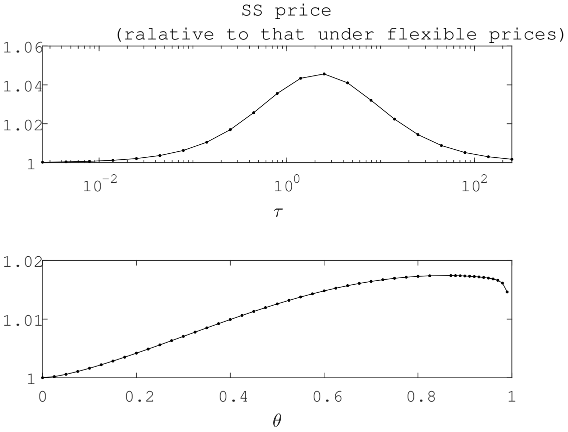
A higher stickiness as τ increases



Note: The figure shows the coefficients of policy functions for the optimal reset price by firm A given by $p_t^{A*} = \Gamma \hat{p}_{t-1}^A + \Gamma^* \hat{p}_{t-1}^B + \Gamma^\varepsilon \varepsilon_t$. The lower right-hand panel shows the coefficient on past inflation (π_{t-1}) for the equation of inflation (π_t). The horizontal axis represents transport cost (τ, log scale).

Steady-State Price

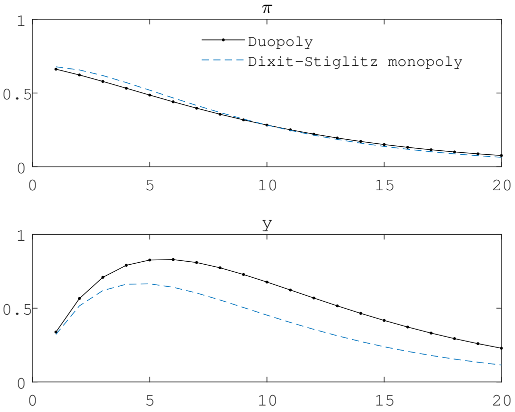
There is a certain θ that maximizes the SS price ratio.



Note: The vertical axis represents the ratio of the steady-state price under sticky prices to that under flexible prices. The horizontal axis represents transport cost (τ, log scale) and price stickiness (θ) in the upper and lower panels, respectively.

IRFs to a Money Supply Shock

Strategic complementarity of price setting increases the real effect of monetary policy. Larger by approximately one third.



Note: The horizontal axis represents quarters after a positive money supply shock occurs at $t = 1$.

- The model we propose is simple. We can extend the model in several directions.
- As an illustration, we allow heterogeneous transport costs.
  - Consumers are heterogenous in terms of not only their location (x) but also their transport cost (τ).
- Some consumers may have access to a car and be more mobile, whereas others may not be, for example, because they are aged, unhealthy, or busy working.
  - This also represents how some consumers are loyal to a particular firm (brand) (i.e., price-insensitive) whereas others are bargain hunters (i.e., price-sensitive). The former customers have a higher τ than the latter.

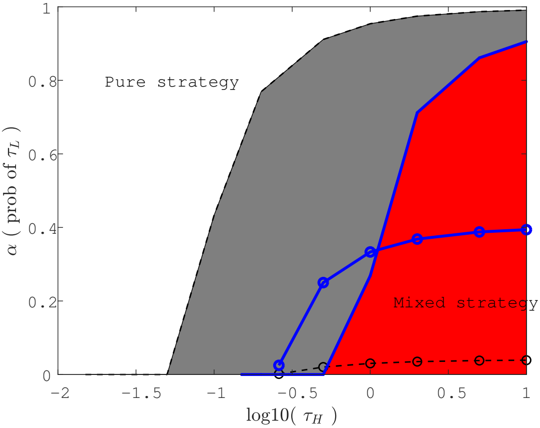
- τ takes τ_L with the probability of α or τ_H otherwise $(0 < \tau_L < \tau_H)$.
  - independent of locations.
- Firms A and B cannot observe consumers' transport cost, but know the distribution characterized by τ_H,τ_L, and α correctly.

Steady State without Price Stickiness

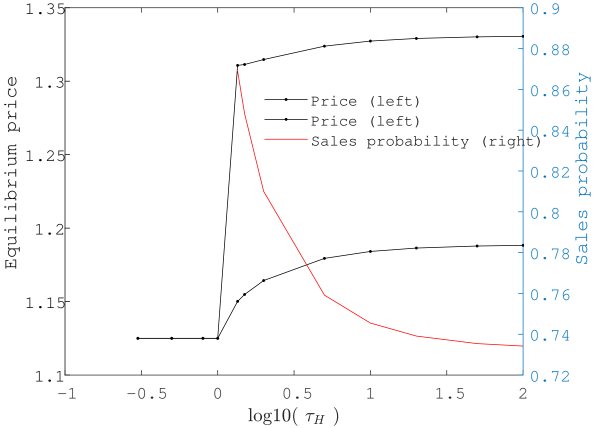
- Pure Strategy
  - Equilibrium price:

$$p^* = \left\{1 + 1/2 \cdot \left(\mathbb{E}\left[1/\tau\right]\right)^{-1}\right\} W, \tag{15}$$

    where $\left(\mathbb{E}\left[1/\tau\right]\right)^{-1}$ is the harmonic mean of τ.
  - May be better off by giving up revenues from price-sensitive bargain hunters and charging a higher price.
- Mixed Strategy (Regular and Sales)
  - Firms choose a mixed strategy, in which price is p_H with the probability of $1 - s$ and p_L with the probability of s ($p_H > p_L$).
  - Indifference of $\Pi(p_H) = \Pi(p_L)$.
  - The price dispersion decreases utility by increasing shopping distance.



Note: The thick solid line (in blue) and the thin dashed line (in black) represent the boundary between pure and mixed strategy when the parameter τ_L is set at 0.01 and 0.1, respectively. The thick solid line with circles (in blue) and the thin dashed line with circles (in black) indicate the combination of τ_H and α that keeps the harmonic mean of τ at 0.25, respectively.

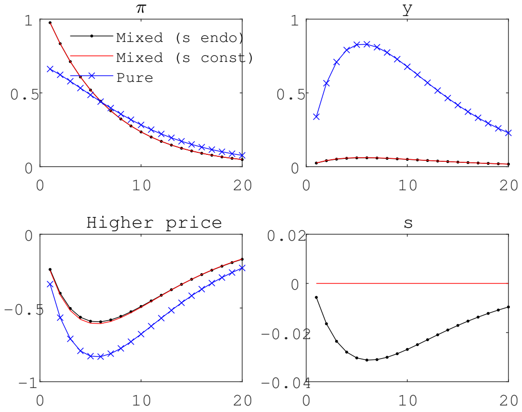


Note: The parameter τ_L is set at 0.1, and α is chosen to keep the harmonic mean of τ at 0.25.

- In mixed strategy equilibruim, $\Pi(p_H) = \Pi(p_L)$.
- The difference in profit, $\Pi(p_H) - \Pi(p_L)$, is decreasing with s.
  - As the frequency of sales increases, the profit from choosing the lower price increases more than that from choosing the higher price.
- Thus, there is a strategic complementarity.

Pricing under Consumers' Unobservable Heterogeneity and Price Stickiness

- Pure starategy eqm: the same as before
  - Importantly, p^* increases by the term of Γ^* under price stickiness, which increases firm profit and decreases the incentive to deviate from this strategy.
- Mixed strategy eqm: several additional assumptions
  - As in Guimaraes and Sheedy (2011), the higher price is subject to Calvo-type price stickiness, while the lower price is perfectly flexible.
    - ★ The lower price $p_{L,t}$ is set at $p_L W_t$. Not necessarily optimal.
  - A certain constraint (such as limited information-processing capacity) prevents firms from optimizing both the higher price ($p_{H,t}$) and the frequency of sales (s_t) simultaneously.
    - ★ When firms can revise their higher price, $s_t = s$ and the equality of payoffs does not hold.
    - ★ We check the robustness of our results with respect to this assumption.



Note: For the pure strategy, τ is homogeneous and equals 0.25. For the mixed strategy, τ_L and τ_H equal 0.1 and 10, respectively, whereas the parameter α is chosen to make the harmonic mean of τ equal 0.25 (i.e., $\alpha = 0.39$).

- Strategic complementarities.
  - Although the aggregate higher price under the mixed strategy is negative, the extent to which it deviates from the steady state is smaller than the extent to which the aggregate price deviates under the pure strategy.
  - Under the mixed strategy, the lower (i.e., sale) price is revised upward fully in response to the positive money supply shock.
  - Combined with the strategic complementarity effect, this induces firms to increase their higher price more when they can reset it.
- Therefore, nominal prices are adjusted upward more strongly, which weakens the real effect of monetary policy.
- This result is markedly different from that reported in Guimaraes and Sheedy (2011).
  - There, sales are strategic substitutes.

Final Thoughts

- Implications for monetary policy change when we incorporate strategic pricing behaviors of oligopolistic firms.
- Extensions
  - A generalized value for the elasticity of substitution
  - Competition between more than two firms. E.g., Salop's circular location model.
  - Asymmetry between two firms
  - Nonlinearity
- Recent information-technology developments have enabled firms to collect consumers' preferences at an individual level at a low cost.
  - Customer-dependent prices, also known as third-degree price discrimination

Welfare without Price Stickiness

In equilibrium, each consumer spends M/p for consumption C and supplies labor L for the same amount. Shopping distance D equals $2\int_0^{1/2} x dx = 1/4$.
Thus, household utility U:

$$\begin{aligned} U &= \{\log(M/p) - (M/p + \tau/4)\}/(1-\beta) \\ &= -\left\{\log(1+\tau/2) + (1+\tau/2)^{-1} + \tau/4\right\}/(1-\beta). \end{aligned} \tag{16}$$

$U \downarrow$ when $\tau \uparrow$ because $\tau \uparrow \Rightarrow C \downarrow$ disutility from going shopping$\uparrow$ although $L \downarrow$.

Welfare under Price Stickiness

- Household intertemporal utility is expressed as

$$
\begin{aligned}
U &= \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log C_t - (L_t + \tau D_t)\right] \\
&= \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log(M_t/P_t) - M_t/P_t - \tau D_t\right].
\end{aligned}
$$

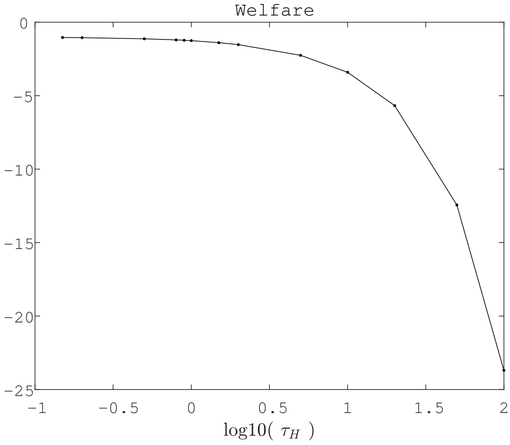
- The terms of $\log(M_t/P_t) - M_t/P_t$ are approximated up to the second order as

$$
-\log(1+\tau/2) - \frac{1}{1+\tau/2} - \frac{\tau/2}{1+\tau/2}\hat{P}_t - \frac{1/2}{1+\tau/2}\hat{P}_t^2. \tag{17}
$$

- The term of D_t is approximated up to the second order as

$$
\frac{1}{4} + \left(\frac{\hat{p}_t^A - \hat{p}_t^B}{\tau}\right)^2. \tag{18}
$$

  Some consumers have to walk a longer distance (an increase in d) when there is a price difference between firms A and B. A new effect to consider.



Note: The parameter τ_L is set at 0.1, and α is chosen to keep the harmonic mean of τ at 0.25.