JSPS Grants-in-Aid for Scientific Research (S)

Understanding Persistent Deflation in Japan

Working Paper Series

No. 034

January 2014

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Mayumi Ojima

Junnosuke Shino

Kozo Ueda

UTokyo Price Project
702 Faculty of Economics, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Tel: +81-3-5841-5595
E-mail: watlab@e.u-tokyo.ac.jp
http://www.price.e.u-tokyo.ac.jp/english/

Buyer-Size Discounts and Inflation Dynamics

Mayumi Ojima[*], Junnosuke Shino[†], Kozo Ueda[‡]

January 8, 2014

Abstract

This paper considers the macroeconomic effects of retailers' market concentration and buyer-size discounts on inflation dynamics. During Japan's "lost decades," large retailers enhanced their market power, leading to increased exploitation of buyer-size discounts in procuring goods. We incorporate this effect into an otherwise standard New-Keynesian model. Calibrating to the Japanese economy during the lost decades, we find that despite a reduction in procurement cost, strengthened buyer-size discounts did not cause deflation; rather, they caused inflation of 0.1% annually. This arose from an increase in the real wage due to the expansion of production.

[*]Bank of Japan

[†]Bank of Japan

[‡]Waseda University, kozo.ueda@waseda.jp. The authors are grateful to Yuko Miyoshi for collecting data, and Kosuke Aoki, Takayuki Tsuruga, and other seminar and conference participants at the 15th Macroeconomic Conference and the Bank of Japan for their useful comments. The views expressed in this paper are those of the authors and do not necessarily reflect the official views of the Bank of Japan.

1 Introduction

In this paper, we aim to consider the macroeconomic effects of buyer-size discounts on inflation dynamics. It is the conventional wisdom that large buyers (downstream firms) are better bargainers than small buyers in procuring goods from sellers (upstream firms). Retailers, wholesalers, and manufacturers negotiate prices, taking account of trade size. The increase in sales of retail giants such as Wal-Mart in the United States, Tesco in the United Kingdom, and Aeon in Japan has been accompanied by the increase in their bargaining power over wholesalers and manufacturers. Figure 1 shows evidence that larger buyers enjoy larger price discounts in Japan. In 2007, the National Survey of Prices by the Statistics Bureau reported the prices of the same types of goods sold by retailers with differing floor space. For nine kinds of goods, from perishables to durable goods, retail prices decrease with the floor space of retailers. This suggests that large retailers purchase goods from wholesalers and manufacturers at lower prices than small retailers do.[1] It is natural to think that these buyer-size discounts influence macro inflation dynamics.

To examine the macro effects of buyer-size discounts and market concentration on inflation dynamics, this paper incorporates these factors into an otherwise standard New-Keynesian model. Our model is based on the model developed by Sbordone (2010); the demand function is quasi-kinked following Kimball (1995); and the number of differentiated goods (retailers) is finite. These features help analyze endogenous developments in retailers' markups, subject to a change in the market share. To the model, we add a stochastic shock for the number of differentiated goods sold by retailers and buyer-size discounts. This enables us to study how a rise in the retailers' concentration rate influences the magnitude of buyer-size discounts, retailers' profit margins, and in turn, macro inflation dynamics.

This paper is also motivated by Japan's "lost decades" from the early 1990s to the

[1]This is merely indirect evidence. Other possibilities exist, such as large retailers somehow sell the goods more cheaply than small firms do, whereas their purchase prices are the same as that of small retailers. Another possibility is that the causality moves in the opposite direction. That is, retailers who sell goods for lower prices may have established bigger stores.

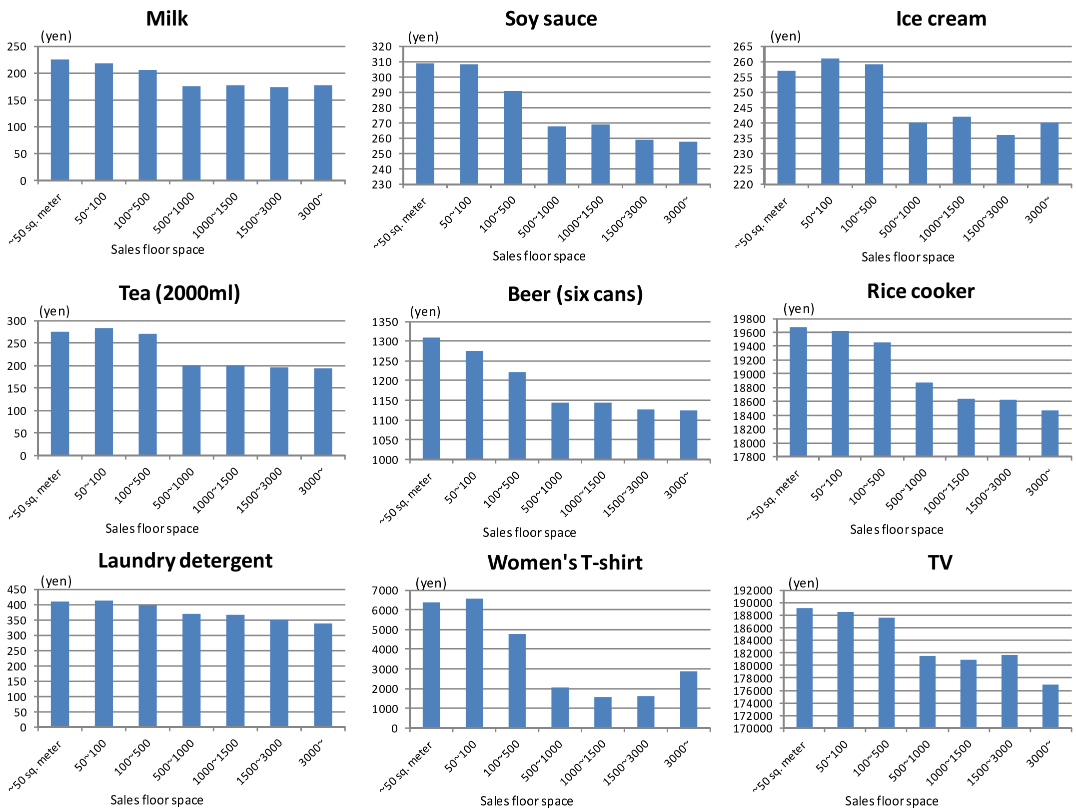

Figure 1: Retailers' floor space and retail prices

Source: Statistics Bureau (2007) "National Survey of Prices" present that have been accompanied by prolonged deflation. During this period, a noteworthy development is the enhanced market power of a limited number of big retailers. Figure 2 demonstrates changes in market concentration for retailers, wholesalers, and manufacturers, all of which are associated with the food industry. The left panel reveals that the market share of the top 100 retailers has doubled in 20 years. The market share of the top 20 wholesalers has also increased. This change is said to have been brought about by the monopolization of retailers. As for manufacturers, the Herfindahl-Hirschman index has been almost unchanged, except that there have been considerable mergers and acquisitions among manufacturers of cooking oil and flour. Furthermore, as Figure 3 shows, the gross margin of retailers increased from 25.8 to 28.5% in 15 years, while that of wholesalers and manufacturers hardly changed. These trends, in particular, the rise in retailers' concentration rate, is considered to have implications for the magnitude of buyer-size discounts as well as retailers' profit margins, and in turn, macro inflation dynamics. Enhanced buyer-size discounts, combined with market concentration, may have led to Japan's deflation.[2] In this paper, we construct a dynamic stochastic general equilibrium model to address whether these trends gave rise to Japan's prolonged deflation.

Constructing the model and calibrating it to the Japanese economy during the lost decades, we find that the enhanced market concentration of retailers and buyer-size discounts had qualitatively counterintuitive and quantitatively modest effects on macro inflation dynamics.[3] First, when buyer-size discounts are absent, the enhanced concentration in the retail market exerts a downward pressure on the aggregate inflation rate. This direction is counterintuitive in that the enhanced concentration leads to a rise in the retailers' markup and output price. The key to understanding this is the fact that the real wage declines in its steady state. Under a quasi-kinked demand, the steady-state

[2] In Japan, the term of *kakaku hakai*, meaning price destruction, often appeared in the media in this context. See the article at http://www.theglobeandmail.com/report-on-business/economy/disinflation-troubles-poloz-cites-retail-competition/article15758683 that refers to the fear of deflation due to retailers' discounts in Canada.

[3] In addition, consistent with Sbordone (2010), the slope of the Phillips curve is altered by strengthening or weakening strategic complementarity.

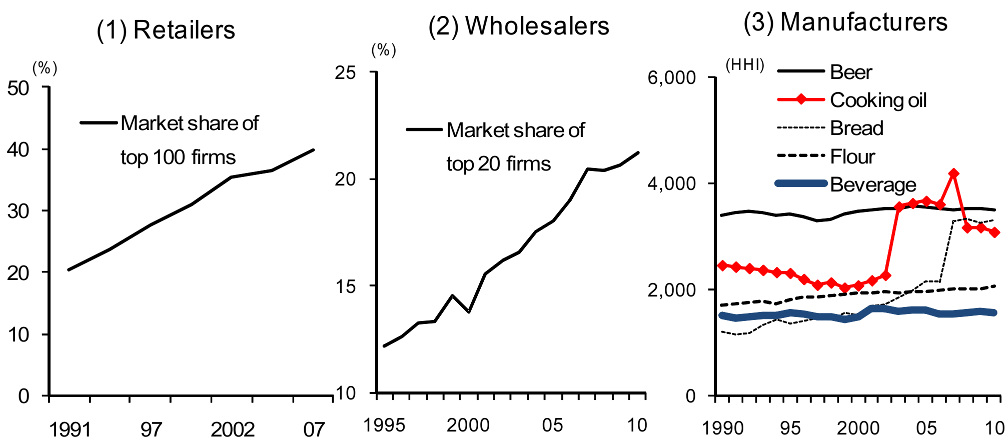

Figure 2: Market concentration in Japan's food industry

Notes: Market shares are the ratio of the food sales of the top 100 or 20 firms to total food sales. HHI represents the Herfindahl-Hirschman index. All firms are associated with the food industry.

Sources: Distribution Economics Institute of Japan, Nikkan Keizai Tsushin

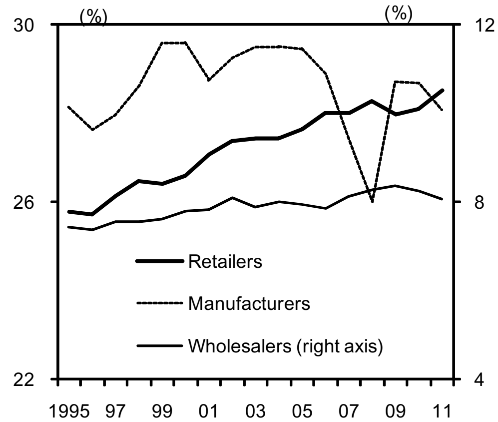

Figure 3: Gross margin in Japan's food industry

Notes: Gross margin is defined as (sales minus wholesale cost)/sales. All firms are associated with the food industry. The firms consist of 45 retailers, 103 manufacturers, and 28 wholesalers.

Source: Financial Quest

markup increases because of enhanced concentration. This dampens production, leading to a decrease in labor demand, and hence, the real wage. In other words, from the labor-supply perspective, a decrease in production leads to a decrease in consumption. Households thus increase labor supply, owing to the income effect. Anticipating such a drop in the steady-state real wage, retailers reset their prices downward immediately, whereas the improvement in their markup proceeds gradually to raise the inflation rate. Quantitatively, the effect of enhanced concentration on the aggregate inflation rate is modest, amounting to around minus 0.10% annually.

Second, in the presence of buyer-size discounts, enhanced concentration in the retail market yields an upward pressure on the aggregate inflation rate. This is again counterintuitive, because it strengthens the exploitation of buyer-size discounts and lowers wholesale good prices. In this case, the steady-state real wage rises, because the enhanced concentration in the retail market leads to increased production in order to exploit buyer-size discounts. Thus, labor demand increases and the real wage rises. Anticipating the rise in the steady-state real wage, retailers reset their prices upward, whereas they improve their markup and exploit more buyer-size discounts gradually during the transition process. Quantitatively, the effect of buyer-size discounts on the inflation rate is almost the same size as that of the quasi-kinked demand or increased markup, around 0.12% annually. Therefore, in total, the effect amounts to around 0.02% annually.

This result revokes the widely seen argument in Japan that buyer-size discounts caused deflation. It is true that the retail price decreases if only a small number of idiosyncratic retailers exploit buyer-size discounts. However, when market concentration increases and buyer-size discounts are exploited in the retail market as a whole, our model reveals that the level of production expands and the real wage rises. This contributes to inflation.

Reviewing the literature, it seems that despite their importance, buyer-size discounts have been neglected in macroeconomics. Galbraith (1952) raised this issue by coining the term "countervailing power" to describe the ability of large buyers to exploit buyer-size discounts.[4] In microeconomics, related studies have started to accumulate since the late 1980s and provide several justifications for buyer-size discounts. One of these is the survey by Inderst and Shaffer (2006). In the textbook view, they cite the Cournot model of competition to explain buyer-size discounts in an economy where a seller and a finite number of buyers interact via a market interface. In the alternative view, they consider a situation in which firms interact via a bargaining interface. A single seller and a single buyer negotiate the price, given their bargaining power and outside options. In this strand of research, the concavity of a total surplus function, the large buyers' credible threat of integration, and the difficulty in collusion in the presence of large buyers is pointed out as necessary for the emergence of buyer-size discounts.[5] The aims of these microeconomic papers are mainly twofold: first, to illustrate the source of buyer-size discounts and second, to discuss its implications for social welfare and competition policy. Our paper does not delve into these issues; instead, it aims to investigate the macroeconomic effects of buyer-size discounts on inflation dynamics. As was noted, our macroeconomic model is constructed with reference to Sbordone (2010). In the paper, she investigated the effect of globalization on the slope of the Phillips curve.

[4]Buyer-size discounts are also called quantity discounts or volume discounts.

[5]See also review by Normann, Ruffle, and Snyder (2007).

This paper proceeds as follows. In Section 2, we briefly discuss the microfoundations of buyer-size discounts. The model is presented in Section 3 and a simulation in Section 4. In Section 5, we present the conclusions of the paper.

2 Microfoundations of Buyer-Size Discounts

In this section, we briefly provide two examples to illustrate the microfoundations of buyer-size discounts.

2.1 Manufacturers under Perfect Competition with IRS Technology

Retailers and manufacturers exist in a centralized market. Manufacturers face perfect competition and earn zero profits. Each manufacturer uses labor input h to produce goods with increasing-returns-to-scale (IRS) technology, where the marginal cost of production $C(h)$ is given by $C'(h) > 0$ and $C''(h) < 0$. By selling goods to retailers, each manufacturer earns a profit of

$$\Sigma_i \left(P^w(h_i)h_i - C(h_i) \right), \tag{1}$$

where i represents the retailers' index and $P^w(h_i)$ indicates the wholesale price.

In this environment, the equilibrium wholesale price is characterized by

$$P^{w*}(h_i) = C'(h_i). \tag{2}$$

Owing to the assumption of $C''(h) < 0$, the wholesale price decreases as quantity increases. This captures the buyer-size discounts.

2.2 Bargaining between a Retailer and a Manufacturer

A retailer and a manufacturer meet in a decentralized market and negotiate on a wholesale price P^w. The retailer's and manufacturer's unit profits are given by

$$\pi^r =(P^r - P^w)Q(e) - e, \tag{3}$$

$$\pi^m = (P^w - C)Q(e), \tag{4}$$

respectively, where retail price P^r and marginal production cost C are exogenous. $Q(e)$ is the share of the retailer in the market, satisfying $0 < Q(e) < 1$, $Q'(e) > 0$, and $Q''(e) < 0$, where e represents investment by the retailer.

The negotiation runs as follows. At the first stage, the retailer chooses e. At the second stage, the retailer and the manufacturer meet to negotiate on P^w. When the negotiation fails, the retailer purchases $Q(e)$ from other manufacturers for W^r, and the manufacturer sells $1 - Q(e)$ to other retailers for W^m, where W^r and $W^m > c$. Disagreement points are thus depicted as

$$d^r = (P^r - W^r)Q(e) - e, \tag{5}$$

$$d^m = (W^m - C)(1 - Q(e)). \tag{6}$$

As the share of the retailer $Q(e)$ increases, the disagreement point for the manufacturer falls; this enhances the bargaining power of the retailer. However, increasing the share is costly for the retailer, because of the investment cost of e.

The Nash product of this bargaining game, Φ, is given by

$$\Phi = (\pi^r - d^r)(\pi^m - d^m). \tag{7}$$

The first order condition with respect to P^w yields

$$P^{w*} = \frac{1}{2}\left(W^r - W^m + 2C + \frac{W^m - C}{Q(e)}\right). \tag{8}$$

This equation implies buyer-size discounts. The retailer's higher share $Q(e)$ lowers the wholesale price, owing to the assumption of W^r and $W^m > C$. The wholesale price falls, as W^r or W^m decreases, that is, as the retailer's disagreement point rises or the wholesaler's disagreement point falls.

By inserting this equation into π^r and solving the first order condition with respect to e, we obtain the following condition for the optimal investment level:

$$Q(e^*) = \frac{2}{2(P^r - C) - W^r + W^m}. \tag{9}$$

The retailer's investment and share increase when the retailer's disagreement point increases because of a rise in W^r. In contrast, they decrease when the wholesaler's disagreement point increases because of a rise in W^m. Note that the efficient level of investment satisfies $Q(e^f) = 1/(P^r - C)$. Furthermore, unless $W^r = W^m$, over-investment or under-investment occurs.

3 New-Keynesian Model of Buyer-Size Discounts

In this section, we explain the New-Keynesian model that includes the buyer-size discount effect. As in Sbordone (2010), the demand function is quasi-kinked following Kimball (1995) and the number of differentiated goods (retailers) is finite. The model depicts the mechanism in which an exogenous increase in the retailer's market share lowers its wholesale price because of strengthened buyer-size discounts and raises its markup because of a fall in the price elasticity of demand. The former results in a reduction in the retailer's price, whereas the latter does the opposite. Combined with a change in strategic complementarity, both effects influence macro inflation dynamics.

3.1 Manufacturer

A manufacturer faces perfect competition, earning zero profits. It has a linear production technology of $y_t(j)$ with respect to labor as the only input $h_t(j)$.

$$y_t(j) = h_t(j), \tag{10}$$

where the manufacturer sells goods to a retailer j. The manufacturer's sales price that equals nominal marginal cost for retailers is described as

$$NMC_t(j) = W_t \{1 + T(x_t(j))\}, \tag{11}$$

where W_t represents nominal wage, $x_t(j)$ is the share of retailer j in the retail market, and $T(x_t(j))$ represents sales cost given by

$$T'(x_t(j)) \leq 0. \tag{12}$$

This captures the buyer-size discounts. As sales to a retailer increase, the sales cost decreases. Although it is not strictly consistent, this setup is based on the foundations discussed in the previous section.[6]

[6] Alternatively, we can think of a situation in which the retailer's sales cost reduces because of learning-by-doing. As the retailer's size increases, it accumulates know-how that helps to expand the

3.2 Household

A representative home consumer maximizes

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\frac{C_{t+j}^{1-\sigma}}{1-\sigma} - \chi \frac{H_{t+j}^{1+\omega}}{1+\omega} \right],$$

subject to the budget constraint

$$P_t C_t + B_{t+1} = W_t H_t + (1 + i_{t-1}) B_t + \Pi_t,$$

where C_t and H_t represent aggregate consumption and hours worked, respectively; P_t indicates the aggregate price index or the household's living cost index; B_t represents nominal risk-free bonds held at the beginning of period t; and i_t and Π_t represent a nominal interest rate and a transfer, respectively. As for parameters, $\beta \in (0, 1)$ is the subjective discount factor, $\sigma > 0$ measures the risk aversion, $\omega > 0$ is the inverse of the labor supply elasticity, and $\chi > 0$ is the scale factor.

Following Kimball (1995) and Sbordone (2010), we define the aggregate consumption C_t by

$$\frac{1}{N_t \psi (1/N_t)} \int_0^{N_t} \psi \left(\frac{c_t(j)}{C_t} \right) dj = 1, \tag{13}$$

where $\psi(x)$ is an increasing and strictly concave function, and $\psi(0) = 0$.[7] N_t is the number of differentiated goods sold by retailers and varies over time.[8] The elasticity of demand is given by

$$\theta(x) = -\frac{\psi'(x)}{x\psi''(x)} \tag{14}$$

and the desired markup is given by

$$\mu(x) = \frac{\theta(x)}{\theta(x) - 1}. \tag{15}$$

business and reduce the marginal cost.

[7]Unlike Sbordone (2010), we add the term of $1/N_t/\psi(1/N_t)$ to make the steady-state level of $c_t(j)/C_t$ be $1/N_t$ and the steady-state level of the relative price, $p_t(j)/P_t$, be one. Otherwise, the steady-state relative price would depend on the number of differentiated goods; this would complicate the following analysis. Even though the term is absent, our main results do not change.

[8]The model assumes that the number of retailers equals the number of differentiated goods. Retailers are monopolistic in their locations, non-price services, and choices of products. They sell sell a bundle of products as a single differentiated good monopolistically.

From the form of aggregate consumption, the demand curve is given by

$$c_t(j) = C_t \psi'^{-1}\left(\frac{p_t(j)}{\widetilde{P}_t}\right), \tag{16}$$

where $\widetilde{P}_t = 1/(C_t\Lambda_t)$ and Λ_t represents the constraint for an expenditure minimization problem. Rewriting this with previously defined $x_t(j)$, that is, the share of retailer j in the market, we get

$$x(j) = \psi'^{-1}\left(\frac{p_t(j)}{\widetilde{P}_t}\right). \tag{17}$$

Note that $\widetilde{P}_t$ is not necessarily equal to the conventional price index P_t

$$\begin{aligned} P_t &= \frac{1}{C_t}\int_0^{N_t} p_t(j)c_t(j)dj \\ &= \int_0^{N_t} p_t(j)\psi'^{-1}\left(\frac{p_t(j)}{\widetilde{P}_t}\right)dj. \end{aligned} \tag{18}$$

3.3 Retailer

Under the Calvo-type price stickiness, each retailer j chooses $\bar{p}_t(j)$ to maximize

$$\begin{aligned} &\sum_{k=0}^{\infty}\alpha^k \mathrm{E}_t\beta^k \frac{C_{t+k}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+k}}\left[\bar{p}_t(j)y_{t+k|t}(j) - NMC_{t+k|t}(j)y_{t+k|t}(j)\right] \\ = &\sum_{k=0}^{\infty}\alpha^k \mathrm{E}_t\beta^k \frac{C_{t+k}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+k}}C_{t+k}\left[\begin{array}{c}\bar{p}_t(j)\psi'^{-1}\left(\frac{\bar{p}_t(j)}{\widetilde{P}_{t+k}}\right) \\ -W_{t+k}\left\{1+T(x_{t+k|t}(j))\right\}\psi'^{-1}\left(\frac{\bar{p}_t(j)}{\widetilde{P}_{t+k}}\right)\end{array}\right], \end{aligned} \tag{19}$$

when it has a chance to reset its price. The Calvo parameter is denoted by α. Note that $y_{t+k|t}(j)$ and $NMC_{t+k|t}(j)$ are the output and nominal marginal cost, respectively, of the firm j whose price is last set at t. This can be arranged as

$$\begin{aligned} 0 = &\sum_{k=0}^{\infty}\alpha^k \mathrm{E}_t\beta^k \frac{C_{t+k}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+k}}C_{t+k}x_{t+k|t}(j)\left(1-\theta_{t+k|t}(j)\right) \\ &\left[\ \frac{\bar{p}_t(j)}{P_{t+k}} - \mu(x_{t+k|t}(j))w_{t+k}\tau(x_{t+k|t}(j))\ \right], \end{aligned} \tag{20}$$

where we define

$$\tau(x_t) = 1 + T(x_t) + x_t T'(x_t). \tag{21}$$

3.4 Resource constraint

The resource constraint for goods j is given by

$$y_t(j) = c_t(j). \tag{22}$$

Here, we assume that the sales cost $T(x_t(j))$ does not contribute to goods consumption, but decreases the households' income in a lump-sum manner.

3.5 Steady state

In the steady state, all relative prices are unity and the inflation rate is zero as follows:

$$\pi = 0, \tag{23}$$

$$x = 1/N, \tag{24}$$

$$x = \psi^{-1}(1/N), \tag{25}$$

$$\frac{\overline{p}}{\widetilde{P}} = \psi'(1/N), \tag{26}$$

$$\mu \tau w = \frac{\overline{p}}{P} = \frac{1}{Nx} = 1. \tag{27}$$

Equation (27) comes from equations (18) and (20).

Equation (27) implies that if market concentration raises the markup μ, the steady-state real wage w should decline. If market concentration leads to buyer-size discounts that lower τ to a greater extent than the rise in the markup μ, the steady-state real wage w should rise.

3.6 Log-Linearization

The log-linearization of $\frac{\bar{p}_t}{\widetilde{P}_{t+k}} = \psi'(x_{t+k|t})$ is given by

$$\hat{p}_t^* + \hat{p}_t - \widetilde{p}_{t+k} = \frac{x\psi''}{\psi'}\hat{x}_{t+k|t} = -\theta^{-1}\hat{x}_{t+k|t}, \tag{28}$$

where a hat $(\hat{\ })$ denotes the log-deviation from the steady state and $\hat{p}_t^*$ represents the log-deviation of $\bar{p}_t(j)/P_t$. This equation suggests that market concentration captured by a rise in x lowers the relative price of a good to the aggregate price index, provided $\theta > 0$.

Define parameters

$$\varepsilon_\mu = \frac{\mu' x}{\mu}, \tag{29}$$

$$\varepsilon_\tau = \frac{\tau' x}{\tau}. \tag{30}$$

The parameters ε_μ and ε_τ indicate strategic complementarity that plays an important role in macro inflation dynamics.

After some calculations, we obtain the New-Keynesian Phillips curve as follows:

$$\begin{aligned} \hat{\pi}_t = \beta \mathrm{E}_t \hat{\pi}_{t+1} + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)} \hat{w}_t \\ - \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)} (\varepsilon_\mu + \varepsilon_\tau) \hat{n}_t. \end{aligned} \tag{31}$$

This equation reveals that a fall in N, or an increase in the retailer's market share, exerts both downward and upward pressure on the aggregate inflation rate through the following two channels. First, its effect depends on the sign of $(\varepsilon_\mu + \varepsilon_\tau)$, stemming from the third term on the right-hand side of the equation. When $(\varepsilon_\mu + \varepsilon_\tau) > 0$, the rising share of the retailer pushes up the inflation rate. This is the case when the effect of the quasi-kinked demand is dominant. The rising share of retailers lowers the price elasticity of demand, and in turn, raises the retailers' markup. This increases the aggregate inflation rate if the wholesale price is unchanged. On the other hand, buyer-size discounts may be sufficiently large to bring $(\varepsilon_\mu + \varepsilon_\tau) < 0$. In this case, the rising share of retailers pushes down the inflation rate, because retailers can get higher buyer-size discounts and reduce wholesale prices.

Second and most important, the fall in N influences the real wage, and in turn, the aggregate inflation rate through the second term on the right-hand side. The effect on the real wage is discussed below. The sensitivity of aggregate inflation to the real wage depends on the degree of strategic complementarity, $\varepsilon_\mu + \varepsilon_\tau$. An increase in $\varepsilon_\mu + \varepsilon_\tau$ due to the presence of quasi-kinked demand, for example, intensifies strategic complementarity and flattens the slope of the Phillips curve. The economic intuition runs as follows.

When the real wage (marginal cost) increases, the retailer raises its price, if it has a chance to reset prices. This raises its relative price. In the presence of kinked demand ($\varepsilon_\mu > 0$), this lowers the retailer's market share, and in turn, raises the price elasticity of demand. This checks the magnitude of upward price revision by the retailer.[9]

Other than the Phillips curve, we have the following equations:

$$\hat{w}_t = (\omega + \sigma)\hat{c}_t, \tag{32}$$

$$\hat{c}_t = \mathrm{E}_t \hat{c}_{t+1} - (1/\sigma)(\hat{i}_t - \mathrm{E}_t \hat{\pi}_{t+1}), \tag{33}$$

$$\hat{y}_t = \hat{c}_t. \tag{34}$$

These equations represent labor supply, the Euler equation, and the relation between production and consumption, respectively.

As for monetary policy, we assume the interest rate rule responding to the CPI inflation rate only:

$$\hat{i}_t = \phi_\pi \hat{\pi}_t. \tag{35}$$

3.7 Characteristics of Equilibrium

In the following simulation, we argue that the effect of N on the real wage is important. To prepare for the argument, we now examine the impact of a steady-state change in N on the steady-state values of variables, including the real wage. Suppose $\hat{n}_t$ changes to a new level $\hat{n}^*$ permanently, where a hat $(\hat{})$ denotes the log-deviation from an initial steady state. In such a case, the new steady state is characterized by

$$\hat{\pi}^* = \hat{i}^* = 0. \tag{36}$$

The labor supply curve and the Phillips curve respectively imply

$$\hat{w}^* = (\omega + \sigma)\hat{c}^*, \tag{37}$$

$$\hat{w}^* = (\varepsilon_\mu + \varepsilon_\tau)\hat{n}^*. \tag{38}$$

[9]See Sbordone (2010) for a discussion on the slope of the Phillips curve.

The second equation illustrates how the steady-state real wage responds to $\hat{n}^*$. A permanent fall in N has no effect on the real wage, when neither quasi-kinked demand nor buyer-size discounts are present. Under the quasi-kinked demand $\varepsilon_\mu > 0$ and $\varepsilon_\tau = 0$, the real wage declines. On the other hand, the real wage increases when both quasi-kinked demand and buyer-size discounts are present and the latter effect is dominant, that is, $\varepsilon_\mu + \varepsilon_\tau < 0$.

Economic intuition can be understood by equation (27). In the steady state, the relative price is one and equals the real wage multiplied by the markup and the sales cost. The market concentration captured by the fall in N plays no role in the markup and the sales cost when $\varepsilon_\mu = \varepsilon_\tau = 0$. Hence, the real wage is unchanged. Under the quasi-kinked demand $\varepsilon_\mu > 0$ and $\varepsilon_\tau = 0$, market concentration raises the markup, and in turn, lowers the real wage. When $\varepsilon_\mu + \varepsilon_\tau < 0$, the effect of buyer-size discounts is dominant. Market concentration raises the markup, but it lowers the sales cost more than it raises the markup. Hence, the real wage increases. These changes in the steady-state real wage influence the inflation rate through equation (31).

Next, consider when $\hat{n}_t$ changes from zero to $\hat{n}^*$ permanently at $t = t_0$. From $t_0 + 1$, the economy is at the above steady state denoted by *. In period t_0, the labor supply curve, the Euler equation, and the Phillips curve respectively imply

$$\hat{w}_{t_0} = (\omega + \sigma)\hat{c}_{t_0}, \tag{39}$$

$$\hat{c}_{t_0} = \hat{c}^* - (1/\sigma)\hat{i}_{t_0}, \tag{40}$$

$$\begin{aligned} \hat{\pi}_{t_0} &= \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)}\hat{w}_{t_0} \\ &\quad - \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)}(\varepsilon_\mu+\varepsilon_\tau)\hat{n}^* \\ &= \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)}\left(\hat{w}_{t_0} - \hat{w}^*\right). \end{aligned} \tag{41}$$

Evidently $\hat{\pi}_{t_0} = 0$, as well as $\hat{w}_{t_0} = \hat{w}^*$, and $\hat{c}_{t_0} = \hat{c}^*$ satisfy the above equilibrium conditions, given $\phi_y = 0$. In other words, when agents face an unexpected, permanent shift in the degree of market concentration, the inflation rate does not change. The inflation rate may change, however, when agents expect a change in the degree of market concentration in future. This will be confirmed in the following simulation.

4 Model Simulation

4.1 Parameterization

In conducting the simulation, we consider the following three cases: (i) a basic case in which quasi-kinked demand and buyer-size discounts are absent, (ii) a case of quasi-kinked demand, and (iii) a case of quasi-kinked demand and buyer-size discounts. Each case corresponds to zero, positive, and negative $\varepsilon_\mu + \varepsilon_\tau$, respectively.

(i) Basic case

The demand elasticity is constant and the Dixit–Stiglitz form is applied to $\psi(x)$. In the formulation below, it corresponds to $\eta = 0$. This yields $\varepsilon_\mu = 0$, as well as $\varepsilon_\tau = 0$. We assume $\theta = 7$.

(ii) Quasi-kinked demand

As for quasi-kinked demand by Kimball (1995), we follow Dotsey and King (2005).

$$\psi(x) = \frac{1}{(1+\eta)\gamma}\{(1+\eta)x - \eta\}^\gamma - \frac{1}{(1+\eta)\gamma}(-\eta)^\gamma. \tag{42}$$

The demand function becomes

$$c_t(j) = C_t \frac{1}{1+\eta}\left[\left(\frac{p_t(j)}{\widetilde{P}_t}\right)^{1/(\gamma-1)} + \eta\right].$$

As in Sbordone (2010), we set the benchmark parameters from the work of Levin, Lopez-Salido, and Yun (2006). They use $x = 1$, $\eta = -2$, and $\theta = 7$. This yields $\varepsilon_\mu = 0.333$.[10] We neglect the effect of buyer-size discounts, and hence, set $\varepsilon_\tau = 0$.

[10]Even if we assume $x = 0.01$, the results hardly change.

Table 1: Estimation of the elasticity of retail prices to retailers' size

	Coefficient	Std. Error
LOG(AREA)	-0.051162	(0.008105)

Note: Cross-section estimation with 27–item dummy. Dependent variables are the logarithm of retail prices, and independent variables are the logarithm of retailers' floor area in seven categories.

(iii) Buyer-size discounts

The third case corresponds to case (ii) plus buyer-size discounts. To evaluate $\varepsilon_\mu + \varepsilon_\tau$, recall the steady-state condition (27).

$$\frac{\bar{p}}{P} = w\mu(x)\tau(x). \tag{43}$$

Its log derivative is given by

$$\frac{\partial \log}{\partial \log(x)} \left(\frac{\bar{p}}{P} \right) = \varepsilon_\mu + \varepsilon_\tau, \tag{44}$$

owing to definitions (29) and (30).

This equation suggests that we can estimate $\varepsilon_\mu + \varepsilon_\tau$ by estimating the retail-price elasticity to firm size. Using more detailed price data than those shown in Figure 1 consisting of 27 items, we run a cross-sectional regression with an item dummy.

$$\log\left(\bar{p}_i\right) = c_i + \alpha \log(f_i) + \mu_i, \tag{45}$$

where c_i, f_i, and μ_i represent an item dummy, the retailer's floor space (m^2), and residuals for item i, respectively.[11] As Table 1 shows, the slope α is significantly different from zero and estimated as -0.0511. Therefore, we have $\varepsilon_\mu + \varepsilon_\tau = -0.0511$. For other parameters, we continue to use the same values as (ii), such as η, θ, and x.

[11] The size variable x may not necessarily correspond to floor space f. For example, if the retailer's size is proportional to its volume (m^3) rather than area (m^2), the estimated α should be multiplied by 2/3 to obtain $\varepsilon_\mu + \varepsilon_\tau$.

Common parameterization

Common to all three cases, we use parameter values following Sugo and Ueda (2008), who estimated a medium-scale DSGE model for Japan. These parameter values are $\beta = 0.995$, $\alpha = 0.875$, $\omega = 2.149$, and $\sigma = 1.249$. For the monetary policy rule, we set $\phi_\pi = 1.5$.

Evolution of shock $\hat{n}_t$

Let us calibrate the time-series path of the shock $\hat{n}_t$, the index of the inverse of retail market concentration, by using the actual developments in retailers' gross margin. Equations (27) and (29) provide the relationship between $\hat{n}_t$ and the log-linearized gross margin $\hat{\mu}_t$ in its steady state.

$$\begin{aligned}\hat{\mu}_t &= \varepsilon_\mu \hat{x}_t \\ &= -\varepsilon_\mu \hat{n}_t. \qquad (46)\end{aligned}$$

Figure 3 illustrates a trend increase in retailers' gross margin μ from 1.258 to 1.285 in 15 years. Assuming that this change is constant, we calibrate the time-series path of the shock $\hat{n}_t$ over 15 years. As long as $\varepsilon_\mu > 0$, an increase in the gross margin is interpreted as being caused by a decrease in $\hat{n}_t$.

4.2 Simulation Results

In this subsection, we present the results of a simulation that examines the effect of retail market concentration on the aggregate inflation rate. First, for illustrative purposes, suppose that the economy is hit by an unexpected, permanent negative shock to N_t at $t = 1$, such that $\hat{n}_t = 0$ for $t \leq 0$ and -1 for $t \geq 1$. Figure 4 demonstrates the impulse response of the inflation rate ($\hat{\pi}_t$) to the shock. The inflation rate is unchanged, as Section 3.7 shows. This exercise illustrates that retail market concentration should have no effect on the inflation rate, if the permanent $\hat{n}_t$ shock arises unexpectedly at every period. On the other hand, if the shock is anticipated, then we have the next result.

We simulate the model using the previously calibrated path of the shock $\hat{n}_t$. Assume that agents perfectly foresee the future path at the beginning of the shock. The path

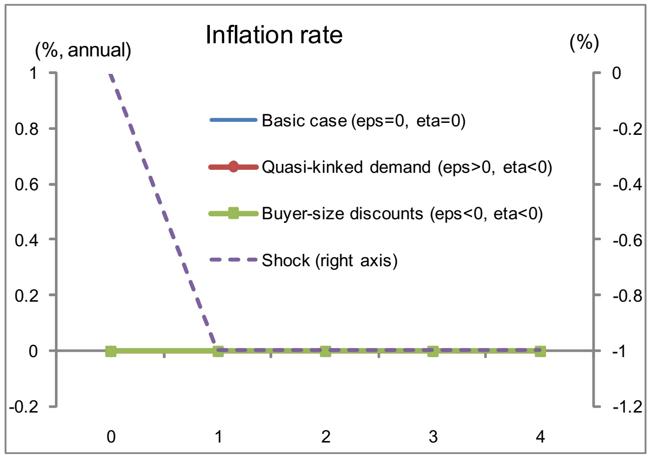

Figure 4: Impulse response of inflation to the shock of retail market concentration

of the shock is the same in the three cases of (i) through (iii). In (i), however, the steady-state gross margin should not change because $\varepsilon_\mu = 0$; hence, the path of the shock cannot be calculated. In Figure 5, we plot simulated paths of inflation rates and the shock $\hat{n}_t$. The calculated size of the shock $\hat{n}_t$ amounts to about 6% in 15 years.

This figure shows that the enhanced market concentration of retailers and buyer-size discounts had qualitatively counterintuitive and quantitatively modest effects on macro inflation dynamics. In case (i), the enhanced market concentration of retailers has no effect on the inflation rate. In case (ii), the enhanced concentration in the retail market yields a downward pressure on the aggregate inflation rate. This direction may be counterintuitive, in that the enhanced concentration functions to raise retailers' markup and leads them to raise reset prices. The average size of this effect amounts to minus 0.10% annually. In case (iii), with buyer-size discounts, the enhanced concentration in the retail market yields an upward pressure on the aggregate inflation rate. This is again counterintuitive, because it strengthens the exploitation of buyer-size discounts and lowers wholesale good prices. This inflationary effect is almost the same size as the previous deflationary effect of the quasi-kinked demand in case (ii), that is, 0.12% annually. The combined effect on the inflation rate amounts to around 0.02% annually.

The economic intuition runs as follows. In case (ii), the expectation of enhanced concentration in the retail market lowers the real wage. This is because the enhanced

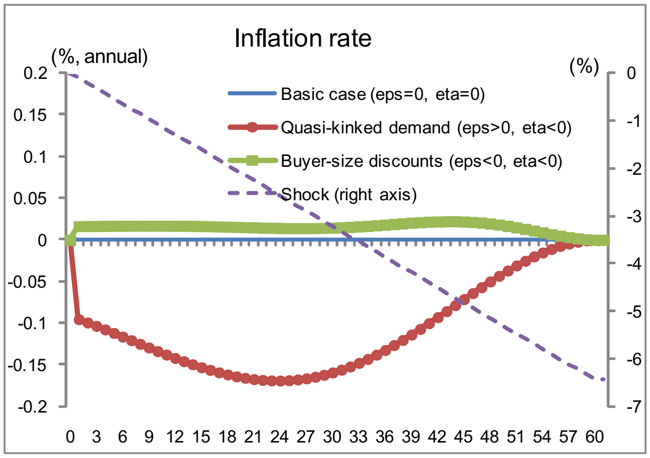

Figure 5: Calibrated path of inflation corresponding to the shock of retail market concentration

concentration in the retail market increases the markup and decreases production. Labor demand decreases, which in turn, lowers the real wage. In other words, from the labor supply perspective, a decrease in production leads to a decrease in consumption. Households thus increase labor supply owing to the income effect. Hence, the real wage falls.[12] Anticipating such a drop in the steady-state real wage, retailers reset their prices downward. On the other hand, their markup expands, thereby exerting an upward pressure on their revised prices. However, the latter force is small, because concentration in the retail market proceeds only gradually.

In case (iii), the expectation of enhanced concentration in the retail market raises the real wage. The enhanced concentration in the retail market increases the amount of production to exploit buyer-size discounts; this increases labor supply and the real wage. Or, consumption increases and thus households decrease their labor supply owing to the income effect. Hence, the real wage rises. Anticipating such a rise in the steady-state real wage, retailers reset their prices upward. Meanwhile, the exploitation of buyer-size discounts functions to lower the revised prices, but this effect proceeds only gradually during the transition process.

[12]Another explanation is as follows. As we discussed in Section 3.7, the relative price equals markup times the real wage in the steady state. Hence, the steady-state real wage should drop, when the relative price is constant and the steady-state markup increases because of enhanced concentration.

4.3 Robustness

Our analyses suggest that real-wage movements are key to the counterintuitive changes in the inflation rate. Therefore, it is important to examine the robustness of the results, in particular, to various labor-market specifications. To this end, we first checked the sensitivity of our results to parameters associated with labor supply. We confirmed that a higher risk aversion σ and a lower inverse of the labor supply elasticity ω both increase the size of the inflation rate responses. Second, we modified our model to incorporate a sticky wage, following Erceg, Henderson, and Levin (2000). The model assumes Calvo-type wage stickiness with a Calvo parameter of 0.516 and the steady-state wage markup of 0.2, following Sugo and Ueda (2008). This extended model yielded almost unchanged results, that is, no effect in case (i), minus 0.11% annual inflation on average in case (ii), and 0.02% annual inflation on average in case (iii).

5 Concluding Remarks

In this paper, we have incorporated market concentration and buyer-size discounts into an otherwise standard New-Keynesian model. Calibrating to the Japanese economy during the lost decades, we have found that strengthened buyer-size discounts did not cause deflation; instead, they caused inflation of 0.10% annually. Combined with quasi-kinked demand reflecting the increase in markup, buyer-size discounts yielded a slight inflation of around 0.02% annually.

This result revokes the casual argument in Japan that buyer-size discounts caused deflation. It is true that the retail price decreases if only a small number of idiosyncratic retailers exploit buyer-size discounts. In contrast, when market concentration grows and buyer-size discounts are exploited in the retail market as a whole, our model reveals that the level of production is expanded and the real wage rises, which contributes to inflation.[13]

[13] The recent developments in the strategy of Japanese retailers support this situation partially. In the process of expanding the variety of private label products, big retailers are starting to provide not just conventional low-priced products but also high-priced, high-quality products such as beer and bread. For example, while similar-sized bread is sold for 105 yen, new bread is sold for 250 yen and is a huge

Future work needs to address mainly two issues. The first is heterogeneity. In our model, all retailers are of equal size in the steady state. However, large and small retailers coexist in the real world, and their pricing may well differ. Although we found that the size of the effects stemming from enhanced market concentration and buyer-size discounts was moderate, if the shock $\hat{n}_t$ is larger, the size should increase. Figure 2 illustrated the twofold rise in the retail market concentration. Once an uneven rise in market concentration is taken into account, our results may well change quantitatively.

Second, future analysis needs to shed light on the determinants of the number of differentiated goods sold by retailers. In this paper, we assumed that number to be exogenous. The number of differentiated goods is important for the magnitude of buyer-size discounts and impact on macroeconomic inflation dynamics. However, reverse causality is possible. That is, intensified exploitation of buyer-size discounts may have enabled large retailers to survive and led to higher market concentration. It is thus important to incorporate market concentration as endogenously determined by the economic situation.

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A Detailed Model

A.1 Resource constraint

The resource constraint for goods j is given by

$$y_t(j) = c_t(j). \tag{47}$$

Aggregate output is

$$Y_t = \int_0^{N_t} y_t(j)\,\mathrm{d}j = \int_0^{N_t} h_t(j)\,\mathrm{d}j = H_t \tag{48}$$

that becomes

$$Y_t = \int_0^{N_t} c_t(j)\,\mathrm{d}j = C_t \int_0^{N_t} \psi'^{-1}\left(\frac{p_t(j)}{\widetilde{P}_t}\right) dj,$$

$$Y_t = \Delta_t C_t, \tag{49}$$

where

$$\Delta_t \equiv \int_0^{N_t} \psi'^{-1}\left(\frac{p_t(j)}{\widetilde{P}_t}\right) dj.$$

A.2 Retailer

Under the Calvo-type price stickiness, each retailer j chooses $\bar{p}_t(j)$ to maximize

$$\begin{aligned} & \sum_{k=0}^{\infty}\alpha^k \mathrm{E}_t\beta^k\frac{C_{t+k}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+k}}\left[\bar{p}_t(j)y_{t+k|t}(j) - NMC_{t+k|t}(j)y_{t+k|t}(j)\right] \\ = & \sum_{k=0}^{\infty}\alpha^k \mathrm{E}_t\beta^k\frac{C_{t+k}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+k}}C_{t+k}\left[\bar{p}_t(j)\psi'^{-1}\left(\frac{\bar{p}_t(j)}{\widetilde{P}_{t+k}}\right) - W_{t+k}\left\{1+T(x_{t+k|t}(j))\right\}\psi'^{-1}\left(\frac{\bar{p}_t(j)}{\widetilde{P}_{t+k}}\right)\right], \end{aligned}$$

when it has a chance to reset its price. Note that $y_{t+k|t}(j)$ and $NMC_{t+k|t}(j)$ are respectively the output and nominal marginal cost of the firm j whose price is last set at t. The first order condition (FOC) with respect to $\bar{p}_t(j)$ is written as

$$0 = \sum_{k=0}^{\infty}\alpha^k \mathrm{E}_t\beta^k\frac{C_{t+k}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+k}}C_{t+k}\left[\begin{array}{c} x_{t+k|t}(j) - x_{t+k|t}(j)\theta_{t+k|t}(j) \\ +W_{t+k}\left\{1+T(x_{t+k|t}(j))\right\}x_{t+k|t}(j)\theta_{t+k|t}(j)\frac{1}{\bar{p}_t(j)} \\ +W_{t+k}T'(x_{t+k|t}(j))\theta_{t+k|t}(j)\frac{1}{\bar{p}_t(j)}x_{t+k|t}^2(j) \end{array}\right].$$

Here, we used

$$\begin{aligned} x_{t+k|t}(j) = & \psi'^{-1}\left(\frac{\bar{p}_t(j)}{\widetilde{P}_{t+k}}\right), \\ \bar{p}_t(j)\frac{\partial}{\partial\bar{p}_t(j)}\psi'^{-1}\left(\frac{\bar{p}_t(j)}{\widetilde{P}_{t+k}}\right) = & \frac{\psi'\left(x_{t+k|t}(j)\right)}{\psi''\left(x_{t+k|t}(j)\right)} = -x_{t+k|t}(j)\theta_{t+k|t}(j). \end{aligned}$$

It is rearranged as

$$\begin{aligned} 0 = & \sum_{k=0}^{\infty}\alpha^k \mathrm{E}_t\beta^k\frac{C_{t+k}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+k}}C_{t+k}x_{t+k|t}(j)\left(1-\theta_{t+k|t}(j)\right) \\ & \left[\ \frac{\bar{p}_t(j)}{P_{t+k}} - \mu(x_{t+k|t}(j))w_{t+k}\left\{1+T(x_{t+k|t}(j)) + x_{t+k|t}(j)T'(x_{t+k|t}(j))\right\}\ \right], \end{aligned} \tag{50}$$

where

$$\mu(x_t) = \frac{\theta(x_t)}{\theta(x_t)-1}. \tag{51}$$

For simplicity, we omit j below, because the optimal price is independent of j if the timing of resetting the price is the same. We also define $\tau(x_t)$ as follows by using sales cost $T(x_t)$:

$$\tau(x_t) = 1 + T(x_t) + x_tT'(x_t). \tag{52}$$

A.3 Steady State

The labor supply curve is

$$\chi H^{\omega} = C^{-\sigma} w. \tag{53}$$

$$i = \frac{1-\beta}{\beta}. \tag{54}$$

Equation (13) suggests

$$x = 1/N. \tag{55}$$

$$\theta = -\frac{\psi'}{x\psi''}, \tag{56}$$

$$\mu = \frac{\theta}{\theta - 1}. \tag{57}$$

Equation (17) reads

$$\frac{\overline{p}}{\widetilde{P}} = \psi'\left(1/N\right). \tag{58}$$

Equations (18) and (50) imply

$$\mu w \tau = \frac{\overline{p}}{P} = \frac{1}{Nx} = 1. \tag{59}$$

$$Y = H, \tag{60}$$

$$Y = \Delta C, \tag{61}$$

$$\Delta = N\psi'^{-1}\left(\frac{\overline{p}}{\widetilde{P}}\right) = 1. \tag{62}$$

The last three equations with the labor supply curve yield the steady-state values of C, Y, and H.

A.4 Log-Linearization

Log-linearizing equation (50) yields

$$0 = \mathrm{E}_t \sum_{k=0}^{\infty} \alpha^k \beta^k \left[\hat{p}_t^* + \hat{p}_t - \hat{p}_{t+k} - \hat{\mu}(x_{t+k|t}) - \hat{w}_{t+k} - \hat{\tau}(x_{t+k|t}) \right], \tag{63}$$

where a hat $(\hat{\ })$ denotes the log-deviation from the steady state and $\hat{p}_t^*$ represents the log-deviation of $\bar{p}_t(j)/P_t$. Note that the log-linearization of $\frac{\bar{p}_t}{\widetilde{P}_{t+k}} = \psi'(x_{t+k|t})$ is

$$\hat{p}_t^* + \hat{p}_t - \widetilde{p}_{t+k} = \frac{x\psi''}{\psi'} \hat{x}_{t+k|t} = -\theta^{-1} \hat{x}_{t+k|t}. \tag{64}$$

This equation is particularly important. It suggests that a rise in market concentration x captured by a low N reduces the relative price of the good to the aggregate price index, provided $\theta > 0$. We also have

$$\begin{aligned} \hat{\mu}(x_{t+k|t}) &= \frac{\mu' x}{\mu} \hat{x}_{t+k|t} = \varepsilon_\mu \hat{x}_{t+k|t} \\ &= -\varepsilon_\mu \theta \left(\hat{p}_t^* + \hat{p}_t - \widetilde{p}_{t+k} \right), \end{aligned}$$

$$\begin{aligned} \hat{\tau}(x_{t+k|t}) &= \frac{\tau' x}{\tau} \hat{x}_{t+k|t} = \varepsilon_\tau \hat{x}_{t+k|t} \\ &= -\varepsilon_\tau \theta \left(\hat{p}_t^* + \hat{p}_t - \widetilde{p}_{t+k} \right). \end{aligned}$$

Parameters ε_μ and ε_τ indicate strategic complementarity and play an important role in the macro inflation dynamics. Equation (63) is rearranged as

$$0 = \mathrm{E}_t \sum_{k=0}^{\infty} \alpha^k \beta^k \left[\hat{p}_t^* + \hat{p}_t - \hat{p}_{t+k} + \varepsilon_\mu \theta \left(\hat{p}_t^* + \hat{p}_t - \widetilde{p}_{t+k} \right) - \hat{w}_{t+k} + \varepsilon_\tau \theta \left(\hat{p}_t^* + \hat{p}_t - \widetilde{p}_{t+k} \right) \right]. \tag{65}$$

Log-linearizing equation (13) yields

$$\frac{1}{N} \int_0^N \hat{x}_t(j) dj = -\hat{n}_t.$$

An increase in N_t lowers the share of each good, x_t. This is rewritten as

$$\frac{1}{N} \int_0^N \theta \left(\hat{p}_t(j) - \widetilde{p}_t \right) dj = \hat{n}_t. \tag{66}$$

An increase in N_t lowers the share of each good x_t. This is accompanied by an increase in the price of the good j relative to $\widetilde{P}_t$.

We now turn to equation (18).

$$\begin{aligned} P_t &= \int_0^{N_t} p_t(j)\psi'^{-1}\left(\frac{p_t(j)}{\widetilde{P}_t}\right) dj \\ &= \alpha \int_0^{N_t} p_{t-1}(j)\psi'^{-1}\left(\frac{p_{t-1}(j)}{\widetilde{P}_t}\right) dj + (1-\alpha)N_t\bar{p}_t\psi'^{-1}\left(\frac{\bar{p}_t}{\widetilde{P}_t}\right). \end{aligned}$$

The first line is log-linearized as

$$\begin{aligned} \hat{p}_t &= \hat{n}_t + \frac{1}{N}\int_0^N \hat{p}_t(j)dj - \frac{1}{N}\int_0^N \theta\left(\hat{p}_t(j) - \widetilde{p}_t\right) dj \\ &= \hat{n}_t + \left(\frac{\hat{n}_t}{\theta} + \widetilde{p}_t\right) - \hat{n}_t \\ &= \widetilde{p}_t + \frac{1}{\theta}\hat{n}_t, \end{aligned} \tag{67}$$

from equation (66).

The second line is log-linearized as

$$\begin{aligned} \hat{p}_t &= \hat{n}_t + \frac{1}{N}\int_0^N \hat{p}_t(j)dj - \frac{1}{N}\int_0^N \theta\left(\hat{p}_t(j) - \widetilde{p}_t\right) dj \\ &= \alpha\left\{\hat{n}_t + \frac{1}{N}\int_0^N \hat{p}_{t-1}(j)dj - \frac{1}{N}\int_0^N \theta\left(\hat{p}_{t-1}(j) - \widetilde{p}_t\right) dj\right\} + (1-\alpha)\left\{\hat{n}_t + \hat{p}_t^* + \hat{p}_t - \theta\left(\hat{p}_t^* + \hat{p}_t - \widetilde{p}_t\right)\right\} \\ &= \alpha\left\{\hat{n}_{t-1} + \frac{1}{N}\int_0^N \hat{p}_{t-1}(j)dj - \frac{1}{N}\int_0^N \theta\left(\hat{p}_{t-1}(j) - \widetilde{p}_{t-1}\right) dj\right\} + \alpha(\hat{n}_t - \hat{n}_{t-1}) + \alpha\theta(\widetilde{p}_t - \widetilde{p}_{t-1}) \\ &+ (1-\alpha)\left\{\hat{n}_t + \hat{p}_t^* + \hat{p}_t - \theta\left(\hat{p}_t^* + \hat{p}_t - \widetilde{p}_t\right)\right\}, \end{aligned}$$

and hence,

$$\hat{p}_t = \alpha\hat{p}_{t-1} + \alpha(\hat{n}_t - \hat{n}_{t-1}) + \alpha\theta(\widetilde{p}_t - \widetilde{p}_{t-1}) + (1-\alpha)\left\{\hat{n}_t + \hat{p}_t^* + \hat{p}_t - \theta\left(\hat{p}_t^* + \hat{p}_t - \widetilde{p}_t\right)\right\}. \tag{68}$$

Inserting equation (67), we have

$$\begin{aligned} \hat{p}_t &= \alpha\hat{p}_{t-1} + \alpha(\hat{n}_t - \hat{n}_{t-1}) + \alpha\theta\left(\hat{p}_t - \frac{1}{\theta}\hat{n}_t - \hat{p}_{t-1} + \frac{1}{\theta}\hat{n}_{t-1}\right) \\ &+ (1-\alpha)\left\{\hat{n}_t + \hat{p}_t^* + \hat{p}_t - \theta\left(\hat{p}_t^* + \hat{p}_t - \hat{p}_t + \frac{1}{\theta}\hat{n}_t\right)\right\} \\ \hat{\pi}_t &= \frac{1-\alpha}{\alpha}\hat{p}_t^*. \end{aligned} \tag{69}$$

Using this and (67), equation (65) is rearranged as

$$\frac{\alpha}{(1-\alpha)(1-\alpha\beta)}(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)\hat{\pi}_t = \mathrm{E}_t\sum_{k=0}^{\infty}\alpha^k\beta^k\left[\begin{array}{c} -(\hat{p}_t-\hat{p}_{t+k}) \\ -(\varepsilon_\mu\theta+\varepsilon_\tau\theta)\left(\hat{p}_t-\hat{p}_{t+k}+\frac{1}{\theta}\hat{n}_{t+k}\right) \\ +\hat{w}_{t+k} \end{array}\right],$$

which leads to the New-Keynesian Phillips curve.

$$\begin{aligned}\hat{\pi}_t &= \beta\mathrm{E}_t\hat{\pi}_{t+1} + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)}\hat{w}_t \\ &- \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\varepsilon_\mu\theta+\varepsilon_\tau\theta)}(\varepsilon_\mu+\varepsilon_\tau)\hat{n}_t. \end{aligned} \tag{70}$$

The Euler equation is log-linearized as

$$\hat{c}_t = \mathrm{E}_t\hat{c}_{t+1} - (1/\sigma)(\hat{i}_t - \mathrm{E}_t\hat{\pi}_{t+1}). \tag{71}$$

The labor supply is log-linearized as

$$\omega\hat{y}_t = -\sigma\hat{c}_t + \hat{w}_t. \tag{72}$$

The relationship between consumption and production is

$$\hat{y}_t = \hat{\Delta}_t + \hat{c}_t, \tag{73}$$

where

$$\begin{aligned}\hat{\Delta}_t = &\quad \hat{n}_t - \tfrac{1}{N}\textstyle\int_0^N \theta\left(\hat{p}_t(j) - \widetilde{p}_t\right)dj \\ = &\quad 0 \end{aligned} \tag{74}$$

Eliminating $\hat{y}_t$, we have

$$\hat{w}_t = (\omega+\sigma)\hat{c}_t. \tag{75}$$

A.5 Parameterization

As for the quasi-kinked demand by Kimball (1995), we follow Dotsey and King (2005) as follows:

$$\psi(x) = \frac{1}{(1+\eta)\gamma}\{(1+\eta)x-\eta\}^\gamma - \frac{1}{(1+\eta)\gamma}(-\eta)^\gamma. \tag{76}$$

This yields

$$\psi'(x) = \{(1+\eta)x - \eta\}^{\gamma-1}. \tag{77}$$

The demand function becomes

$$\begin{aligned} c_t(j) &= C_t \psi'^{-1}\left(\frac{p_t(j)}{\widetilde{P}_t}\right), \\ &= C_t \frac{1}{1+\eta}\left[\left(\frac{p_t(j)}{\widetilde{P}_t}\right)^{1/(\gamma-1)} + \eta\right]. \end{aligned} \tag{78}$$

We then have

$$\begin{aligned} \theta &= -\frac{\psi'}{x\psi''} \\ &= -\frac{\{(1+\eta)x-\eta\}^{\gamma-1}}{x(\gamma-1)(1+\eta)\{(1+\eta)x-\eta\}^{\gamma-2}} \\ &= -\frac{(1+\eta)x-\eta}{x(\gamma-1)(1+\eta)}, \end{aligned} \tag{79}$$

$$\mu = \frac{\theta}{\theta-1}, \tag{80}$$

$$\begin{aligned} \varepsilon_\mu &= \frac{\mu' x}{\mu} \\ &= \frac{\eta(\gamma-1)(1+\eta)x}{[\eta-(1+\eta)x][\eta-\gamma(1+\eta)x]} && (81) \\ &= \frac{\eta(1+\eta)x}{\theta x(1+\eta)} \frac{1}{[\eta - \frac{(\theta-1)x(1+\eta)+\eta}{\theta}]} && (82) \\ &= \frac{\eta}{(\theta-1)\{\eta - x(1+\eta)\}}. && (83) \end{aligned}$$

where

$$x = 1/N. \tag{84}$$

As a special case, if the elasticity is constant and the Dixit–Stiglitz form is applied, then we have $\eta = 0$ and

$$\varepsilon_\mu = 0. \tag{85}$$

As for the sales cost, for illustrative purposes, suppose the following form holds:

$$T(x_t) = T_0 \left(N x_t\right)^{-\phi}. \tag{86}$$

Then, noting

$$\tau(x) = 1 + T(x_t) + x_t T'(x_t),$$

we have

$$\begin{aligned}
\varepsilon_\tau &= \frac{\tau' x}{\tau} \\
&= \frac{-2\phi N T_0 \left(N x\right)^{-\phi-1} + \phi(\phi+1) x N^2 T_0 \left(N x\right)^{-\phi-2}}{1 + T_0 \left(N x\right)^{-\phi} - \phi N x T_0 \left(N x\right)^{-\phi-1}} x \\
&= \frac{(\phi-1)\phi N T_0 \left(N x\right)^{-\phi-1}}{1 + T_0 \left(N x\right)^{-\phi} (1-\phi)}.
\end{aligned} \tag{87}$$

Therefore, the sign of ε_τ is

$$\begin{aligned}
\varepsilon_\tau &< 0 \text{ if } 0 < \phi < 1 \\
&= 0 \text{ if } \phi = 1 \\
&> 0 \text{ if } \phi > 1,
\end{aligned}$$

as long as T_0 is positive and sufficiently small.