ECONOMIC RESEARCH CENTER DISCUSSION PAPER

August 2003

No. 145

CYCLICAL PRICE MOVEMENTS IN AN ATOMISTIC MARKET

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ABSTRACT

This paper explains price movements countercyclical to business cycles in an atomistic market. A recession makes a portion of low-income consumers leave the market and the fraction of low-price stores decreases. Thus, the remaining consumers' reservation prices for storage increase and consequently low-price stores charge higher prices, and vice versa. It is also shown that the equilibrium is characterized as a symmetric mixed strategy Nash equilibrium.

JEL classification: L11, L16

KEYWORDS
Price movements, Business cycles, Atomistic market, Mixed strategy

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This paper is received July23 2003.

1 Introduction

Empirical studies show that price markups over marginal cost behave countercyclically to business cycles (see, for example, Bils, 1987). This behavior is observed particularly in unconcentrated industries (see Domowitz, et al., 1986a,b).[1] If these observations are accurate, we cannot predict that price moves procyclically to business cycles. Classical theory, however, insists that price always moves procyclically to business cycles[2] if the short-run marginal cost curves are upward sloping. It seems that the classical theory fails to explain some of the actual markets' price phenomena.

The purpose of this paper is to explain theoretically the countercyclical behavior of price[3] to business cycles in an atomistic market. By the atomistic market we mean the market which retains all the usual characteristics of perfectly competitive markets except in that individual firms decide the price they will charge, and the purchasers react passively to these prices (see Hey, 1974). Although the study of price movements has been devoted mainly to the explanation of *price rigidities*, which are represented by the *kinked demand curve theory* (see, for example, Okun, 1981 and Stiglitz, 1987), several papers make clear countercyclical price behavior (Phelps and Winter, 1970; Stiglitz, 1984; Rotemberg and Saloner, 1986; Bils, 1989a,b; and Wilson and Reynolds, 2002). They explain, for example within customer markets, that customers with high elasticity of demands leave the market while customers with inelastic demands remain in a period of recession. As a result, the market demand curve becomes inelastic and firms can increase the price in order to maximize their profits. These studies, however, focus mainly on imperfectly competitive markets such as monopolies and oligopolies and

[1] For a survey of these empirical studies, see Carlton (1989).
[2] We consider business cycles which are caused by movements in demand.
[3] We are interested in price movements rather than markups.

thus only a few attempts have been made to analyze atomistic markets. In the following, we exploit the Stiglitz's model (1979)(1989), which studies the relation between *price distribution* and *search costs*. In our model, a difference in income, instead of a distribution of search costs, is introduced. A recession makes a portion of low-income consumers leave the market and the fraction of low-price stores decreases.[4] Thus, the remaining consumers' reservation prices for the storage increase and consequently low-price stores charge higher prices, and vice versa. We also find that equilibrium is attained by firms' mixed strategic pricing behavior in the atomistic market.

The next section constructs a model for consumers and firms in partial equilibrium. Section 3 provides countercyclical movements in price. In section 4, equilibrium is characterized as a symmetric mixed strategy Nash equilibrium. Section 5 provides concluding remarks.

2 The Model

This economy is an overlapping generations model. Time is discrete, starts at $t = 1$, and is infinite, thus $t = 1, 2, \ldots$. There is one *indivisible* commodity x. There are always L *new-born* consumers in each period. They live for two periods.[5] They are identical in tastes but differing in income; let $1 - \pi$ be the percentage of consumers with high-income y_h and $\pi \in (0, 1)$ be the fraction with low-income y_l. There are N identical firms (or stores) which sell the commodity x. Let $1 - \lambda$ be the proportion of firms selling at p_h and $\lambda \in [0, 1]$ be the fraction selling at p_l in each period. Each firm is engaged in random pricing. Suppose that both L and N are a large number and both consumers and firms take π and λ as given.

Consider the market which retains all the usual characteristics of per-

[4] We treat business cycles as exogenously given.

[5] Since our model is partial equilibrium, we ignore the decision problems in labor market.

fectly competitive markets except in that individual firms decide the price they will charge, and the purchasers react passively to these prices. Further, each individual goes shopping and chooses one store randomly among N stores. They cannot shop at the other stores in that period.[6] Suppose that the consumers know *a priori* the distributions of prices and incomes but they cannot differentiate between stores of high and low price until one is chosen. Assume that the firms know *a priori* both distributions but they cannot distinguish between the high- and low-income consumers at their store.[7]

2.1 Consumer's problem

Each individual consumes at most one unit commodity x in each period. They can *purchase* another unit for future consumption in the first period.[8] Let $X = \{0, 1\}$ be the consumption set of x, and $x_1 \in X$ denote the consumption of x in the first period. Let $x_{21} \in X$ and $x_{22} \in X$ denote the x's second period consumption purchased in the *first* period and that purchased in the *second* period, respectively. They are mutually exclusive (i.e. $x_{21}x_{22} = 0$). The common preferences of consumers are defined by the expected utility function:

$$
\begin{aligned}
& u(x_1, x_{21}, x_{22}) \\
& \quad = E[(1 + ax_1)(y - p_1(x_1 + x_{21})) + \beta(1 + ax_{21} + ax_{22})(y - p_2 x_{22})], \quad (1) \\
& \quad x_{21}x_{22} = 0,\ 0 < \beta < 1,\ a > 0
\end{aligned}
$$

[6] For simplicity, it is assumed that the second search cost is prohibitively expensive. For more detailed discussion about search costs, see Stiglitz (1989).

[7] Hence, there is no price discrimination in this market.

[8] The *storage cost* is not entailed directly in this model. Instead, discount factor β plays the same role as the storage cost.

where β, $y \in \mathbb{R}_+$ and $p_i \in \mathbb{R}_+$ are a discount factor, the income of each period, and the price of the i-th period, respectively.[9] Prices are random variable with a certain distribution λ. Note that the cases $u(0,1,1)$ and $u(1,1,1)$ do not exist by definition. Assume now the following condition:

ASSUMPTION 1.

$$\beta(1+a) < 1.$$

The following lemma is established.

LEMMA 1. *Let the utility function* (1) *satisfy Assumption 1. If a consumer chooses* $x_{21} = 1$*, then he has already chosen* $x_1 = 1$*.*

Proof. See Appendix A. □

Lemma 1 means that if a consumer purchases only one unit of the commodity x in the first period, then he consumes it in that period, that is, the assumption excludes the case u(0,1,0). The utility function, for example, takes the following forms:[10]

$$u(0,0,0) = y + \beta y, \tag{2}$$

$$u(1,0,1) = (1+a)(y-p_1) + \beta(1+a)(y-p_2), \tag{3}$$

$$u(1,1,0) = (1+a)(y-2p_1) + \beta(1+a)y. \tag{4}$$

Although the discrete choice of consumption is originated in the early writings of A. Marshall,[11] the above type of utility function is used by Gabszewicz and Thisse (1979)(1980) or Shaked and Sutton (1982). Because of this form, even with identical preferences, the consumers' *reservation prices*[12] are no longer identical since they will vary in accordance with their income.

[9] The term $(y - p_i x_i)$ represents the *residual income* in each period.

[10] There are basically five cases, that is, $u(1,0,0)$ and $u(0,0,1)$ are also possible.

[11] See Whitaker (1975); Ch.II.

[12] The term *reservation price* is defined as a price which makes the consumer indifferent

The method of dynamic programming

Here, we apply the *method of dynamic programming.* This method is useful for analysis of dynamical discrete choice with uncertainty. Figure 1 illustrates the *decision tree* of this program. There are five stages of decision

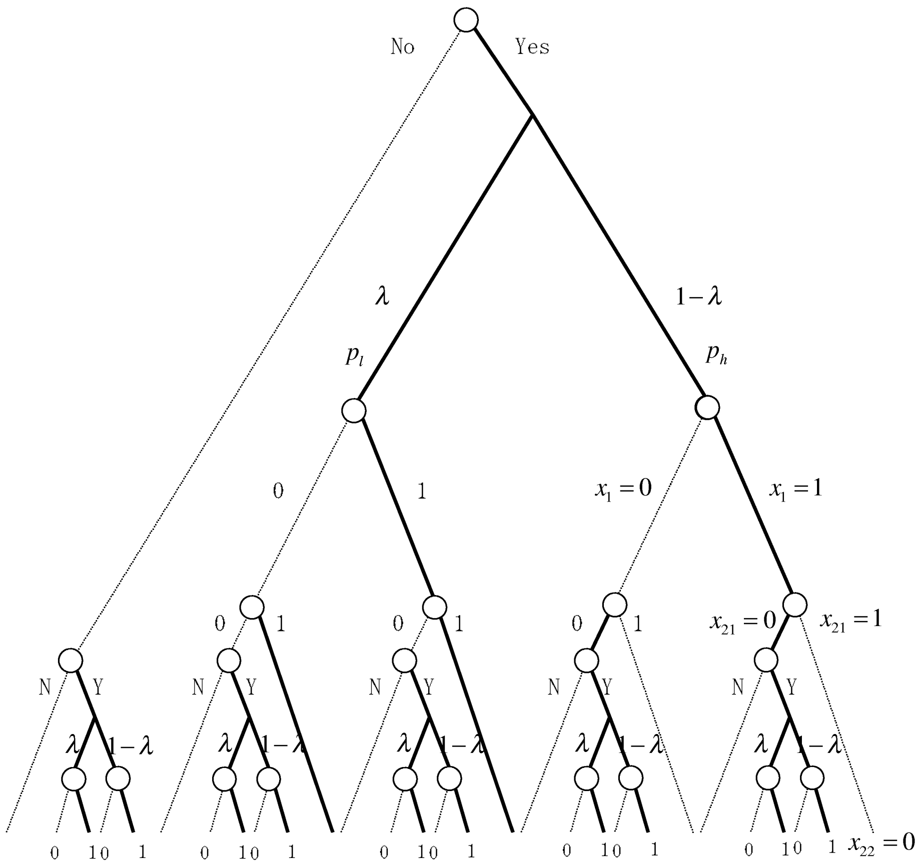


Figure 1: The decision tree: The bold line illustrates the optimal paths when condition (5) is satisfied.

to purchasing the commodity or not. We assume that consumers purchase the commodity when the price is equal to their reservation price: they purchase it when the price is equal to or less than the reservation price.

making. The first period contains three of these stages. First, the consumer decides *not to enter*, or else *to enter* the market and chooses one store randomly. If he decides to enter, he finds a high-price store with probability $(1-\lambda)$ or a low-price store with probability λ. Second, in the store, the consumer decides to purchase x (i.e. $x_1 = 1$) or not (i.e. $x_1 = 0$), taking the price charged by the store as given (i.e. p_h or p_l). Third, he decides to purchase another x for storage (i.e. $x_{21} = 1$) or not. If he purchases it for storage, then the total life plan is finished and he merely consumes it in the second period. The latter two stages in the second period are the same as the former one in the first period. The bold line illustrates the optimal paths when the reservation prices satisfy the following condition:

$$\hat{p}_1 = \hat{p}_{22} \geq p_h > \hat{p}_{21} \geq p_l, \tag{5}$$

where $\hat{p}_i$ denotes x_i-reservation price. Since there is no participation cost (or transactions cost), we can conclude that the individual enters the market as long as there is a chance to purchase x; i.e., $p_h > p_l > \hat{p}_i$ is not satisfied.[13] In next three arguments, we derive the three reservation prices $\hat{p}_1$, $\hat{p}_{21}$, $\hat{p}_{22}$ at which the consumer decides purchase x in each stage and deduces the corresponding individual demand functions.

The choice of x_{22}

Suppose the consumer has been at the bottom nodes of the decision tree. In this stage, the consumer is in a store in the second period. Hence, he doesn't have x for storage (i.e. $x_{21} = 0$). The x_{22}-reservation price is derived from the following condition:

$$u(x_1, 0, 1) = u(x_1, 0, 0) \tag{6}$$

[13] We can skip the question of entering the market in each period. See Appendix B.

or, from (1),

$$(1 + ax_1)(y - p_1x_1) + \beta(1 + a)(y - p_2) = (1 + ax_1)(y - p_1x_1) + \beta y \quad (7)$$

where (p_1, x_1) is a history which has already been realized at this stage. Solving for p_2, we obtain the x_{22}-reservation price:

$$\hat{p}_{22}(y) = \left(\frac{a}{1 + a}\right) y. \quad (8)$$

We find that $\hat{p}_{22}$ depends on y. Therefore, the demand function of period 2 can be written as

$$x_{22} = \begin{cases} 1, & \hat{p}_{22}(y) \geq p_2, \\ 0, & p_2 \geq \hat{p}_{22}(y). \end{cases} \quad (9)$$

Since there is no participation cost, it is the sufficient condition of entering the market that there is a store charging equal to or less than the x_{22}-reservation price.[14]

The choice of x_{21}

From Lemma 1, we can conclude that the consumer has already purchased x for immediate consumption (i.e. $x_1 = 1$) when he decides whether or not to purchase for storage or not. Here, we encounter an interperiod substitution problem. The x_{21}-reservation price is deduced from the following equation: from (1),

$$\begin{aligned} &(1 + a)(y - 2p_1) + \beta(1 + a)y \\ &= (1 + a)(y - p_1) + \beta E[(1 + ax_{22})(y - p_2x_{22})], \end{aligned} \quad (10)$$

where $E[\,\cdot\,]$ is an expected utility function of the second period when $x_{21} = 0$. Note that, from (9), this function varies according to the level of $\hat{p}_{22}(y)$, hence income levels.

[14] See Appendix B.

If $\hat{p}_{22}(y) \geq p_h > p_l$, then the consumer purchases x (i.e. $x_{22} = 1$) irrespective of price charged by stores. Thus, in this case, the expected utility function of the second period becomes

$$\begin{aligned} E[(1+ax_{22})(y-p_2x_{22})] &= (1-\lambda)(1+a)(y-p_h) + \lambda(1+a)(y-p_l) \\ &= (1+a)(y-((1-\lambda)p_h + \lambda p_l)). \end{aligned} \tag{11}$$

Substituting (11) into (10) and solving for p_1, we obtain the x_{21}-reservation price when $\hat{p}_{22}(y) \geq p_h > p_l$:

$$\hat{p}_{21}(\lambda, p_h, p_l) = \beta((1-\lambda)p_h + \lambda p_l). \tag{12}$$

We find that $\hat{p}_{21}$ depends on the average price $\bar{p}$ ($= (1-\lambda)p_h + \lambda p_l$).

Next, if $p_h > \hat{p}_{22}(y) \geq p_l$, then the consumer does not purchase x (i.e. $x_{22} = 0$) at a high price store while he purchases x (i.e. $x_{22} = 1$) at a low price store. Therefore, the expected utility function of the second period becomes

$$\begin{aligned} E[(1+ax_{22})(y-p_2x_{22})] &= (1-\lambda)y + \lambda(1+a)(y-p_l) \\ &= (1+\lambda a)y - \lambda(1+a)p_l. \end{aligned} \tag{13}$$

Substituting (13) into (10), we obtain the x_{21}-reservation price when $p_h > \hat{p}_{22}(y) \geq p_l$:

$$\hat{p}_{21}(\lambda, p_l, y) = \beta((1-\lambda)\hat{p}_{22}(y) + \lambda p_l). \tag{14}$$

Hence, these x_{21}-reservation prices (12), (14) can be written as

$$\hat{p}_{21}(\lambda, p_h, p_l, y) = \min\{\beta((1-\lambda)p_h + \lambda p_l), \beta((1-\lambda)\hat{p}_{22}(y) + \lambda p_l)\}. \tag{15}$$

The choice of x_1

From Lemma 1, if p_1 is equal to or less than $\hat{p}_{21}(\lambda, p_h, p_l, y)$, then $x_{21} = 1$; hence, $x_1 = 1$. Thus, we must deduce the x_1-reservation price when $x_{21} = 0$.

The x_1-reservation price is deduced from the following equation: from (1),

$$\begin{aligned}&(1+a)(y-p_1)+\beta E[(1+ax_{22})(y-p_2x_{22})]\\&=y+\beta E[(1+ax_{22})(y-p_2x_{22})].\end{aligned} \tag{16}$$

Solving for p_1, we obtain the x_1-reservation price:

$$\hat{p}_1(y)=\left(\frac{a}{1+a}\right)y. \tag{17}$$

We find that $\hat{p}_1(y)=\hat{p}_{22}(y)$. From (15), we also find that

$$\hat{p}_1(y)=\hat{p}_{22}(y)>\hat{p}_{21}(\lambda,p_h,p_l,y). \tag{18}$$

From (18), we can confirm that, when $x_{21}=1$ (i.e. $\hat{p}_{21}(\lambda,p_h,p_l,y)\geq p_1$), the consumer has already purchased x for consumption in this period: i.e., $x_1=1$.

Summing up the above three arguments, individual demand functions can be written as

period 1

$$x_1+x_{21}=\begin{cases}2, & \hat{p}_1(y)>\hat{p}_{21}(\lambda,p_h,p_l,y)\geq p_1,\\ 1, & \hat{p}_1(y)\geq p_1>\hat{p}_{21}(\lambda,p_h,p_l,y),\\ 0, & p_1>\hat{p}_1(y)>\hat{p}_{21}(\lambda,p_h,p_l,y),\end{cases} \tag{19}$$

period 2 (when $x_{21}=0$),

$$x_{22}=\begin{cases}1, & \hat{p}_{22}(y)\geq p_2,\\ 0, & p_2\geq\hat{p}_{22}(y).\end{cases} \tag{20}$$

These demand functions are illustrated in Figure 2.

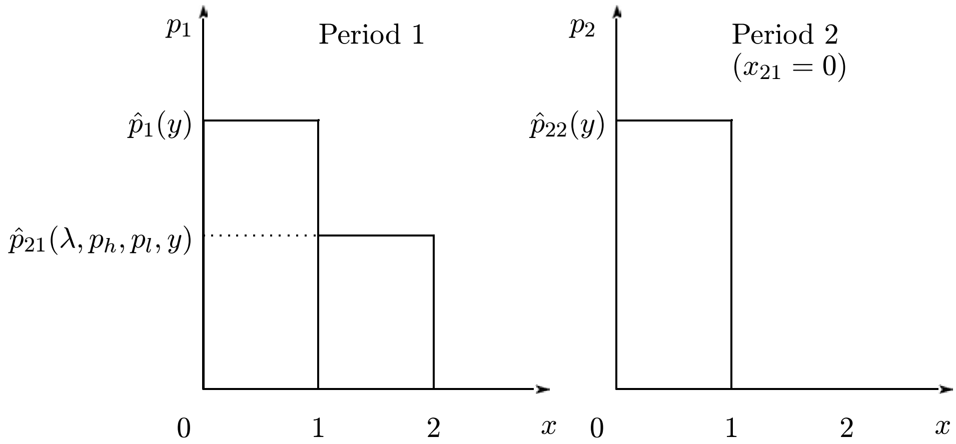


Figure 2: Indivisual demand curves.

2.2 Firm's problem and market equilibrium

We now turn to a discussion of firm's problem and market equilibrium. Since consumers cannot change the store during the period, firms have some monopolistic power against them. However, they cannot discriminate between high- and low-income consumers. There is thus no price discrimination in our model. The store sets one of the reservation prices in each period in order to maximize its profit. For simplicity, we assume that the marginal cost of production is zero.[15] Therefore, the profit maximization is equal to maximization of its revenue.[16]

Suppose that the firms (or stores) know the income distribution and

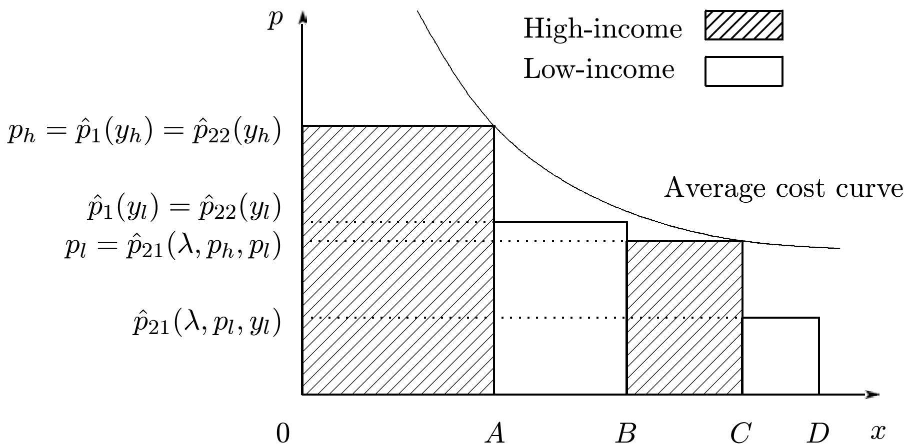
[15] Each period has a fixed cost that determines the number of firms in the market.

[16] The total profit of the representative firm is described as follows:

$$\sum_{t=1}^{\infty} \delta^{t-1}(p_t q_t - c), \tag{21}$$

where δ and c denote discount factor and fixed costs respectively. Since we assume that firms and consumers take price distributions λ as constant, we are allowed to treat the maximization problem as static. Furthermore, we can ignore the fixed cost when comparing profits.

the demand function which they face (the individual firm's demand function). Since there are high-income and low-income consumers, the reservation prices can be divided into two values, respectively. The form of the demand function, thus, varies in accordance with a difference in income and the corresponding strategies used by firms. Consider a set of alternative strategies: a high price strategy which sells *one unit* to each *high-income* consumer at his reservation price (i.e. $p_h = \hat{p}_1(y_h) = \hat{p}_{22}(y_h)$), or a low price strategy which sells *two units* to each *high-income* consumer at a low price (i.e. $p_l = \hat{p}_{21}(\lambda, p_h, p_l)$). Figure 3 illustrates the demand function under this strategy.[17] Each firm attracts not only L/N young consumers but also



$A : (2 - \lambda)(1 - \pi)(L/N)$ $\quad$ $B : (2 - \lambda(1 - \pi))(L/N)$
$C : (2 + (1 - \lambda)(1 - \pi))(L/N)$ $\quad$ $D : (3 - \lambda(1 - \pi))(L/N)$

Figure 3: An individual firm's demand curve.

$[(1 - \lambda)L]/N$ old consumers who selected a high-price store and $(\pi\lambda L)/N$ low-income old consumers who selected a low-price store, when they were

[17]It is assumed that $\hat{p}_1(y_l) \geq \hat{p}_{21}(\lambda, p_h, p_l) = p_l$. In this case, $\hat{p}_{21}(\lambda, p_h, p_l) > \hat{p}_{21}(\lambda, p_l, y_l)$. See Appendix C.

young.[18] Furthermore, each high-income consumer purchases one unit of x in high-price stores. Then, sales q_h of each p_h firm are given by (A in Fig. 3)

$$q_h = \frac{((1-\pi) + (1-\pi)(1-\lambda))L}{N}. \tag{22}$$

Sales of the low price firms are higher; each high-income young consumer purchases two unit of x and each low-income one purchases one unit of x (C in Fig. 3), hence,

$$q_l = \frac{(2(1-\pi) + \pi + (1-\lambda) + \pi\lambda)L}{N}. \tag{23}$$

Since we are interested in this particular case,[19] we make the following assumption about a range of relative income.

ASSUMPTION 2.

$$(1-\pi) > \theta_y \geq \beta, \quad \theta_y \equiv \frac{y_l}{y_h}.$$

The former inequality guarantees that the high price strategy which sells at the reservation prices of high-income consumers (i.e. $p_h = \hat{p}_1(y_h) = \hat{p}_{22}(y_h)$) is more profitable than that of low-income consumers. The latter inequality guarantees that $\hat{p}_1(y_l) \geq \hat{p}_{21}(\lambda, p_h, p_l) = pl$.

LEMMA 2. *Let utility function* (1) *satisfy Assumption 1, and let* θ_y *satisfy Assumption 2, then the profit maximizing conditions of high price and low price strategies are determined by*

$$p_h = \left(\frac{a}{1+a}\right) y_h, \tag{24}$$

$$p_l = \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) p_h. \tag{25}$$

[18] Each low-income consumer purchases at most one unit of x in each period.

[19] Although it is possible to consider several strategies in general cases, some of them are not irrelevant to the main subject and the others only complicate the discussion. See Appendix C.

Proof. See Appendix C. □

This lemma ensures that there are at most two prices in equilibrium. If a *two price equilibrium* (TPE) exists, then the profit from each strategy must be equal to each other: i.e. $p_h q_h = p_l q_l$. Therefore, profit maximizing and equal profit conditions must be satisfied in TPE: from (22), (23) and (24), (25),

$$P_l \equiv \frac{p_l}{p_h} = \frac{\beta(1-\lambda)}{1-\beta\lambda}, \quad \text{profit maximizing condition,} \tag{26}$$

$$P_l \equiv \frac{p_l}{p_h} = \frac{(2-\lambda)(1-\pi)}{(2+(1-\lambda)(1-\pi))}, \quad \text{equal profit condition.} \tag{27}$$

This establishes the following proposition.

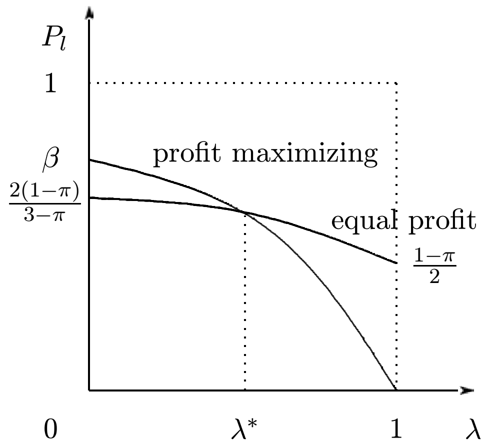


Figure 4: The existence and uniqueness of λ^* and P_l.

PROPOSITION 1. *Let utility function* (1) *satisfy Assumption 1, let* θ_y *satisfy Assumption 2, and if* $\beta \geq 2/3$*, then there is unique distribution* $\lambda^* \in (0,1)$ *which satisfies profit maximizing and equal profit conditions:*

$$\frac{(2-\lambda^*)(1-\pi)}{(2+(1-\lambda^*)(1-\pi))} = \frac{\beta(1-\lambda^*)}{1-\beta\lambda^*}. \tag{28}$$

Proof. See Appendix D. □

3 Cyclical price movements

We are now ready to consider the firm's reaction to changes in economic situations. In order to focus on two-price equilibrium, we make the following assumption regarding β.

ASSUMPTION 3.

$$\beta \geq \frac{2}{3}.$$

This assumption seems reasonable. Further, together with Assumption 2, this implies that the proportion of high-income consumers is a large enough and the difference in income is not large in the economy.

Figure 4 indicates that the proportion of low-price stores decreases with decreasing the fraction of low-income consumers; as a result, low prices increase. The following proposition formalizes this argument.

PROPOSITION 2. *Let utility function* (1) *satisfy Assumption 1 and let* θ_y *and* β *satisfy Assumptions 2 and 3, respectively, then*

$$\frac{dp_l}{d\pi} < 0. \tag{29}$$

Proof. See Appendix E. □

This is our main proposition.[20] The movements of prices are countercyclical to business cycles. For simplicity, suppose that only a fraction of low-income consumers lost their jobs in recessions.[21] As a result, they reduce their reservation prices below the prevailing prices and leave the market; the fraction of low-income π decreases. Since the low price strategy becomes less profitable, the proportion of low-price stores λ^* decreases with π. On the other hand, high-income young consumers in a low-price store raise their reservation

[20] Although we assume that β is constant, it can change with business cycles.

[21] See Appendix F.

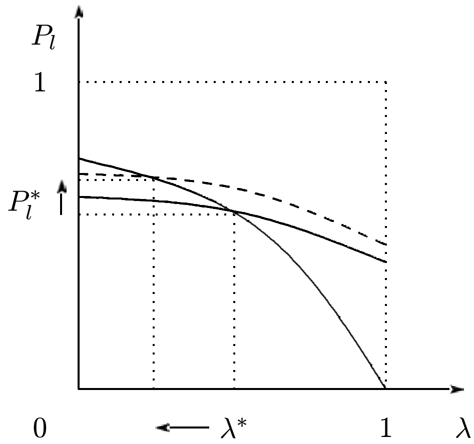


Figure 5: Effect of the decrease in fraction of low-income consumers

price for storage with decreases in λ^* because the probability of choosing a low-price store diminishes in the next period. Therefore, firms can raise the level of low prices during recessions,[22] and vice versa.(See Figure 5)

4 TPE as a mixed strategy Nash equilibrium

The equilibrium discussed above (TPE) is derived from profit maximizing and equal profit conditions. The equal profit condition, however, is applied externally to the model. It does not indicate how firms determine the strategy in each period. We provide here that TPE can be derived merely from a firm's profit maximizing behavior. We will find that the equal profit condition is obtained endogenously as a result of this behavior. The equilibrium is characterized as a *symmetric mixed strategy Nash equilibrium.*[23] In the equilibrium, we find that firms price p_h with probability $(1-\lambda^*)$ and p_l with λ^*. We shall discuss this in detail.

Consider a strategic game which consists of N identical firms, and two

[22]The average price $\bar{p}$ increases as λ^* decreases, while p_h remain constant.
[23]See Osborne and Rubinstein (1994), Ch.3.

strategies which consists of *high-price strategy* and *low-price strategy.* Payoff functions are defined by their revenue: from (22), (23), (24), and (25),

$$p_h q_h = \left(\frac{a}{1+a}\right) y_h \left\{\frac{((1-\pi)+(1-\pi)(1-\lambda))L}{N}\right\}, \tag{30}$$

$$p_l q_l = \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) p_h \left\{\frac{(2(1-\pi)+\pi+(1-\lambda)+\pi\lambda)L}{N}\right\}. \tag{31}$$

We now focus on a symmetric Nash equilibrium. Let firm i denote i-th individual firm and let firms $-i$ denote the other firms which take the same strategy. Since N is a large number, we can treat it as $\lambda = 0$ when firms $-i$ take a high-price strategy and as $\lambda = 1$ when they take a low-price strategy. Therefore, from (30) and (31), the payoff matrix for this game is given by Figure 6. If firms $-i$ take a high-price strategy, then the low-price strategy is more profitable for firm i, and vice versa. This implies that there is no single price equilibrium. The following lemma formalizes this argument.

		Firms $-i$: High	Firms $-i$: Low
Firm i	High	$p_h\left(\frac{2(1-\pi)L}{N}\right)$	$p_h\left(\frac{(1-\pi)L}{N}\right)$
	Low	$\beta p_h\left(\frac{(3-\pi)L}{N}\right)$	0

Figure 6: Payoff matrix: Firm i's payoff is written in each cell.

LEMMA 3. *Let utility function* (1) *satisfy Assumption 1 and let* θ_y *and* β *satisfy Assumptions 2 and 3, respectively; then there is no symmetric pure strategy Nash equilibrium.*

Proof. See Appendix G. □

Next, consider each firm adopts a mixed strategy composed of both high-price and low-price strategies. If firms $-i$ take a low-price strategy with probability λ (hence a high-price strategy with probability $1-\lambda$), then it coincides with the price distribution λ in the market according to the law of large numbers. Corresponding firm i's payoff function of each pure strategy is shown by (30), (31). Hence, firm i's expected payoff function of mixed strategy q is

$$\begin{aligned}&(1-q)\left\{p_h\left(\frac{(2-\lambda)(1-\pi)L}{N}\right)\right\}\\&\quad+q\left\{\left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right)p_h\left(\frac{(2+(1-\lambda)(1-\pi))L}{N}\right)\right\}.\end{aligned}\tag{32}$$

From this payoff function (32) and the equal profit condition (28) in Proposition 1, we can find that symmetric mixed strategy Nash equilibrium coincides with TPE. The following proposition formalizes this argument.

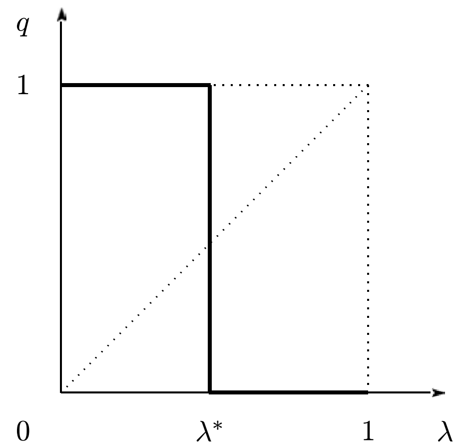


Figure 7: Symmetric Mixed Strategy Nash Equilibrium

PROPOSITION 3. *Let utility function* (1) *satisfy Assumption 1 and let* θ_y *and* β *satisfy Assumptions 2 and 3, respectively; there is then a unique symmetric mixed strategy Nash equilibrium* $\lambda^* \in (0,1)$. *This equilibrium coincides with TPE.*

Proof. See Appendix H. □

5 Concluding remarks

We demonstrated how market prices are determined and react to business cycles in an atomistic market. Prices move countercyclically to business cycles because a low-price strategy becomes less (more) profitable during a recession (boom).[24] We must, however, notice that our results depend strongly on the type of commodity addressed. For example, low-income consumers may not leave grocery markets during a recession, though they will leave the durable goods markets. Our model seems more suitable for the latter case because we consider the market from which a fraction of low-income consumers exit during a recession.

Although we focused on the equilibrium of steady states, cyclical price movements should be analyzed from a dynamic point of view since they have intrinsically dynamic structures. However, as Bils (1989) shows, such an analysis will be extremely complicated.

Finally, we supposed here that firms are engaged in random pricing; that is, the store which charges low prices does not necessarily charge the same price in the next period. In some actual markets, however, we can observe that each firm continues to charge the same price even though prices are distributed in the market. In this case, consumers' information regarding low price stores increases, and, as a result, uncertainty may diminish. It will be necessary to extend our model along this line.

[24] By the structure of overlapping generations, there are always potential consumers having a *new* demand for storage in the market. This is important to show the benefits of a low-price strategy, and hence our main propositions. It is not assumed clearly in Stiglitz (1979)(1989).

Appendix A. *proof of Lemma 1*

LEMMA 1. *Let the utility function* (1) *satisfy Assumption 1. If a consumer chooses* $x_{21} = 1$*, then he has already chosen* $x_1 = 1$*.*

Proof. Suppose $x_1 = 0$ when $x_{21} = 1$, then , from $x_{21}x_{22} = 0$, the utility is $u(0,1,0)$. From (1), the conditions $u(1,0,0) \geq u(0,0,0)$ and $u(0,1,0) \geq u(0,0,0)$ are the following, respectively:

$$\begin{aligned} (1+a)(y-p_1) + \beta y &\geq y + \beta y, \\ \left(\frac{a}{1+a}\right) y &\geq p_1, \end{aligned} \tag{33}$$

and

$$\begin{aligned} y - p_1 + \beta(1+a)y &\geq y + \beta y, \\ \beta a y &\geq p_1. \end{aligned} \tag{34}$$

From Assumption 1, (33) and (34),

$$\left(\frac{a}{1+a}\right) y > \beta a y \geq p_1. \tag{35}$$

This inequality means that if $p_1 \leq \beta a y$ he can choose both $u(1,0,0)$ and $u(0,1,0)$ in the store. Here, the condition $u(1,0,0) > u(0,1,0)$ is

$$\begin{aligned} (1+a)(y-p_1) + \beta y &> y - p_1 + \beta(1+a)y, \\ (1-\beta)y &> p_1. \end{aligned} \tag{36}$$

From Assumption 1, this condition is satisfied for all $p_1 \leq \beta a y$; that is, he does not choose the case $u(0,1,0)$. It is a contradiction. The desired result is satisfied. □

Appendix B. *conditions of entering the markets*

The condition of entering the second period market

case#1 If $\hat{p}_{22}(y) \geq p_h > p_l$, then, from (11), the expected utility function of the second period is

$$\begin{aligned} E[(1+ax_{22})(y-p_2x_{22})] &= (1+a)(y-((1-\lambda)p_h+\lambda p_l)) \\ &= (1+a)(y-\bar{p}), \end{aligned} \tag{37}$$

where $\bar{p} = (1-\lambda)p_h + \lambda p_l$. A consumer decides to enter the second period market if

$$\begin{aligned} &(1+ax_1)(y-p_1x_1) + \beta[(1+a)(y-\bar{p})] \\ &\geq (1+ax_1)(y-p_1x_1) + \beta y. \end{aligned} \tag{38}$$

Hence,

$$\begin{aligned} (1+a)(y-\bar{p}) &\geq y, \\ \left(\frac{a}{1+a}\right) y &\geq \bar{p}, \\ \hat{p}_{22}(y) &\geq \bar{p}. \end{aligned} \tag{39}$$

Since case#1 always satisfies this inequality, the consumer enters the market.

case#2 If $p_h > \hat{p}_{22}(y) \geq p_l$, then, from (13), the expected utility function of the second period is

$$E[(1+ax_{22})(y-p_2x_{22})] = (1+\lambda a)y - \lambda(1+a)p_l. \tag{40}$$

A consumer decides to enter the market if

$$\begin{aligned} &(1+ax_1)(y-p_1x_1) + \beta[(1+\lambda a)y - \lambda(1+a)p_l] \\ &\geq (1+ax_1)(y-p_1x_1) + \beta y \end{aligned} \tag{41}$$

Hence,

$$
\begin{aligned}
(1+\lambda a)y-\lambda(1+a)p_l &\geq y,\\
\left(\frac{a}{1+a}\right)y &\geq p_l, \qquad (42)\\
\hat{p}_{22}(y) &\geq p_l.
\end{aligned}
$$

Since case#2 satisfies this inequality, the consumer enters the market.

The condition of entering the first period market

case#1-1 If $\hat{p}_1=\hat{p}_{22}(y)\geq p_h>\hat{p}_{21}(\lambda,p_h,p_l)\geq p_l$, then the condition of entering the market is

$$
\begin{aligned}
&(1-\lambda)\left\{(1+a)(y-p_h)+\beta(1+a)(y-\bar{p})\right\}\\
&+\lambda\left\{(1+a)(y-2p_l))+\beta(1+a)y\right\} \qquad (43)\\
&\geq y+\beta(1+a)(y-\bar{p}).
\end{aligned}
$$

Hence,

$$(\hat{p}_{22}(y)-(1-\lambda)(1-\beta\lambda)p_h)\geq(\lambda(2-\lambda\beta))p_l. \qquad (44)$$

Since $\hat{p}_1(y)=\hat{p}_{22}(y)\geq p_h$, this condition is satisfied if

$$
\begin{aligned}
(1+\beta(1-\lambda))p_h &\geq (2-\beta\lambda)p_l,\\
p_h &\geq 2p_l-\beta\bar{p},\\
p_h &\geq 2p_l-\hat{p}_{21}(\lambda,p_h,p_l). \qquad (45)
\end{aligned}
$$

and from $\hat{p}_{21}(\lambda,p_h,p_l)\geq p_l$, the sufficient condition of (45) is

$$p_h\geq\hat{p}_{21}(\lambda,p_h,p_l). \qquad (46)$$

Since case#1-1 satisfies this inequality, the consumer enters the market.

case#1-2 If $\hat{p}_1(y) = \hat{p}_{22}(y) \geq p_h > p_l > \hat{p}_{21}(\lambda, p_h, p_l)$, then the condition of entering the market is

$$\begin{aligned}
&(1-\lambda)\left\{(1+a)(y-p_h)+\beta(1+a)(y-\bar{p})\right\} \\
&+\lambda\left\{(1+a)(y-p_l))+\beta(1+a)(y-\bar{p})\right\} \\
&\geq y+\beta(1+a)(y-\bar{p}).
\end{aligned} \tag{47}$$

Hence,

$$\begin{aligned}
(1+a)(y-\bar{p}) &\geq y, \\
\left(\frac{a}{1+a}\right) y &\geq \bar{p}, \\
\hat{p}_1(y) = \hat{p}_{22}(y) &\geq \bar{p}.
\end{aligned} \tag{48}$$

Since case#1-2 satisfies this inequality, the consumer enters the market.

case#2-1 If $p_h > \hat{p}_1(y) = \hat{p}_{22}(y) > \hat{p}_{21}(\lambda, p_l, y) \geq p_l$, then the condition of entering the market is

$$\begin{aligned}
&(1-\lambda)\left\{y+\beta[(1+\lambda a)y-\lambda(1+a)p_l]\right\} \\
&+\lambda\left\{(1+a)(y-2p_l)+\beta(1+a)y\right\} \\
&\geq y+\beta[(1+\lambda a)y-\lambda(1+a)p_l].
\end{aligned} \tag{49}$$

Hence,

$$\begin{aligned}
(1+\beta(1-\lambda))\hat{p}_{22}(y) &\geq (2-\beta\lambda)p_l, \\
\hat{p}_{22}(y) &\geq 2p_l - \hat{p}_{21}(\lambda, p_l, y).
\end{aligned} \tag{50}$$

Since $\hat{p}_{21}(\lambda, p_l, y) \geq p_l$, the sufficient condition of (50) is

$$\hat{p}_{22}(y) \geq \hat{p}_{21}(\lambda, p_l, y). \tag{51}$$

Since case#2-1 satisfies this inequality, the consumer enters the market.

case#2-2 If $p_h > \hat{p}_1(y) = \hat{p}_{22}(y) \geq p_l > \hat{p}_{21}(\lambda, p_l, y)$, then the condition of entering the market is

$$\begin{aligned}
&[(1+\lambda a)y - \lambda(1+a)p_l] \\
&+ \beta[(1+\lambda a)y - \lambda(1+a)p_l] \\
&\geq y + \beta[(1+\lambda a)y - \lambda(1+a)p_l].
\end{aligned} \tag{52}$$

Hence,

$$\begin{aligned}
[(1+\lambda a)y - \lambda(1+a)p_l] &\geq y, \\
\left(\frac{a}{1+a}\right) y &\geq p_l, \\
\hat{p}_{22}(y) &\geq p_l.
\end{aligned} \tag{53}$$

Since case#2-2 satisfies this inequality, the consumer enters the market.

Appendix C. *proof of Lemma 2*

LEMMA 2. *Let utility function* (1) *satisfy Assumption 1, and let* θ_y *satisfy Assumption 2, then the profit maximizing conditions of high price and low price strategies are determined by*

$$p_h = \left(\frac{a}{1+a}\right) y_h, \tag{54}$$

$$p_l = \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) p_h. \tag{55}$$

Proof. There are three steps. First, consider the profit of a high-price strategy. We have already known the profit of setting price p_h for high-income: $p_h = \hat{p}_1(y_h) = \hat{p}_{22}(y_h)$; that is,

$$p_h q_h = \left(\frac{a}{1+a}\right) y_h (1-\pi)(2-\lambda)(L/N). \tag{56}$$

If the firm set a price p_h for low-income consumers: i.e., $p_h = \hat{p}_1(y_l) = \hat{p}_{22}(y_l)$, then the x_{21}-reservation price of high-income consumers coincides with that of low-income consumers; i.e., $\hat{p}_{21}(\lambda, p_h, p_l) = \hat{p}_{21}(\lambda, p_l, y_l)$. Hence $\hat{p}_1(y_l) > \hat{p}_{21}(\lambda, p_h, p_l)$. Therefore, each firm attracts L/N young consumers and $[(1-\lambda)L]/N$ old consumers who selected a high price store when they were young. The profit of this case is

$$p_h q_h = \left(\frac{a}{1+a}\right) y_l(2-\lambda)(L/N). \tag{57}$$

Comparing (56) with (57), we find that setting (54) as a high-price strategy is more profitable if

$$(1-\pi)y_h > y_l. \tag{58}$$

This condition is satisfied by Assumption 2. Notice that, under this assumption, we can exclude the case $p_h = \hat{p}_1(y_l) = \hat{p}_{22}(y_l)$.

Next, consider the profit of a low-price strategy under $p_h = \hat{p}_1(y_h)$. Suppose that $\hat{p}_1(y_l) \geq \hat{p}_{21}(\lambda, p_h, p_l)$. There are two reservation prices for a low-price strategy in accordance with income levels (See Fig. 3):

$$\hat{p}_{21}(\lambda, p_h, p_l) = \beta((1-\lambda)p_h + \lambda p_l), \tag{59}$$

$$\hat{p}_{21}(\lambda, p_l, y_l) = \beta((1-\lambda)\hat{p}_{22}(y_l) + \lambda p_l). \tag{60}$$

Note that $\hat{p}_{21}(\lambda, p_h, p_l) > \hat{p}_{21}(\lambda, p_l, y_l)$. If the firm sets a low price for high-income consumers: i.e., $p_l = \hat{p}_{21}(\lambda, p_h, p_l)$, hence,

$$p_l = \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) p_h, \tag{61}$$

then, each firm attracts L/N young consumers, $[(1-\lambda)L]/N$ old consumers who selected a high-price store when they were young and $(\pi\lambda L)/N$ low-income old consumers who selected a low-price store when they were young. Since each young high-income consumer purchases two units of x, the profit of this case can be written as (C in Fig. 3)

$$p_l q_l = \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) \left(\frac{a}{1+a}\right) y_h(2 + (1-\lambda)(1-\pi))(L/N). \tag{62}$$

If the firm sets a low price for low-income consumers: i.e., $p_l = \hat{p}_{21}(\lambda, p_l, y_l)$, then each firm attracts L/N young consumers, $[(1-\lambda)L]/N$ old consumers who selected a high-price store when they were young and and $(\pi\lambda L)/N$ low-income old consumers who selected a low-price store when they were young. Since each young consumer purchases two units of x, the profit of this case can be written as (D in Fig. 3)

$$p_l q_l = \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right)\left(\frac{a}{1+a}\right) y_l(3-\lambda(1-\pi))(L/N). \tag{63}$$

Comparing (62) with (63), we find that setting (61) as a low-price strategy is more profitable if

$$y_h(2+(1-\lambda)(1-\pi)) > y_l(3-\lambda(1-\pi)). \tag{64}$$

It follows that

$$1 - \frac{\pi}{3-\lambda(1-\pi)} > (1-\pi) > \theta_y, \quad \forall\ \lambda \in (0,1).$$

This condition is satisfied by Assumption 2.

Last, from (61), the sufficient condition of $\hat{p}_1(y_l) \geq \hat{p}_{21}(\lambda, p_h, p_l)$ for any $\lambda \in (0,1)$ under $p_h = \hat{p}_1(y_h)$ is

$$\left(\frac{a}{1+a}\right) y_l \geq \frac{\beta(1-\lambda)}{1-\beta\lambda}\left(\frac{a}{1+a}\right) y_h,$$

$$\theta_y \geq \frac{\beta(1-\lambda)}{1-\beta\lambda}. \tag{65}$$

This inequality is satisfied by Assumption 2 for all $\lambda \in [0,1]$. □

Appendix D. *proof of Proposition 1*

PROPOSITION 1. *Let utility function* (1) *satisfy Assumption 1, let θ_y satisfy Assumption 2, and if $\beta \geq 2/3$, then there is unique distribution $\lambda^* \in (0,1)$ which satisfies profit maximizing and equal profit conditions:*

$$\frac{(2-\lambda^*)(1-\pi)}{(2+(1-\lambda^*)(1-\pi))} = \frac{\beta(1-\lambda^*)}{1-\beta\lambda^*}. \tag{66}$$

Proof. Consider LHS and RHS in (66) as functions of λ, that is,

$$LHS(\lambda) = \frac{(2-\lambda)(1-\pi)}{(2+(1-\lambda)(1-\pi))}, \tag{67}$$

$$RHS(\lambda) = \frac{\beta(1-\lambda)}{1-\beta\lambda}. \tag{68}$$

These functions are continuous and strictly decreasing with respect to λ: i.e.,

$$\forall\ \lambda \in [0,1], \quad \frac{\partial LHS(\lambda)}{\partial \lambda} < 0, \quad \frac{\partial RHS(\lambda)}{\partial \lambda} < 0. \tag{69}$$

Next, if $\lambda = 1$, then

$$LHS = \frac{1-\pi}{2}, \quad RHS = 0. \tag{70}$$

This means that $LHS > RHS$ when $\lambda = 1$.

If $\lambda = 0$, then

$$LHS = \frac{2(1-\pi)}{3-\pi}, \quad RHS = \beta. \tag{71}$$

From (71), if

$$\frac{2(1-\pi)}{3-\pi} < \beta, \tag{72}$$

then, from (69), there is unique $\lambda^* \in (0,1)$. This condition is satisfied for all $\pi \in (0,1)$ if $\beta \geq 2/3$. (See Fig. 4) $\square$

Appendix E. *proof of Proposition 2*

PROPOSITION 2. *Let utility function* (1) *satisfy Assumption 1 and let θ_y and β satisfy Assumptions 2 and 3, respectively, then*

$$\frac{dp_l}{d\pi} < 0. \tag{73}$$

Proof. Since Proposition 1 is satisfied under Assumptions 1, 2, and 3, let $\lambda^* \in (0,1)$ denote the equilibrium in which profit maximizing and equal profit conditions (66) are satisfied; i.e., $LHS(\lambda^*) = RHS(\lambda^*)$. Taking the implicit derivative of (66) with respect to π at λ^*:

$$\begin{aligned}\frac{d\lambda^*}{d\pi} &= \frac{\frac{2(2-\lambda^*)}{(2+(1-\lambda^*)(1-\pi))^2}}{\left(\frac{\beta}{1-\beta\lambda^*}(1-RHS(\lambda^*)) - \frac{1-\pi}{2+(1-\lambda^*)(1-\pi)}(1-LHS(\lambda^*))\right)} \\ &= \frac{\frac{2(2-\lambda^*)}{(2+(1-\lambda^*)(1-\pi))^2}}{\left(\frac{\beta}{1-\beta\lambda^*} - \frac{1-\pi}{2+(1-\lambda^*)(1-\pi)}\right)(1-LHS(\lambda^*))}.\end{aligned} \tag{74}$$

The sufficient condition that the denominator of (74) remains positive is $\beta > 1/2$. From Assumption 3, this condition is satisfied. Hence, from (74),

$$\frac{d\lambda^*}{d\pi} > 0, \tag{75}$$

and from (61),

$$\frac{dp_l}{d\lambda} < 0. \tag{76}$$

Therefore, from (75) and (76),

$$\frac{dp_l}{d\pi} = \frac{dp_l}{d\lambda^*} \cdot \frac{d\lambda^*}{d\pi} < 0. \tag{77}$$

(See Fig. 5) □

Appendix F. *changes in* π

Consider a phase of a recession. Let $1-\beta$ and $1-\alpha$ be the proportion of high-income and low-income consumers, respectively, who remain in the market and let β and α be the fraction of those who leave the market because of unemployment. The fraction π decreases if

$$\frac{(1-\alpha)\pi L}{(1-\beta)(1-\pi)L + (1-\alpha)\pi L} < \pi. \tag{78}$$

Hence,

$$\alpha > \beta. \tag{79}$$

Therefore, we find that π decreases as long as α is larger than β.

Appendix G. *proof of Lemma 3*

LEMMA 3. *Let utility function* (1) *satisfy Assumption 1 and let θ_y and β satisfy Assumptions 2 and 3, respectively; then there is no symmetric pure strategy Nash equilibrium.*

Proof. The payoff matrix for this game is given by Figure 6. First, consider that firms $-i$ take a low-price strategy; i.e., $\lambda = 1$, then

$$p_h \left(\frac{(1-\pi)L}{N} \right) > 0. \tag{80}$$

Thus, firm i takes a high-price strategy. Under an assumption of symmetricity, this implies $\lambda = 0$. It is a contradiction. Next, consider firms $-i$ take a high-price strategy; i.e., $\lambda = 0$. If the following inequality is satisfied,

$$\beta p_h \left(\frac{(3-\pi)L}{N} \right) > p_h \left(\frac{2(1-\pi)L}{N} \right). \tag{81}$$

Hence,

$$\beta > \frac{2(1-\pi)}{3-\pi}. \tag{82}$$

From $\pi \in (0,1)$, RHS in (82) takes the value of interval $(0, 2/3)$. This condition is satisfied by Assumption 3. Thus, firm i takes a low-price strategy. This implies $\lambda = 1$. It is a contradiction. Therefore, the desired result is satisfied. □

Appendix H. *proof of Proposition 3*

PROPOSITION 3. *Let utility function* (1) *satisfy Assumption 1 and let θ_y and β satisfy Assumptions 2 and 3, respectively; there is then a unique symmetric mixed strategy Nash equilibrium $\lambda^* \in (0,1)$. This equilibrium coincides with TPE.*

Proof. Let $1-q$ and q denote firm i's mixed strategy of high price and low price, respectively. Similary, let $1-\lambda$ and λ denote the firms $-i$'s mixed strategy. Since there are a large number of firms, firms $-i$'s mixed strategy can be regarded as an actually observed price distribution λ. Thus the profit of each pure strategy for firm i can be written as

$$p_h q_h = \left(\frac{a}{1+a}\right) y_h \left\{\frac{((1-\pi)+(1-\pi)(1-\lambda))L}{N}\right\}, \tag{83}$$

$$p_l q_l = \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) p_h \left\{\frac{(2(1-\pi)+\pi+(1-\lambda)+\pi\lambda)L}{N}\right\}. \tag{84}$$

Hence, the expected payoff function is

$$\begin{aligned} &(1-q)\left\{p_h\left(\frac{(2-\lambda)(1-\pi)L}{N}\right)\right\} \\ &\quad + q\left\{\left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) p_h \left(\frac{(2+(1-\lambda)(1-\pi))L}{N}\right)\right\}. \end{aligned} \tag{85}$$

From (85), if

$$p_h\left(\frac{(2-\lambda)(1-\pi)L}{N}\right) > \left(\frac{\beta(1-\lambda)}{1-\beta\lambda}\right) p_h \left(\frac{(2+(1-\lambda)(1-\pi))L}{N}\right).$$

Hence

$$\frac{(2-\lambda)(1-\pi)}{(2+(1-\lambda)(1-\pi))} > \frac{\beta(1-\lambda)}{1-\beta\lambda}. \tag{86}$$

Firm i then chooses $q=0$ to maximize its profit since the expected payoff function (85) is linear with respect to q. To the contrary, if $LHS < RHS$ in (86), then firm i chooses $q=1$. If $LHS = RHS$, then the payoff is indifferent for $q \in [0,1]$. Similar to the arguments in the proof of Proposition 1, there exists unique $\lambda^* \in (0,1)$ such that

$$\frac{(2-\lambda^*)(1-\pi)}{(2+(1-\lambda^*)(1-\pi))} = \frac{\beta(1-\lambda^*)}{1-\beta\lambda^*}. \tag{87}$$

Then, $LHS > RHS$ for all $\lambda \in [0, \lambda^*)$ and $LHS < RHS$ for all $\lambda <\in (\lambda^*, 1]$. Therefore, the best response function of firm i is given by Figure 7. Under the symmetricity assumption, $q = \lambda^*$ is the symmetric mixed strategy Nash equilibrium. From (87) and (28) in Proposition 1, the value of λ^* coincides with TPE. □

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