Consumer Surplus Moderated Price Competition

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Abstract

Standard models of price competition assume that firms are pure profit maximizers. With no direct government intervention in a market, this assumption is sensible and empirically useful in inferring the product markups. However, in markets for essential goods such as food and healthcare, a government may wish to address its consumer surplus concerns by imposing regulatory constraints or actively participating as a player in the market. As a consequence, some firms may have objectives beyond profit maximization and standard models may induce systematic biases in empirical estimation.

This paper develops the structural model of price competition where some firms have consumer surplus concerns. Our model is applied in order to understand demand and supply behaviors in a retail grocery market where the dominant retailer publicly declares its consumer surplus objective. Our estimation results show that the observed low prices of this retailer arise indeed as a consequence of its consumer surplus concerns instead of its low marginal costs. The estimated degree of consumer surplus concerns suggests that the dominant retailer weighs consumer surplus to profit in a 1 to 7 ratio. The counterfactual analysis reveals that if the dominant retailer were to be profit maximizing as in the standard model, its prices would increase by 6.09% on average. As a consequence, its profit would increase by 1.16% and total consumer surplus would decrease by 7.18%. To the contrary, competitors lower their prices in response to the dominant retailer's increased prices, i.e., become less aggressive as if they are strategic substitutes. Interestingly, even though profit of all firms increases, total social surplus would decrease by 3.21% suggesting that profit maximization by all firms induces an inefficient outcome for the market.

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1 Introduction

> *"Thirty nine years ago, NTUC FairPrice was formed for one social purpose—to share the load of rising costs with our customers. Everything we do is driven by this unique social mission of moderating the cost of living in Singapore."*
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> *"We keep the prices of daily essentials stable to stretch the hard-earned money of our customers. [...] We have been able to consistently achieve excellence in both the business and social front."*
>
> — *FairPrice Annual Report 2012.*

Standard models of price competition assume that firms are driven solely by profit concerns. With no direct government intervention in a market, such assumption is realistic and powerful because one can then interpret observed market prices as equilibrium behaviors among profit maximizing firms. This equilibrium interpretation is empirically very useful because it allows one to systematically infer the product markup and hence the marginal cost of each product in the market.

This profit-maximization assumption however does not apply to every market. In fact, in markets for essential goods such as food, healthcare, and housing (i.e., products that satisfy physiological and safety needs in the Maslow's hierarchy of needs), a government may wish to address its consumer surplus concerns by imposing regulatory constraints on price levels. Sometimes, the government may even take an additional step to actively participate in the market in order to have better market information and directly serve the consumers. In these markets, some firms will have different objectives than pure profit maximization and the nature of market competition may change dramatically. As a result, applying standard models to these markets may induce systematic biases in empirical estimation.

There are many examples of consumer surplus moderated price competition. Surplus concerns can arise in at least 3 ways. First, there are countries where a significant portion of the enterprises are state-owned (e.g., China). China has moved from a communist country with no market prices to a regulated market where stated-owned enterprises actively

participate in many product markets from housing and food to energy and telecommunications.[1] Anecdotal evidence suggests that these state-owned enterprises are not pure profit maximizers since a significant portion of profit is used to increase public surplus and to stabilize cost of living for people.[2] Second, healthcare market in most countries is often heavily regulated and has active participation by a high number of nonprofit organizations. This is so because healthcare is considered a basic need to which every human being is entitled. For example, of the 3,900 nonfederal, short-term, acute care general hospitals in the United States in 2003, about 62 percent were nonprofit, 20 percent were government hospitals, and 18 percent were for-profit hospitals.[3] Non-profit hospitals are not investor-owned and hence often have different objectives than pure profit maximization. Third, government of countries with high income inequality may choose to participate in essential good markets in order to keep the cost of living low and stable. For example, Singapore government builds 85% of the apartments in the country in order to make housing affordable. In all three scenarios, one or more firms are likely to have a consumer surplus moderated objective and as a consequence will significantly change the nature of price competition.

Given this wide prevalence of consumer surplus moderated price competition, it is surprising that little research has investigated its equilibrium implications and that the existing research to date has been largely confined to the healthcare market. There exist a few works on consumer surplus concerned players in non-healthcare markets. Shiver and Srinivasan (2011) consider a duopoly market where one firm is profit maximizing while the other firm is consumer surplus maximizing given some constraint on its profit level. The competitive game is two-stage: firms sequentially decide on quality in the first stage and simultaneously decide on price in the second stage. Their key finding is that when the consumer surplus maximizing firm is the follower in the first stage, it can significantly improve consumer surplus by forgoing only small amounts of profit.

[1]Chinese government manages a total of 117 large state-owned conglomerates according to the State-owned Assets Supervision and Administration Commission of China. Each of these conglomerates owns hundreds of subsidiaries and they compete actively with non-state-owned enterprises in many markets.

[2]Keith Bradsher. "China's Grip on Economy Will Test New Leaders". The New York Times. November 9, 2012.

[3]GAO Testimony before Committee on Ways and Means, House of Representatives, by David M. Walker, Comptroller General of the United States, May 26 2005, p.4.

Miravete, Seim and Thurk (2013) also investigate a government regulated market where the social planner (i.e., Pennsylvania state) is assumed to have consumer surplus concerns. Their work is based on the interesting observation that the Pennsylvania state imposes a statewide uniform markup policy on liquor, and one of its key findings is that the uniform markup policy induces cross-subsidization across customers compared with product-specific pricing scheme. Theoretically, investigating a consumer surplus moderated market is important because it allows a modeler to understand how the nature of competition changes as a result of some firms having consumer surplus concerns. Practically, it is relevant because it provides useful guidelines for both the policy makers and firms on how to compete in such markets.

This paper develops the structural model of retail price competition in which some firms (i.e., retailers) have consumer surplus concerns. We posit that if a firm has consumer surplus concerns, it optimizes a weighted average of its profit and total consumer surplus (i.e., $(1-\alpha)\cdot(\text{Profit})+\alpha\cdot(\text{Total Consumer Surplus})$), where α measures the degree of the firm's consumer surplus concerns and may vary from firm to firm. When α is set to 0 for all firms, the model reduces to the standard models of price competition. Hence our empirical model naturally nests standard models as special cases.

The total consumer surplus is modeled as the sum of the net utility of all consumers in the market, not just the consumers who are served by the firm itself. Unlike most existing research on healthcare markets, we do not resort to using a proxy for consumer welfare such as accessibility to patients (e.g., Newhouse, 1970; Frank and Salkever, 1991; Horwitz and Nichols, 2009).[4] Instead, we structurally derive a consumer surplus measure from first principles and hence, the derived measure is theoretically more sound and empirically more accurate.

We first investigate the theoretical properties of our model. We prove analytically that the total consumer surplus always increases when any firm decreases its price. In addition,

[4]An accessibility measure such as the number of beds and quantity of provided medical service is indeed relevant to the healthcare industry more than the consumer surplus measure because patients having insurance pay deductibles and as a consequence, their surplus does not significantly depend on the price level.

we show that a firm's price and profit always decrease when its concerns for consumer surplus increase. Both results prove useful for estimating the model and interpreting the key results in the empirical estimation.

Before describing the main empirical results, let us illustrate how equilibrium prices in a single-product duopoly market competition may change as a result of one firm having consumer surplus concerns, and how our model can yield meaningful insight on such competition. *Ceteris paribus*, the consumer surplus moderated firm will wish to lower its price in order to increase the total consumer surplus. This lower price has a direct effect of increasing the firm's market share as well as an indirect effect on the price of the other firm who is a pure profit maximizer. This other firm may decrease or increase its price in response to the lower price set by the consumer surplus moderated firm, depending on whether it is a strategic complement or substitute. As a consequence, the total effect on total consumer surplus becomes compounded. Our model is useful in empirically estimating this compound effect of a firm with consumer surplus concerns. Furthermore, upon observing market prices, a modeler can also infer the degree to which the firm is consumer surplus concerned, implying that our model can effectively disentangle the two forces causing low prices: consumer surplus concerns and price competition.

Is it empirically true, however, that a firm with consumer surplus concerns indeed lowers its equilibrium price? Let us compare prices of 2 dominant retailers in Singapore: *FairPrice* and *Dairy Farm*. *FairPrice* has 131 supermarket outlets and is the largest retailer with 49.04% total market share of consumer packaged goods. *FairPrice*, owned by the national labor union of Singapore (NTUC), has significantly deep ties with the government[5] and has openly stated its consumer surplus objectives as shown in the above quotations. On the other hand, *Dairy Farm*, the second largest retailer with a market share of 15.44%, is a pure profit maximizing firm.[6] Figure 1 shows the average prices of

[5] *FairPrice* is owned by a cooperative of National Trades Union Congress (NTUC), which has close ties with the Singapore government. The head of the NTUC is always a cabinet minister. Also, the boards of the cooperatives owned by NTUC always have government representatives. See Appendix for the summary table of historical secretary generals and presidents of NTUC and their concurrently held government positions while incumbent at NTUC.

[6] *Dairy Farm*, the 2nd largest grocery retailer in the market, is a private company and is publicly listed on the Singapore stock exchange. In addition, *Dairy Farm*'s annual report in 2011 puts forward a

the most popular 3 national brands that are carried by both retailers in 2 food categories: rice and infant milk. We choose rice and infant milk because they represent the top 2 spending categories among the essential goods. As shown, in both categories, *FairPrice* has a systematically lower price than *Dairy Farm*.[7] This pattern of lower prices in essential goods is indeed consistent with *FairPrice*'s firm objective of "moderating the cost of living" for consumers. However, it is also consistent with an alternative explanation that *FairPrice*, as the dominant retailer in the market, may enjoy lower marginal costs than its competitor.

[INSERT FIGURE 1 HERE]

Figure 2 shows the average price of the most popular 3 national brands carried by both retailers in the chocolate category. We choose the chocolate category because it has the highest market share among the discretionary categories in terms of consumer expenditure (ranked 15th in dollar spending).[8] Unlike in Figure 1, *FairPrice* did not charge a systematically lower price than *Dairy Farm*.[9] If *FairPrice* indeed had lower marginal costs due to its higher market power, one is likely to see the same pattern of low prices in Figure 1 occur in the chocolate category as well. Thus, we conjecture that standard models of competition may not be able to account for the differing pattern of average prices between essential and nonessential food. To account for this differing pattern of prices, one must explicitly account for *FairPrice*'s customer surplus concerns in the model. In addition, it will be also interesting to investigate how *Dairy Farm*'s prices respond to *FairPrice*'s lower prices arising from consumer surplus concerns.

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slogan that their main goal is to "satisfy the appetites of Asian shoppers for wholesome food and quality consumer and durable goods at competitive prices" and it does not specifically mention their consumer surplus goal.

[7]We conducted Student's t-test on the quarterly average prices of the two retailers. In both of the two product categories, we rejected the null hypothesis that the means of price distributions of the two retailers are equal ($p < 0.005$).

[8]The biscuit category is not considered despite higher expenditure because it is too differentiated over brands, flavor and types.

[9]We conducted Student's t-test on the quarterly average prices of the two retailers. We could not reject the null hypothesis that the mean of price distributions of the two retailers are equal ($p > 0.10$).

[INSERT FIGURE 2 HERE]

To empirically investigate whether *FairPrice* indeed has consumer surplus concerns and how such concerns affect the price competition, we apply our structural model to understand demand and supply behaviors in the Singaporean grocery market. Assuming that *FairPrice* possesses consumer surplus concerns while the other retailers do not, we empirically estimate *FairPrice*'s consumer surplus moderating parameter α. If *FairPrice* does not have consumer surplus concerns, the model would empirically yield a corner solution $\alpha = 0$, suggesting that the standard model describes the data well. We obtain a panel dataset from a major marketing research firm, which contains grocery shopping data of 646 households from October 2008 to December 2010 in Singapore. Besides capturing a total of 190,959 shopping trips and 709,112 product purchase incidences on 118 consumer packaged good categories, the comprehensive dataset also contains 18 demographic variables including monthly income, size of the household, and the primary grocery buyer's age.

The estimation results and counterfactual analysis based on the rice category show that (the estimation on infant milk and chocolate categories are currently underway):

1. *FairPrice*'s low prices on rice are indeed a consequence of its consumer surplus concerns and its α is estimated to be 0.13 averaged across all markets.

2. If the low prices were to maximize profit as in standard models, the estimated markups for *FairPrice* would be implausibly high (and hence their marginal costs would be implausibly low).

3. If *FairPrice* were to be profit maximizing, its profit would increase by 1.16% and the total consumer surplus would decrease by 7.18%. On the other hand, the profit of *Dairy Farm* would increase by 5.54%. Interestingly, the total social surplus would decrease by 3.21% suggesting that that profit maximization by all firms induces an inefficient outcome for the market.

4. The decrease in total consumer surplus due to all firms' profit maximization consists of two components: 1) the direct effect due to *FairPrice*'s higher prices under profit maximization objective and 2) the indirect effect due to price competition,

i.e., competitors' response to such higher prices. The indirect effect is positive, suggesting that competitors respond to *FairPrice*'s price increase by lowering their prices (i.e. becoming less aggressive in price competition as if they are its strategic substitutes). Despite the positive indirect effect, the total consumer surplus loss is retained at 97.60% of the direct effect.

The remainder of paper is organized as follows. Section 2 describes the model of a consumer surplus moderated price competition. Section 3 describes data on Singapore's grocery retail market. Section 4 discusses the empirical results. Section 5 concludes.

2 The Model

2.1 Notations

We consider M retail markets of a category of products served by I ($I \geq 2$) firms. Firms are indexed by i ($i = 1, 2, \ldots, I-1, I$) and markets are indexed by m ($m = 1, 2, \ldots, M-1, M$). Each market m consists of K^m consumers and offers the set $\mathcal{J}^m$ ($\mathcal{J}^m = \{0, 1, \ldots, J^m\}$) of products (i.e., choice menu) to consumers. Let $\mathcal{J}_i^m$ be the set of products offered by firm i in market m. Consumers are indexed by k ($k = 1, 2, \ldots, K^m-1, K^m$) and products are indexed by $j \in \mathcal{J}^m$.

Each firm i may or may not possess consumer surplus concerns and thus has a different objective $\Pi_i(.)$. Firms choose retail prices simultaneously to maximize their respective objectives. Let $\pi_i^m(.)$ be firm i's profit and $\Phi^m(.)$ be the total consumer surplus in market m, respectively. Specifically, we posit that firm i maximizes a weighted average of its profit and total consumer surplus in market m:

$$\Pi_i(\alpha_i) = (1 - \alpha_i) \cdot \pi_i^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m) + \alpha_i \cdot \Phi^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m).$$

where α_i is the weight assigned to consumer surplus and $\mathbf{p}_i^m$ is the price vector of all products of firm i and $\mathbf{p}_{-i}^m$ is the price vector of all products of all other firms in market m. Price equilibrium is realized as a result of each firm's optimal pricing decision.

Each firm i offers multiple products in a retail market of a grocery category. Firms offer both national and store brands to compete with each other and firms' offerings of national

brands may overlap. A product is defined as a brand-retailer combination and thus $\mathcal{J}_i^m$ and $\mathcal{J}_{i'}^m$ are mutually exclusive for all $i \neq i'$. A consumer in market m is assumed to choose a product out of her choice menu $\mathcal{J}^m$. We posit that the consumer choice process follows a random coefficient discrete choice model. We ignore choice dynamics over time in this paper.

In following 3 subsections, we describe the 3 components of price equilibrium in a consumer surplus moderated market: 1) demand model, 2) consumer surplus, and 3) supply model.

2.2 Demand

Consumer k ($k = 1, 2, \ldots, K^m$) chooses a product $j \in \mathcal{J}^m$ ($\mathcal{J}^m = \{0, 1, 2, \ldots, J^m\}$), where $\mathcal{J}^m$ is the entire product space of market m and $j = 0$ refers to the outside product. Let u_{kj}^m be the indirect utility that consumer k obtains from consuming product j in market m. Then,

$$\begin{aligned} u_{kj}^m &= -\beta_k \cdot p_j^m + \mathbf{x}_j^m \cdot \gamma_k + \xi_j^m + \epsilon_{kj}^m \\ &= v_{kj}^m + \epsilon_{kj}^m \end{aligned} \tag{2.1}$$

where

$$v_{kj}^m = -\beta_k \cdot p_j^m + \mathbf{x}_j^m \cdot \gamma_k + \xi_j^m$$

$$\begin{pmatrix} \beta_k \\ \gamma_k \end{pmatrix} = \begin{pmatrix} \beta \\ \gamma \end{pmatrix} + \begin{pmatrix} \Omega_p \\ \Omega_x \end{pmatrix} D_k + \begin{pmatrix} \Sigma_p \\ \Sigma_x \end{pmatrix} v_k$$

p_j^m is the price of product j in market m, $\mathbf{x}_j^m$ is the vector of observed product characteristics of product j in market m, D_k is a vector of consumer k's observed demographic variables, and v_k are consumer k's unobserved consumer characteristics. In addition, ξ_j^m is the product-market level disturbance. ϵ_{kj}^m is an i.i.d shock which follows a type I extreme value distribution. Ω_p and Ω_x are the price and product characteristic coefficients that are interacted with observed demographic variables, respectively. Σ_p and Σ_x are the price and product characteristic coefficients that are interacted with unobserved consumer characteristics, respectively. The mean of indirect utility for the outside product

in any market m, u_{k0}^m, is normalized to zero.

The above demand specification is the random coefficient discrete choice model, which is a generalization of the standard multinomial logit model (Berry, 1994; Berry et al., 1995; Nevo, 2000). The standard multinomial logit model is parsimonious because it expresses consumer k's underlying utility for a product j in terms of its price and characteristics only, instead of those of all products in the consumer's choice menu (Luce, 1959; Luce and Suppes, 1965; Marschak, 1960; McFadden, 1974, 2001). This simplification dramatically reduces the number of parameters to estimate in empirical analyses. However, the standard multinomial logit model possesses the independence of irrelevant alternatives (IIA) property that makes a sharp prediction on price elasticities: if two products have the same market share, they should have an identical cross-price elasticity with respect to any other product in the choice menu. This prediction, however, frequently does not describe actual choice substitution well. The above random coefficient discrete choice model overcomes this inadequacy by allowing for a more flexible and realistic substitution pattern. This is accomplished by interacting consumers' demographic variables with price and product characteristics. Hence, if consumers with similar demographic variables have similar preferences for certain product characteristics, they will have similar choice and substitution patterns.

Let s_j^m be the market share of product j in market m, s_{kj}^m be consumer k's probability of choosing product j in market m, and A_{kj}^m be the region of i.i.d. shocks $(\epsilon_{k0}^m, \ldots, \epsilon_{kJ^m}^m)$ that lead to consumer k's choosing product j. Then, by the random coefficient discrete choice model, s_j^m is given by:

$$\begin{aligned} s_j^m &= \int_D \int_v s_{kj}^m \, dF_v(v) \, dF_D(D) \\ &= \int_D \int_v \left(\int_{A_{kj}^m} dF_\epsilon(\epsilon) \right) dF_v(v) \, dF_D(D) \\ &= \int_D \int_v \frac{\exp(v_{kj}^m)}{\sum_{j \in \mathcal{J}^m} \exp(v_{kj}^m)} \, dF_v(v) \, dF_D(D) \end{aligned} \tag{2.2}$$

where $F_\epsilon(\epsilon)$ is a joint distribution function of the consumer-level i.i.d. product shocks,

$F_D(D)$ is a joint distribution function of the population's observed demographic variables, and $F_v(v)$ is a joint distribution function of the population's unobserved demographic shocks.

2.3 Consumer Surplus

To derive consumer surplus, we need to define consumer k's willingness to pay for product j in market m, denoted by ω_{kj}^m. We posit that ω_{kj}^m is the hypothetical price for product j that sets u_{kj}^m equal to u_{k0}^m, which is the utility of the outside product. As a consequence, the unit of consumer surplus is identical to that of profit. Since the mean of u_{k0}^m is normalized to zero, we have

$$-\beta_k \cdot \omega_{kj}^m + \mathbf{x}_j^m \cdot \gamma_k + \xi_j^m + \epsilon_{kj}^m = \epsilon_{k0}^m$$

and ω_{kj}^m is given by

$$\omega_{kj}^m = \frac{\mathbf{x}_j^m \cdot \gamma_k + \xi_j^m + \epsilon_{kj}^m - \epsilon_{k0}^m}{\beta_k} \tag{2.3}$$

Consumer k purchases product j in market m only if her indirect utility u_{kj}^m from product j is greater than that from the outside product u_{k0}^m, suggesting that consumer k was willing to pay more for product j up to the price point where u_{kj}^m becomes equal to u_{k0}^m.

We posit that consumer k's surplus Φ_{kj}^m for product j she purchased in market m equals her willingness to pay for product j less the price she actually paid. That is,

$$\Phi_{kj}^m = \omega_{kj}^m - p_j^m$$

Plugging in equations (2.1) and (2.3), we obtain:

$$\begin{aligned} \Phi_{kj}^m &= \frac{\mathbf{x}_j^m \cdot \gamma_k + \xi_j^m + \epsilon_{kj}^m - \epsilon_{k0}^m}{\beta_k} - p_j^m \\ &= \frac{u_{kj}^m - \epsilon_{k0}^m}{\beta_k} \end{aligned}$$

Note that $\Phi^m_{k0} = 0$. Φ^m_{kj} is specific to each purchase decision that consumer k makes. Consumer k's total surplus Φ^m_k is then defined as the expectation of this purchase decision specific surplus Φ^m_{kj} over all possible purchase scenarios. Specifically,

$$\begin{aligned}\Phi^m_k &= \sum_{j\in\mathcal{J}^m}\left(\int_{A^m_{kj}} \Phi^m_{kj}\; dF_\epsilon(\epsilon)\right) \\ &= \sum_{j\in\mathcal{J}^m}\left(\int_{A^m_{kj}} \frac{u^m_{kj}-\epsilon^m_{k0}}{\beta_k}\; dF_\epsilon(\epsilon)\right)\end{aligned}$$

Recall that A^m_{kj} is the region of i.i.d. shocks $(\epsilon^m_{k0},\ldots,\epsilon^m_{kJ^m})$ that lead to consumer k's choosing product j.

Finally, total consumer surplus Φ^m in market m with market size K^m is defined as the consumer surplus of the entire population where each consumer k enjoys consumer-specific surplus Φ^m_k. That is,

$$\begin{aligned}\Phi^m &= K^m\cdot\int_D\int_v \Phi^m_k\; dF_v(v)\, dF_D(D) \\ &= K^m\cdot\int_D\int_v\left(\sum_{j\in\mathcal{J}^m}\left(\int_{A^m_{kj}}\frac{u^m_{kj}-\epsilon^m_{k0}}{\beta_k}\; dF_\epsilon(\epsilon)\right)\right)\; dF_v(v)\, dF_D(D) \qquad (2.4)\end{aligned}$$

If ϵ^m_{kj} is distributed i.i.d Type I extreme value, Φ^m_{kj} has a closed-form log-sum formula (Small and Rosen, 1981) and Φ^m is expressed as:

$$\Phi^m = K^m\cdot\int_D\int_v\left(\frac{1}{\beta_k}\cdot\log\sum_{j\in\mathcal{J}^m}\exp\left(v^m_{kj}\right)\right)\; dF_v(v)\, dF_D(D) \qquad (2.5)$$

Theorem 1. *In market m, ceteris paribus, total consumer surplus decreases in p^m_j, $\forall j\in\mathcal{J}^m$, i.e., $\frac{\partial\Phi^m}{\partial p^m_j}<0$, $\forall j\in\mathcal{J}^m$.*

Proof of Theorem 1. See Appendix A. □

Theorem 1 demonstrates that if the price of *any* product offered in the market becomes lower, the total consumer surplus increases. This is because the total consumer surplus is defined as the sum of consumer surplus resulting from possible purchase scenarios of *all* products offered in the market, and not necessarily those products offered by the consumer surplus concerned firm.

2.4 Supply

We consider an oligopoly retail market of a product category where each firm i offers multiple products. Specifically, firm i chooses prices $\mathbf{p}_i^m$ that maximize a weighted average of its total profit π_i^m from all of its products, and total consumer surplus Φ^m in market m. That is, firm i's objective function is given by

$$\Pi_i^m(\alpha_i) = (1-\alpha_i)\cdot \pi_i^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m) + \alpha_i \cdot \Phi^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m), \tag{2.6}$$

where

$$\pi_i^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m) = K^m \cdot \sum_{j\in\mathcal{J}_i^m} s_j^m \cdot (p_j^m - c_j^m)$$

and c_j^m is the marginal cost (i.e., wholesale price) of product j in market m. Recall that the total consumer surplus is given in equation (2.4) as:

$$\Phi^m \;=\; K^m \cdot \int_D \int_v \left(\frac{1}{\beta_k} \cdot \log \sum_{j\in\mathcal{J}^m} \exp\left(v_{kj}^m\right) \right) \, dF_v(v)\, dF_D(D)$$

Note that firm i considers the total consumer surplus in market m instead of surplus of only those consumers it serves. $\alpha_i \in [0,1]$ is exogenously given for each firm i and is the weight assigned to the total consumer surplus, capturing the degree to which firm i is consumer surplus concerned, i.e., the higher α_i is, the bigger firm i's concern is. The proposed weighted objective function necessarily nests the standard objective function. When $\alpha_i = 0$, $\forall i$, equation (2.6) reduces to the standard objective function and gives rise to the standard price equilibrium solution. Thus, we set $\alpha_{i'} = 0$ for any pure profit

maximizing firm i' in our empirical estimation in the Section 4.

Price equilibrium is realized as a result of each firm's optimal pricing decision. Thus, for each firm i, each price p_j^m, $\forall j \in \mathcal{J}_i^m$, must satisfy its first order condition:

$$0 \;=\; (1-\alpha_i)\cdot\left(s_j^m + \sum_{j'\in\mathcal{J}_i^m}(p_{j'}^m - c_{j'}^m)\frac{\partial s_{j'}^m}{\partial p_j^m}\right) + \alpha_i \cdot \int_D\int_v \left(-s_{kj}^m\right)\, dF_v(v)\, dF_D(D)$$

2.5 Theoretical Properties

Theorem 2. *Let $p_j^m(\alpha_i)$ be the price of product j ($j \in \mathcal{J}_i^m$) that optimizes the objective function of a consumer-surplus concerned firm i in market m, given the other firms' prices. Then, $\forall j \in \mathcal{J}_i^m$, $p_j^m(\alpha_i)$ decreases in α_i. I.e., $\frac{\partial p_j^m(\alpha_i)}{\partial \alpha_i} < 0$, $\forall j \in \mathcal{J}_i^m$.*

Proof. See Appendix A. □

Theorem 3. *Given the other firms' prices, the profit of a consumer surplus concerned firm i decreases in α_i, i.e., $\frac{\partial \pi_i^m}{\partial \alpha_i} < 0$.*

Proof. See Appendix A. □

Theorem 2 suggests that the more a firm is concerned with consumer surplus, the lower the prices of *all* of its products are. It is noteworthy that prices of all products in the firm's portfolio decrease unanimously as a result of increased consumer surplus concerns. As a result, theorem 3 shows that its profit decreases as well given that other retailers keep their prices unchanged. As will be shown in Section 4.3, theorems 2 and 3 provide useful insight on how the total gain on consumer surplus due to a firm's consumer surplus concerns decomposes into the direct effect of these concerns and the indirect effect of competitors' response to them.

Let us emphasize an interesting feature of this weighted objective function: prices can be strategic substitutes even under the Hotelling model-like demand. Consider a price competition between two firms. Firms are denoted by i ($i = 1, 2$) and produce one product each at price p_i with zero marginal cost. These two products are horizontally differentiated (Hotelling, 1929)

and each consumer buys only one product. In this horizontally differentiated market, demand of firm i can be expressed as $D_i(p_i, p_{-i}) = 1 - p_i + p_{-i}$. Firm i chooses p_i that maximizes its profit $\pi_i(p_i, p_{-i}) = p_i \cdot D_i(p_i, p_{-i})$. Then, it can be shown that $\partial p_i^*(p_{-i})/\partial p_{-i} = 1/2 > 0$ and p_1 and p_2 are strategic complements of each other.

Now consider that firm 1 is consumer surplus concerned and optimizes a weighted objective function:

$$\Pi_1(p_1, p_2) \quad = \quad (1 - \alpha_1) \cdot \pi_1(p_1, p_2) + \alpha_1 \cdot (\text{Consumer Surplus})$$

where

$$\text{Consumer Surplus} \quad = \quad \frac{(1 - p_1 + p_2)^2}{2} + \frac{(1 - p_2 + p_1)^2}{2}$$

Then, firm 1's best response function depending on α_1 can be summarized as:

$$\frac{\partial p_1^*(p_2)}{\partial p_2} \begin{cases} \geq 0, & \text{if } 0 \leq \alpha_1 \leq \frac{1}{3} \text{ or } \alpha_1 \geq \frac{1}{2} \\ < 0, & \text{if } \frac{1}{3} < \alpha_1 < \frac{1}{2} \end{cases}$$

This suggests that when firm 1's level of consumer surplus concerns is too low ($\alpha_1 \leq \frac{1}{3}$), p_1 is a strategic complement of p_2, and firm 1 becomes more aggressive as firm 2 lowers its price. Note that when firm 1 weighs consumer surplus more than its profit ($\alpha_1 \geq \frac{1}{2}$), firm 1 will price at marginal cost regardless of p_2, i.e., $\frac{\partial p_1^*(p_2)}{\partial p_2} = 0$. On the other hand, when α_1 is moderate ($\frac{1}{3} < \alpha_1 < \frac{1}{2}$), firm 1 becomes less aggressive in price competition and p_1 increases (decreases) when p_2 decreases (increases). This is because consumer surplus increases in $(p_1 - p_2)^2$ and aggressive price competition (i.e., smaller price gap between p_1 and p_2) will cause reduction in consumer surplus.

3 Data

We use the household panel data in Singapore obtained from a major marketing research company. The company installed scanners at a representative sample of 646 households in the country and collected shopping basket data of each household for 9 quarters from October 2008

to December 2010.[10] The dataset contains households' purchasing history of a total of 118 consumer packaged goods.

The dataset also contains a total of 18 demographic variables for each household. Among those, we have the full name of the head of the household, household size, zip code, primary grocery buyer's age, household monthly income (one of the 11 income brackets), race, type of dwelling (private or subsidized public housing), work status (1 if primary grocery buyer works), maid (1 if the household has a maid), child below 4 (1 if the household has a child aged below 4), child between 5 and 14 (1 if the household has a child aged between 5 and 14), family (1 if the household is of family type and 0 if of singles/couples type), female below 9 (1 if the household has a female aged below 9), female between 10 and 19 (1 if the household has a female aged between 10 and 19), female between 20 and 29 (1 if the household has a female aged between 20 and 29), female between 30 and 39 (1 if the household has a female aged between 30 and 39), female between 40 and 49 (1 if the household has a female aged between 40 and 49), and female above 50 (1 if the household has a female aged above 50). Table 1 provides summary statistics for these variables. This rich set of demographic variables allows us to capture individual heterogeneity in product preferences and price sensitivities in the demand model. In our empirical estimation, we include household size, income, primary grocery buyer's age, work status, two race dummies (Chinese and Indian), child below 4, child between 5 and 14, and family in order to capture individual heterogeneity. The variable names used in empirical estimation and their corresponding description are listed in Appendix B.

[INSERT TABLE 1 HERE]

The primary grocery buyer at each household was instructed to scan all grocery items after each shopping trip.[11] For each product scanned, the dataset contains the following 7 variables: 1) barcode, 2) date of scanning, 3) the name of retailer where the item was bought, 4) product category, 5) price, 6) quantity purchased, and 7) product description (a combination of brand, product name, and packaging size). From the product description, we have created 3 additional variables (brand, product name, and packaging size), yielding a total of 9 variables for each product. All expenditures in the summary statistics below are in Singaporean currency (SGD).

[10]The company started recruiting panelists in early 2008. We only include households who joined before October 1, 2008 and who have shopped at least once per month since joining.

[11]The company uses store-level data to check whether the recruited households scan regularly. It appears that a significant majority of them do scan their shopping baskets regularly.

Table 2 shows the top 20 consumer packaged good categories by expenditures. As shown, the top 10 categories are infant milk (5.84%), rice (5.41%), liquid milk (4.52%), frozen food (4.38%), bread (3.29%), biscuit (2.73%), yoghurt (2.69%), facial care (2.65%), edible oil (3.26%), and detergent (2.51%). Note that most of these categories are food items. These top 10 categories accounted for 36.61% of the total spending on consumer packaged goods. Note that chocolate is ranked 15th in terms of expenditure.

Table 3 provides the summary statistics of households' shopping trips. In total, households spent $4,348,076.54 over the entire period, among which $2,195,455.72 (50.49%) was on consumer packaged goods. They made a total of 190,959 shopping trips to retailers and scanned 709,112 product purchase incidences. On average, a household made a total of 295.60 trips, spent $22.77 per trip and $249.29 per month, and recorded 3.71 purchase incidences on each trip. The average inter-shopping time was 4 days.

[INSERT TABLE 2 HERE]

[INSERT TABLE 3 HERE]

In the empirical estimation, we investigate top 2 nondiscretionary product categories (infant milk and rice), and 1 discretionary product category (chocolate).[12] Note that we determine whether a category is discretionary or nondiscretionary based on Classification of Individual Consumption According to Purpose (COICOP) provided by the United Nations statistics division.

Table 4 provides the distribution of total expenditure, total number of outlets, and total number of shopping trips by retailers. The same table also shows the dollar share of the top 3 retailers for the 3 focused categories (infant milk, rice, and chocolate). The top three retailers are *FairPrice*, *Dairy Farm*, and *Sheng Siong*. These 3 retailers received 55.03% of the total expenditures where *FairPrice* accounted for 34.44%, *Dairy Farm* 13.16% and *Sheng Siong* 7.42% respectively. Similarly, the top 3 retailers accounted for 53.88% of the total number of shopping trips. In both total expenditure and total number of shopping trips, *FairPrice* is clearly the

[12]Based on COICOP, we determine that categories such as facial care, laundry detergent and shampoo among top grossing categories fit more into the semi-discretionary categories, which consumers tend to downgrade instead of dispense with when facing financial restraint.

market leader.

[INSERT TABLE 4 HERE]

The market leadership of *FairPrice* is as pronounced when we restrict ourselves to the 3 focused consumer packaged good categories. As shown, *FairPrice* is the market leader for all 3 categories and received 51.34%, 55.04%, and 52.82% from the category-specific total expenditure of infant milk, rice, and chocolate, respectively. *Dairy Farm* is the second largest retailer enjoying 15.68%, 14.77%, and 18.64% in the three categories respectively.

4 Empirical Results

4.1 Estimation of Demand

A market for a product category is defined as a quarter of a year.[13] Since a purchase incidence contains combined information of total quantity purchased and packaging size, each purchase incidence is teased out by unit weight (e.g., 1kg for rice category). As a consequence, a consumer's choice problem reduces to the choice of a brand of unit weight. For example, if a household input a purchase incidence of 2 bags of 5kg *Royal Umbrella* rice, such purchase incidence is considered as 10 separate choice incidences of 1kg *Royal Umbrella*. Note that a choice model posits that a consumer (i.e., household) makes only one choice out of her choice menu in each market. Thus, we treat those teased out 10 choice incidences as if 10 households of exactly same demographic characteristics purchased the same 1kg *Royal Umbrella* respectively.

Each household's potential level of consumption is defined as the maximum quantity of unit weight it ever consumed in a market across all markets. For those households who never purchased the product category across all markets (but purchased other product categories and thus remain in the data), their potential level of consumption is defined as the bottom 1 percentile level of consumption of the households who ever purchased the product category.

Each product $j \in \mathcal{J}^m$ in market m is defined as a combination of retailer and brand. In the rice category, if the brand *Royal Umbrella* is offered by both *FairPrice* and *Dairy Farm*, then

[13] Since we only have national level data and Singapore is a small, well-connected city country, whose population is 5.3 millions and size is 3.5 times Washington D.C. of the United States, we define the entire nation as one geographical market.

Royal Umbrella by these two retailers are considered two different products. As a consequence, $\mathcal{J}_i^m$ and $\mathcal{J}_{i'}^m$ are mutually exclusive for any two firms $i \neq i'$ in each market m. Consumers' choice menu includes the top 19 products with highest market share and the outside product. *FairPrice*, *Dairy Farm* and *Sheng Siong* carry 7, 5, and 7 of these 19 products, respectively.We adjust prices by inflation using Singapore's quarterly CPI data. We derive the representative unit price of each product in a market (corresponding to the unit weight) as the weighted average of prices that are input into the scanner by each individual household, where the weight is the quantity of unit weight.

In the full model, price, product dummies and market dummies enter the mean-level utility and correlation between price and product-market level disturbance (ξ_j^m) is controlled for by these dummies.[14] Product characteristics that are interacted with demographic variables are: price, dummies of store brands by *FairPrice* and *Sheng Siong*, dummies of major national brands (*New Moon*, *Royal Umbrella*, and *Songhe*), and retailer dummies.[15] A total of 12 demographic variables interact with these product characteristics: household size, grocery buyer's age, monthly income, work status, child below 4, child between 5 and 14, family, female, maid, government-housing (*HDB*) and race dummies of Chinese and Indian.

Since our dataset contains rich individual level purchase records, we use the simulated maximum likelihood estimation method to identify the demand model parameters, where the unobserved independent demographic shock v_k is the only variable to be simulated.[16] Note that the observed demographic variables D_k do not need to be simulated since we know exactly what these variables are for each household.

Since we do not observe v_k, we define the expected probability p_{kj}^m that household k purchases product j *given its observed demographic variables* D_k as[17]:

[14]More rigorous parameter estimation using supply-side cost shock data as an instrument is under way.

[15]The mean level utilities of these dummy variables are estimated by projecting estimated product dummies onto these variables.

[16]We searched over parameter values to maximize the simulated log-likelihood using unconstrained nonlinear optimization in the MATLAB optimization toolbox.

[17]We assume that v_k follows the standard normal distribution and is independent between product characteristics it interacts with. Final estimation results are based on 100 random draws of v_k. Random draws are generated using the Halton sequence. We varied the number of draws up to 200 and found similar results.

$$
\begin{aligned}
p_{kj}^m &= \mathbb{E}_v\left[s_{kj}^m\right] \\
&= \int_v \frac{\exp(v_{kj}^m)}{\sum_{j\in\mathcal{J}^m}\exp(v_{kj}^m)}\, dF_v(v)
\end{aligned}
$$

where s_{kj}^m is defined in equation (2.2) as household k's probability of purchasing product j given both its observed and unobserved demographic variables.

Let $o_k^m \in \mathcal{J}^m$ and $\mathbf{o}^m = (o_1^m, o_2^m, \ldots, o_{K^m}^m)$ be household k's observed product choice and the vector of observed product choices by all K^m households in market m, respectively. Then, the likelihood $L(o_k^m)$ of observing choice o_k^m by household k is given by:

$$
L(o_k^m) = \prod_{j\in\mathcal{J}^m} \left(p_{kj}^m\right)^{\mathbf{1}(j,o_k^m)}
$$

where

$$
\mathbf{1}(j, o_k^m) = \begin{cases} 1, & \text{if } j = o_k^m \\ 0, & \text{if } j \neq o_k^m \end{cases}
$$

The total log-likelihood of observing entire data, $LL(\mathbf{o}^1, \mathbf{o}^2, \ldots, \mathbf{o}^M)$, is then given by:

$$
\begin{aligned}
LL(\mathbf{o}^1, \mathbf{o}^2, \ldots, \mathbf{o}^M) &= \sum_{m=1}^{M}\sum_{k=1}^{K^m} \log L(o_k^m) \\
&= \sum_{m=1}^{M}\sum_{k=1}^{K^m} \log\left(\prod_{j\in\mathcal{J}^m}\left(p_{kj}^m\right)^{\mathbf{1}(j,o_k^m)}\right)
\end{aligned}
$$

Table 5 list the parameter estimates of the full demand model. It has a total of 17 rows and 5 columns. The 17 rows are respectively labeled mean, standard deviation, each of the 12 demographic variables that are interacted with product characteristics, maximized log-likelihood, average price coefficient of the population, and the percentage of price coefficients that are positive in the model. The 5 columns are respectively labeled the 5 product characteristics the 12 demographic variables interact with: price, constant, store brand dummy, *FairPrice* dummy and *Dairy Farm* dummy.

The first row, mean, shows the mean level utility coefficient for each product characteristic variable, i.e, how the mean level utility responds to $1 price increase or to each dummy variable. First column shows that the price coefficient for mean level utility is negative at -1.91 at a statistically significant level. We estimate the full model with product and market dummies and thus the last 4 product characteristics (constant, store brand dummy, *FairPrice* dummy and *Dairy Farm* dummy) are subsumed in product dummies in the mean-level utility estimation. Hence, we project the estimated product dummies onto these 4 product characteristic variables to estimate their mean level utilities. Estimates obtained this way are listed in the last 4 columns of the first row. The model estimates that baseline utility of any product is 0.73 higher than that of the outside product. Store brand *NTUC* induces 4.28 higher mean level utility than non-major national brands. This is because unlike in most other countries where store brands are usually not popular, store brand rice occupies highest market shares in Singapore.[18] Also, as will be shown in Table 5, own price elasticities of these two brands are lower than other high market share products, suggesting that the store brands increase households' utility and makes them less sensitive towards price change.

[INSERT TABLE 5 HERE]

The second row, standard deviation, captures the effect of unobserved demographic variables. We see that the unobserved demographic effect is less significant for all 5 product characteristics than other parameter estimates. This implies that individual heterogeneity is effectively captured by the 12 observed demographic variables that are interacted in the full model.

The 12 demographic variables in the 3rd to the 14th row in general interact significantly with the 5 product characteristic variables. Quite a few parameter estimates are worth highlighting. Higher income level households are less price sensitive and prefer *FairPrice* more. They also less prefer *NTUC* brand. 16% of Singaporean households hire maids and interestingly, households with maids are more price sensitive. Chinese are less price sensitive than Indian or Malay (the base group).

The value of maximized log-likelihood is -158380.19, while that of the standard logit model is -163650.15. Log-likelihood test rejects the standard logit model in favor of the full model

[18] *FairPrice*'s two major store brands, *NTUC* and *Golden Royal Dragon*, have a total of 22.68% of market share (including outside product), which is about 51.57% of market share conditional on rice consumption.

($p < 0.001$). About 97.21% of the entire population has negative price coefficients and price increase strictly reduces their utility.

Table 6 list the own- and cross-price elasticities of the top 4 brands offered by *FairPrice* and *Dairy Farm*. Price elasticities are estimated at the median price level. We see that own price elasticities range from -2.20 to -3.48 among top 4 brands of the two retailers, suggesting that for every 1 percent increase in the price of a major product, its own market share reduces by about 2.20 to 3.48 percent. Given the high market share of *FairPrice*, it is not surprising that cross-price elasticities of *FairPrice*'s products are bigger for the other *FairPrice*'s own products than for *Dairy Farm*'s products.

[INSERT TABLE 6 HERE]

4.2 Estimation of Supply

For notational simplicity, hereafter subscript i' refers to the profit maximizing firm (i.e., *Dairy Farm* and *Sheng Siong*) and subscript i refers to the consumer surplus concerned firm (i.e., *FairPrice*). Setting $\alpha_{i'} = 0$ for both *Dairy Farm* and *Sheng Siong*,[19] we estimate in this section: 1) the consumer surplus moderating parameter α_i for *FairPrice* and 2) the marginal costs and markups of all products offered in the market.

In the following 2 subsections, we describe the optimization problem of firms competing in the consumer surplus moderated market. The first subsection recaps the objective function and optimization problem of a profit maximizing firm (*Dairy Farm* and *Sheng Siong*). The second subsection formulates those of a consumer surplus concerned firm (*FairPrice*) and discusses how α_i can be identified.

4.2.1 Profit Maximizing Firm

A pure profit maximizing firm i' maximizes

$$\sum_{j \in \mathcal{J}_{i'}^m} s_j^m \cdot (p_j^m - c_j^m)$$

[19]The estimation of fully general model where α_i of all three retailers are identified is under way.

Thus, each product $j \in \mathcal{J}_{i'}^m$ satisfies its first order condition:

$$0 \quad = \quad s_j^m + \sum_{j' \in \mathcal{J}_{i'}^m} (p_{j'}^m - c_{j'}^m) \frac{\partial s_{j'}^m}{\partial p_j^m}$$

Let $\mathbf{c}_{i'}^m$ be the vector of marginal cost and $\mathbf{s}_{i'}^m$ be the vector of market share of all products offered by firm i' in market m. Let $\Gamma_{i'}^m$ be the own- and cross-price elasticity matrix of firm i' in market m, where $\Gamma_{i'}(j, j') = \frac{\partial s_{j'}^m}{\partial p_j^m}$, $j, j' \in \mathcal{J}_{i'}^m$. Then, the marginal cost vector $\mathbf{c}_{i'}^m$ solving the above set of first order conditions is given by

$$\mathbf{c}_{i'}^m \quad = \quad \mathbf{p}_{i'}^m + (\Gamma_{i'}^m)^{-1} \cdot \mathbf{s}_{i'}^m \tag{4.1}$$

Hence, upon observing market prices and correctly identifying the underlying demand model, we can structurally derive the marginal costs of all products offered by profit maximizing firms, i.e., *Dairy Farm* and *Sheng Siong*.

4.2.2 Consumer Surplus Concerned Firm

We consider a consumer surplus concerned firm i with consumer surplus moderating parameter α_i. Identifying marginal costs and α_i for firm i is not as simple as the above. This is because there are more degrees of freedom than the number of first order conditions. Specifically, maximizing equation (2.6) is equivalent to solving:

$$\mathbf{c}_i^m \quad = \quad \mathbf{p}_i^m + (\Gamma_i^m)^{-1} \cdot \left(\mathbf{s}_i^m + \frac{\alpha_i}{(1 - \alpha_i)} \cdot \Lambda_i^m \right) \tag{4.2}$$

where Λ_i^m is a $|\mathcal{J}_i^m| \times 1$ vector[20] and

$$\Lambda_i^m(j, 1) = \frac{\partial \Phi^m}{\partial p_j^m}, \qquad j \in \mathcal{J}_i^m.$$

Note that equation (4.2) is a system of first order conditions that are just as many as the number of products of firm i. However, what we wish to identify is all of its marginal costs as well as α_i, the total number of which exceeds the number of first order conditions by 1. Thus, identification becomes infeasible without further information on the firm's marginal cost or its degree of consumer surplus concerns.

[20] $|\mathcal{J}_i^m|$ refers to the cardinality of product space $\mathcal{J}_i^m$.

Empirically, we go about this issue by utilizing a separate dataset that we obtained from the highest market share national brand rice company: *Royal Umbrella* . The dataset from the *Royal Umbrella* company contains quarterly wholesale prices for all 3 retailers (*FairPrice*, *Dairy Farm*, and *Sheng Siong*) of its rice brand under the same name, *Royal Umbrella*. Availability of wholesale prices on *FairPrice*'s *Royal Umbrella* will effectively reduce 1 degree of freedom that needs be identified and will make feasible identification of the rest of *FairPrice*'s marginal costs as well as its α_i.

The identification process of α_i is formulated as follows. Let j denote the product subscript for *FairPrice*'s *Royal Umbrella*. From equation (4.2), we obtain

$$c_j^m = p_j + (\Gamma_i^m)_j^{-1} \cdot \left(\mathbf{s}_i^m + \frac{\alpha_i}{(1-\alpha_i)} \cdot \Lambda_i^m \right) \tag{4.3}$$

where $(\Gamma_i^m)_j^{-1}$ refers to the j-th row of $(\Gamma_i^m)^{-1}$. Inverting equation (4.3), we can identify α_i as:

$$\hat{\alpha}_i = \frac{p_j^m - c_j^m + (\Gamma_i^m)_j^{-1} \cdot \mathbf{s_i^m}}{p_j^m - c_j^m + (\Gamma_i^m)_j^{-1} \cdot \mathbf{s_i^m} - (\Gamma_i^m)_j^{-1} \cdot \Lambda_i^m}$$

Table 7 lists the estimate of α_i averaged across all markets and the prices and marginal costs of products of all three firms. Marginal costs are listed in the parentheses next to the prices. Out of the 19 products, 4 national brands overlap between *FairPrice* and *Dairy Farm*.[21] *FairPrice*'s consumer surplus moderating parameter $\hat{\alpha}_i$ is estimated to be about 0.13 on average, suggesting that *FairPrice* weighs consumer surplus to profit in a 1 to 7 ratio. In other words, to *FairPrice*, every \$7 increase in consumer surplus is worth as much as \$1 increase in its profit.

[INSERT TABLE 7 HERE]

The results show that prices and estimated marginal costs go hand in hand overall. *FairPrice*'s marginal costs are lower in general since its prices are lower. Given their high market share, it is not surprising to see that prices of *FairPrice*'s store brands (*Double*, *NTUC*, and *Golden Royal Dragon*) are cheaper than or very similar to the estimated marginal cost of some national brands such as *Royal Umbrella* and *Songhe*. Estimated marginal costs for the same overlapping brands are in general lower for *FairPrice*, suggesting that *FairPrice* enjoys lower wholesale

[21] All national brands except for the store brands are overlapping in the data but some are excluded from the empirical estimation (e.g., *FairPrice*'s *Golden Pineapple*) since its market share is negligible.

prices due to its high market share in the grocery market.

4.3 Counterfactual Analysis

In this section, we conduct a counterfactual analysis of our model setting $\alpha_i = 0$, i.e., *FairPrice* is purely profit driven like other firms and our model reduces to the standard model of price competition. We study 3 aspects of this counterfactual analysis: 1) counterfactual equilibrium prices, 2) counterfactual profit level of all firms, and 3) counterfactual consumer surplus level and the decomposition of surplus gain due to consumer surplus concerns into the direct effect of α_i and indirect effect of price competition among firms.

Let us first briefly investigate why the standard price competition model is not likely to correctly describe the pricing pattern of *FairPrice* observed in the data. We test this by artificially setting α_i to zero and estimate *FairPrice*'s marginal costs. Table 8 juxtaposes the marginal costs and product markups of *FairPrice* predicted by the standard model with those predicted by our model. As shown, the marginal costs of the top 2 brands, *NTUC* and *Golden Royal Dragon*, are estimated to be really low at 0.93 and 0.68 respectively, yielding unreasonably high markups of 133.00% and 171.58% respectively. Note that when the same standard model is applied to *Dairy Farm* and *Sheng Siong*, the estimated marginal costs and markups are in a sensible range. Their markups from 43.49% to 75.79%. Were the standard model to predict the data well, it would not give such distinctively different ranges of estimated markups between *FairPrice* and other firms. Thus, the standard price competition model may not be adequate to capture the underlying pricing behavior of firms shown in the data.

[INSERT TABLE 8 HERE]

We now describe each of the 3 aspects of the counterfactual analysis of our model. First, Table 9 shows the counterfactual equilibrium prices of all firms when α_i is set to zero (i.e., *FairPrice* only maximizes its profit) as well as the observed market prices where $\alpha_i = 0.13$. Prices that increase under the counterfactual analysis are marked with asterisks. The counterfactual analysis reveals that if *FairPrice* were to be profit maximizing, prices of all of its products would increase by 6.09% on average. That the store brands' prices would increase the most suggests that *FairPrice* would enjoy much higher markups for store brands but it is letting them go due to its consumer surplus concerns. On the other hand, prices of *Dairy Farm* and *Sheng Siong* all

decrease in response to *FairPrice*'s increased prices. As a consequence, price dispersion among firms has widened.

[INSERT TABLE 9 HERE]

Next, we investigate percentage changes in all firms' profit, consumer surplus and total surplus. Table 10 compares profits when $\alpha_i = 0$ with those when $\alpha_i = 0.13$. As shown, if *FairPrice* were profit maximizing, the profit of *FairPrice*, *Dairy Farm* and *Sheng Siong* would all increase by 1.16%, 5.54% and 6.47% respectively. It is interesting that these profits increase for quite different reasons: *FairPrice*'s profit increases because it increases prices for almost all of its products as in Table 9. Note that higher prices induce two opposite effects on the profit: the *market share effect* and *surplus extraction effect*. First, the *market share effect* means that higher prices decrease market share. Second, the *surplus extraction effect* means that the firm extracts more surplus for each product sold due to higher price. Under the profit maximization objective, *FairPrice* increases its prices so that the surplus extraction effect overrides the market share effect, which in turn increases its profit. On the contrary, the other two firms' profit increases despite their lower prices due to the market share effect.

In addition, Table 10 shows that consumer surplus would decrease by 7.18% and the total surplus, which is defined as the sum of profit (i.e., retailer surplus) and consumer surplus, would decrease by 3.21%. The latter is particularly worth highlighting since it suggests that profit maximization by all three retailers decreases total surplus in the market in spite of increase profit level of all retailers, and thus induces an inefficient outcome for the market.

[INSERT TABLE 10 HERE]

Lastly, we decompose the loss in consumer surplus into two effects: direct and indirect effects. In a nutshell, the direct effect captures the sole effect of profit maximizing behavior of *FairPrice*. That is, it captures how much the consumer surplus would decrease due to loss of consumer surplus concerns by *FairPrice*. As shown in theorem 1, *FairPrice* would increase prices of *all* of its products as it becomes more profit concerned. Note that this will then be followed by price competition among firms and the new price equilibrium will be reached ultimately. The indirect effect captures the effect of such price competition that follows.

Let us formulate the direct and indirect effect. Let $\mathbf{p_i^m}(\alpha_i)$ and $\mathbf{p_{-i}^m}(\alpha_i)$ be respectively the

equilibrium prices of *FairPrice* and those of the other firms in market m when *FairPrice*'s consumer surplus moderating parameter is α_i. Further, let $BR_i(\mathbf{p}^{\mathbf{m}}_{-\mathbf{i}} \,|\, \alpha_i)$ be *FairPrice*'s prices that best respond to $\mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}$ given α_i, i.e., $BR_i(\mathbf{p}^{\mathbf{m}}_{-\mathbf{i}} \,|\, \alpha_i)$ optimizes its objective function given $\mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}$ and α_i. Then,

$$\begin{aligned}
\text{Direct Effect} &= \Phi^m(BR_i(\mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}(\alpha_i) \,|\, 0), \mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}(\alpha_i))) - \Phi^m(\mathbf{p}^{\mathbf{m}}_{\mathbf{i}}(\alpha_i), \mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}(\alpha_i))) \\
\text{Indirect Effect} &= \Phi^m(\mathbf{p}^{\mathbf{m}}_{\mathbf{i}}(0), \mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}(0))) - \Phi^m(BR_i(\mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}(\alpha_i) \,|\, 0), \mathbf{p}^{\mathbf{m}}_{-\mathbf{i}}(\alpha_i)))
\end{aligned}$$

Table 11 shows the direct and indirect effect of decreasing in α_i from 0.13 to 0. Two aspects are worth highlighting. First, the size of indirect effect (0.0009) is marginal so that the total surplus loss at the new price equilibrium (0.0375) is 97.60% of the direct effect (0.0366), which is what *FairPrice* would achieve due to α_i decreasing to 0 were other firms' prices to remain unchanged, i.e., no subsequent price competition. Second, we see that the indirect effect is positive at +0.0009. This is because *Dairy Farm* and *Sheng Siong* decrease its prices as shown in Table 9, and behave as if they are strategic substitutes of *FairPrice*.

4.4 Validity Check

In this section, we conduct a validity check using a separate dataset on the quarterly aggregate import price of rice obtained from the International Enterprise of Singapore.[22] Through this validity check, we confidently reject the standard model of price competition in favor of the consumer surplus moderated model.

[INSERT TABLE 12 HERE]

Singapore is a small city country that does not have enough land to produce rice. Thus, it imports its entire rice from other countries, mostly from Thailand. As a consequence, the import price of rice represents the (minimum) marginal cost for wholesalers, which is listed in the 1st row of Table 12. On the other hand, the marginal costs of retailers recovered from the standard model (listed in the 2nd row) or our model (listed in the 3rd row) represent the (maximum) price

[22]International Enterprise of Singapore is a statutory board under the Ministry of Trade and Industry of the Singapore Government that facilitates the overseas growth of Singapore-based companies and promotes international trade. All prices and quantities of rice imported into Singapore should be reported to International Enterprise of Singapore.

at which the wholesalers may sell rice to the retailers. Considering the wholesalers' positive markup, these recovered marginal costs of retailers must be higher than the import price of rice.

Nonetheless, as shown in Table 12, the marginal costs recovered from the standard model are lower than the import price of rice in almost all quarters, or only marginally bigger. To the contrary, marginal costs recovered from our consumer surplus moderated model are reasonably bigger than the import price of rice, likely reflecting the wholesalers' markup. As a consequence, we confidently reject the standard model of price competition in favor of our model and validate that our model better explains the retailers' pricing pattern of rice in the Singaporean grocery retail market.

5 Conclusion

The assumption that firms are interested only in maximizing their own profit has been the pillar of standard price competition models. However, when government actively intervenes or participates in a market, this assumption may not capture the behavior of firms well because some firms may choose prices to maximize a weighted sum of profit and consumer surplus. In such markets, standard models may wrongly predict the outcome of competition or produce systematic biases in parameter estimates.

This paper develops a new structural model of consumer surplus moderated price competition. Since the measure for consumer surplus is explicitly derived as the sum of consumers' net utility from all possible purchase scenarios, it is theoretically more sound and empirically more accurate than other surplus measures used in prior literature. Our model nests standard price competition models as special cases. It allows one to empirically estimate not only the degree of consumer surplus concerns a firm has but also the associated gain in total consumer surplus. Theoretically, our model predicts that total consumer surplus increases whenever the price of any product decreases, and *ceteris paribus*, a firm would always decrease all of its product prices as its concerns for consumer surplus increase. The competitive response by other firms may be either more or less aggressive.

We also apply our model to the Singapore grocery retail market data, where the dominant retailer, *FairPrice*, publicly commits to consumer surplus concerns. Particularly, we investigate the rice category, which is one of the primary nondiscretionary categories within the country.

We find that 1) *FairPrice*'s consumer surplus concern is estimated to be about 0.13, 2) standard price competition model would predict *FairPrice*'s product marginal costs to be implausibly low compared with those of its competitors, 3) under the profit maximization objective, *FairPrice*'s profit would increase by 1.16% and the total consumer surplus would decrease by 7.18%. 4) the indirect effect of *FairPrice*'s profit maximization is positive, suggesting that competitors respond to *FairPrice*'s higher price level by lowering their prices, i.e., behave as *FairPrice*'s strategic substitutes. Even though the total consumer surplus gain is mitigated by the negative indirect effect, the total consumer surplus gain is retained at 97.60% of the direct effect.

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Appendix A: Proofs of Theorems

Proof of Theorem 1. Recall that

$$\begin{aligned} u_{kj}^m &= -\beta_k \cdot p_j^m + \mathbf{x}_j^m \cdot \gamma_k + \xi_j^m + \epsilon_{kj}^m \\ &= v_{kj}^m + \epsilon_{kj}^m \end{aligned}$$

Let $u_k^m(i)$ be the i-th order statistic among u_{kj}^m that result from realized $\{\epsilon_{k0}^m, \ldots, \epsilon_{kJ}^m\}$. Thus, A_{kj}^m can be interpreted as the region where $u_k^m(1) = u_{kj}^m$. Then, the total consumer surplus can be expressed as:

$$\begin{aligned} \Phi^m &= \int_D \int_v \left(\sum_{j \in \mathcal{J}^m} \left(\int_{A_{kj}^m} \frac{u_{kj}^m - \epsilon_{k0}^m}{\beta_k} \, dF_\epsilon(\epsilon) \right) \right) \, dF_v(v) \, dF_D(D) \\ &= \int_D \int_v \left(\int \frac{u_k^m(1) - u_{k0}^m}{\beta_k} \, dF_\epsilon(\epsilon) \right) \, dF_v(v) \, dF_D(D) \\ &= \int_D \int_v \left(\int \frac{u_k^m(1)}{\beta_k} \, dF_\epsilon(\epsilon) \right) \, dF_v(v) \, dF_D(D) - \int_D \int_v \left(\int \frac{u_{k0}^m}{\beta_k} \, dF_\epsilon(\epsilon) \right) \, dF_v(v) \, dF_D(D) \end{aligned}$$

Since the second term is irrespective of p_j^m,

$$\begin{aligned}\frac{\partial \Phi^m}{\partial p_j^m} &= \frac{\partial}{\partial p_j^m}\left(\int_D \int_v \left(\int \frac{u_k^m(1)}{\beta_k}\, dF_\epsilon(\epsilon)\right)\, dF_v(v)\, dF_D(D)\right) \\ &= \int_D \int_v \frac{1}{\beta_k} \cdot \left(\frac{\partial}{\partial p_j^m} u_k^m(1)\, dF_\epsilon(\epsilon)\right)\, dF_v(v)\, dF_D(D)\end{aligned}$$

Thus, it suffices to show that $\frac{\partial}{\partial p_j^m}\int u_k^m(1)\, dF_\epsilon(\epsilon) < 0$. Let $G(u_k^m(1)\,|\,p_j^m, p_{-j}^m)$ be the distribution of order statistic $u_k^m(1)$, given the price of product j, p_j^m, and the price vector of all other products, p_{-j}^m. We complete the proof by showing below that $G(u_k^m(1)\,|\,p_j^m, p_{-j}^m)$ first-order stochastically dominates $G(u_k^m(1)\,|\,p', p_{-j}^m)$ for any $p' < p_j^m$.

For any $p' < p_j^m$,

$$\begin{aligned}\Pr[u_k^m(1) \le z\,|\,p_j^m, p_{-j}^m] &= \prod_{j' \in \mathcal{J}^m} \Pr[u_{kj'}^m \le z\,|\,p_{j'}^m] \\ &= \Pr[u_{kj}^m \le z\,|\,p_j^m] \cdot \prod_{j' \ne j, j' \in \mathcal{J}^m} \Pr[u_{kj'}^m \le z\,|\,p_{j'}^m] \\ &= \Pr[\epsilon_{kj}^m \le z + \beta_k \cdot p_j^m - (\mathbf{x}_j^m \cdot \gamma_k + \xi_j^m)] \cdot \prod_{j' \ne j, j' \in \mathcal{J}^m} \Pr[u_{kj'}^m \le z\,|\,p_{j'}^m] \\ &< \Pr[\epsilon_{kj}^m \le z + \beta_k \cdot p' - (\mathbf{x}_j^m \cdot \gamma_k + \xi_j^m)] \cdot \prod_{j' \ne j, j' \in \mathcal{J}^m} \Pr[u_{kj'}^m \le z\,|\,p_{j'}^m] \\ &= \Pr[u_{kj}^m \le z\,|\,p'] \cdot \prod_{j' \ne j, j' \in \mathcal{J}^m} \Pr[u_{kj'}^m \le z\,|\,p_{j'}^m] \\ &= \Pr[u_k^m(1) \le z\,|\,p', p_{-j}^m]\end{aligned}$$

Hence, $G(u_k^m(1)\,|\,p_j^m, p_{-j}^m)$ first-order stochastically dominates $G(u_k^m(1)\,|\,p', p_{-j}^m)$ for any $p' < p_j^m$ and the theorem is proved. □

Proof of Theorem 2. The equilibrium price $p_j^m(\alpha_i)$ of product j in market m satisfies its first order condition:

$$(1-\alpha_i) \cdot \frac{\partial \pi_i^m}{\partial p_j^m(\alpha_i)} + \alpha_i \cdot \frac{\partial \Phi^m}{\partial p_j^m(\alpha_i)} = 0$$

Let $g(\alpha_i, p_j^m(\alpha_i))$ denote the lefthand side of the above equation so that α_i and corresponding equilibrium price $p_j^m(\alpha_i)$ satisfies

$$g(\alpha_i, p_j^m(\alpha_i)) = 0$$

Rearranging $g(\alpha_i, p_j^m(\alpha_i))$, we obtain

$$\frac{\partial \pi_i^m}{\partial p_j^m(\alpha_i)} + \alpha_i \cdot \left(\frac{\partial \Phi^m}{\partial p_j^m(\alpha_i)} - \frac{\partial \pi_i^m}{\partial p_j^m(\alpha_i)}\right) = 0$$

Since $\frac{\partial \Phi^m}{\partial p_j^m(\alpha_i)} < 0$ by theorem 1, it must be the case that

$$\frac{\partial \pi_i^m}{\partial p_j^m(\alpha_i)} > 0 \tag{5.1}$$

so that $g(\alpha_i, p_j^m(\alpha_i)) = 0$. Hence,

$$\left(\frac{\partial \Phi^m}{\partial p_j^m(\alpha_i)} - \frac{\partial \pi_i^m}{\partial p_j^m(\alpha_i)} \right) < 0 \tag{5.2}$$

Besides, if $p_j^m(\alpha_i)$ is the equilibrium price of product j of firm i, then firm i's weighted objective function has to be concave in p_j^m at $p_j^m(\alpha_i)$ since $p_j^m(\alpha_i)$ is the objective function maximizer. Specifically,

$$\left. \frac{\partial g(\alpha_i, p_j^m)}{\partial p_j^m} \right|_{p_j^m(\alpha_i)} = (1-\alpha_i) \cdot \left. \frac{\partial^2 \pi_i^m}{(\partial p_j^m)^2} \right|_{p_j^m(\alpha_i)} + \alpha_i \cdot \left. \frac{\partial^2 \Phi^m}{(\partial p_j^m)^2} \right|_{p_j^m(\alpha_i)} < 0 \tag{5.3}$$

We shall use the implicit function theorem to prove the theorem. By the implicit function theorem, it suffices to show that

$$\frac{\partial p_j^m(\alpha_i)}{\partial \alpha_i} = -\frac{\frac{\partial g(\alpha, p_j^m)}{\partial \alpha_i}}{\frac{\partial g(\alpha, p_j^m)}{\partial p_j^m}} < 0$$

By equation (5.2),

$$\frac{\partial g(\alpha, p_j^m)}{\partial \alpha_i} = \left(\frac{\partial \Phi^m}{\partial p_j^m(\alpha_i)} - \frac{\partial \pi_i^m}{\partial p_j^m(\alpha_i)} \right) < 0$$

and by equation (5.3),

$$\frac{\partial g(\alpha, p_j^m)}{\partial p_j^m} < 0$$

Hence,

$$\frac{\partial p_j^m(\alpha_i)}{\partial \alpha_i} < 0$$

as desired.

□

Proof of Theorem 3. By chain rule,

$$\frac{\partial \pi_i^m}{\partial \alpha_i} = \sum_{j \in \mathcal{J}^m} \frac{\partial p_j^m}{\partial \alpha_i} \cdot \frac{\partial \pi_i^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m)}{\partial p_j^m}$$

Since the other firms' prices are assumed to remain unchanged, we have

$$\frac{\partial p_j^m}{\partial \alpha_i} = 0, \qquad \forall j \notin \mathcal{J}_i^m$$

Thus,

$$\frac{\partial \pi_i^m}{\partial \alpha_i} = \sum_{j \in \mathcal{J}_i^m} \frac{\partial p_j^m}{\partial \alpha_i} \cdot \frac{\partial \pi_i^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m)}{\partial p_j^m}$$

We showed that $\frac{\partial p_j^m}{\partial \alpha_i} < 0$, $\forall j \in \mathcal{J}_i^m$ in theorem 2 and $\frac{\partial \pi_i^m(\mathbf{p}_i^m, \mathbf{p}_{-i}^m)}{\partial p_j^m} > 0$, $\forall j \in \mathcal{J}_i^m$ in equation (5.1). Hence, $\frac{\partial \pi_i^m}{\partial \alpha_i} < 0$ as desired. □

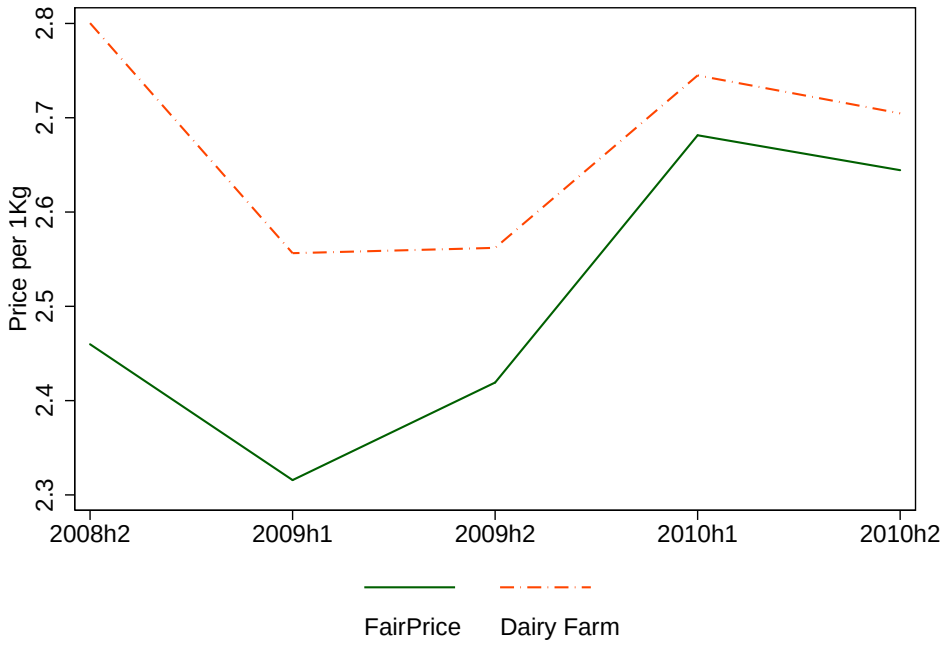
Appendix B: Definition of Variables

- *INCOME* : *INCOME* is monthly income input as one of the 11 income brackets of [$0, $1000], [[$1000, $1500], [$1500, $2000], [$2000, $2500], [$2500, $3000], [$3000, $3500], [$3500, $4000], [$4000, $6000], [$6000, $8000], [$8000, $10000], and above $10000.
- *HHOLDSIZE* : *HHOLDSIZE* is the size of the household.
- *AGE* : *AGE* is the age of the primary grocery buyer.
- *DWELLING* : *DWELLING* is a dummy variable that is equal to one if the household lives in a subsidized public housing and zero if in a private housing.
- *WORK* : *WORK* is a dummy variable that is equal to one if the primary grocery buyer works.
- *MAID* : *MAID* is a dummy variable that is equal to one if the household has a maid.
- *CHILD04* : *CHILD04* is a dummy variable that is equal to one if the household has a child aged 4 or below.
- *CHILD514* : *CHILD514* is a dummy variable that is equal to one if the household has a child aged between 5 and 14.
- *FAMILY* : *FAMILY* is a dummy variable that is equal to one if the household is of singles/couples type and zero if it is of family type.
- *FEMALE* : *FEMALE* is a dummy variable that is equal to one if the household has a female at age of 30 years or older.

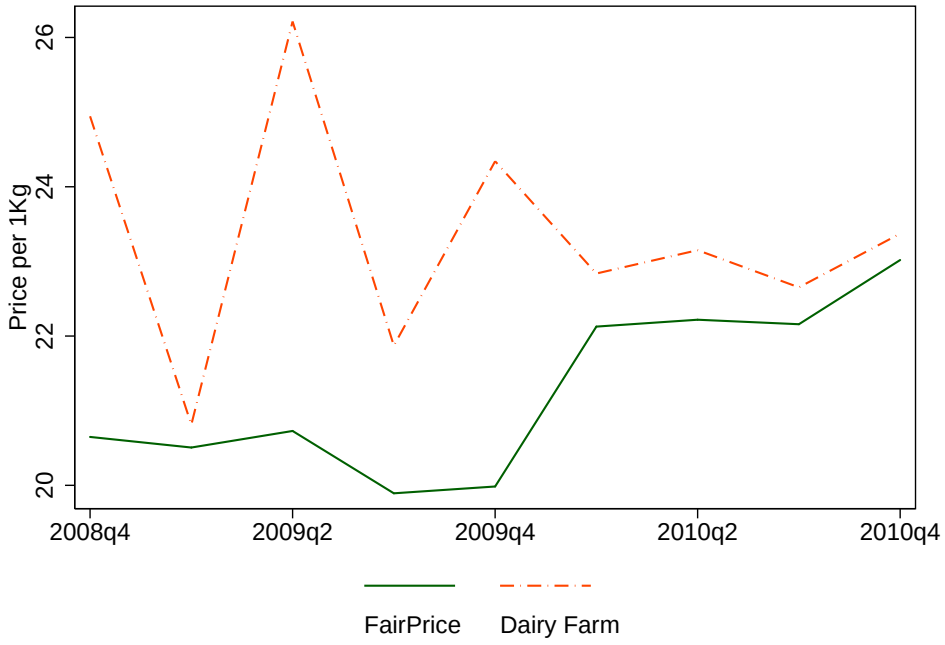
Appendix C: Key Position Holders of NTUC

Name	Position at *NTUC*	Term	Political Career
Devan Nair	Secretary General	'61-'65	President of Singapore ('81-'85)
	Secretary General	'70-'79	
	President	'79-'81	
ST Nagayan	Secretary General	'65-'66	Member of Parliament
Ho See Beng	President	'62-'64	Member of Parliament
	Secretary General	'66-'67	
	Chairman	'66-'67	
Seah Mui Kok	Secretary General	'67-'70	Member of Parliament
Lim Chee Ong	Secretary General	'79-'83	Member of Parliament
Ong Teng Cheong	Secretary General	'83-'93	Cabinet Minister
			Deputy Prime Minister
			President of Singapore ('93-'99)
Lim Boon Heng	Secretary General	'93-'06	Cabinet Minister
			Chairman of PAP[a]
Lim Swee Say	Secretary General	'07-Present	Member of Parliament

[a]People's Action Party is the single most dominant political party in Singapore historically occupying 93% to100% seats of Singapore parliament.



(a) Rice



(b) Infant Milk

Figure 1: Average Prices: Rice and Infant Milk

Figure 2: Average Prices: Chocolate

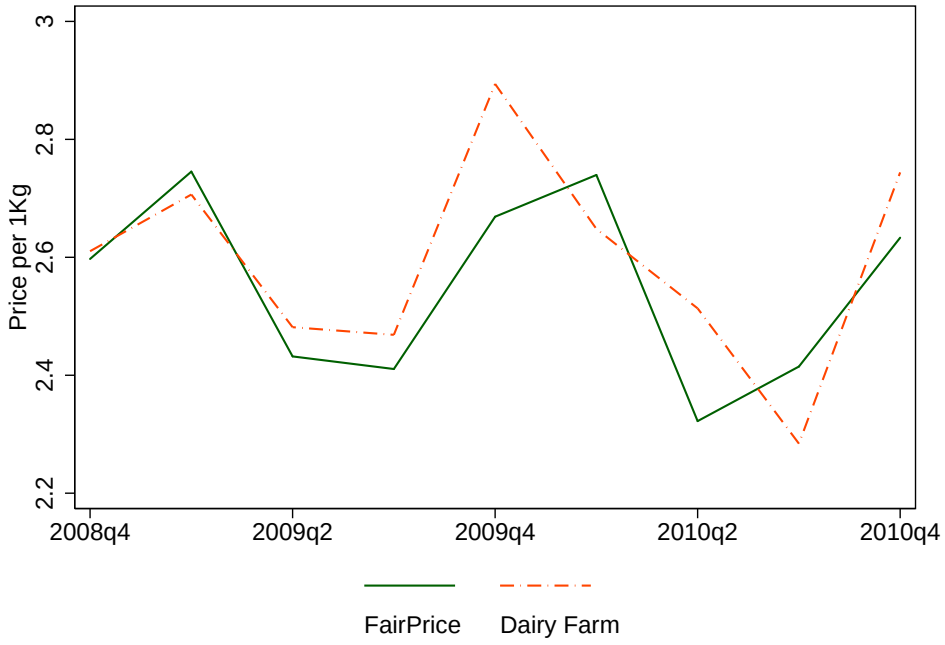


Table 1: Summary of Demographic Variables

Number of households	646			
	Mean	Std. Dev.	Min	Max
Monthly income[a]	4552.63	3540.87	500	15000
Household size	3.82	1.38	1	12
Grocery buyer's age	50.29	8.96	30	81
Type of dwelling	0.86	0.35	0	1
Work status	0.67	0.47	0	1
Child below 4	0.94	0.29	0	1
Child between 5 and 14	0.36	0.48	0	1
Family	0.60	0.49	0	1
Maid	0.16	0.36	0	1
Female below 10	0.10	0.30	0	1
Female between 10 and 19	0.27	0.44	0	1
Female between 20 and 29	0.25	0.43	0	1
Female between 30 and 39	0.24	0.42	0	1
Female between 40 and 49	0.37	0.48	0	1
Female above 50	0.65	0.48	0	1

[a]Monthly income is in Singaporean dollars. Summary statistics are computed based on the median value of each of the 11 income brackets. Highest income bracket is "above $10,000" and its median value is assumed to be $15,000.

Table 2: Top 20 Grossing Categories of Consumer Packaged Goods

Product category	Expenditure (SGD)	Share of Expenditure[a]
Infant milk	128237.30	5.84%
Rice	118879.20	5.41%
Liquid milk	99204.29	4.52%
Frozen food	96098.58	4.38%
Bread	72285.25	3.29%
Biscuit	59828.20	2.73%
Yoghurt	59159.21	2.69%
Facial care	58261.02	2.65%
Edible oil	56691.50	2.58%
Laundry detergent	55013.77	2.51%
Coffee	53520.90	2.44%
Juices	47714.16	2.17%
Liquid soap	47685.44	2.17%
Shampoo	46477.65	2.12%
Chocolate	45692.51	2.08%
Instant noodles	43547.46	1.98%
Health food drink	42761.56	1.95%
Sauces	42729.48	1.95%
Toilet rolls	36659.53	1.67%
Diapers	35191.37	1.60%

[a]Share of expenditure on each product category out of the entire expenditure.

Table 3: Top 20 Grossing Categories of Consumer Packaged Goods

Number of households	646
Number of total shopping trips	190,959
Number of total scannings	709,112
Total expenditure	$4,348,076.54
Total expenditure on consumer packaged goods	$2,195,455.72

	Mean	Std. Dev.	Min	Max
Average number of trips	295.60	197.09	63	1467
Average spending per trip	$22.77	$34.50	$0.01	$1598.62
Average spending per month	$249.29	$292.20	$1.70	$6462.13
Average number of purchase incidences per trip	3.71	3.32	1	52
Average inter-shopping days	3.64	3.67	1	54

Table 4: Expenditure and Shopping Trips by Top 3 Retailers

Firm	Expenditure	Shopping Trips	Number of Outlets[a]
FairPrice	$1,497,565	63,021	131
Dairy Farm	$572,332	23,950	104
Sheng Siong	$322,677	15,910	33
Others	$1,955,501	88,078	N/A
Total	$4,348,076	190,959	N/A

Firm	Rice	Infant milk	Chocolate
FairPrice	$65,428.74	$65,839.86	$24,136.04
Dairy Farm	$17,561.04	$20,101.59	$8,516.25
Sheng Siong	$16,524.08	$7,541.25	$4,332.50
Others	$19,365.34	$34,754.60	$8,707.73
Total	$118,879.20	$128,237.30	$45,692.51

[a]This data is collected separately by visiting each retailer's website.

Table 5: Demand Model Parameter Estimates: Rice Category

	Price	Constant	*NTUC*	*FairPrice*	*Dairy Farm*
Mean	-1.9190***	0.7299***	4.2844***	-3.1280***	-2.2120***
	(0.7123)	(0.1044)	(0.3320)	(0.1138)	(0.1044)
Standard Deviation[a]	0.0006	0.0011	0.0023	0.0017	0.0046
	(0.0014)	(0.1044)	(0.3320)	(0.1138)	(0.1044)
Demographic Variables					
HHOLDSIZE	-0.0480	-0.1771**	0.0769***	0.2320***	0.1445***
	(0.0350)	(0.0770)	(0.0289)	(0.0260)	(0.0275)
INCOME	0.0423***	0.0747**	-0.1679***	-0.0244**	-0.1191***
	(0.0139)	(0.0308)	(0.0115)	(0.0103)	(0.0108)
CHILD04	0.1185	-1.3423***	1.0047***	0.4550***	0.6041***
	(0.1481)	(0.3275)	(0.1166)	(0.1121)	(0.1167)
CHILD514	-0.5063***	0.6258***	-0.3709***	0.7974***	0.3981***
	(0.1064)	(0.2294)	(0.0834)	(0.0698)	(0.0744)
AGE	0.0103	-0.0193	0.0286***	-0.0095**	-0.0144***
	(0.0063)	(0.0136)	(0.0048)	(0.0038)	(0.0039)
HDB	-0.8379***	2.4885***	-2.1051***	0.7852***	-0.1841**
	(0.1212)	(0.2702)	(0.1023)	(0.0846)	(0.0848)
WORK	-0.2924***	0.7716***	0.2572***	-0.4885***	-0.5401***
	(0.0847)	(0.1852)	(0.0670)	(0.0572)	(0.0611)
MAID	-1.3321***	3.0250***	-1.5975***	0.7637***	0.9101***
	(0.0978)	(0.2088)	(0.0775)	(0.0733)	(0.0764)
CHINESE	0.7632***	-2.8738***	-0.8130***	1.6220***	1.3200***
	(0.1290)	(0.2655)	(0.1016)	(0.0875)	(0.0956)
INDIAN	-0.1857	-0.0901	-0.3401**	0.8266***	-0.0444
	(0.1875)	(0.3906)	(0.1718)	(0.1714)	(0.2184)
FAMILY	0.3613***	0.4742*	-0.1259	-0.6978***	-0.7544***
	(0.1171)	(0.2590)	(0.0963)	(0.0796)	(0.0850)
FEMALE	0.4363	-2.5602**	-0.6295	2.2131***	2.9543***
	(0.5824)	(1.1610)	(0.7226)	(0.6857)	(1.0220)
Maximized log-likelihood[b]	-158380.1894				
Average price coefficient	-1.4614				
% of price coefficient > 0	0.0279				

[a]Standard deviation parameters are exponentiated within the log-likelihood function, so that it can enter log-likelihood function positively and can be estimated unconstrained at the same time. Listed parameter estimates are transformed (i.e., exponentiated) values of those unconstrained estimates and standard errors are computed using the delta method.

[b]Standard logit model yields maximized log-likelihood of -163650.1475 and the log-likelihood test rejects it in favor of the full model ($p < 0.001$).

Table 6: Price Elasticities of Top 4 Brands of *FairPrice* and *Dairy Farm*: Rice Category

Brand[a]	Double (F)	Golden Royal Dragon (F)	NTUC (F)	Royal Umbrella (F)	Golden Phoenix (D)	New Moon (D)	Royal Umbrella (D)	Songhe (D)
Double (F)	-2.6487	0.1405	0.1490	0.1125	0.1261	0.1288	0.0990	0.1269
Golden Royal Dragon (F)	0.1610	-2.3005	0.1618	0.1459	0.1577	0.1609	0.1440	0.1711
NTUC (F)	0.3065	0.2904	-2.2043	0.2204	0.2513	0.2523	0.2260	0.2589
Royal Umbrella (F)	0.0652	0.0738	0.0621	-2.8337	0.0736	0.0731	0.0768	0.0795
Golden Phoenix (D)	0.0039	0.0042	0.0038	0.0039	-3.4843	0.0043	0.0038	0.0044
New Moon (D)	0.0472	0.0515	0.0450	0.0462	0.0516	-2.6647	0.0474	0.0599
Royal Umbrella (D)	0.0208	0.0263	0.0230	0.0278	0.0259	0.0271	-2.9533	0.0311
Sonhe (D)	0.0254	0.0299	0.0252	0.0274	0.0287	0.0327	0.0297	-3.4400

[a] *(F)* refers to *FairPrice* and (D) refers to *Dairy Farm*.

Table 7: Estimate of α_i and Marginal Costs of All Products: Rice Category

Consumer Surplus Moderating Parameter ($\hat{\alpha}_i$)
FairPrice
0.1262^{***}
(0.0168)

	Prices (Marginal Costs)[a]		
Brand[b]	*FairPrice*	*Dairy Farm*	*Sheng Siong*
Double	2.0027 (1.0906)	–	–
Golden Royal Dragon	1.7284 (0.8451)	–	–
NTUC	1.6685 (0.8192)	–	–
Happy	–	–	1.4970 (0.9282)
Nangrum	–	–	1.7437 (1.1302)
Royal Golden Grain	–	–	2.1726 (1.4673)
Golden Phoenix	2.3390 (1.4838)	2.7500 (1.9146)	–
New Moon	2.3573 (1.3561)	2.1211 (1.2950)	2.3823 (1.4735)
Royal Umbrella	2.4813 (1.4906)	2.5497 (1.6311)	2.5117 (1.5597)
Songhe	2.4917 (1.5884)	2.5104 (1.7340)	2.4943 (1.6222)
Golden Pineapple	–	2.0867 (1.4642)	1.9384 (1.2993)

[a]Prices and marginal costs are with respect to 1kg.

[b]First 6 rows list storebrands; the rest are national brands.

Table 8: Estimated Marginal Costs and Markups of *FairPrice* when $\alpha_i = 0$.

	$\alpha_i = 0$	$\alpha_i = 0.13$		
Brand	*FairPrice*	*FairPrice*	*Dairy Farm*	*Sheng Siong*
Double	0.9283 (133.00%)	1.0906 (84.21%)	–	–
Golden Royal Dragon	0.6850 (171.58%)	0.8451 (106.33%)	–	–
NTUC	0.6657 (168.34%)	0.8192 (105.04%)	–	–
Golden Phoenix	1.3298 (84.65%)	1.4838 (57.93%)	1.9146 (43.49%)	–
New Moon	1.1757 (115.20%)	1.3561 (74.55%)	1.2950 (63.87%)	1.4735 (61.69%)
Royal Umbrella	1.3152 (102.54%)	1.4906 (66.71%)	1.6311 (56.34%)	1.5597 (61.06%)
Songhe	1.4275 (84.22%)	1.5884 (57.04%)	1.7340 (44.85%)	1.6222 (53.89%)

Table 9: Counterfactual Equilibrium Prices when $\alpha_i = 0$

	$\alpha_i = 0$			$\alpha_i = 0.13$		
Brand	*FairPrice*	*Dairy Farm*	*Sheng Siong*	*FairPrice*	*Dairy Farm*	*Sheng Siong*
Double	2.1246*	–	–	2.0027	–	–
Golden Royal Dragon	1.8508*	–	–	1.7284	–	–
NTUC	1.7734*	–	–	1.6685	–	–
Happy	–	–	1.4968	–	–	1.4970
Nangrum	–	–	1.7423	–	–	1.7437
Royal Golden Grain	–	–	2.1679	–	–	2.1726
Golden Phoenix	2.4457*	2.7315	–	2.3390	2.7500	–
New Moon	2.5179*	2.1070	2.3615	2.3573	2.1211	2.3823
Royal Umbrella	2.6427*	2.5315	2.4940	2.4813	2.5497	2.5117
Songhe	2.6124*	2.5013	2.4844	2.4917	2.5104	2.4943
Golden Pineapple	–	2.0790	1.9345	–	2.0867	1.9384

Table 10: Counterfactual Analysis: Profit, Consumer Surplus and Total Surplus

	$\alpha_i = 0.13$	$\alpha_i = 0$	% Change
Profit[a]			
FairPrice	0.3014	0.3049	+1.16%
Dairy Farm	0.0325	0.0343	+5.54%
Sheng Siong	0.0433	0.0461	+6.47%
Consumer Surplus[b]	0.5091	0.4725	−7.18%
Total Surplus[c]	0.8862	0.8578	−3.21%

[a]Expected per capita profit for unit weight (1kg) products in dollar terms is listed.

[b]Expected per capita consumer surplus resulting from consumption of a unit weight (1kg) product is computed. The unit is in dollar terms, the same as profit.

[c]Total surplus is defined as the sum of producer surplus and consumer surplus. The quantity sold at each retailer under the counterfactual policy scenario remains unchanged. Robustness checks where quantities change according to quantity discount scheme yielded similar results.

Table 11: Counterfactual Consumer Surplus Analysis

Total Effect	-0.0366
Direct Effect	-0.0375
Indirect Effect	+0.0009

Table 12: Validity Check of the Consumer Surplus Moderated Model

(Unit: SGD per 1kg)	2008	2009				2010			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Wholesaler's marginal cost	1.17	1.14	1.17	1.17	1.15	1.20	1.11	1.04	1.06
Retailer's marginal cost (from standard model)	0.95	1.03	0.90	1.01	1.09	1.11	1.11	1.05	1.07
Retailer's marginal cost (from our model)	1.39	1.25	1.27	1.39	1.44	1.42	1.44	1.19	1.30