

# Adopting Cost Transparency as a Marketing Strategy: Analytical and Experimental Exploration

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September 21, 2018

## Abstract

Should sellers disclose their cost information to potential buyers? If yes, under what conditions should firms adopt this cost transparent strategy? We examine these questions by using an analytical approach followed by an experimental analysis. To begin, we develop a monopolistic model to show that the transparent strategy is optimum if and only if products are of low perceived quality and relatively high unit cost. This result implies that luxury goods firms (with high perceived quality and relatively low unit cost) should not disclose their cost information. Next, our analytical result reveals that the quality differentiation between firms in a duopoly is a key driver for predicting whether different firms should adopt the transparent strategy or not. Specifically, no firm should adopt the transparent strategy when the quality differentiation is high because different firms can set different selling price to segment the market. However, when the quality differentiation becomes less prominent, competitive pricing alone is not sufficient and the transparent strategy becomes the additional lever for firms to segment the market. Using a laboratory experiment, we validate our analytical results to show that as quality differentiation decreases, the adoption of the transparent strategy increases but the selling price decreases.

**Keywords:** voluntary cost transparency, market competition, marketing.

## 1 Introduction

In general, firms are tight-lipped about supply chain processes (e.g., supply source of materials, identity of contract manufacturers, supplier environmental compliance, etc.) and costs (e.g., material cost, labor cost, etc.) to maintain a competitive edge. However, partly due to regulatory

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measures and consumer concerns over environmental sustainability and social responsibility, we witness a sea change recently where more firms are disclosing different types of information including: supplier information<sup>5</sup>, environmental footprint<sup>6</sup>, supplier workplace safety compliance<sup>7</sup>, and product provenance.<sup>8</sup> Sodhi and Tang (2018) articulated that the economic benefits of being transparent in terms of market shares, sales, and profit remain unclear. Specifically, product cost is a closely-guarded secret because: (1) cost transparency can make a firm more vulnerable to competition; and (2) cost transparency can cause “dual entitlement” concerns (Kahneman et al. (1986)) in the market and create unhappy consumers who feel that the firm’s profit margin is unreasonably high (i.e., the selling price is too high relative to the manufacturing cost). For these reasons, we are intrigued by the fact that Everlane.com is the *only* apparel firm in the US that discloses its supply chain (input) costs (material and labor costs) as well as the average profit margin by other firms selling similar apparel items.<sup>9</sup> This observation motivates us to examine whether cost transparency is an effective marketing strategy in a competitive market.

In a recent laboratory experimental study of a single firm, Mohan et al. (2015) show that cost transparency can enable a firm to increase its sales because it motivates consumers to become more likely to purchase (even when the profit margin is higher than what consumers had expected). Mohan et al. (2017)’s findings on the general appeal of cost transparency, in conjunction with dual entitlement concerns (Kahneman et al. (1986)), create a dilemma for firms when considering the adoption of cost transparency. The picture is even more complicated in a competitive situation such as a duopoly, in which one or both firms might adopt cost transparency to gain competitive advantage. This set of issues motivated us to examine the following research questions about cost

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<sup>5</sup>Nike discloses supplier’s name, location, and activity since 2005; and Patagonia discloses information about its supply chain process information.

<sup>6</sup>Kering Group, parent company of Alexander McQueen, Bottega Veneta, and Puma, discloses greenhouse gas emissions, air and water pollution, land use and water consumption incurred by its suppliers in its “Environmental Profit and Loss Statement”.

<sup>7</sup>PVH Corporation, owner of Calvin Klein and Tommy Hilfiger, discloses their suppliers’ compliance with Environment, Health and Safety (EHS) regulations.

<sup>8</sup>Intel discloses information about its processes to assure its customers that the minerals used for its products are conflict-free. Source Collections discloses the whereabouts of its factory in Dongguan to indicate that the garments are produced under safe working conditions and sans child labor, and its packaging is plastic-free and the recycled paper is made from wood from responsible sources (The Straits Times, <https://www.straitstimes.com/lifestyle/fashion/sustainability-is-in-style>. Accessed June 22, 2018).

<sup>9</sup>In a similar vein, Source Collections, a sustainable Singapore lifestyle brand, is the only apparel company in Singapore that breaks down the costs of producing each garment, including materials, labor and transport.

transparency in a broader context. Firstly, what are the economic benefits (i.e., sales and profit) for a monopoly to adopt the transparent strategy? What are the key drivers for explaining these economic benefits? Secondly, in a duopolistic setting, how would the adoption of the transparent strategy affects a firm's market share, sales and profit? Under what conditions should a firm adopt the transparency strategy? In equilibrium, when will one firm adopt the transparent strategy and the other firm adopt the opaque strategy (as observed in the marketplace where Everlane.com is the only apparel seller who adopts the transparent strategy)?

To examine the above questions, we first develop a parsimonious and tractable analytical framework to capture the trade off arising from cost transparency: cost transparency boosts consumer's willingness to pay so that a firm can afford to charge a higher price; however, cost transparency discloses information about "fair market reference price" so that the firm cannot afford to charge a higher price without offending potential customers. Faced with this trade off, we identify the conditions under which a monopoly should adopt the transparent strategy. We then extend our analysis to a competitive duopolistic setting with two asymmetric firms and identify the conditions under which 0, 1 or 2 firms would adopt the transparent strategy in equilibrium. To validate our analytical findings, we conduct a laboratory experiment for the duopoly case.

Our findings are as follows. First, we show analytically that a monopoly firm should adopt the transparent strategy if and only if the quality is sufficiently low. This is because, when the quality is low, a monopoly can benefit more from adopting the transparent strategy (due to the increased consumer's willingness to pay caused by the firm's cost transparency) despite being constrained by a reference price. This result is consistent with the practice of Uber as follows. Before Lyft's entrance, Uber operated as a monopolistic ride-sharing service. As consumers were using the relatively high taxi fare as the reference price, Uber's "labor cost" was transparent because it was paying its independent drivers 80% of the revenue collected from the passengers (Bai et al. (2018)).

Second, in a duopolistic setting, we show analytically that the quality differentiation between firms is a key factor for a firm to decide whether to adopt the cost transparency strategy. Specifically, when the quality differentiation between the firms is high, both firms should adopt the opaque strategy because different firms can set different prices to segment the market. On the contrary, both firms should adopt the transparency strategy when the quality differentiation is low. Interestingly, when quality differentiation is medium, there are potentially two equilibria. In particular, when the voluntary disclosure of cost garners a substantial increase in consumer's willingness to pay, we find that the high quality firm would adopt the opaque strategy, while the low quality firm would

adopt the transparent strategy. This result is caused by the fact that, when quality differentiation is less pronounced, the lower quality firm needs to use cost transparency as an additional lever to compete. This finding provides a plausible explanation for explaining why Everlane.com is the only firm that adopts the transparent strategy. Specifically, our result predicts that Gap (the firm with higher quality) should adopt the opaque strategy and Everlane.com (the firm with lower quality) should adopt the transparent strategy to compete when its quality falls short. However, when the change in consumer's willingness to pay is somewhat muted in response to voluntary cost transparency, the higher quality firm adopts the transparency strategy while the lower quality firm does not. That we do not observe this in reality perhaps bears testimony that voluntary adoption of cost transparency has a substantial impact on consumer's willingness to pay. Third, through our statistical analysis of the data generated from our laboratory experiment, we find support for our analytical results: as quality differentiation decreases, both firms are more likely to adopt cost transparency and reduce prices.

This paper is organized as follows. In §2, we review related literature briefly. In §3, we first analyze the monopolistic and a competitive settings; respectively. We then propose various hypotheses based on our theoretical findings. In §4, we outline our experimental design, describe the experimental procedures, and discuss our experimental results. We conclude in §5. All proofs are given in Appendix A. Appendix B offers further data analysis for the experiment. Finally, to validate the robustness of our key analytical findings, we examine an extension in the Online Appendix which also contains the detailed description of the experiment.

## 2 Literature Review

Researchers have examined the issues of operational, price, and cost transparency. First, operational transparency refers to the case when a firm discloses its service delivery efforts that can increase consumers' willingness to pay (Buell and Norton (2011), Gershoff et al. (2012), Morales (2005), Chinander and Schweitzer (2003)). Kraft et al. (2017) examine whether disclosure of supplier information, voluntary or mandatory, can improve the supplier's social responsibility practices. Second, price transparency refers to the case when a firm separates its price into royalties and taxes so that consumers perceive the price to be lower. Carter and Curry (2010) show that it can increase consumers' purchase intentions. In our context, cost transparency refers to a firm's disclosure various costs involved in the production of the product or service and includes materials,

labor, research & development among others. By using a signaling game, Jiang et al. (2017) examine the effect of cost transparency on the firm's pricing strategy and new product innovation. As noted previously, cost transparency triggers the notion of "dual entitlement" as consumers are less willing to buy from firms whose profit margins are deemed to be too large (Kahneman et al. (1986), Bazerman (1985), Köszegi and Rabin (2015)). However, voluntary cost transparency increases a firm's trustworthiness (Laurenceau et al. (1998), Aron et al, (1997), Sedikides et al. (1999), Mohan et al. (2015)). We explore the following questions: How should firms tradeoff these two effects? How does competition between firms change the firms' propensity towards voluntary cost transparency?

Next, our experimental study investigated participants' cost transparency and pricing decisions when they play the role as competing sellers. This experimental study is related to the voluminous literature of experimental oligopolistic studies. In that literature, the typical setup involves quantity and/or price competition. A major concern is the influence of industry structure on the rise of collusive behavior (see van den Berg and Bos 2017). The major industry structure elements that have been studied include the information flow in the market (e.g., Gomez-Martinez, Onderstal, and Sonnemans 2016, Kalayci 2016), the number of competitors (e.g., Huck, Normann, and Oechssler 2004), and regulations (e.g., Dijkstra, Haan, and Mulder 2017).

In recent years, a rising number of experimental studies examines how industry players' and consumers' preferences beyond self-interest maximization can influence experimental oligopolistic competition. This trend is largely motivated by the fact that people often have significant fairness perceptions, particularly towards prices (Haws and Bearden 2006), that can have an impact on their economic behavior. Subsequent experimentation on fairness perceptions in a competitive market falls into three categories. The first category studies fairness perceptions among industry players. For example, Iris and Santos-Pinto (2014) used Fehr and Schmidt (1999)'s inequity aversion model among competitors to account for the occurrence of collusive behavior in Cournot oligopoly experiments. Bartling et al. (2017) examined how perceptions of pricing fairness in a marketing channel can influence its pricing mechanisms. The second category focuses on consumers' fairness perceptions. For example, Schmidt et al. (2015) investigated how consumers behaved in a competitive market when they could pay whatever they wanted for one or more of the sellers' products. The third category focuses on firms' transparency and information disclosure policies (see also Kraft et al. 2018). Pigors and Rockenbach (2016a) examined a scenario in which a firm may release wage information to consumers so that consumers can evaluate the firm's fairness, which could then

have an impact on the consumers' own purchase decisions. Pigors and Rockenbach (2016b) studied similar issues when a firm may reveal production-related information truthfully to its workers.

The experimental investigation in our study is a novel development in the third category, as it looks at competitive interactions under cost transparency. It also adopts a different methodological approach from the related previous studies. The related previous studies tend to focus on participants' behavioral responses as consumers to firms' transparency and information disclosure policies. Because of this, it is difficult to formulate game-theoretic benchmark predictions on competitive strategies that are predicated on the recipients' behavior - unless basic demand characteristics, such as consumer heterogeneity in their valuations of the products, are assumed to be highly simplistic. Our work instead uses computer programming to *simulate* the behavior of the recipients i.e., consumers' response to cost transparency - as a demand function following our theoretical model as well as previous behavioral studies. We focus on the competitive behavior of the participants in the role of sellers, *given* the simulated demand function. We thus have the advantage of being able to formulate point predictions of competitive strategy (which involves cost transparency as well as pricing decisions) given our demand function. Importantly, this methodological approach allows us to obtain unambiguous results and managerial insights on how quality differentiation in a vertically differentiated market can affect cost transparency adoption in an experimental duopoly, as we report in Section 4.

### 3 Analytical Framework and Analysis

In this section, we present a parsimonious and tractable theoretical framework and determine the conditions under which a firm should adopt cost transparency in equilibrium. As a benchmark, we first present the monopolistic case followed by the duopolistic case. Our analytical results form the hypotheses that enable us to investigate via laboratory experimentation in §4.

#### 3.1 Monopoly

Consider a monopoly firm,  $M$ , whose product is of exogenous quality  $q$  and the marginal cost of production is  $c$ . Without loss of generality, we assume that  $c < q$ .

### 3.1.1 Sequence of Events

The sequence of events is as follows. In Period 1, Firm  $M$  decides whether to adopt the transparency strategy  $T$ . If Firm  $M$  adopts the transparency strategy  $T$ , it announces its marginal cost  $c$  and markup  $m$  ( $m \geq 1$ ) so that consumers know the breakdown of the selling price  $p_M = mc$ . If Firm  $M$  adopts the opaque strategy  $O$ , then consumers observe only the selling price  $p_M$  (because  $m$  and  $c$  are not disclosed).<sup>10</sup> In Period 2, all consumers observe the quality  $q$  and observe either  $m$  and  $c$  (if Firm  $M$  adopts the transparent strategy  $T$ ) or the selling price  $p_M$  (if Firm  $M$  chooses the opaque strategy  $O$ ) before making their purchase decisions.

### 3.1.2 Consumers

We model consumer heterogeneity by assuming that consumers vary along the dimension of valuation for quality. More formally, a consumer's value for quality,  $v_j$ , follows a uniform distribution along the interval  $[0, 1]$ . If Firm  $M$  adopts the opaque strategy ( $O$ ) and announces price  $p_M$  only, then the utility for Consumer  $v_j$  for purchasing the product from  $M$  is given as:

$$U_M(v_j, O) = v_j q - p_M. \quad (1)$$

If Firm  $M$  adopts the transparency strategy ( $T$ ) and announces  $m$  and  $c$  where  $p_M = mc$ , then we shall assume that consumers will take into account both the impact of the 'feel good' factor when a firm adopts cost transparency (Mohan et al. (2015)) as well as the effect from dual entitlement as explained earlier (Kahneman et al. (1986)). In this case, the purchase utility for Consumer  $v_j$  from  $M$  is given as:

$$U_M(v_j, T) = v_j q - mc + \phi + \gamma c(k - m), \quad (2)$$

where  $\phi(> 0)$  denotes the additional utility that the consumer enjoys from the firm's 'trustworthiness' owing to its voluntary cost transparency. Essentially, the term  $\phi$  captures the increased in consumer's willingness to pay when the firm adopts cost transparency. According to the principle of "dual entitlement", consumers also care about price fairness. To incorporate the notion of fairness, we define  $\gamma(> 0)$  as the extent in which consumers care about price fairness and  $k(\geq 1)$  as the reference point for a 'fair' markup, or equivalently, one can interpret the term  $kc$  as the fair market

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<sup>10</sup>Throughout the paper, we use  $p$  to denote the pricing decision of the firm when it does not adopt cost transparency but write  $p$  as  $mc$  instead when it does adopt cost transparency.

reference price.<sup>11</sup> Thus,  $c(k - m)$  measures the extent to which consumers ‘reward’ (or ‘penalize’) the firm when  $mc < kc$  (or when  $mc > kc$ ). By using a single parameter  $\gamma$ , we assume that the effect of ‘reward’ and ‘penalty’ is symmetric. (We shall discuss the implications and the limitations of our model regarding  $\phi$  and  $\gamma$  in §5. For instance, we can extend our analysis to the case of asymmetric reward and penalty; however, the analysis is intractable.)

The utility functions as shown in (1) and (2) capture the underlying trade off arising from cost transparency. On one hand, cost transparency boosts consumer’s willingness to pay via  $\phi$  so that a firm can afford to charge a higher price. On the other hand, because cost transparency discloses information about fair market reference price  $kc$ , cost transparency limits the freedom for the firm to set a higher price: a firm will suffer from a lower demand when it sets the selling price  $mc$  way above the reference price  $kc$ . By taking this dilemma into consideration, we first examine the conditions under which a monopoly should adopt the transparency strategy before we extend our analysis to the duopolistic setting. (For ease of reference, we provide a list of notations in the following table.)

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<sup>11</sup>Notably, the reference point for the markup,  $k$ , may be interpreted as the industry average, or some acceptable level posited by consumers. Alternatively,  $k$  can also be interpreted as the markup that consumers expect. Any deviation from this expectation affects the willingness-to-pay. We assume that  $k$  is exogenous and is common knowledge as  $k$  may be influenced by a number of factors, including firms in and out of the industry and the overall business community, amongst others. For example, Everlane provides information about its  $m$  and  $c$ , and the average market price for a similar item. This average market price conveys the notion of a fair price, which can be converted to a fair markup if one uses  $c$  as the average cost.

$v_j$	Consumer valuation
$q_i$	Quality of product $i$ produced and sold by Firm $i$ , $i = 1, 2$
$c_i$	Marginal cost of production for Firm $i$
$p_i$	Price of Firm $i$
$m_i$	Markup of Firm $i$ ( $m_i \geq 1$ )
$\phi$	Additional utility accrued by consumers when a firm adopts voluntary cost transparency
$\gamma$	Extent to which consumers care about price fairness
$k$	Reference point for a fair markup ( $k \geq 1$ )
$\Delta$	Quality differentiation between Firm 1 and Firm 2: ( $\Delta = (q_1 - q_2)$ )
$T$	Transparent strategy: the firm discloses cost $c_i$ and markup $m_i$ to consumers.
$O$	Opague streategy: the firm discloses only the selling price $p_i$
$U_i(v_j, O)$	Utility for Consumer $v_j$ who purchases from Firm $i$ who adopts the opaque strategy $O$
$U_i(v_j, T)$	Utility for Consumer $v_j$ who purchases from Firm $i$ who adopts the transparent strategy $T$

Table 1: Summary of Notations

### 3.1.3 Analysis: Monopoly

We first use (1) and (2) to determine the demand for the case when firm  $M$  adopts the opaque strategy ( $O$ ) and the transparency strategy ( $T$ ) respectively. By using these demand functions, we can determine the optimal price  $p_M^{O*}$  that maximizes the firm's profit under the opaque strategy  $O$  and the optimal mark up  $m^{T*}$  under the transparent strategy  $T$ . By comparing the optimal profits for Firm  $M$  that correspond to these two cases, we obtain a major result that is summarized in Proposition 1. (See Appendix A for details.)

**Proposition 1.** *It is optimal for a monopoly firm  $M$  to adopt cost transparency ( $T$ ) if and only if*

$$q \leq c + \frac{\phi + k\gamma c - 1}{\sqrt{\gamma + 1} - 1}. \quad (3)$$

Observe from (3) that the monopoly firm should adopt the transparency strategy if and only if the quality is sufficiently low, the threshold of which, depends on  $k$ ,  $\phi$ ,  $\gamma$  and  $c$ . In other words, when the quality is low, the monopoly finds it beneficial to leverage on the higher willingness to pay brought about by the adoption of cost transparency. With a low quality, the extent to which the firm can set a high price is limited. This implies that the constraint brought about owing to cost transparency more than compensates for by the increase in the consumer's willingness to pay.

In the following, we elaborate on how  $k$ ,  $\phi$ ,  $\gamma$  and  $c$  affect the adoption of cost transparency.

First, when the industry average markup  $k$  is sufficiently high, (3) is more likely to hold and so it is beneficial for Firm  $M$  to adopt the transparency strategy  $T$ . However, when  $k$  is low, the monopoly firm is better off *not* revealing its cost  $c$  and its optimal markup  $m^{T^*}$ . This is because when the optimal markup  $m^{T^*}$  is much higher than the reference  $k$ , the penalty  $\gamma \cdot (k - m^{T^*})$  overshadows the reward  $\phi$  associated with cost transparency. Hence, the firm is better off adopting the opaque strategy  $O$  when the industry average markup  $k$  is low. Second, when consumers value cost transparency by rewarding firms with a higher  $\phi$ , Condition (3) is again more likely to hold. To capitalize on such consumer sentiment, the monopoly firm is more likely to adopt the transparency strategy. Third, when consumers care a lot about fairness as captured by a higher  $\gamma$ , the right-hand-side of (3) increases so that it is more likely for a monopoly firm to adopt the transparency strategy.

Finally, when Firm  $M$  sells a product whose cost is low so that Condition (3) is less likely to hold, the firm prefers the opaque strategy  $O$ . This is because when  $c$  is low, the benefit accrued from cost transparency is insufficient to compensate for the constraints imposed on the markup owing to the dual entitlement term  $(k - m)$  arising from cost transparency as stated in (2). Thus, the firm is better off being opaque. As an example, consider a luxury goods firm that tends to possess a low value of  $c$  but a relatively high value of  $q$ . In this case, (3) is unlikely to hold. Hence, Proposition 1 reveals that the monopoly firm is better off adopting the opaque strategy  $O$ . This result provides a plausible reason as to why luxury goods firms should not reveal their price breakdown by disclosing its markup  $m$  and its cost  $c$ . Proposition 1 thus identifies quality as pivotal in the adoption of the transparent strategy. In the following, we explore how quality plays a role in our duopoly setting.

### 3.2 Duopoly: Analysis of Asymmetric Firms

We now extend our analysis of the monopoly case to the duopoly case while taking into consideration the possibility of having each firm to adopt either the opaque strategy  $O$  or the transparent strategy  $T$ . Without loss of generality, we assume Firm 1 produces and sells a product with a higher unit cost that is of higher quality than Firm 2 so that  $q_1 > q_2$ , and  $k \geq 1 > c_1 \geq c_2$ . As explained earlier, we assume that the consumers observe the quality  $q_i$ , but they do not observe the unit cost  $c_i$  (or markup  $m_i$ ) unless firm  $i$  adopts the transparent strategy ( $T$ ).

### 3.2.1 Sequence of Game

Consider two firms engaged in a non-cooperative game over three time periods as follows. In Period 1, Firms 1 and 2 simultaneously decide whether to adopt the opaque strategy  $O$  or the transparent strategy  $T$ . If Firm  $i$  ( $i = 1, 2$ ) chooses to adopt strategy  $T$ , it discloses its marginal cost  $c_i$  and markup  $m_i$  so that consumers know that the breakdown of the selling price  $p_i = m_i c_i$ . If Firm  $i$  adopts strategy  $O$ , consumers can only observe the selling price  $p_i$ . In Period 2, Firm  $i$  observes the cost transparency policy of both firms and chooses  $m_i$  where  $p_i = m_i c_i$  if it has adopted  $T$  in period 1. Otherwise, Firm 1 chooses  $p_i$ . In Period 3, all consumers first observe either the markup  $m_i$  and  $c_i$  if Firm  $i$  adopts strategy  $T$ , or just the selling price  $p_i$  if Firm  $i$  adopts strategy  $O$ , and then make their purchase decisions. (To validate our analytical results, we shall conduct a laboratory experiment based on the same sequence of events in §4.)

In the following subsections, we use backward induction to analyze the game by considering four possible subgames associated with the strategy (i.e.,  $O$  or  $T$ ) selected by each firm. We present the main results here and provide the detailed analysis in Appendix A. Our analysis is based on the assumption that the market is fully covered; i.e., consumers have unit demands and will buy one unit from one of the firms that offers a higher utility.<sup>12</sup> Besides tractability, the assumption that the market is fully covered is applicable to the case when the market consists of consumers who are committed to buy a unit from one of the firms which occurs when the price is not too high. Also, the full market coverage assumption is commonly used in the marketing literature to simplify the expositions (Chen et al. (2009), Desai et al. (2016), Chen et al. (2017)).<sup>13</sup>

### 3.2.2 Subgame 1: ( $O$ , $O$ )

In this subgame, both firms adopt the opaque strategy  $O$  so that the purchase utility  $U_i(v_j, O) = v_j q_i - p_i$  for  $i = 1, 2$ . For ease of exposition, let us define  $\Delta$  as the “quality differentiation” between firms. Because we assume that  $q_1 > q_2$  (without loss of generality),

$$\Delta = (q_1 - q_2) > 0. \quad (4)$$

When none of the firms adopts cost transparency, Lemma 1 (below) reveals that the higher-quality firm (Firm 1) always earns a higher profit than the lower-quality firm (Firm 2). In fact, the

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<sup>12</sup>This is the conventional approach for fully covered markets (Fudenberg and Tirole (1991), Page 15)

<sup>13</sup>We have extended our analysis by relaxing the full market coverage assumption and obtain similar structural results. The details of this extension is provided in the Online Appendix.

difference in the equilibrium prices is increasing in the quality differentiation  $\Delta$  as well as the cost difference, while the profit difference is increasing in quality differentiation but decreasing in cost difference. This is because, although Firm 1 sets a relatively higher price when its cost is higher, this does not translate into a higher profit difference. However, a higher quality differentiation  $\Delta$  leads to a higher profit difference.

**Lemma 1. Subgame (O,O).** *When both firms adopt the opaque strategy O, the equilibrium price for each firm satisfies:  $p_1^{O,O} = \frac{2}{3}(\Delta + c_1 + \frac{1}{2}c_2)$  and  $p_2^{O,O} = \frac{1}{3}(\Delta + c_1 + 2c_2)$ . Also, the equilibrium profit for each firm satisfies:  $\pi_1^{O,O} = \frac{1}{9\Delta}(2\Delta - (c_1 - c_2))^2$ ,  $\pi_2^{O,O} = \frac{1}{9\Delta}(\Delta + c_1 - c_2)^2$ .*

### 3.2.3 Subgame 2: (T, O)

In this subgame, observe from (2) that the purchase utility for Firm 1 can be rewritten as  $U_1(v_j, T) = v_j q_1 + \phi + \gamma c_1 k - m_1 c_1 (\gamma + 1)$ , and observe from (1) that the purchase utility for Firm 2 is given as  $U_2(v_j, O) = v_j q_2 - p_2$ .

**Lemma 2. Subgame (T,O).** *When Firm 1 adopts the transparent strategy T and Firm 2 adopts the opaque strategy O, Firm 1's optimal mark up  $m_1^{T,O}$  and Firm 2's optimal selling price  $p_2^{T,O}$  satisfy:*

$$\begin{aligned} m_1^{T,O} &= \frac{2}{3(\gamma + 1)c_1} \left( \Delta + (\gamma + 1)c_1 + \frac{c_2 + \phi + \gamma k c_1}{2} \right), \text{ and} \\ p_2^{T,O} &= \frac{1}{3} (\Delta + (\gamma + 1)c_1 + 2c_2 - \phi - \gamma k c_1). \end{aligned}$$

*Also, the corresponding optimal profit for each firm is given as:*

$$\begin{aligned} \pi_1^{T,O} &= \frac{(2\Delta - (\gamma + 1)c_1 + (c_2 + \phi + \gamma c_1 k))^2}{9(\gamma + 1)\Delta}, \\ \pi_2^{T,O} &= \frac{(\Delta + (\gamma + 1)c_1 - c_2 - \phi - \gamma c_1 k)^2}{9\Delta}. \end{aligned}$$

Clearly, when the quality differentiation  $\Delta$  is sufficiently large and  $\gamma$  is not too big, Firm 1 sets a higher price than Firm 2. At the same time, Firm 1 earns a higher profit than Firm 2 in equilibrium.

### 3.2.4 Subgame 3: (O, T)

When the higher quality firm, Firm 1, adopts the opaque strategy O and Firm 2 adopts the transparent strategy T, we can use the same approach as before to obtain the following result.

**Lemma 3. Subgame (O, T).** *When Firm 1 adopts the opaque strategy O and Firm 2 adopts the transparent strategy T, Firm 1's optimal selling price  $p_1^{O,T}$  and Firm 2's optimal mark up  $m_2^{O,T}$  satisfy:*

$$p_1^{O,T} = \frac{1}{3}(2\Delta - \phi - \gamma c_2 k + 2c_1 + c_2(\gamma + 1)), \text{ and}$$

$$m_2^{O,T} = \frac{1}{3(\gamma + 1)c_2}(\Delta + \phi + \gamma c_2 k + c_1 + 2c_2(\gamma + 1)).$$

*Also, the corresponding optimal profit for each firm is given as:*

$$\pi_1^{O,T} = \frac{(2\Delta - \phi - \gamma c_2 k - c_1 + c_2(\gamma + 1))^2}{9\Delta},$$

$$\pi_2^{O,T} = \frac{(\Delta + \phi + \gamma c_2 k + c_1 - (\gamma + 1)c_2)^2}{9(\gamma + 1)\Delta}.$$

Analogous to Subgame 2, when the quality differentiation  $\Delta$  is sufficiently large and  $\gamma$  is not too big, the above lemma reveals that Firm 1 sets a higher price than Firm 2 and earns a higher profit than Firm 2 in equilibrium.

### 3.2.5 Subgame 4: (T, T)

Finally, when both firms adopt the transparent strategy T, the purchase utility for Firm  $i$  is given as  $U_i(v_j, T) = v_j q_i + \phi + \gamma c_i k - m_i c_i (\gamma + 1)$ , for  $i = 1, 2$ . By comparing the utilities associated with both firms, it is clear that consumers do not generate additional consumer utility  $\phi$  relative to its competitor owing to voluntary cost transparency adopted by both firms. Hence,  $\phi$  plays no role in the equilibrium, which is as shown in the following lemma.

**Lemma 4. Subgame (T,T).** *When both firms adopt the transparent strategy T, the optimal markup and the corresponding profit of each firm satisfy:*

$$m_1^{T,T} = \frac{1}{3(\gamma + 1)c_1}(2\Delta + \gamma c_1 k - \gamma c_2 k + 2c_1(\gamma + 1) + c_2(\gamma + 1)),$$

$$m_2^{T,T} = \frac{1}{3(\gamma + 1)c_2}(\Delta + \gamma c_2 k - \gamma c_1 k + (\gamma + 1)c_1 + 2c_2(\gamma + 1)),$$

$$\pi_1^{T,T} = \frac{(2\Delta + \gamma c_1 k - \gamma c_2 k - (\gamma + 1)c_1 + c_2(\gamma + 1))^2}{9(\gamma + 1)\Delta},$$

$$\pi_2^{T,T} = \frac{(\Delta + \gamma c_2 k - \gamma c_1 k + c_1(\gamma + 1) - (\gamma + 1)c_2)^2}{9(\gamma + 1)\Delta}.$$

When both firms adopt the transparent strategy T, it is straightforward to check that the price of Firm 1,  $p_1 (= m_1 c_1)$  is always higher than that of Firm 2 because  $p_1^{T,T} - p_2^{T,T} = m_1^{T,T} c_1 - m_2^{T,T} c_2 = \frac{\Delta + (c_1 - c_2)(2\gamma k + \gamma + 1)}{3(\gamma + 1)} > 0$ . Furthermore, Firm 1 earns a higher profit at the equilibrium if and only

if the quality differentiation  $\Delta > 2(c_1 - c_2)(-\gamma k + \gamma + 1)$ . In other words, for sufficiently large difference in quality, Firm 1 is always better off than Firm 2 profit-wise even when both firms adopt the same transparency strategy  $T$ .

### 3.2.6 Equilibrium Strategies

To determine whether a firm should adopt the transparent strategy  $T$  in a competitive environment, we compare the payoffs of the firms in each subgame as stated in Lemmas 1-4. Recall from Lemmas 1-4 that the quality differentiation  $\Delta$  affects each firm's payoff in each subgame. Consequently, the equilibrium strategy for predicting whether a firm adopts the transparency strategy  $T$  would hinge upon the quality differentiation and we shall explore this issue in this section.

To begin, let us consider the case where Firm 1 adopts the opaque strategy  $O$ . Then, we note that Firm 2 is better off by similarly not adopting voluntary cost transparency when  $\pi_2^{O,O} - \pi_2^{O,T} \geq 0$ , which occurs if and only if:

$$\Delta \geq \frac{\phi + \gamma c_2(k-1)}{\sqrt{\gamma+1}-1} - (c_1 - c_2) = \tau_{2,1}. \quad (5)$$

Next, consider the case where Firm 1 adopts the transparent strategy  $T$ . Then, it is optimum for Firm 2 to remain opaque about its cost when  $\pi_2^{T,O} - \pi_2^{T,T} \geq 0$ , which occurs if and only if

$$\Delta \geq \frac{\phi + \gamma c_2(k-1)}{\sqrt{\gamma+1}-1} - (c_1 - c_2) + \phi + \gamma c_1(k-1) = \tau_{2,2}. \quad (6)$$

Note that  $\tau_{2,2} = \tau_{2,1} + \phi + \gamma c_1(k-1) > \tau_{2,1}$ . The intuition of the above analysis is that when the quality differentiation  $\Delta \equiv q_1 - q_2$  is large, firms are already sufficiently differentiated to mitigate aggressive pricing competition. Thus, voluntary cost transparency is not attractive since adopting voluntary cost transparency means that the markup (and thus price), cannot be too much higher than  $k$ . Further examination also shows that  $\tau_{2,1}, \tau_{2,2}$  are increasing in  $\phi, k, \gamma$ . Thus, adoption of voluntary cost transparency is less likely when  $\phi, k$  are high. Combining (5) and (6), we get:

**Lemma 5.** *If  $\Delta \geq \tau_{2,2}$ , the opaque strategy  $O$  is a dominant strategy for Firm 2. If  $\Delta \leq \tau_{2,1}$ , adopting transparent strategy  $T$  is a dominant strategy for Firm 2.*

Using the same analysis for Firm 1 by considering the cases where Firm 2 does not adopt voluntary cost transparency and when Firm 2 does, we can deduce that, when Firm 2 does not adopt voluntary cost transparency, Firm 1 also does not adopt voluntary cost transparency when  $\pi_1^{O,O} - \pi_1^{T,O} \geq 0$ , which occurs if and only if:

$$\Delta \geq \frac{1}{2} \left( \frac{\phi + \gamma c_1(k-1)}{\sqrt{\gamma+1}-1} + (c_1 - c_2) \right) = \tau_{1,1}. \quad (7)$$

Likewise, when Firm 2 adopts voluntary cost transparency, it is optimum for Firm 1 not to adopt voluntary cost transparency when  $\pi_1^{O,T} - \pi_1^{T,T} \geq 0$ , which occurs if and only if

$$\Delta \geq \frac{1}{2} \left( \frac{\phi + \gamma c_1 (k-1)}{\sqrt{\gamma+1} - 1} + (c_1 - c_2) + \phi + c_2 \gamma (k-1) \right) = \tau_{1,2}. \quad (8)$$

As before,  $\tau_{1,2} = \tau_{1,1} + \frac{1}{2}(\phi + c_2 \gamma (k-1)) > \tau_{1,1}$ . Hence, (7) and (8) together imply the following lemma.

**Lemma 6.** *If  $\Delta \geq \tau_{1,2}$ , the opaque strategy  $O$  is a dominant strategy for Firm 1. If  $\Delta \leq \tau_{1,1}$ , adopting the transparent strategy  $T$  is a dominant strategy for Firm 1.*

By combining our results as stated in Lemmas 5 and 6, we can map out the conditions associated with  $\Delta$  that specify the strategy to be adopted by each firm in equilibrium. For ease of exposition, we order  $\tau_{1,1}, \tau_{1,2}, \tau_{2,1}, \tau_{2,2}$  and re-write them as  $\sigma_1, \sigma_2, \sigma_3, \sigma_4$  where  $\sigma_1 \leq \sigma_2 \leq \sigma_3 \leq \sigma_4$ . Specifically, we get:

**Theorem 1. (Asymmetric Duopoly).** *In a duopoly, the strategy for each firm to adopt in equilibrium can be described as follows.*

- *When  $\Delta \leq \sigma_2$ , both firms should adopt the transparent strategy  $T$ .*
- *When  $\Delta \in (\sigma_2, \sigma_3)$  and if  $\{\sigma_2, \sigma_3\} = \{\tau_{1,2}, \tau_{2,1}\}$ , Firm 1 adopts the opaque strategy  $O$ , while Firm 2 adopts the transparent strategy  $T$ . If  $\{\sigma_2, \sigma_3\} = \{\tau_{2,2}, \tau_{1,1}\}$ , Firm 1 adopts the transparent strategy  $T$  while Firm 2 adopts the opaque strategy  $O$ . Otherwise, there exist two equilibria whereby both firms adopt the transparent strategy  $T$  or the opaque strategy  $O$ .*
- *When  $\Delta \geq \sigma_3$ , both firms should adopt the opaque strategy  $O$ .*

Theorem 1 can be interpreted as follows. When the quality differentiation,  $\Delta$  is low, both firms adopt cost transparency ( $T, T$ ). This result is based on the following intuition. When quality differentiation is low, competition intensifies and both firms have to adopt transparency as an alternative lever. This result suggests that when both firms are of similar quality, both firms are forced to pull the transparency lever before they enter the fierce price competition. This is because the firm who remains opaque will lose market share and profit margin. This result suggests that, when quality differentiation is low, firms are likely to adopt the transparency strategy to compete along with price.

On the other hand, when the quality differentiation,  $\Delta$ , is high, no firm adopts voluntary cost transparency ( $O, O$ ). This result is based on the following intuition. When quality differentiation is

high, both firms can simply use selling price to segment the market without pulling the transparency lever to restrict their pricing decisions. This result has the following implications: when a luxury brand (e.g., Cartier) competes with a regular jeweler, neither firms have incentive to adopt the transparent strategy because they can use different selling price to segment the market.

Finally, when the quality differentiation  $\Delta$  is moderate, there are three possible scenarios, depending on the magnitude of  $\phi$ . More specifically, the condition,  $\sigma_2 = \tau_{1,2}$ ,  $\sigma_3 = \tau_{2,1}$  holds if and only if  $\phi$  is sufficiently large.<sup>14</sup> In this case, the first statement in the theorem suggests that the high quality firm will choose the opaque strategy while the low quality firm will choose the transparent strategy. This result is based on the following intuition. When quality differentiation is moderate but the increase in consumers' willingness to pay owing to cost transparency; i.e.,  $\phi$ , is high, the low quality firm can use transparency to compensate for its low quality. In this case, the constraint on the price markup is compensated for by the high  $\phi$ . However, because of its moderate higher quality, the high quality firm finds it sufficient to use its selling to compete without pulling the transparency lever to compete that would limit its freedom in setting its own price. This result has the following implications: when a new entrant with slightly lower (perceived) quality (e.g., Everlane.com) competes with a well established firm with slightly higher (perceived) quality (e.g., Gap), it is beneficial for Everlane to use transparency to compensate for its lower quality. However, with a slight quality edge, Gap can afford to use the opaque strategy so that it can continue to enjoy a higher margin without worrying about the penalty associated with the selling price  $m_1 c_1$  being higher than the fair market reference price  $kc$ . Hence, this result is consistent with what we observe in the market place.

The second condition in the statement, i.e.,  $\sigma_2 = \tau_{2,2}$ ,  $\sigma_3 = \tau_{1,1}$  holds when  $\phi$  is low.<sup>15</sup> In this instance, the benefit from cost transparency is insufficient for the low-quality to compensate for the resultant constraint on the price markup owing to cost transparency. As a result, the low-quality firm foregoes the transparency strategy but opts to be opaque while the high quality firm adopts the transparency strategy. That this outcome where the high-quality firm is transparent on its cost while the low-quality firm is not is not evident in reality. Perhaps this enables us to infer that  $\phi$  is indeed sufficiently high so that the second case when the quality difference is moderate is not observed in reality.

Finally, we note the existence of multiple (symmetric) equilibria,  $(T, T)$ ,  $(O, O)$  for moderate

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<sup>14</sup>  $\sigma_2 = \tau_{1,2} < \sigma_3 = \tau_{2,1}$  if and only if  $\phi > ((\sqrt{\gamma+1}-1)(3(c_1-c_2)+\gamma c_2(k-1))-2\gamma c_2(k-1)+\gamma c_1(k-1))\frac{1}{2-\sqrt{\gamma+1}}$ .

<sup>15</sup>  $\sigma_2 = \tau_{2,2} < \sigma_3 = \tau_{1,1}$  if and only if  $\phi < \frac{1}{2\sqrt{\gamma+1}-1}((\sqrt{\gamma+1}-1)(3(c_1-c_2)-2\gamma c_1(k-1))-2\gamma c_2(k-1)+\gamma c_1(k-1))$ .

values of  $\phi$  and  $\Delta$ . In this instance, either both firms remain opaque about their respective costs, or if one firm adopts the transparent strategy, the other firm finds it optimum too to be transparent as the benefit of being transparent owing to a moderate  $\phi$ , is higher than staying opaque.

In summary, our analysis thus far identifies quality differentiation  $\Delta$  as a key driver for the adoption of the transparency strategy  $T$ . When the firms are sufficiently differentiated in terms of quality, both adopt the opaque strategy and do not disclose their respective cost information. However, when the firms are close in quality, adopting the transparency strategy constitutes the equilibrium for both firms as being transparent about its cost enables a firm to differentiate itself from the competitor. Essentially, as the level of quality differentiation between the firms decreases, firms capitalize on transparency as a lever to differentiate itself from its competitor. This intuition is formalized in the following Theorem:

**Theorem 2. (Impact of Quality Differentiation on Cost Transparency in Asymmetric Duopoly).** *As the quality differentiation  $\Delta$  between the firms decreases, firms tend towards adopting the transparent strategy  $T$ .*

By examining the equilibrium prices in the respective subgames and incorporating the transparency strategy adopted by the firms at the equilibrium, we are able to deduce the following result, that is, as the firms become less differentiated in terms of their quality, pricing competition between the firms become more intense, resulting in lower prices for both firms.

**Theorem 3. (Impact of Quality Differentiation on Prices in Asymmetric Duopoly).** *As the quality differentiation  $\Delta$  between the firms decreases, the prices at equilibrium decrease.*

In summary, we have showed that, in a duopolistic setting, the quality differentiation  $\Delta$  between firms in a duopoly plays a pivotal role in determining the adoption of cost transparency at the equilibrium. When the quality differentiation between firms is high, both firms adopt the opaque strategy. However, both firms adopt the transparency strategy when the quality differentiation is low. Interestingly, when quality differentiation is medium, we find that the high quality firm would adopt the opaque strategy, while the low quality firm would adopt the transparent strategy. This finding corroborates with the case when Everlane.com is the only firm that adopts the transparent strategy. As a new startup with lesser known quality than its competitor (e.g., Gap), our equilibrium analysis predicts that Gap (the firm with higher quality) should adopt the opaque strategy, while Everlane.com (the firm with lower quality) should adopt the transparent strategy. Specifically, by leveraging the transparent strategy, Everlane can boost consumer's willingness to pay despite

the perceived quality is lower. In other words, cost transparency serves as an alternative lever for differentiation and kicks in when quality differentiation falls short to mitigate intensive pricing competition.

## 4 Experimental Study: Two Asymmetric Firms in a Duopoly

By establishing certain modeling assumptions about the consumer response to cost transparency that are based on previous research, we have examined the strategic interactions between two competing sellers and their transparency adoption behavior in a duopolistic environment. In this section, we report a laboratory experiment on participants strategic interactions in the role of sellers given the same stylized model of demand. Our investigation is concerned with the following research questions: will competing sellers in the laboratory make cost transparency and pricing decisions that are consistent with model predictions? Or, instead, will there be any systematic deviations in the sellers decisions from model predictions?

In our experiment, we paired participants up as duopolistic sellers who engaged in pricing competition, with an additional decision variable involving cost transparency adoption. The stages of the experimental competition game, as well as the computer-simulated demand that responded to the sellers decisions, were set up to replicate the asymmetric duopoly model as presented in Section 3. In particular, our experimental design is intended to examine the impact of quality differentiation ( $\Delta = q_1 - q_2$ ) on the competitors' cost transparency and pricing decisions.

### 4.1 Design of Experiment and Development of Hypotheses

Our experiment involved three between-subjects conditions. Specifically, the **quality differentiation**  $\Delta = q_1 - q_2$  was the “treatment” variable that was manipulated across three conditions: high ( $\Delta = 20$ ), medium ( $\Delta = 12$ ), and low ( $\Delta = 4$ ) quality differentiation. In our experiment, the simulated demand in all three conditions was generated by setting  $\phi = 0.2$ ,  $\gamma = 0.4$ , and  $k = 1.5$ . To make the decision scenarios more concrete to the participants, the simulated demand was described as a market of  $N = 1,000$  “buyers” in the experiment, in contrast with the continuum of consumer population in the theoretical model. In practice, we calculated the continuum demand in the experiment given participants' decisions, and then multiplied by  $N$  (with necessary rounding off) to generate the unit sales for the participants. Prices were measured in Experimental Currency Units (ECUs) with a fixed and pre-announced conversion rate to real money (see the Procedure

Table 1. Equilibrium predictions for the experiment

<i>Quality differentiation in the duopoly</i>	<i>Equilibrium predictions for (high-quality seller, low-quality seller)</i>			
	<i>Cost</i>			<i>Profit (ECU)/N</i>
	<i>transparency policy</i>	<i>Price (ECU)</i>	<i>Demand/N</i>	
High: $\Delta q = 20$	(O, O)	(23.33,16.67)	(0.67,0.33)	(8.89,2.22)
Medium: $\Delta q = 12$	(O, T)	(17.27,13.38)	(0.61,0.39)	(4.40,1.33)
Low: $\Delta q = 4$	(T, T)	(11.90,10.95)	(0.67,0.33)	(1.27,0.32)

Note:  $\phi = 0.2$ ,  $\gamma = 0.4$ ,  $k = 1.5$ ,  $c_1 = c_2 = 10$ ; market size in the experiment is  $N = 1,000$ . The unit of price and profit is **Experimental Currency Unit (ECU)**.

section). Lastly, to further simplify the decision scenarios, the marginal cost (known as the “selling cost” in our experiment) was set at  $c_1 = c_2 = c = 10$  for all three conditions. An implication is that the reference price  $kc$  was set at  $kc = 15$  in all conditions for both sellers.

By considering the conditions as stated above, we can apply Lemmas 1-4 and Theorem 1 in §3 to compute various theoretical equilibrium predictions. Table 1 lists the **equilibrium predictions** for the major decision variables of cost transparency adoption and price, as well as the outcome variables of demand and profit, for each of the three experimental conditions. It is apparent from the table that the treatment conditions (as defined by different levels of  $\Delta$ ) generate dramatically different equilibrium cost transparency adoption decisions. Specifically, at high quality differentiation (i.e., when  $\Delta = 20$ ), both sellers adopts the opaque strategy in equilibrium (i.e.,  $(O, O)$ ) and both sellers price relatively high (compared with other conditions). At medium quality differentiation (i.e., when  $\Delta = 12$ ), the high-quality seller adopts the opaque strategy ( $O$ ) while the low-quality seller adopts cost transparency ( $T$ ) respectively, and the equilibrium prices are set at moderate levels. Finally, at low quality differentiation (i.e., when  $\Delta = 4$ ), both sellers adopt cost transparency (i.e.,  $(T, T)$ ): the low quality differentiation leads to intense price competition, resulting in low equilibrium prices.

Given the theoretical equilibrium predictions as stated in Table 1, we design our experiment to test, across conditions, a variety of equilibrium cost transparency adoption patterns in the duopoly. Also, we derive a number of hypotheses from the theoretical equilibrium predictions as discussed in Theorems 1-3 of Section 3 and as illustrated in Table 1, which highlight how cost transparency

adoption and pricing decisions change with quality differentiation  $\Delta$ :

**Hypothesis H1 (Impact of Quality Differentiation on Cost Transparency Adoption).**

1a. The high-quality seller (Firm 1) is equally likely (*more likely*) to adopt cost transparency when quality differentiation decreases from high to medium (*medium to low*).

1b. The low-quality seller (Firm 2) is more likely (*equally likely*) to adopt cost transparency when quality differentiation decreases from high to medium (*medium to low*).

1c. The low-quality seller (Firm 2) is more or equally likely to adopt cost transparency than the high-quality seller (Firm 1) at all levels of quality differentiation. The difference between the two sellers' likelihoods to adopt cost transparency is the highest at medium quality differentiation, compared with either low or high quality differentiation.

**Hypothesis H2 (Impact of Quality Differentiation on Pricing Decisions).**

2a. Both sellers' prices decrease when quality differentiation decreases.

2b. The high-quality seller (Firm 1) sets higher prices than the low-quality seller (Firm 2) at all levels of quality differentiation.

## 4.2 Subjects

A total of 308 participants, with approximately equal proportions of males and females, took part in the experiment. The participants were recruited from the undergraduate subject pool of the behavioral laboratory at a major university in Singapore. The recruitment initiative was conducted with a target of 100 participants per condition for our three-condition design, and the target was achieved. Each experimental session lasted approximately one hour on average. Inclusive of a fixed participation payment of 15 Singapore Dollars that was institutionally required for the duration of the session, participants' earnings from the experiment - which were contingent on their performances - were on average 18.8 Singapore Dollars (US\$1  $\approx$  1.3 Singapore Dollars). Ethical clearance was obtained from the laboratory's institution prior to the experiment.

## 4.3 Procedure

Upon entering the laboratory, every participant was seated in a cubicle with a computer terminal. The programmed interface on the computer terminal was the only channel through which the participant submitted his/her decisions during the experiment.

Each participant was then asked to read through an instructions sheet (see Online Appendix), which he/she could refer to throughout the experimental session. Once every participant had fin-

ished reading the instructions and clicked a button on his/her computer screen to indicate readiness to begin, the participants were randomly and anonymously matched in pairs by the program to form duopolies of sellers. The pairing remained the same throughout the session. We adopted this fixed-pairing arrangement in order to maximize the number of independent data points under our resource constraints. Had we re-matched participants at some point in the session, the re-matching would have introduced some interdependence between different pairs afterwards, which would then have complicated rigorous data analysis. The tradeoff of the fixed-pairing arrangement was that it probably made participants more inclined to attempt tacit collusion during the experimental session. However, as we shall see, while there were indeed some attempts at collusive pricing among the participants, the attempts were far from successful.

Within each matched pair, one participant was randomly assigned to be the high-quality seller (labelled as “Seller P” in the experiment), while the other participant was assigned to be the low-quality seller (labelled as “Seller Q” in the experiment). A participant’s seller role also remained fixed throughout the session. Each experimental session consisted of 30 rounds, each round being an iteration of the experimental game. The experimental game followed our theoretical model for asymmetric duopolies, and involved two decision stages as described in §3:

1. Each seller decided independently whether to adopt cost transparency or not, without any knowledge about the other seller’s cost transparency decision;
2. When both of the cost transparency decisions from Stage (1) were submitted, they became common knowledge to both sellers in the duopoly. Then each seller decided independently his/her own price (i.e., the selling price if the seller adopts the opaque strategy, or the price markup if the seller adopts the transparency strategy) without knowledge about the other seller’s pricing decision.

When both of the pricing decisions from Stage (2) were submitted, they became common knowledge in the duopoly as well. The demands (i.e., unit sales out of the 1,000 simulated buyers) and profits for the sellers were then realized and made common knowledge in the duopoly, which concluded the game.

At the end of the experiment, each participant was paid his/her profit in one randomly chosen round out of the 30 rounds played. The participants’ earnings in ECUs would be converted to real money according to the exchange rate of 1,000 ECUs = 1 Singapore Dollar.

Some of the challenges in the implementation of the experiment were to convey to the par-

ticipants the simulated consumer behavior on the demand side, as well as the idea of quality differentiation. Our approach to these challenges is expressed in the “Buyers’ Responses to the Sellers’ Decisions” section of the Instruction Sheet (see Online Appendix).

Firstly, to convey the demand impact of cost transparency, we stated that, if a seller decided to adopt cost transparency (described as “disclosing his/her selling cost” in the experiment), (i) the buyers would appreciate the decision and become more inclined to purchase from the seller, and (ii) the buyers would “compare the seller’s price with the disclosed selling cost, and judge whether the seller is making a *‘fair’* profit or not”. Importantly, we next pointed out to the participants that “a 50% profit over the selling cost is considered *‘fair’*, in connection with our choice of  $k = 1.5$ .

Secondly, to convey the demand impact of quality difference, we stated that “if both sellers make the same disclosure decisions and set the same price, Seller P [the high-quality seller] will capture all the market, i.e., all of the 1,000 buyers will purchase Seller P’s product, because of the higher quality”.

Lastly, to convey the idea of quality differentiation, we stated how many more unit sales a seller could gain if the seller lowered his/her price by one ECU, in the following format: “If a seller (Seller P or Seller Q) lowers the price per unit of his/her product by 1 ECU, the demand for his/her product could increase by up to  $x$ . That is, up to  $x$  more buyers - would purchase from a sellers for every ECU’s decrease in his/her price”, where  $x$  is 70, 116, and 350 in the high, medium, and low quality differentiation conditions, respectively. This approach is motivated by our observation that, according to the model setup, the quality differentiation variable  $\Delta$  formally affects the profit functions only through its impact as a denominator in the demand function (see §3). Moreover, with our parameters, one ECU’s decrease in a seller’s price could lead to an increase of at most  $\frac{(1+\gamma)N}{\Delta} = \frac{1,400}{\Delta}$  in unit sales. This translates to the values of  $x$  as described above.

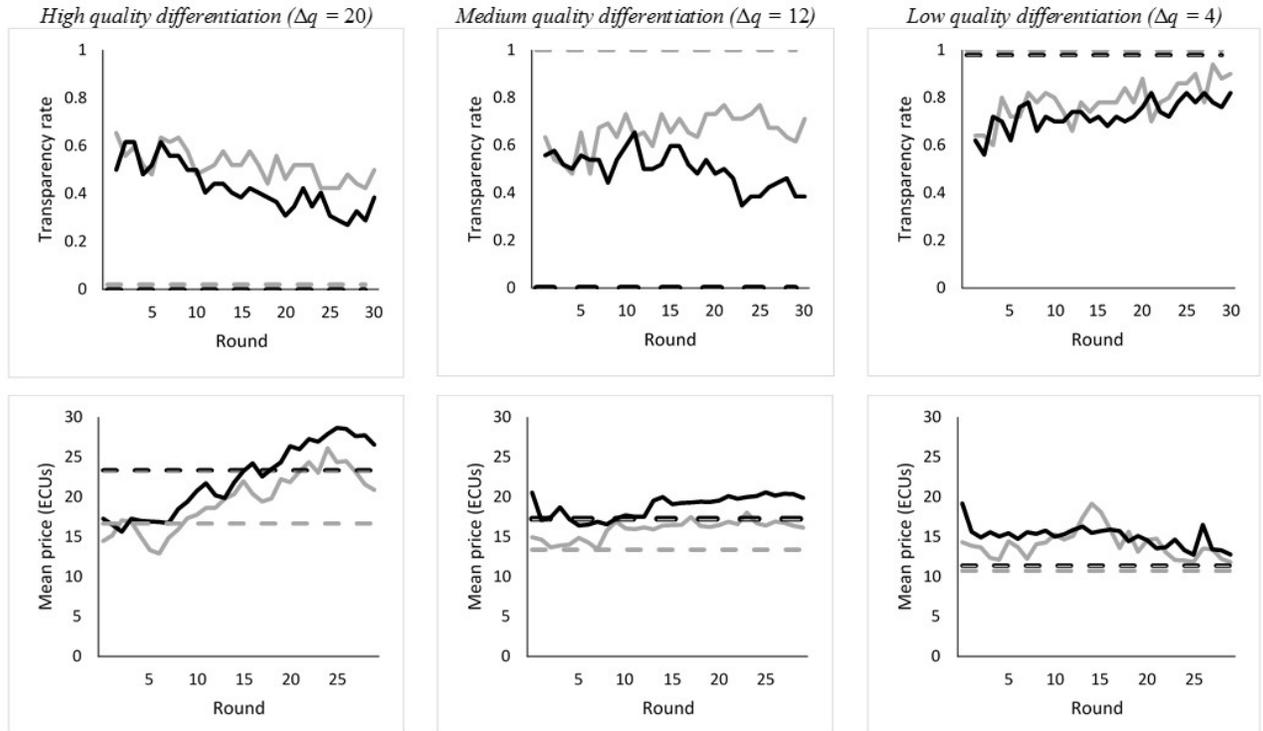
While our approach had not conveyed the full formal details of the demand function, we considered that the participants could grasp our descriptions intuitively within the time constraint of the experimental session. The participants could then learn to improve their decisions from round to round in the session, based on such initial intuitions.

#### 4.4 Results and Analysis

In this section, we report our major findings from our experiment. Our data analysis focuses on two major dependent variables that correspond to the decision variables of cost transparency and pricing decisions; respectively:

Figure 1. Transparency rate and mean price in ECUs by condition, seller role, and round

Observed: high-quality seller ——— Theoretical equilibrium prediction: high-quality seller - - -  
 Observed: low-quality seller ——— Theoretical equilibrium prediction: low-quality seller - - -



1. Transparency rate: the *proportion* of participant sellers' decisions that adopted cost transparency, which can also be seen as a population likelihood measure for the adoption of cost transparency. The measure could be defined over a specific round (Figure 1) or a specific number of rounds (as in Table 2), and is always defined with respect to a particular seller role (high/low-quality) in a particular quality differentiation ( $\Delta$ ) condition in our analysis.
2. Mean price (in ECUs): the *average* selling price selected by all participant sellers with respect to a particular seller role (high/low-quality) in a particular quality differentiation ( $\Delta$ ) condition. Again, this measure could be defined over a specific round (Figure 1) or a specific number of rounds (as in Table 2).

#### 4.4.1 Learning effects

Figure 1 illustrates how these dependent variables (i.e., Transparency rate and Mean price in ECUs) evolved in the sessions. The figure suggests that there were overall “learning effects” in

Table 2. Observed means of major dependent variables (DVs) by condition, seller role, and block of 10 rounds.

(a) Transparency rate		#Subj	Block 1: Round 1-10	Block 2: Round 11-20	Block 3: Round 21-30	Overall	Eq. prediction
<b>High quality differentiation condition (<math>\Delta q = 20</math>)</b>							
High-quality seller	52	0.55	0.40	0.34	0.43	0	
Low-quality seller	52	0.58	0.52	0.47	0.52	0	
<b>Medium quality differentiation condition (<math>\Delta q = 12</math>)</b>							
High-quality seller	52	0.54	0.54	0.42	0.50	0	
Low-quality seller	52	0.60	0.67*	0.70**	0.66*	1	
<b>Low quality differentiation condition (<math>\Delta q = 4</math>)</b>							
High-quality seller	50	0.68*	0.72*	0.78**	0.73**	1	
Low-quality seller	50	0.73**	0.78	0.84*	0.78*	1	
<b>(b) Mean price in ECUs</b>							
		#Obs	Block 1: Round 1-10	Block 2: Round 11-20	Block 3: Round 21-30	Overall	Eq. prediction
<b>High quality differentiation condition (<math>\Delta q = 20</math>)</b>							
High-quality seller	52	17.2 <sup>++</sup>	22.2	27.4	22.3	23.33	
Low-quality seller	52	15.3	19.9	23.3 <sup>+</sup>	19.5	16.67	
<b>Medium quality differentiation condition (<math>\Delta q = 12</math>)</b>							
High-quality seller	52	17.5	18.9	20.1*	18.8	17.27	
Low-quality seller	52	14.7	16.4	16.7	15.9	13.38	
<b>Low quality differentiation condition (<math>\Delta q = 4</math>)</b>							
High-quality seller	50	15.7 <sup>++</sup>	15.5 <sup>+</sup>	13.9 <sup>***</sup>	15.1 <sup>++</sup>	11.90	
Low-quality seller	50	13.5 <sup>++</sup>	15.8 <sup>+</sup>	13.0 <sup>++</sup>	14.1 <sup>++</sup>	10.95	

Note. In any cell, we indicate the results of two types of *t*-tests. First, one or more asterisks (\* $p < 0.05$ , \*\* $p < 0.01$ ) indicate a significant difference from the corresponding cell in the condition with the next higher  $\Delta q$ , according to a between-subjects *t*-test. Second, in any cell in panel (b), one or more superscript plus signs (<sup>+</sup> $p < 0.05$ , <sup>++</sup> $p < 0.01$ ) indicate a significant deviation from equilibrium prediction according to a *t*-test.

all of the experiment conditions. This is understandable, as the experimental game involved a complex scenario of duopolistic competition with two sequential decisions for each player, as well as a demand function that had to be fully appreciated through experience. To further examine the learning effects, we divide the 30 rounds of the experimental session into three blocks. Block 1 includes Round 1 to 10, Block 2 includes Round 11 to 20, and Block 3 includes Round 21 to 30. For each condition and each role, we conducted a within-subjects 3-condition (blocks) ANOVA for each of the two major dependent variables. We find a significant effect in block ( $p < 0.05$ ) in the transparency rate for the high-quality seller across all conditions, as well as for the low-quality seller in the low quality differentiation condition. We also find a significant effect in block ( $p < 0.01$ ) in the mean price in ECUs for either seller role in the high quality differentiation condition. These observations confirm that there were indeed widespread learning in the experiment.

Hence, in the subsequent data analysis, we typically examine the dependent variables separately in each block, as well as the session overall means. Accordingly, Table 2 shows the block-by-block as well as session overall means of each of the major dependent variables, together with the equilibrium predictions (right-most column).

#### 4.4.2 Adoption of cost transparency: Hypothesis H1

Table 2(a) focuses on the transparency rate (i.e., the proportion of participant sellers' who adopted the transparent strategy  $T$ ). Because our equilibrium predictions for the transparency rate are at the endpoints (i.e., either 0 or 1) of the possible range of this dependent variable, standard statistical tests would not be applicable in testing for adherence to equilibrium predictions. Nevertheless, Table 2(a) shows - with statistical results notated in the table - that, directionally across conditions, the transparency rates are consistent with equilibrium analysis as expressed in Hypothesis H1. Specifically, from observing either the Block 3 or the session overall means, we can make the following conclusions:

- (a) The high-quality sellers were not significantly more or significantly less likely to adopt cost transparency when quality differentiation decreased from high to medium. This is consistent with hypothesis H1(a).
- (b) The high-quality sellers were significantly more likely to adopt cost transparency when quality differentiation decreased from medium to low, as indicated by the asterisks (\* or \*\*) in the rows that correspond to low quality differentiation (i.e., when  $\Delta = 4$ ) in Table 2(a). This is consistent with Hypothesis H1(a).

(c) The low-quality sellers were significantly more likely to adopt cost transparency when quality differentiation decreased from high to medium, as indicated by the asterisks (\* or \*\*) in the rows that correspond to medium quality differentiation (i.e., when  $\Delta=12$ ) in Table 2(a). This is consistent with Hypothesis H1(b).

Finally, as shown in the rows that correspond to low quality differentiation (i.e., when  $\Delta=4$ ) in Table 2(a), the low-quality sellers were significantly more likely to adopt cost transparency when quality differentiation decreased from medium to low - whereas equilibrium analysis (Table 1) predicts that transparency rates should have peaked at 1 at medium quality differentiation and remained so at low quality differentiation. This experimental result is therefore not consistent with Hypothesis H1(b). The result suggests that the low-quality sellers had not been adopting cost transparency sufficiently often in the medium quality differentiation condition. The reason behind this observation could be that the low-quality sellers were pricing around - though not significantly above, in a statistical sense - the reference price of 15 in that condition (see Table 2(b)), so that they could be more wary in adopting cost transparency than theoretically predicted.

Next, in order to test Hypothesis H1(c), we compare the differences in the likelihood of adoption of cost transparency by role (high-quality vs. low-quality seller) controlling for the quality differentiation condition. Within-subjects *t*-tests (with each observed duopoly pair as a “subject”) suggest that, under high and medium quality differentiation, the high-quality sellers were less likely to adopt cost transparency than the low-quality sellers overall as well as in Blocks 2 and 3 ( $p < 0.05$  in all comparisons). This is consistent with hypothesis H1(c). The difference under medium quality differentiation is, in particular, highly consistent with equilibrium predictions, which suggest a transparency rate of 0 for high-quality sellers and 1 for low-quality sellers. However, equilibrium predictions suggest equal transparency rate (= 0) by role in the high quality differentiation condition. This in turn suggests that low-quality sellers in that condition overused cost transparency to compete against the high-quality sellers, perhaps because they were too sensitive of their weak competitive position. Note that the differences in transparency rate by role is larger under medium quality differentiation than under high quality differentiation in Block 3 ( $p \approx 0.05$  for the relevant interaction effect). In other words, the difference between the two sellers’ likelihoods to adopt cost transparency is the highest at medium quality differentiation, compared with either low or high quality differentiation. This is consistent with Hypothesis H1(c).

Overall, we have obtained evidence that participants used cost transparency policy strategically in accordance with the competitive environment, in a way that is largely consistent with theory.

### 4.4.3 Pricing decisions: Hypothesis H2

Table 2(b) focuses on the mean price in ECUs, with statistical results notated in the table. First of all, it shows that prices were largely non-significantly different from equilibrium predictions for both seller roles in the medium and high quality differentiation conditions; this is reflected by the fact that there are few '+' or '+ +' signs in Table 2(b) when  $\Delta = 12$  or 20. However, in the low quality differentiation condition where  $\Delta = 4$ , prices were prevalently and significantly above equilibrium predictions; this is reflected by the prevalence of '+' or '+ +' signs in Table 2(b) when  $\Delta = 4$ . Note, however, that these deviations did not affect the fact that both sellers adopted cost transparency with relatively high likelihoods, which is consistent with hypothesis H1(a) (see also Table 1(a)).

The positive deviation in prices from equilibrium predictions under low quality differentiation might be attributed to the human sellers' attempt to "collude" tacitly, since the intense price competition in that condition could erode profits seriously (note the relatively low equilibrium prices and profits in this condition, as listed in Table 1). Within our assumed regime of full market coverage, collusion could theoretically lead to indefinitely high prices, because full market coverage means that every consumer always buys from one of the sellers whatever the prices. But in practice, our computer programme sets an upper limit on prices to 100 ECUs. If we use 100 as a default benchmark for successful collusive pricing, then the seller populations in all three experimental conditions clearly fell short of that benchmark. To sum up, under low quality differentiation, collusive *tendencies* led to a general significant positive deviation from equilibrium predictions. In the other two conditions, there were no significant deviations from equilibrium predictions.

Table 2(b) also offers some evidence in support of Hypothesis H2, which is concerned with directional changes in prices across conditions. Specifically, the high-quality sellers' prices in Block 3 exhibit consistently significant decreases as quality differentiation decreases across conditions, as indicated by the asterisks (\* or \*\*) in the Block 3 column in Table 2(b). Specifically, the high-quality seller's mean price in ECUs decreases from 27.4 to 20.1, and then to 13.9, when quality differentiation decreases from high to medium, and then to low. That is, the high-quality seller's prices were consistent with Hypothesis H2(a) at least upon sufficiently learning. Meanwhile, in Block 3, the low-quality seller's mean price in ECUs also decreases from 23.3 to 16.7, and then to 13.0, when quality differentiation decreases from high to medium, and then to low, although these decreases are statistically non-significant. Possibly, the low-quality seller's prices were too affected by collusive tendencies to offer statistically significant support to Hypothesis H2(a) even

upon learning. Another possible reason is that the high-quality seller's prices should change more dramatically than the low-quality seller's prices across conditions according to equilibrium predictions (see Table 1), and would therefore be less likely to be overwhelmed by noises in our statistical tests.

In order to test hypothesis H2(b), we also compare the differences in prices by role (high-quality vs. low-quality seller) controlling for the quality differentiation condition. Within-subjects t-tests (with each observed duopoly pair as a "subject") suggest that, under high and medium quality differentiation, the low-quality sellers set lower prices than the high-quality sellers overall as well as in every block ( $p < 0.05$  in all comparisons), with the single exception of Block 2 in the low quality differentiation condition. This is consistent with Hypothesis H2(b). The result highlights the intuition that the low-quality sellers had to price lower than the high-quality sellers, in order to overcome their competitive disadvantage.

#### 4.4.4 Correlation between cost transparency and pricing decisions

It is also worth noting that the transparency rate is often *negatively correlated* with the mean price in ECUs for either seller role and in every condition; i.e., a seller tends to set a higher price when he/she adopts the opaque strategy, and set a lower price when he/she adopts cost transparency strategy. Specifically, point-biserial correlation analysis reveals significant ( $p < 0.05$ ) negative correlations in overall as well as Blocks 2 and 3 measures for either seller role and in every condition, *except* for the low-quality seller in Blocks 2 and 3 under the medium quality differentiation condition (where the correlations are non-significant). This can be understood by the intuition that low-quality sellers in that condition adopted cost transparency more often than the high-quality sellers, and with the competitive advantage thus obtained, they were under less pressure to lower prices.

#### 4.4.5 Additional analysis

The results reported in this section focus on the decision variables of cost transparency adoption (i.e., transparency rate) and pricing (i.e., mean price in ECUs). In Appendix B, we summarize the results of additional analysis on the outcome variables of demand and profit. As discussed in the Appendix B, the observed demands were often different from equilibrium predictions. This could be partly driven by the deviations in cost transparency rates from the extreme value equilibrium predictions (i.e., either never or always adopt cost transparency). However, the demand deviations did not translate into profit deviations: profits were largely not significantly different from equilib-

rium predictions. An exception is that the collusive tendencies benefited the high-quality seller's profits significantly in the low quality differentiation condition. But the same is not observed in the other conditions; nor did the tendencies benefit the low-quality seller significantly in any condition.

To conclude, our experimental data offers evidence in support of the intuition from our theoretical equilibrium analysis as presented in Section 3. We find support for both of the hypotheses H1 and H2, which are derived from equilibrium analysis and describe how cost transparency adoption and prices change with quality differentiation. In particular, in keeping with theory, as quality differentiation decreased in the experiment, the sellers (especially the low-quality sellers) adopted cost transparency more prevalently.

## 5 Discussion and Conclusion

Motivated by the observations that some sellers are becoming more transparent by disclosing information about their supply chain process or supply chain cost, we made an initial attempt to understand the economic benefits and the underlying factors for firms to adopt a cost transparency strategy. We first set up a parsimonious and tractable analytical framework to study our research questions. Our model is based on simplifying assumptions about consumers' response to cost transparency - assumptions that are consistent with the empirical findings on the general appeal of cost transparency (Mohan et al. (2015)) as well as dual entitlement concerns (Kahenmann et al. (1986)). Through our analysis of a monopoly, we have found that the transparent strategy is dominant when the perceived product quality is relatively low compared to the unit cost. This result may help to justify why luxury goods firms (with high perceived quality and relative low unit cost) should not disclose their cost information.

We have also extended our analysis to the case when two asymmetric firms compete in a duopoly. Our analytical results revealed that the quality differentiation between firms is the key driver for predicting whether different firms should adopt the transparent strategy or not. Specifically, we have found that both firms should adopt the transparent strategy when the quality differentiation is low, only the low quality firm would adopt the transparent strategy when the quality differentiation is medium, and no firms should should adopt the transparent strategy when the quality differentiation is high. This result is based on the intuition that, when quality differentiation is high, different firms can set different selling price to segment the market. However, as quality differentiation becomes less prominent, competitive pricing alone is not sufficient and the transparent strategy becomes the

additional lever for firms to segment the market.

Our equilibrium predictions based on our analytical results revealed the relationship between: (1) quality differentiation and cost transparency; and (2) quality differentiation and competitive pricing. To examine the causality between quality differentiation and cost transparency adoption of each firm as well as selling price determined by each firm, we conducted a laboratory experiment. Our experiment provided supportive evidence that, as quality differentiation decreases, both firms are more likely to adopt cost transparency and reduce prices.

In our theoretical model, we have made several assumptions. Firstly, we have assumed that the increase in the consumer's willing to pay owing to the firm's adoption of the transparency strategy (denoted by  $\phi$ ) is a constant. Undoubtedly, this could depend on other market parameters such as the marginal cost of the firms. As long as  $\phi$  is independent of the price of the firms, the essence of our results remain, that the extent of quality differentiation drives the adopt of the transparency strategy at the equilibrium. Secondly, we have also assumed that the impact of price fairness, as denoted by  $\gamma$  is symmetric in that consumers react to price above and below the reference point in the same way. Undoubtedly, consumers may potentially respond more to a price above the reference price than when the price is below the reference price, or vice versa. If indeed consumers react more aversely to a price above (below) the reference price, it would imply that there is less tendency for the firm to price higher (lower). In other words, adoption of the cost transparency strategy is less attractive when the reference price is low (high). Nonetheless, quality differentiation between the firms is pivotal on the adoption of the transparency strategy.

Our intent is to make an initial attempt to explore the underlying factors that drive cost transparency in a competitive setting, and there is much more to examine further in future research. For instance, our analytical model is based on perfect information and we relegate the issue of information asymmetry as future research. Also, there is a need to examine the impact of competition intensity on the firm's transparency decision: would firms be more transparent when market competition becomes more intense? Finally, it is conceivable that some firms may use transparency as a "signal" to the market that they are "more honest". Hence, it is of interest to examine the value of this signal and how consumers can use this signal to learn about the underlying quality of the product.

## 6 References

- Aron, A., E. Melinat, E.N. Aron, R.D. Vallone, R.J. Bator. 1997. The experimental generation of interpersonal closeness. *Personality and Social Psychology Bulletin*, 23(4), 363-377.
- Bai, J., KC So, CS Tang, X Chen, H Wang. 2018. Coordinating supply and demand on an on-demand service platform with impatient customers. *Manufacturing and Service Operations Management*, forthcoming.
- Bartling, B., M. Grieder, C. Zehnder. 2017. Competitive pricing reduces wasteful counterproductive behaviors. *Journal of Public Economics*, 156, 34-47.
- Bazerman, M.H. 1985. Norms of distributive justice in interest arbitration. *Industrial & Labor Relations Review*, 38(4), 558-570.
- Buell, R.W., M. Norton, 2011. The labor illusion: How operational transparency increases perceived value. *Management Science*, 57(9), 1564-1579.
- Carter, R.E., D.J. Curry. 2010. Transparent pricing: Theory, tests and implications for marketing practice. *Journal of the Academy of Marketing Science*, 38(6), 759-774.
- Chen, Y., O. Koenigsberg, J. Zhang. 2017. Pay-as-You-Wish pricing. *Marketing Science*, 36(5), 780-791.
- Chen, L., H. L. Lee. 2017. Sourcing under supplier responsibility risk: The effects of certification, audit and contingency payment. *Management Science*, 63(9), 2795-2812.
- Chen, Y., J. Yogesh, R. Jagmohan, J. Zhang. 2009. A theory of combative advertising. *Marketing Science*, 28(1), 1-19.
- Chinander, K.R., M. E. Schweitzer. 2003. The input bias: The misuse of input information in judgments of outcomes. *Organizational Behavior and Human Decision Processes*, 91(2), 243-253.
- Desai, P., D. Purohit, B. Zhou. 2016. The strategic role of exchange promotions. *Marketing Science*, 35(1), 93-112.
- Dijkstra, P. T., M. A. Haan, M. Mulder. 2017. Industry structure and collusion with uniform yardstick competition: Theory and experiments. *International Journal of Industrial Organization*, 50, 1-33.
- Fehr, E., K. M. Schmidt. 1999. A theory of fairness, competition, and cooperation. *Quarterly Journal of Economics*, 114(3), 817-868.
- Fudenberg, D., J. Tirole. 1991. *Game Theory*. MIT Press.
- Gershoff, A. D., R. Kivetz, A. Keinan. 2012. Consumer response to versioning: How brands'

- production methods affect perceptions of unfairness. *Journal of Consumer Research*, 39(2), 382-398.
- Gomez-Martinez, F., S. Onderstal, J. Sonnemans. 2016. Firm-specific information and explicit collusion in experimental oligopolies. *European Economic Review*, 82, 132-141.
- Haws, K., W. O. Bearden. 2006. Dynamic pricing and consumer fairness perceptions. *Journal of Consumer Research*, 33(3), 304-311.
- Huck, S., H.-T. Normann, J. Oechssler. 2004. Two are few and four are many: Number effects in experimental oligopolies. *Journal of Economic Behavior and Organization*, 53(4), 435-446.
- Iris, D., L. Santos-Pinto. 2014. Experimental Cournot oligopoly and inequity aversion. *Theory and Decision*, 76(1), 31-45.
- Jiang, B., K. Sudhir, T. Zou. 2017. Effects of cost-information transparency on intertemporal pricing and innovation. *Working Paper*.
- Kahneman, D., J.L. Knetsch, R. Thaler. 1986. Fairness as a constraint on profit seeking: Entitlements in the market. *The American Economic Review*, 76(4), 728-741.
- Kalayci, K. 2016. Confusopoly: Competition and obfuscation in markets. *Experimental Economics*, 19(2), 299-316.
- Kalkanci, B., E. L. Plambeck. 2015. Measuring and improving supplier responsibility under voluntary vs mandatory disclosure. *Working Paper, Georgia Institute of Technology, Atlanta, GA*.
- Köszegi, B., M. Rabin. 2015. A model of reference-dependent preferences. *The Quarterly Journal of Economics*, 121(4), 1133-1165.
- Kraft, T., L. Valdés, Y. Zheng. 2018. Supply chain visibility and social responsibility: Investigating consumers' behaviors and motives. *Manufacturing & Service Operations Management*, Articles in Advance, June 2018.
- Laurenceau, J., L.F. Barrett, P.R. Pietromonaco. 1998. Intimacy as an interpersonal process: The importance of self-disclosure, partner disclosure and perceived partner responsiveness in interpersonal exchanges. *Journal of Personality and Social Psychology*, 74(5), 1238-1251.
- Marshall, D. MacCarthy, L. McGrath, P. Harrigan, F. 2016. What's your strategy for supply chain disclosure? *MIT Sloan Management Review*, 57(2), 37-45.
- Mohan, Bhavya, R. Buell, L. John. 2015. Lifting the Veil: the Benefits of Cost Transparency. *Advances in Consumer Research*, 43, eds. Kristin Diehl and Carolyn Yoon, Duluth, MN : Association for Consumer Research, Pages: 224-228.
- Morales, A.C. 2005. Giving firms an 'E' for effort: Consumer responses to high-effort firms. *Journal*

of *Consumer Research*, 31(4), 806-812.

Pigors, M., B. Rockenbach. 2016a. Consumer social responsibility. *Management Science*, 62(11), 3123-3137.

Pigors, M., B. Rockenbach. 2016b. The competitive advantage of honesty. *European Economic Review*, 89, 407-424.

Schmidt, K. M., M. Spann, R. Zeithammer. 2015. Pay what you want as marketing strategy in monopolistic and competitive markets. *Management Science*, 61(6), 1217-1236.

Sedikides, C., K. Campbell, G.D. Reeder, A.J. Elliot. 1999. The relationship closeness induction task. *Representative Research in Social Psychology*, 23, 1-4.

Sodhi, M., Tang, C.S. 2018. Research Opportunities in Supply Chain Transparency. Forthcoming, *Production and Operations Management*.

van den Berg, A., I. Bos. 2017. Collusion in a price-quantity oligopoly. *International Journal of Industrial Organization*, 50, 159-185.

## 7 Appendix A: Proofs

### 7.1 Analysis: Monopoly

There are essentially two cases to consider, depending on whether  $M$  adopts the opaque or transparent strategy. To begin, let us consider the case when the firm adopts the opaque strategy  $O$  so that consumers will purchase the product if:

$$U_M(v_j, O) = v_j q - p_M \geq 0,$$

which is equivalent to  $v_j \geq \frac{p_M}{q}$ . By applying the assumption that  $v_j \sim U[0, 1]$ , the product demand is  $D_M^O = 1 - \frac{p_M}{q}$ . By maximizing the firm's profit, the optimal selling price under strategy  $O$  can be written as:  $p_M^{O*} = \operatorname{argmax}_{p_M} \pi_M^O$ , where the profit function  $\pi_M^O = (p_M - c)(1 - \frac{p_M}{q})$ . Solving yields Lemma 7.

**Lemma 7. (Monopoly (Opaque).)** *When a monopoly Firm  $M$  adopts the opaque strategy  $O$ , it is optimal to set the optimal price  $p_M^{O*} = \frac{q+c}{2}$ , and earn  $\pi_M^{O*} = \frac{(q-c)^2}{4q}$ . Furthermore,  $p_M^{O*}$  is increasing in  $q$ ,  $c$ .  $\pi_M^{O*}$  is decreasing in  $c$ , increasing in  $q$ .*

When Firm  $M$  adopts the transparency strategy ( $T$ ), consumers will purchase the product if:

$$U_M(v_j, T) = v_j q - mc + \phi + \gamma c(k - m) \geq 0,$$

which is equivalent to  $v_j \geq \frac{mc(\gamma+1)-\phi-\gamma ck}{q}$ . By applying the assumption that  $v_j \sim U[0, 1]$ , the corresponding demand for  $M$  is  $D_M^T (= \frac{q-(c+k)+\sigma}{q})$ . To maximize its profit with a given cost  $c$ , it is sufficient for the firm to set its optimal margin  $m^{T*} = \operatorname{argmax}_m \pi_M^T$ , where the firm's profit  $\pi_M^T = (m-1)c[\frac{q+\phi+\gamma ck-(\gamma+1)mc}{q}]$ . By considering the first order condition, we obtain Lemma 8.

**Lemma 8. (Monopoly (Transparent))** *When a monopoly Firm  $M$  adopts the transparency strategy  $T$ , the optimal margin  $m^{T*} = \frac{1}{2} + \frac{q+\phi+\gamma ck}{2(\gamma+1)c}$ , the optimal selling price  $p_M^{T*} = m^{T*} \cdot c$ , and the optimal profit  $\pi_M^{T*} = \frac{(q+\phi+\gamma ck-(\gamma+1)c)^2}{4q(\gamma+1)}$ . Furthermore, (i)  $m^{T*}$  is decreasing in  $c$  but increasing in  $q$ ,  $k$ ,  $\phi$ , and increasing in  $\gamma$  for  $ck > q + \phi$ ; (ii)  $p^{T*}$  is increasing in  $q$ ,  $c$ ,  $k$ ,  $\gamma$  and  $\phi$ ; (iii)  $\pi_M^{T*}$  is increasing in  $q$ ,  $k$ ,  $\gamma$ ,  $\phi$  and increasing in  $c$  if and only if  $k > \frac{\gamma+1}{\gamma}$ .*

Comparing the optimal profits as stated in Lemmas 7 and 8, we obtain Proposition 1.

## 7.2 Analysis: Asymmetric Duopoly

We examine the four subgames to derive the adoption of the transparency strategy at equilibrium.

**Subgame 1: ( $O, O$ )** In this subgame, both firms adopt the opaque strategy  $O$  so that the purchase utility  $U_i(v_j, O) = v_j q_i - p_i$  for  $i = 1, 2$ . Hence, from (1), it is easy to check that:

$$U_1(v_j, O) - U_2(v_j, O) = v_j(q_1 - q_2) - p_1 + p_2 = v_j \Delta - p_1 + p_2.$$

In this case,  $U_1(v_j, O) - U_2(v_j, O) \geq 0$  if and only if  $v_j \geq \frac{p_1 - p_2}{q_1 - q_2}$ . By applying the assumption that  $v_j \sim U[0, 1]$ , Firm 1's demand  $D_1^{O,O} = \frac{(q_1 - q_2) - (p_1 - p_2)}{q_1 - q_2}$ , and Firm 2's demand  $D_2^{O,O} = \frac{p_1 - p_2}{q_1 - q_2}$ . Also, each Firm  $i$  chooses  $p_i^{O,O}$  to maximize its profit that can be expressed as:  $\pi_i^{O,O}(p_1, p_2) = D_i^{O,O}(p_i - c_i)$ . By considering the best response function simultaneously, we can determine the equilibrium price  $p_i^{O,O}$  for Firm  $i$  as stated in Lemma 1.

**Subgame 2: ( $T, O$ )** In this subgame, we examine the case where the higher quality firm, Firm 1, adopts the transparent strategy  $T$  while Firm 2 adopts the opaque strategy  $O$ . In this case, the purchase utility for Firm 1 is given as  $U_1(v_j, T) = v_j q_1 + \phi + \gamma c_1 k - m_1 c_1 (\gamma + 1)$ , while the purchase utility for Firm 2 is given as  $U_2(v_j, O) = v_j q_2 - p_2$ . Thus, from (2) and (1), we get:

$$U_1(v_j, T) - U_2(v_j, O) = v_j \Delta + \phi + \gamma c_1 k - m_1 (\gamma + 1) c_1 + p_2,$$

where  $U_1(v_j, T) - U_2(v_j, O) \geq 0$  if and only if  $v_j \geq \frac{1}{\Delta}(m_1(\gamma+1)c_1 - m_2 c_2 - \phi - \gamma c_1 k)$ . By applying the assumption that  $v_j \sim U[0, 1]$ , we can use the same approach as above to determine the demand for each firm  $D_i$ ,  $i = 1, 2$ . Also, as each firm chooses its price to maximize its profit  $\pi_i = (p_i - c_i)D_i$ ,

we can derive the best response functions as:

$$m_1(p_2) = \frac{\Delta + p_2 + \phi + (\gamma k + \gamma + 1)c_1}{2(\gamma + 1)c_1}, \quad (9)$$

$$p_2(m_1) = \frac{m_1(\gamma + 1)c_1 + c_2 - \phi - \gamma c_1 k}{2}. \quad (10)$$

Solving (9) and (10) simultaneously, we obtain Lemma 2.

**Subgame 3:**  $(O, T)$  Next, when the higher quality firm, Firm 1, adopts the opaque strategy  $O$  and Firm 2 adopts the transparent strategy  $T$ , it is easy to check from from (1) and (2) that  $U_1(v_j, O) = v_j q_1 - p_1$ ,  $U_2(v_j, T) = v_j q_2 + \phi + \gamma c_2 k - m_2 c_2 (\gamma + 1)$ . Thus,

$$U_1(v_j, O) - U_2(v_j, T) = v_j \Delta - p_1 - \phi - \gamma c_2 k + m_2 (\gamma + 1) c_2 \geq 0$$

if and only if  $v_j \geq \frac{1}{\Delta}(p_1 + \phi + \gamma c_2 k - m_2 c_2 (\gamma + 1))$ . Solving this non-cooperative subgame in the same manner as in Subgame 2, we obtain Lemma 3.

**Subgame 4:**  $(T, T)$  Finally, when both firms adopt the transparent strategy  $T$ , consumers do not generate additional consumer utility relative to its competitor owing to voluntary cost transparency adopted by both firms. Hence,  $\phi$  plays no role in the equilibrium and for  $i = 1, 2$ ,  $U_i(v_j, T) = v_j q_i + \phi + \gamma c_i k - m_i c_i (\gamma + 1)$ . From (2), we get:

$$U_1(v_j, T) - U_2(v_j, T) = v_j \Delta + \gamma c_1 k - \gamma c_2 k - m_1 c_1 (\gamma + 1) + m_2 c_2 (\gamma + 1) \geq 0$$

if and only if  $v_j \geq \frac{1}{\Delta}(m_1 c_1 (\gamma + 1) - m_2 c_2 (\gamma + 1) - \gamma c_1 k + \gamma c_2 k)$ . Using the same approach as described above, we obtain Lemma 4.

**Proof of Theorem 1.** To prove the theorem, we need only apply Lemmas 1-4 to the following six cases since  $\tau_{2,2} > \tau_{2,1}$  and  $\tau_{1,2} > \tau_{1,1}$ .

**Case 1:**  $\tau_{2,1} \leq \tau_{2,2} \leq \tau_{1,1} \leq \tau_{1,2}$ . The equilibrium strategies are  $(T, T)$  for  $\Delta \leq \tau_{2,2}$ ,  $(T, O)$  for  $\Delta \in [\tau_{2,2}, \tau_{1,2}]$  and  $(O, O)$  for  $\Delta \geq \tau_{1,2}$ .

**Case 2:**  $\tau_{2,1} \leq \tau_{1,1} \leq \tau_{2,2} \leq \tau_{1,2}$ . The equilibrium strategies are  $(T, T)$  for  $\Delta \leq \tau_{2,2}$  and  $(O, O)$  for  $\Delta \geq \tau_{1,1}$ . Note that when  $\Delta \in (\tau_{1,1}, \tau_{2,2})$ , there exist two equilibria  $(T, T)$ ,  $(O, O)$ .

**Case 3:**  $\tau_{1,1} \leq \tau_{2,1} \leq \tau_{2,2} \leq \tau_{1,2}$ . The equilibrium strategies are  $(T, T)$  for  $\Delta \leq \tau_{2,2}$  and  $(O, O)$  for  $\Delta \geq \tau_{2,1}$ . Note that when  $\Delta \in (\tau_{2,1}, \tau_{2,2})$ , there exist two equilibria  $(T, T)$ ,  $(O, O)$ .

**Case 4:**  $\tau_{2,1} \leq \tau_{1,1} \leq \tau_{1,2} \leq \tau_{2,2}$ . The equilibrium strategies are  $(T, T)$  for  $\Delta \leq \tau_{1,2}$  and  $(O, O)$  for  $\Delta \geq \tau_{1,1}$ . Note that when  $\Delta \in (\tau_{1,1}, \tau_{1,2})$ , there exist two equilibria  $(T, T)$ ,  $(O, O)$ .

**Case 5:**  $\tau_{1,1} \leq \tau_{2,1} \leq \tau_{1,2} \leq \tau_{2,2}$ . The equilibrium strategies are  $(T, T)$  for  $\Delta \leq \tau_{1,2}$  and  $(O, O)$  for  $\Delta \geq \tau_{2,1}$ . Note that when  $\Delta \in (\tau_{2,1}, \tau_{1,2})$ , there exist two equilibria  $(T, T)$ ,  $(O, O)$ .

**Case 6:**  $\tau_{1,1} \leq \tau_{1,2} \leq \tau_{2,1} \leq \tau_{2,2}$ . The equilibrium strategies are  $(T, T)$  for  $\Delta \leq \tau_{1,2}$ ,  $(O, T)$  for  $\Delta \in [\tau_{1,2}, \tau_{2,1}]$  and  $(O, O)$  for  $\Delta \geq \tau_{2,1}$ .

By ordering  $\tau_{1,1}, \tau_{1,2}, \tau_{2,1}, \tau_{2,2}$  and re-writing them as  $\sigma_1, \sigma_2, \sigma_3, \sigma_4$ , we derive Theorem 1.  $\square$

## 8 Appendix B: Additional Data Analysis for the Experiment

Table A1 lists the observed means of demand and profit by condition, seller role, and block, all normalized by the market size  $N = 1,000$ .

Panel (a) of Table A1 shows that the demands were often significantly different from equilibrium predictions. Under the high and medium quality differentiation conditions, the high-quality (low-quality) seller consistently captured higher (lower) demands than theoretically predicted (the only exception was over Block 3 under the high quality differentiation condition). These demand deviations could be partly driven by the deviations in cost transparency rates from the extreme value equilibrium predictions (i.e., either never or always adopt cost transparency). For example, the high-quality sellers over-adopted cost transparency in the high and medium quality differentiation conditions (see Figure 1) relative to the equilibrium prescription of never adopting cost transparency. Coupled with the high-quality sellers' intrinsic competitive advantage, their over-adoption of cost transparency contributed to the significant demand deviations as observed. Meanwhile, the changes in demands from the high to the medium quality differentiation conditions followed the directions suggested by equilibrium predictions, that is, decrease for the high-quality seller and increase for the low-quality seller.

In the low quality differentiation condition, the high-quality (low-quality) seller consistently captured lower (higher) demands than theoretically predicted. This could be attributed to the more significant collusive tendencies in that condition, as discussed in the main text. Correspondingly, the changes in demands from medium to low quality differentiation conditions were opposite to the directions suggested by equilibrium predictions. Panel (b) of Table A1 shows that the observed profits were largely not significantly different from equilibrium predictions, at least upon sufficient learning after Block 1. Only in the low quality differentiation condition did the collusive tendencies lead to the high-quality sellers earning significantly more profits than predicted. Nevertheless, such collusive tendencies did not benefit the low-quality sellers over and above the equilibrium predictions. The changes in the high-quality seller's profit across conditions also followed the directions suggested by equilibrium predictions, i.e., a consistently significant decrease as the quality differentiation decreased. However, the low-quality sellers profit did not register a similar significant change across conditions. This is possibly because, compared with the high-quality seller, the low-quality seller's equilibrium profits are relatively near to each other across conditions, so that any directional changes across conditions in the experiment could be more easily overwhelmed by noises.

Table A.1. Observed means of demand and profit by condition, seller role, and block of 10 rounds (normalized by  $N = 1,000$ ).

(a) Demand/ $N$		#Subj	Block 1: Round 1-10	Block 2: Round 11-20	Block 3: Round 21-30	Overall	Eq. prediction
<b>High quality differentiation condition (<math>\Delta q = 20</math>)</b>							
High-quality seller	52	0.80 <sup>++</sup>	0.76 <sup>++</sup>	0.70	0.76 <sup>++</sup>	0.67	
Low-quality seller	52	0.20 <sup>++</sup>	0.24 <sup>++</sup>	0.30	0.24 <sup>++</sup>	0.33	
<b>Medium quality differentiation condition (<math>\Delta q = 12</math>)</b>							
High-quality seller	52	0.73 <sup>***+</sup>	0.69 <sup>***</sup>	0.66 <sup>++</sup>	0.69 <sup>***</sup>	0.61	
Low-quality seller	52	0.27 <sup>***+</sup>	0.31 <sup>***</sup>	0.34 <sup>++</sup>	0.31 <sup>***</sup>	0.39	
<b>Low quality differentiation condition (<math>\Delta q = 4</math>)</b>							
High-quality seller	50	0.61 <sup>***+</sup>	0.59 <sup>***</sup>	0.61 <sup>++</sup>	0.60 <sup>***</sup>	0.67	
Low-quality seller	50	0.39 <sup>***+</sup>	0.41 <sup>***</sup>	0.39 <sup>++</sup>	0.40 <sup>***</sup>	0.33	
(b) Profit (E CU)/ $N$		#Obs	Block 1: Round 1-10	Block 2: Round 11-20	Block 3: Round 21-30	Overall	Eq. prediction
<b>High quality differentiation condition (<math>\Delta q = 20</math>)</b>							
High-quality seller	52	4.59 <sup>++</sup>	8.27	11.2	8.02	8.89	
Low-quality seller	52	0.81 <sup>++</sup>	1.68	3.53	2.01	2.22	
<b>Medium quality differentiation condition (<math>\Delta q = 12</math>)</b>							
High-quality seller	52	3.41 <sup>***+</sup>	4.86 <sup>*</sup>	6.13 <sup>*</sup>	4.80 <sup>*</sup>	4.40	
Low-quality seller	52	1.56	2.35	2.17	2.03	1.33	
<b>Low quality differentiation condition (<math>\Delta q = 4</math>)</b>							
High-quality seller	50	1.85 <sup>***</sup>	2.55	1.91 <sup>**</sup>	2.10 <sup>***</sup>	1.27	
Low-quality seller	50	1.02 <sup>+</sup>	1.78	0.81	1.21	0.32	

Note. In any cell, we indicate the results of two types of  $t$ -tests. First, one or more asterisks ( $*$   $p < 0.05$ ,  $**$   $p < 0.01$ ) indicate a significant difference from the corresponding cell in the condition with the next higher  $\Delta q$ , according to a between-subjects  $t$ -test. Second, one or more superscript plus signs ( $^+ p < 0.05$ ,  $^{++} p < 0.01$ ) indicate a significant deviation from equilibrium prediction according to a  $t$ -test.

**Adopting Cost Transparency as a Marketing Strategy:  
Analytical and Experimental Exploration  
Online Appendix**

## 1 Extension: When the market is not necessarily fully covered

In this appendix, we extend our analysis of the asymmetric duopoly to the case when the market may not be fully covered by the firms (because some consumers may decide not to purchase from any firm when the selling price is too high). For ease of exposition, we shall assume without loss of generality that the reservation utility of each consumer is zero. However, all other aspects of the framework remains the same as described in §3.

### 1.1 Analysis of Subgame 1: $(O, O)$

When both firms adopt the opaque strategy  $O$ , (1) suggests that the purchase utility  $U_i(v_j, O) = v_j q_i - p_i$  for  $i = 1, 2$ . Hence,  $U_1(v_j, O) - U_2(v_j, O) \geq 0$  if and only if  $v_j \geq \frac{p_1 - p_2}{q_1 - q_2}$  and  $U_i(v_j, O) \geq 0$  if and only if  $v_j \geq \frac{p_i}{q_i}$ . Now, observe that, if  $\frac{p_2}{q_2} \geq \frac{p_1}{q_1}$ , we can check that the demand of Firm 2 is zero and therefore such a  $p_2$  is not optimum for Firm 2. Thus, it suffices to consider the case when  $\frac{p_2}{q_2} \leq \frac{p_1}{q_1}$ . Also, observe that a consumer will purchase from firm  $i$  if  $U_i(v_j, O) - U_k(v_j, O) \geq 0$  and  $U_i(v_j, O) \geq 0$  for  $i = 1, 2$ ; or purchase nothing if  $U_i(v_j, O) < 0$  for  $i = 1, 2$ . Combining these two observations, we can show that  $D_1^{O,O} = 1 - \frac{p_1 - p_2}{\Delta}$ ,  $D_2^{O,O} = \frac{p_1 - p_2}{\Delta} - \frac{p_2}{q_2}$ . When each Firm  $i$  chooses  $p_i^{O,O}$  to maximize its profit that can be expressed as:  $\pi_i^{O,O}(p_1, p_2) = D_i^{O,O} \cdot (p_i - c_i)$ , we can solve the best response functions simultaneously to get:

**Lemma 1. Subgame  $(O, O)$ .** *When both firms adopt the opaque strategy  $O$ , the equilibrium price for each firm satisfies:  $p_1^{O,O} = \frac{2q_1}{4q_1 - q_2}(\Delta + c_1 + \frac{1}{2}c_2)$  and  $p_2^{O,O} = \frac{q_2}{4q_1 - q_2}(\Delta + c_1 + \frac{c_2}{2}) + \frac{c_2}{2}$ . Also, the equilibrium profit for each firm satisfies:  $\pi_1^{O,O} = \frac{1}{\Delta(4q_1 - q_2)^2}(2q_1\Delta + (-2q_1 + q_2)c_1 + q_1c_2)^2$ ,  $\pi_2^{O,O} = \frac{q_1}{q_2} \frac{1}{\Delta(4q_1 - q_2)^2}(q_2\Delta + q_2c_1 + (-2q_1 + q_2)c_2)^2$ .*

### 1.2 Analysis of Subgame 2: $(T, O)$

When the higher quality firm 1 adopts the transparent strategy  $T$  and Firm 2 adopts the opaque strategy  $O$ , (1) and (2) reveal that the purchase utility for Firm 1 is given as  $U_1(v_j, T) = v_j q_1 + \phi + \gamma c_1 k - m_1 c_1 (\gamma + 1) = v_j q_1 + X_1 - m_1 c_1 (\gamma + 1)$ , where  $X_1 = \phi + \gamma c_1 k$ , and for Firm 2 is given as  $U_2(v_j, O) = v_j q_2 - p_2$ . In this case,  $U_1(v_j, T) - U_2(v_j, O) = v_j \Delta + X_1 - m_1 (\gamma + 1) c_1 + p_2 \geq 0$

if and only if  $v_j \geq \frac{m_1 c_1 (\gamma + 1) - X_1 - p_2}{\Delta}$ . Furthermore,  $U_1(v_j, T) \geq 0$  if and only if  $v_j \geq \frac{m_1 c_1 (\gamma + 1) - X_1}{q_1}$ ,  $U_2(v_j, O) \geq 0$  if and only if  $v_j \geq \frac{p_2}{q_2}$ .

By using the same argument as described in Subgame  $(O, O)$ , we can check that the demand for Firm 2 is zero and thus cannot be optimum if  $\frac{p_2}{q_2} > \frac{m_1 c_1 (\gamma + 1) - X_1}{q_1}$ . Thus, it suffices to consider the case when  $\frac{p_2}{q_2} \leq \frac{m_1 c_1 (\gamma + 1) - X_1}{q_1}$ . By using the same approach as stated above, we can show that  $D_1^{T,O} = 1 - \frac{m_1 c_1 (\gamma + 1) - X_1 - p_2}{\Delta}$ ,  $D_2^{T,O} = \frac{q_2 m_1 c_1 (\gamma + 1) - q_2 X_1 - p_2 q_1}{\Delta q_2}$ . When each Firm  $i$  chooses  $p_i^{T,O}$  to maximize its profit  $\pi_i^{T,O}$  for firm  $i = 1, 2$  that can be expressed as:  $\pi_1^{T,O} = (m_1 - 1)c_1 D_1^{T,O}$ , and  $\pi_2^{T,O} = (p_2 - c_2)D_2^{T,O}$ . By considering the first order condition, the best response functions are:

$$\begin{aligned} m_1^{T,O}(p_2) &= \frac{\Delta + X_1 + p_2 + (\gamma + 1)c_1}{2(\gamma + 1)c_1}, \\ p_2^{T,O}(m_1) &= \frac{q_2 m_1 (\gamma + 1)c_1 - q_2 X_1 + q_1 c_2}{2q_2}. \end{aligned}$$

Solving the above equations simultaneously, we get:

**Lemma 2. Subgame (T,O).** *When Firm 1 adopts the transparent strategy T and Firm 2 adopts the opaque strategy O, Firm 1's optimal mark up  $m_1^{T,O}$  and Firm 2's optimal selling price  $p_2^{T,O}$  satisfy:*

$$\begin{aligned} m_1^{T,O} &= \frac{1}{(4q_1 - q_2)(\gamma + 1)c_1} (2q_1 \Delta + (2q_1 - q_2)X_1 + q_1 c_2 + 2q_1 c_1 (\gamma + 1)), \text{ and} \\ p_2^{T,O} &= \frac{1}{(4q_1 - q_2)} (q_2 \Delta - q_2 X_1 + 2q_1 c_2 + q_2 c_1 (\gamma + 1)). \end{aligned}$$

Also, the corresponding optimal profit for each firm is given as:

$$\begin{aligned} \pi_1^{T,O} &= \frac{(2q_1 \Delta + (2q_1 - q_2)(X_1 - c_1(\gamma + 1)) + q_1 c_2)^2}{\Delta(\gamma + 1)(4q_1 - q_2)^2}, \\ \pi_2^{T,O} &= \frac{q_1}{q_2 \Delta (4q_1 - q_2)^2} (q_2 \Delta - q_2 X_1 + (-2q_1 + q_2)c_2 + q_2 c_1 (\gamma + 1))^2. \end{aligned}$$

### 1.3 Analysis of Subgame 3: $(O, T)$

Next, when the higher quality firm, Firm 1, adopts the opaque strategy  $O$  and Firm 2 adopts the transparent strategy  $T$ , (1) and (2) reveal that  $U_1(v_j, O) = v_j q_1 - p_1$ ,  $U_2(v_j, T) = v_j q_2 + \phi + \gamma c_2 k - m_2 c_2 (\gamma + 1) = v_j q_2 + X_2 - m_2 c_2 (\gamma + 1)$ , where  $X_2 = \phi + \gamma c_2 k$ . Thus,  $U_1(v_j, O) - U_2(v_j, T) = v_j \Delta - p_1 - X_2 + m_2 (\gamma + 1) c_2 \geq 0$  if and only if  $v_j \geq \frac{1}{\Delta} (p_1 + X_2 - m_2 c_2 (\gamma + 1))$ . Also,  $U_1(v_i, O) \geq 0$  if and only if  $v_j \geq \frac{p_1}{q_1}$ ,  $U_2(v_j, T) \geq 0$  if and only if  $v_j \geq \frac{m_2 c_2 (\gamma + 1) - X_2}{q_2}$ . As before, any optimal  $m_2$  must be such that  $\frac{p_1}{q_1} \geq \frac{m_2 c_2 (\gamma + 1) - X_2}{q_2}$ , for otherwise  $D_2 = 0$ . Solving this non-cooperative subgame in the same manner as in Subgame 2  $(T, O)$  as presented above, we obtain the following lemma.

**Lemma 3. Subgame (O, T).** *When Firm 1 adopts the opaque strategy O and Firm 2 adopts the transparent strategy T, Firm 1's optimal selling price  $p_1^{O,T}$  and Firm 2's optimal mark up  $m_2^{O,T}$  satisfy:*

$$p_1^{O,T} = \frac{q_1}{(4q_1 - q_2)}(2\Delta - X_2 + 2c_1 + c_2(\gamma + 1)), \text{ and}$$

$$m_2^{O,T} = \frac{1}{(4q_1 - q_2)(\gamma + 1)c_2}(q_2\Delta + (2q_1 - q_2)X_2 + q_2c_1 + 2q_1c_2(\gamma + 1)).$$

*Also, the corresponding optimal profit for each firm is given as:*

$$\pi_1^{O,T} = \frac{(2q_1\Delta - q_1X_2 + (-2q_1 + q_2)c_1 + q_1c_2(\gamma + 1))^2}{(4q_1 - q_2)^2\Delta},$$

$$\pi_2^{O,T} = \frac{q_1}{q_2\Delta(\gamma + 1)(4q_1 - q_2)^2}(q_2\Delta + (2q_1 - q_2)X_2 + q_2c_1 + (-2q_1 + q_2)(\gamma + 1)c_2)^2.$$

#### 1.4 Analysis of Subgame 4: (T, T)

Finally, when both firms adopt the transparent strategy T, (2) suggests that  $U_i(v_j, T) = v_jq_i + \phi + \gamma c_i k - m_i c_i(\gamma + 1)$  so that  $U_1(v_j, T) - U_2(v_j, T) = v_j\Delta + X_1 + X_2 - m_1c_1(\gamma + 1) + m_2c_2(\gamma + 1) \geq 0$  if and only if  $v_j \geq \frac{1}{\Delta}(m_1c_1(\gamma + 1) - m_2c_2(\gamma + 1) - X_1 + X_2)$ . Furthermore,  $U_i(v_j, T) \geq 0$  if and only if  $v_j \geq \frac{m_i c_i(\gamma + 1) - X_i}{q_i}$ . Using the same approach as before, we get:

**Lemma 4. Subgame (T,T).** *When both firms adopt the transparent strategy T, the optimal markup  $m_i^{T,T}$  and the corresponding profit  $\pi_i^{T,T}$  for firm  $i = 1, 2$  satisfy:*

$$m_1^{T,T} = \frac{1}{(4q_1 - q_2)(\gamma + 1)c_1}(2q_1\Delta + (2q_1 - q_2)X_1 - q_1X_2 + 2q_1c_1(\gamma + 1) + q_1c_2(\gamma + 1)),$$

$$m_2^{T,T} = \frac{1}{(4q_1 - q_2)(\gamma + 1)c_2}(q_2\Delta - q_2X_1 + (2q_1 - q_2)X_2 + q_2(\gamma + 1)c_1 + 2q_1c_2(\gamma + 1)),$$

$$\pi_1^{T,T} = \frac{1}{(4q_1 - q_2)^2(\gamma + 1)\Delta}(2q_1\Delta + (2q_1 - q_2)X_1 - q_1X_2 + (-2q_1 + q_2)(\gamma + 1)c_1 + q_1c_2(\gamma + 1))^2,$$

$$\pi_2^{T,T} = \frac{q_1}{q_2(4q_1 - q_2)^2(\gamma + 1)\Delta}(q_2\Delta - q_2X_1 + (2q_1 - q_2)X_2 + q_2c_1(\gamma + 1) + (-2q_1 + q_2)(\gamma + 1)c_2)^2.$$

#### 1.5 Equilibrium Strategies

To determine whether a firm should adopt the transparent strategy T in a competitive environment, we compare the payoffs of the firms in each subgame as stated in Lemmas 1-4.

##### 1.5.1 When Firm 2 Adopts the Opaque Strategy O

To begin, suppose Firm 2 adopts the opaque strategy O. Then Firm 1 is better off by adopting the opaque strategy O when  $\pi_1^{O,O} - \pi_1^{T,O} \geq 0$ , which occurs if and only if

$$2q_1\Delta(\sqrt{\gamma + 1} - 1) + \sqrt{\gamma + 1}((-2q_1 + q_2)c_1 + q_1c_2) - (2q_1 - q_2)(X_1 - c_1(\gamma + 1)) - q_1c_2 \geq 0.$$

Because  $\Delta = (q_1 - q_2)$ , the left-hand-side of the above equation is a quadratic function in  $q_1$  with a minimum point. This implies that the above condition holds when  $q_1$  is sufficiently large for any given  $q_2$ . This implies that the best response for Firm 1 is to adopt the opaque strategy also when Firm 2 adopts the opaque strategy. This result is consistent with third statement of Theorem 1: both firms should adopt the opaque strategy when the quality differentiation  $\Delta$  is sufficiently high.

### 1.5.2 When Firm 2 Adopts the Transparent Strategy $T$

Next, suppose Firm 2 adopts the transparent strategy  $T$ . Then, it is optimum for Firm 1 to adopt the opaque strategy  $O$  when  $\pi_1^{O,T} - \pi_1^{T,T} \geq 0$ , which occurs if and only if

$$2q_1\Delta(\sqrt{\gamma+1}-1) + \sqrt{\gamma+1}(-q_1X_2 + (-2q_1 + q_2)c_1 + q_1c_2(\gamma+1)) - (2q_1 - q_2)X_1 + q_1X_2 + (2q_1 - q_2)c_1(\gamma+1) - q_1c_2(\gamma+1) \geq 0.$$

Because  $\Delta = (q_1 - q_2)$ , the left-hand-side of the above equation is again a quadratic function in  $q_1$  with a minimum point. As a result, the above condition holds if  $q_1$  is sufficiently large for any given  $q_2$ . We can conclude that, when Firm 2 adopts the transparency strategy  $T$ , it is optimum for Firm 1 to adopt the opaque strategy  $O$  if the quality differentiation is sufficiently large. If we interpret this statement from a different angle; i.e., firm 1 should adopt the transparent strategy  $T$  when the quality differentiation  $\Delta$  is sufficiently low (when firm 2 adopts the transparent strategy  $T$ ), then this interpretation corroborates with first statement of Theorem 1: both firms should adopt the transparent strategy  $T$  when the quality differentiation  $\Delta$  is sufficiently low.

### 1.5.3 When Firm 1 Adopts the Opaque Strategy $O$

Next, suppose Firm 1 adopts the opaque strategy  $O$ . Then Firm 2 is better off by adopting the opaque strategy  $O$  when  $\pi_2^{O,O} - \pi_2^{O,T} \geq 0$ , which occurs if and only if:

$$-q_2\Delta + (2q_1 - q_2)c_2 - q_2c_1 - \frac{(2q_1 - q_2)}{\sqrt{\gamma+1}}(\phi + \gamma c_2(k-1)) \geq 0.$$

Because  $\Delta = (q_1 - q_2)$ , the left-hand-side of the above equation is a quadratic function in  $q_2$  with a minimum point. Thus, for any given  $q_1$ , the above condition holds when  $q_2$  is sufficiently low. This implies that, when Firm 1 adopts the opaque strategy, the opaque strategy is the best response for Firm 2 if the quality differentiation is high. Put differently, this finding supports the third statement in Theorem 1, that both firms adopt the opaque strategy when quality differentiation is high.

#### 1.5.4 When Firm 1 Adopts the Transparent Strategy $T$

Finally, suppose Firm 1 adopts the transparent strategy,  $T$ . Then it is optimal for Firm 2 to adopt the opaque strategy when  $\pi_2^{T,O} - \pi_2^{T,T} \geq 0$ , which occurs if and only if:

$$-q_2\Delta + q_2(\phi + \gamma c_1(k-1)) + (2q_1 - q_2)c_2 - q_2c_1 - \frac{(2q_1 - q_2)}{\sqrt{\gamma + 1}}(\phi + \gamma c_2(k-1)) \geq 0.$$

Because  $\Delta = (q_1 - q_2)$ , the left hand side of the above equation is a quadratic function in  $q_2$  with a minimum point. This implies that, for any given  $q_1$ , the above condition holds when  $q_2$  is sufficiently small. As a result, we conclude that, when Firm 1 adopts the transparency strategy, it is optimal for Firm 2 to adopt the opaque strategy if the quality differentiation is high. Put differently, when Firm 1 adopts the transparent strategy, the transparent strategy is optimum for Firm 2 if the quality differentiation is low. This finding supports the first statement in Theorem 1: when quality differentiation is low, both firms adopt the transparent strategy,  $T$ .

By combining our findings as stated above, we can conclude the following. When the market may not be fully covered, our key findings as stated in Theorem 1 continued to hold. Specifically, both firms should adopt the transparent strategy when the quality differentiation is low, and adopt the opaque strategy when the quality differentiation is high.

## 2 Description of Experiment

### Sample Instructions in the Experiment (High Quality Differentiation Condition)

#### INSTRUCTIONS

*Welcome to this decision-making study. Please read these instructions carefully at your own pace.*

*If you follow them closely, you may earn a considerable amount of money.*

The study consists of **30 rounds** in which you will make many decisions. It will last approximately one hour. If you have any questions at any point, please raise your hand, and a study coordinator will approach you. Please do not ask any questions aloud or communicate with other participants.

#### DESCRIPTION OF THE STUDY

At the beginning of the study, you will be randomly matched with another participant in this session to form a pair of competing sellers. **You will interact with this same participant repeatedly** in all the **30** rounds of the study through the study interface on the computer in front of you.

The sellers (you and the participant who is matched with you to be a competing seller) will be selling their products to a market of 1,000 simulated buyers, who make purchases according to a preset program. In every round, every simulated buyer will purchase exactly one product unit from either of the sellers.

Each product unit costs a seller 10 Experimental Currency Units (ECUs) to sell. This is the **selling cost**. There are no other costs to the sellers. The selling cost is the same for both sellers and remains the same (at 10 ECUs) throughout the study.

The seller' decisions in every round proceed in two stages, which will be indicated in your study interface.

1. Stage 1: Each seller decides independently whether to disclose the selling cost of his/her product to the buyers (called "disclosure decision"). The decision is either "Opaque" (i.e., not disclosing the selling cost) or "Transparent" (i.e., disclosing the selling cost). After both sellers have submitted their disclosure decisions, these decisions will be made public between the sellers, and the round will proceed to Stage 2.
2. Stage 2: Each seller sets the price per unit of his/her product (in ECUs) independently. After both sellers have submitted their prices, the prices will be made public between the sellers.

The simulated buyers will then make purchase decisions according to a preset program. You and the competing seller will be informed about how many buyers (out of the 1,000 buyers in the market) purchase your product. This is the **demand for your product**. You will also be informed about how many buyers purchase the competing seller's product (i.e., the competing seller's demand). Each seller will also be informed about his/her own profit as well as the competing seller's profit. A seller's profit depends on his/her price, the selling cost (fixed at 10 ECUs) and the demand of his/her product according to this formula:

$$\text{Profit} = (\text{Price} - 10 \text{ ECUs}) \times \text{Demand}$$

### **SELLER ROLE**

One of the sellers will be assigned the role of Seller P; the other seller will be assigned the role of Seller Q. Seller P's product has a higher quality than Seller Q's product, and thus, Seller P has a competitive advantage over Seller Q (see below). The participants will be informed about his/her assigned seller roles at the beginning of the study; each participant's role will remain the same throughout the study.

### **BUYERS' RESPONSES TO THE SELLERS' DECISIONS**

The simulated buyers respond to the sellers' decisions according to a preset program. The program has the following features:

1. Seller P's product has a higher quality than Seller Q's product, so that Seller P has a competitive advantage over Seller Q. This means that, for example, if both sellers make the same disclosure decisions and set the same price, Seller P will capture all the market, i.e., all of the 1,000 buyers will purchase Seller P's product, because of the higher quality.
2. If a seller (Seller P or Seller Q) lowers the price per unit of his/her product by 1 ECU, the demand for his/her product could increase by up to 70. That is, up to 70 more buyers (7% of all the 1,000 buyers) would purchase from a seller for every ECU's decrease in his/her price.
3. Disclosing selling cost can have two effects for a seller:
  - (a) The buyers will appreciate the seller's cost transparency and become more inclined to purchase from the seller;

- (b) The buyers will also compare the seller's price with the disclosed selling cost, and judge whether the seller is making a "fair" profit or not. The program is such that a 50% profit over the selling cost is considered "fair". That is, if the selling cost (10 ECUs) is disclosed to the buyers, a price of 15 ECUs (making a profit of 5 ECUs, i.e., 50% of the selling cost) is considered "fair". Any prices that are lower than 15 ECUs will attract more buyers to the seller; any prices that are higher than 15 ECUs will turn buyers away from the seller.

These two effects, when combined, could result in a net increase (when the price is low enough) or a net decrease (when the price too high) in the demand of the seller's product.

Note that, in any round:

1. **The simulated buyers do not know the selling cost of a seller until the seller decides to disclose it in that round.**
2. **The buyers do not know that the sellers' selling costs are the same.** If a seller discloses his/her selling cost but the other seller does not, the buyers will not know (and respond to) whether the latter seller is making a "fair" profit or not.
3. **The buyers have no "memory" from round to round,** and will not remember the disclosed cost from any previous round.

### **HOW WILL YOU BE PAID?**

At the end of the study, after all the 30 rounds are over, your profit in ECUs from **1 randomly chosen round** will be converted into money at the rate of 1,000 ECUs per S \$1. This will be added to your participation bonus of S\$15, and paid to you in private and in cash (rounded to the nearest S\$) at the end of the session.

If you have any questions, please raise your hand and the study coordinator will approach you. Once you have completed reading the instructions, please click the button on your study interface to show that you are ready. The study will begin when every participant in this session has clicked that button on his/her study interface.

**Good luck!**