Endogenous Costs, Market Competition, and Disclosure

Abstract

Firms must often decide whether or not to disclose private information regarding their costs to other market participants. While extant literature has explored firms' incentives to disclose exogenous and uncertain costs, little is known about when firms should disclose their endogenous costs. This paper studies the cost-disclosure strategies of competing firms whose inputs are sourced from and endogenously priced by upstream suppliers. We find, first, that cost disclosure affects not only market competition but also the motivations of suppliers in setting their input prices; as such, firms can make their disclosure decisions strategically to optimize their procurement costs. Second, we find that firms' disclosure decisions vary depending on both the nature of the competition and the market structure at hand. That is, when competing firms source from the same supplier or compete on price, they never disclose their costs but, when they source from different suppliers and compete on quantity, they always disclose. Third, we find that compared to voluntary disclosure, mandatory disclosure and nondisclosure both lead to higher market prices, injuring consumer surplus and social welfare. This finding serves as a warning to policymakers that regulations designed to increase/decrease market transparency may have unintended negative consequences. Together, our results underscore the distinct role that endogenous costs play in firms' disclosure decisions.

Keywords: Disclosure, procurement cost, competition, transparency.

1 Introduction

Firms often possess private information regarding their costs, which may be affected by several factors, including the firm's stochastic production technology, legal and compliance issues, taxation, and the input costs charged by suppliers. None of this information can be easily assessed by other market participants. Instead, firms decide whether to disclose such private information to external firms and consumers.

In practice, firms' disclosure decisions often vary. Publicly listed companies regularly disclose their costs through official announcements or financial statements (Darrough, 1993) and disseminate their cost information through trade associations (Gal-Or, 1986; Shapiro, 1986; Vives, 1990). Many firms also employ modern technologies, such as a blockchain, to effectively communicate their cost information to the public (Jiang et al., 2021).

Certain firms, however, make cost transparency a corporate principle. For instance, the US apparel firm Everlane has built its company upon the premise of "radical transparency" (Testa et al., 2020), publishing the cost breakdown of all its products on its website. Swedish apparel manufacturer Asket[1], US footwear brand Oliver Cabell[2], Singapore homeware manufacturer IUIGA[3], and social media management software Buffer[4] all commit to similar breakdowns of cost via various platforms. Of course, just as many, if not more, firms choose to remain silent regarding their cost information (Mohan et al., 2020). These dichotomies then raise the question of why some firms are willing to disclose their cost information while others are not.

To shed light on varying cost disclosure practices, the literature has extensively investigated firms' incentives to disclose their cost information in an oligopoly (Gal-Or, 1986; Shapiro, 1986). The generally accepted conclusion is that firms should disclose (conceal) their cost information under quantity (price) competition, in which cost disclosure reduces (intensifies) market competition. The intuition is as follows: Under quantity (price) competition, when the cost disclosed by a firm is low, the firm's rival will decrease its output (price); however, when the cost disclosed by the focal firm is high, the rival will increase its output (price). While the former effect benefits (hurts) the focal firm, the latter effect hurts (benefits) it. Overall, the gain (loss) from the former

[1] https://www.asket.com/us/transparency/impact
[2] https://olivercabell.com
[3] https://www.iuiga.com
[4] https://buffer.com/resources/transparent-pricing-buffer/

effect is more consequential since it offsets the loss (gain) incurred from the latter effect. Therefore, a firm should disclose (conceal) its cost information under quantity (price) competition.

Although these findings are insightful, they do not shed light on firms' disclosure of their endogenous cost information. That is, extant literature focuses exclusively on cases in which firms' costs are exogenous and uncertain (e.g., determined by stochastic production technologies) (Gal-Or, 1986). While exogenous costs are common, there are also situations in which firms' costs are endogenously determined. For instance, manufacturers often rely on upstream suppliers to provide essential inputs and, thus, their prices are likely to be determined by the suppliers themselves.

Still, it remains unclear what strategies firms should apply when making disclosure decisions regarding their endogenous costs. To fill this gap in research and business practice, we study the incentives that firms have when considering the disclosure of information regarding their endogenous costs.

Following Gal-Or (1986) and Shapiro (1986), we consider a duopoly model in which two manufacturers produce differentiated products and compete either on quantity or on price. However, we depart from the literature by assuming that the manufacturers source their inputs from their respective suppliers who decide the input prices. Then, the manufacturers choose whether to disclose their procurement costs (i.e., the input prices) to the market.

We investigate two market structures, with the manufacturers sourcing their inputs from either different suppliers or a common supplier. Both conditions represent common business practices. For instance, Boeing and Airbus produce competing aircraft models and procure engines from different suppliers; meanwhile, tech giants Qualcomm and Broadcom both source chips from the same supplier. To eliminate the conventional reasoning for cost disclosure, we assume that the manufacturers incur no costs other than those of procurement and that there is no cost uncertainty.

A number of noteworthy inferences can be drawn from this model. First, we find that the focal manufacturer's disclosure decision affects its rival's quantity or price decision, which, in turn, affects the focal manufacturer's demand and, hence, its procurement from its supplier. Accordingly, the supplier must take its downstream manufacturer's disclosure decision into account when determining its input price.

Consider the case in which the manufacturers source from independent suppliers and com-

pete on quantity. When the focal manufacturer discloses its costs and reveals an increase in its input price, the rival manufacturer increases its output, forcing the focal manufacturer to cut its production and decrease its output, injuring its upstream supplier. This strategic effect, however, vanishes when the focal manufacturer withholds its cost information. Comparing the two scenarios, we find that the supplier is less willing to charge a high input price when its downstream manufacturer chooses to disclose its cost information. This chain of reasoning suggests that a manufacturer can influence the price of its input through strategic cost-disclosure decisions. This effect exists even in the absence of cost uncertainty and, to the best of our knowledge, has not been studied prior.

Second, we investigate the manufacturers' equilibrium cost-disclosure decisions. Our results suggest that, when the manufacturers compete on price or source from a common supplier, both conceal their cost information to secure low procurement costs from their supplier(s). Conversely, when the manufacturers source from independent suppliers and compete on quantity, they both disclose their cost information, which is a unique equilibrium outcome. By making these cost-disclosure decisions, the manufacturers can convince their upstream suppliers to charge lower input prices, thereby widening their profit margins.

These findings contribute to the literature by suggesting that a manufacturer's cost-disclosure decision should depend not only on the nature of the competition (i.e., quantity vs. price) but also on the nature of the costs to be disclosed (i.e., exogenous vs. endogenous) and the market structure (i.e., common supplier vs. independent suppliers). In general, a manufacturer may wish to disclose certain costs while withholding other costs. For instance, under quantity competition, a manufacturer may wish to disclose its exogenous production costs while withholding its endogenous procurement costs when sharing a supplier with its rivals.

Finally, we analyze the economic consequences of mandatory disclosure and nondisclosure. Antitrust authorities are often concerned about the effect that information sharing or withholding has on consumer welfare. Established wisdom suggests that information transmission has both its upside and downside, which public policymakers may wish to better control through mandating the disclosure or concealment of cost information. Our analysis indicates that, compared to voluntary disclosure, both mandatory disclosure and nondisclosure always lead to higher retail prices, injuring consumer surplus and social welfare. As such, public policymakers should leave

the firms to make their disclosure decisions independently.

In sum, our findings suggest that, although endogenous costs are ubiquitous and must be factored into any general picture of business processes, conventional wisdom regarding disclosure of such costs should be applied with caution, given that it affects not only market competition but also how suppliers set their input prices. It is not *a priori* clear whether these effects alter firms' disclosure incentives.

2 Literature Review

While cost disclosure is not practiced uniformly, the importance of studying its implications is well recognized. Mohan et al. (2020), for instance, show that cost disclosure fosters trust and increases consumers' willingness to purchase from the cost-disclosing firm. Cost disclosure particularly affects firms' marketing strategies when consumers care about price fairness and/or when firms are under market competition. For instance, Bearden et al. (2003) analyze the effects of cost transparency on consumers' perceptions of price fairness and show that consumers perceive prices to be fairer when firms' costs are higher. To investigate a firm's optimal pricing and cost-disclosure strategies when consumers are fair-minded, Guo (2015) develops a game-theoretic model through which he shows that a firm will disclose its cost information when its costs are neither too low nor too high.

The literature also extensively addresses competing firms' incentives to share their cost information with each other (Vives, 1984; Fried, 1984; Li, 1985; Gal-Or, 1986; Shapiro, 1986; Darrough, 1993). Researchers generally agree that, when firms can pre-commit to a disclosure policy, they will choose to disclose their costs under quantity competition but not under price competition due to the ramifications of competition. Li (2002) discusses a retailer's incentive to disclose its cost information to its upstream supplier and suggests that information disclosure has a leakage effect given that a retailer may infer its rival's cost through a common supplier's pricing decision. Studying both the acquisition and disclosure of cost information, Ganuza and Jansen (2013) find that cost disclosure increases firms' incentive to acquire information, which can benefit consumers. Meanwhile, Zhu (2002, 2004) shows that cost transparency disincentivizes high-cost firms to participate in the market, thereby reducing their profits and social welfare. Finally, Jiang et al.

(2021) show that cost transparency has significant effects on the intertemporal pricing behavior of a durable goods monopolist. We build upon this volume of research by exploring cases in which firms' costs are endogenously given. We find that the nature of the costs to be disclosed has notable implications on firms' disclosure decisions.

Beyond cost information, firms may disclose other information such as demand, product quality and fit. Vives (1984) and Gal-Or (1985) investigate the disclosure of demand information in an oligopoly and find that firms disclose (conceal) their demand information under price (quantity) competition. Gal-Or et al. (2008) investigate the sharing of demand information between an upstream manufacturer and two downstream retailers and show that this sharing can mitigate distortions in wholesale prices. Jiang et al. (2016) examine information disclosure in a vertical relationship in which an upstream firm possesses better demand information than a downstream firm and find that upstream and downstream firms are misaligned in their preferences regarding disclosure. Probing a supply chain in which the retailer possesses better demand information and can engage in demand-enhancing activities, Mittendorf et al. (2022) show that permitting a retailer to withhold its demand information can increase supply chain efficiency. Focusing on product quality, Guo and Zhao (2009) analyze how competition may influence duopolistic firms' incentives to voluntarily reveal quality information; they find that firms in competitive markets reveal less information than firms operating in a monopoly do. Zhang and Li (2021) extend Guo and Zhao's (2009) work by investigating the role of consumer loss aversion in firms' disclosure incentives. Guo (2009) considers quality-disclosure decisions in a vertical relationship and finds that retail disclosure tends to produce equilibrium information revelation. Finally, with a focus on product fit, Guo and Iyer (2010) study the acquisition and disclosure of product fit information in a vertical relationship and show that, when information acquisition is sequential, the upstream firm may choose not to acquire perfect information even if it is costless to do so. Sun and Tyagi (2020) investigate firms' incentives to disclose product fit information to consumers and suggest that the disclosure decision hinges on the degree of retail competition.

More broadly, our present study contributes to the large body of research on the effects of information (non-)transparency on firms' marketing decisions. Hart and Tirole (1990), O'Brien and Shaffer (1992) and McAfee and Schwartz (1994) have all shown that, when a retailer cannot observe the contract terms between a manufacturer and a rival retailer, the manufacturer is in-

centivized to opportunistically renegotiate another retailer's contract to increase bilateral profits at the rival retailer's expense. Bringing consumers into the equation, Janssen and Shelegia (2015) find that consumers' lack of information regarding the prices that manufacturers charge to retailers causes equilibrium prices to become inefficiently high, thus worsening the problem of double marginalization and consequently lowering manufacturers' profits. Li et al. (2020) analyze the effects of a firm's transparency on its data collection behavior and find that increased data collection transparency can benefit the firm but actually harm consumers. Allender et al. (2021) consider the effect of price non-transparency on a firm's personalized pricing decision and show that price non-transparency effectively reduces peer-induced fairness concerns and increases the firm's pricing power. Investigating a firm selling a network good to consumers, Hajihashemi et al. (2022) find that, when prices are non-transparent, the ability to offer personalized prices to consumers does not necessarily constitute an advantage to the firm. Finally, Guo (2021) examines the economic impact of blockchain-enabled transparency on equilibrium wholesale and resale prices and shows that transparency can influence the externality between negotiations of transfer prices in a supply chain.

3 Model Setup

Firms. Consider a market in which two manufacturers ($i = 1, 2$) compete against each other. Each manufacturer sources inputs (e.g., raw materials, components, licenses, equipment, design, patents and servicing) from an upstream supplier to produce a final product, which it sells to consumers. We consider two scenarios: (1) the manufacturers source from independent suppliers; and (2) the manufacturers source from a common supplier. Both scenarios are common in practice. For example, the aircraft manufacturer Boeing procures GE9X engines from General Electric for its 777X model aircraft, while its competitor, Airbus, procures Trent XWB engines from Rolls-Royce for its A350, a major rival of the 777X. Similarly, Sony procures graphics processing units (GPUs) from AMD for its PlayStation game console, while Nintendo uses Nvidia's GPUs for its Switch console. Meanwhile, the "fabless" companies Qualcomm and Broadcom both rely on TSMC for their chips. The smartphone manufacturers Apple, Samsung and Xiaomi all licence the same processor architecture from ARM Ltd. Let c_i ($i = 1, 2$) denote manufacturer i's unit procurement

cost from its upstream supplier.

We normalize to zero the suppliers' (or the common supplier's) costs of producing and supplying the inputs. We also normalize to zero the manufacturers' manufacturing and selling costs. In this case, the manufacturers' only costs are their procurement costs, which are equal to the input prices c_1 and c_2. (We use the terms "procurement cost" and "input price" interchangeably throughout this paper.) Note that incorporating these assumptions eliminates cost uncertainty from the model, which in turn allows us to rule out the conventional mechanisms of cost disclosure.[5]

Our model assumes that the suppliers and manufacturers are contracted through wholesale price contracts. This assumption mimics real-life conditions under which most supply chain contracts are "governed by simple contracts defined only by a per-unit wholesale price" (Lariviere and Porteus, 2001). While the rationalization of wholesale price contracts is addressed in the literature (e.g., Cui et al. 2007; Ho and Zhang 2008; Carroll 2015; Li and Liu 2021), it is beyond the scope of this paper.

Market Competition. We consider two standard types of competition: Quantity and price competition. Under quantity competition, the two manufacturers simultaneously choose the amount of output q_1 and q_2 to offer to the market. The inverse demand function for manufacturer i's product is

$$p_i = 1 - q_i - \theta q_j, \;\; j = 3 - i,$$

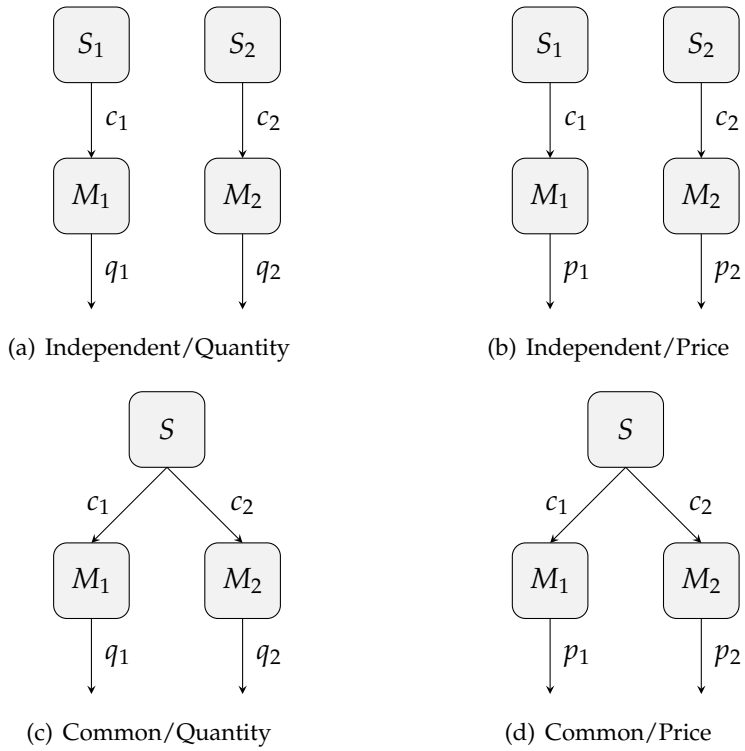
where $0 \leq \theta \leq 1$ captures the extent of market competition.

Under price competition, the manufacturers simultaneously choose their prices p_1 and p_2, and order from their upstream suppliers. A manufacturer's demand is linear in its prices and those of its rival:

$$D_i = 1 - p_i + \theta p_j, \;\; j = 3 - i,$$

where $0 \leq \theta < 1$, again, captures the extent of market competition (Singh and Vives, 1984; Chen, 2003; Gal-Or et al., 2008). Singh and Vives (1984) detail the microstructure that generates the above linear demands under price and quantity competition.

[5]The literature on cost disclosure typically views firms' costs as exogenous and stochastic (e.g., determined by a stochastic technology). When costs are exogenous and deterministic, the issue of cost disclosure does not arise.



(a) Independent/Quantity (b) Independent/Price

(c) Common/Quantity (d) Common/Price

Figure 1: Four scenarios

It is worth mentioning that the literature often uses a different structure to model price and quantity competition, i.e., $p_i = a - bq_i - cq_j$ for quantity competition and $D_i = a - bp_i + cp_j$ for price competition, where $b \geq c \geq 0$. This structure is equivalent to our model. When considering quantity competition, we transform the inverse demand function to $\frac{p_i}{a} = 1 - \frac{b}{a} \cdot q_i - \left(\frac{c}{b}\right) \frac{b}{a} \cdot q_j$. Let $\hat{p}_i = \frac{p_i}{a}$, $\hat{q}_i = \frac{b}{a} \cdot q_i$, and $\theta = \frac{c}{b}$, we rewrite the inverse demand function as $\hat{p}_i = 1 - \hat{q}_i + \theta \hat{q}_j$, which is equivalent to our model. We can similarly transform the above model when considering price competition.

As we consider two types of market structure (i.e., independent suppliers vs. a common supplier) and two types of competition (i.e., quantity vs. price), we investigate four scenarios in total. Our analyses show that both the market structure and the nature of competition have significant implications for the manufacturers' disclosure policies. Figure 1 illustrates these scenarios.

Cost Disclosure. Contract terms between upstream suppliers and downstream manufacturers are typically business secrets not directly accessible by rival firms (McAfee and Schwartz, 1994; Mohan et al., 2020). Nonetheless, manufacturer i can voluntarily disclose its cost information through, for instance, financial filings or public announcements. Therefore, if manufacturer i

chooses to disclose its cost information, rival manufacturer j can observe c_i; otherwise, it cannot observe c_i and must rely on its belief regarding c_i when making its price/quantity decisions.

We assume that disclosure is credible, truthful, and costless for the manufacturers. The assumption of costless disclosure allows us to focus on the strategic effect of disclosure itself. In Section 5.3, however, we consider a scenario in which the manufacturers must incur a fixed cost when choosing disclosure and show that our results remain unchanged when the disclosure cost is not too high.

Sequence of Events. The game unfolds in three stages. In the first stage, the two manufacturers simultaneously commit to a disclosure policy $\alpha_i \in \{D, ND\}$, where D denotes disclosure and ND stands for nondisclosure.[6] In the second stage, the upstream suppliers set (or the common supplier sets) the input prices c_1 and c_2 for their respective manufacturers. If manufacturer i chooses disclosure (i.e., $\alpha_i = D$), it discloses c_i which will be observed by supplier j and manufacturer j. Otherwise, if manufacturer i chooses nondisclosure (i.e., $\alpha_i = ND$), neither supplier j nor manufacturer j can observe c_i. In the last stage, if the manufacturers compete on quantity, they set the amounts of their output q_1 and q_2 to offer to the market. If they compete on price, they set the prices for products p_1 and p_2, and consumers make their purchasing decisions. Figure 2 illustrates the timing of the model.

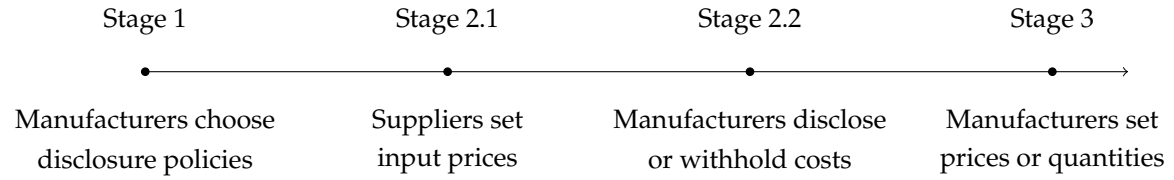


Figure 2: Timing of the model

Our model assumes that the manufacturers can pre-commit to a disclosure policy before their actual costs are set. This *ex-ante* disclosure assumption is commonly made in the disclosure literature (Gal-Or, 1985; Shapiro, 1986; Darrough, 1993; Guo, 2009, 2020; Xiong and Yang, 2021) and can be justified in several ways. For example, the literature on industry organization typically considers trade associations as ways to implement ex-ante disclosure (Vives, 1984; Gal-Or, 1985): Firms joining a trade association that collects and publicizes information can commit to a disclo-

[6]The results are unchanged if the manufacturers sequentially choose their disclosure policies.

sure strategy before observing their private information. Meanwhile, the accounting literature suggests that firms' commitment power may be tied to the reputation concerns of their managers (Lanen and Verrecchia, 1987; Graham et al., 2005) and that disclosure may be coordinated and enforced by regulatory agencies such as the Financial Accounting Standards Board and the Securities Exchange Commission (Darrough, 1993). Lastly, as noted by Guo (2020), our model's timing captures scenarios in which the disclosure decision constitutes a strategic, long-term move (e.g., designing an information system) and involves significant financial and human resources, whereas the input price can be flexibly adjusted between the firms. The assumption of ex-ante disclosure is also consistent with our motivating examples: Everlane commits to disclosing the costs for all of its products sold online while IUIGA states that it brings "quality everyday goods to you at completely transparent prices."

Solution Concept. When one or both manufacturers choose nondisclosure, the model falls into a game of imperfect information, and we resort to a perfect Bayesian equilibrium as the solution concept. Roughly speaking, a perfect Bayesian equilibrium consists of a strategy profile and a belief system. The belief system must be sequentially rational given the strategy profile, and the belief system satisfies Bayes' rule whenever it is applicable.

4 Model Analysis

In this section, we investigate the manufacturers' disclosure policies under different types of competition and market structures.

4.1 Independent Suppliers and Quantity Competition

We start with the case in which the manufacturers source from independent suppliers and engage in quantity competition. To solve for the manufacturers' disclosure policies, we first derive the equilibrium strategies depending on which disclosure policies are chosen. Thus, we consider the following three subgames: (1) both manufacturers choose disclosure ($\alpha_1 = \alpha_2 = D$); (2) neither manufacturer chooses disclosure ($\alpha_1 = \alpha_2 = ND$); and (3) the manufacturers adopt asymmetric disclosure policies. We analyze these subgames separately and compare the equilibrium outcomes to derive the manufacturers' disclosure decisions.

Both manufacturers disclose $(\alpha_1 = \alpha_2 = D)$

Consider first the subgame in which both manufacturers choose disclosure. With disclosure, each manufacturer observes the rival manufacturer's procurement cost.

Working backward in the game, given their procurement costs c_1 and c_2, the manufacturers choose outputs q_1 and q_2 to maximize their own payoffs, $\pi_i = (p_i - c_i)q_i = (1 - q_i - \theta q_j - c_i)q_i$. Solving the manufacturers' profit maximization problem yields

$$q_i = \frac{2 - 2c_i - \theta(1 - c_j)}{4 - \theta^2}.$$

Now consider the suppliers. Knowing the downstream manufacturers' responses, supplier i chooses c_i to maximize its own profit $\Pi_i = c_i q_i$. Solving the suppliers' profit maximization problem, we come up with the equilibrium input prices

$$c_i = \frac{2 - \theta}{4 - \theta}.$$

The suppliers' and manufacturers' equilibrium profits are given by

$$\Pi_i = \frac{2(2 - \theta)}{(4 - \theta)^2(2 + \theta)}, \quad \pi_i = \frac{4}{(4 - \theta)^2(2 + \theta)^2}.$$

Neither manufacturer discloses $(\alpha_1 = \alpha_2 = ND)$

Consider next a case in which neither manufacturer discloses its cost information. Without disclosure, each manufacturer knows only its own unit procurement cost and relies on its beliefs regarding the rival manufacturer's cost when engaging in quantity competition. Let $\tilde{c}_j$ and $\tilde{q}_j$ be manufacturer i's belief regarding c_j and q_j, respectively, which must be fulfilled in equilibrium.

Note that a perfect Bayesian equilibrium does not impose any restrictions on beliefs off the equilibrium path; thus, manufacturer i is free to change its belief regarding c_j upon receiving an unexpected offer $c_i \neq c_i^*$ from supplier i, where c_i^* is supplier i's equilibrium offer. However, because neither supplier j nor manufacturer j observes c_i, their behaviors are not affected by the actual cost c_i. Following the above reasoning, $\tilde{c}_j$ and $\tilde{q}_j$ should not depend on c_i, which is consistent with *passive beliefs* that are commonly adopted in the literature (McAfee and Schwartz,

1994; Inderst and Ottaviani, 2012; Janssen and Shelegia, 2015). Passive beliefs, in essence, place a natural restriction on equilibrium outcomes: It requires that, when a manufacturer receives an off-equilibrium contract and does not directly observe its rival's procurement costs, it may not have its beliefs regarding the contract offered to its rival be influenced.[7]

Our analysis is provided in detail in the appendix, but we outline here the intuitions involved in solving the game. Consider first the manufacturers' quantity decisions. Given its own cost c_i and its belief regarding the rival manufacturer's quantity decision, manufacturer i chooses q_i to maximize its (anticipated) profit $\pi_i = q_i(1 - q_i - \theta\tilde{q}_j - c_i)$, where $1 - q_i - \theta\tilde{q}_j$ is manufacturer i's conjecture regarding its retail price. Solving the manufacturer's profit maximization problem leads to $q_i = \frac{1-c_i-\theta\tilde{q}_j}{2}$. Consider next supplier i. It chooses c_i to maximize its own profit $\Pi_i = q_i c_i$. Solving the supplier's profit maximization problem yields $c_i = \frac{1-\theta\tilde{q}_j}{2}$. In equilibrium, the firms' beliefs must be fulfilled, i.e., $c_i = \tilde{c}_i$, $q_i = \tilde{q}_i$. Using these conditions we come up with

$$c_i = \tilde{c}_i = \frac{2}{4+\theta}, \;\; q_i = \tilde{q}_i = \frac{1}{4+\theta}.$$

The suppliers' and manufacturers' equilibrium profits are

$$\Pi_i = \frac{2}{(4+\theta)^2}, \;\; \pi_i = \frac{1}{(4+\theta)^2}.$$

Manufacturers adopt asymmetric disclosure policies $(\alpha_i \neq \alpha_j)$

Last, consider the subgame in which the manufacturers adopt asymmetric disclosure policies. Assume, without loss of generality, that $\alpha_1 = D$ and $\alpha_2 = ND$, i.e., only manufacturer 1 chooses disclosure.

Again, we outline below the intuitions involved in solving the game and provide our detailed analysis in the appendix. Because manufacturer 2 conceals its cost information, manufacturer 1 must rely on its beliefs about c_2 and q_2 to determine its output, q_1. More specifically, manufacturer 1 chooses q_1 to maximize its anticipated profit $\pi_1 = (1 - q_1 - \theta\tilde{q}_2 - c_1)q_1$ while manufacturer 2 chooses q_2 to maximize its profit $\pi_2 = (1 - q_2 - \theta q_1 - c_2)q_2$.[8] Solving the manufacturers' profit

[7] Here, the manufacturers source from different suppliers so that supplier j does not observe c_i, and it is reasonable to assume passive beliefs. When the manufacturers source from a common supplier, however, there may be other beliefs. We discuss this issue in detail later.

[8] Because manufacturer 2 observes c_1, it can calculate the value of q_1, which is a function of c_1. Please refer to the

maximization problems yields

$$q_1 = \frac{1 - c_1 - \theta\tilde{q}_2}{2}, \tag{1}$$

and

$$q_2 = \frac{2 - 2c_2 - \theta + c_1\theta + \tilde{q}_2\theta^2}{4}. \tag{2}$$

Manufacturer 1's belief must be sequentially rational, i.e., it replaces c_2 with $\tilde{c}_2$ in (2) to obtain its belief regarding q_2:

$$\tilde{q}_2 = \frac{2 - 2\tilde{c}_2 - \theta + c_1\theta + \tilde{q}_2\theta^2}{4}. \tag{3}$$

Solving for $\tilde{q}_2$ in (3) yields

$$\tilde{q}_2 = \frac{2 - 2\tilde{c}_2 - \theta(1 - c_1)}{4 - \theta^2}.$$

Plugging $\tilde{q}_2$ into Equations (1) and (2) yields

$$q_1 = \frac{2 - 2c_1 - \theta(1 - \tilde{c}_2)}{4 - \theta^2}, \;\; q_2 = \frac{4 - \theta(2 - 2c_1 + \theta\tilde{c}_2) - c_2(4 - \theta^2)}{8 - 2\theta^2}.$$

Consider next the suppliers' pricing decisions. Supplier i chooses c_i to maximize its own profit, $\Pi_i = c_i q_i$. Solving the suppliers' profit maximization problem, we come up with

$$c_1 = \frac{2 - \theta(1 - \tilde{c}_2)}{4}, \;\; c_2 = \frac{8 - \theta(2 + \theta + \theta\tilde{c}_2)}{4(4 - \theta^2)}.$$

The manufacturers' beliefs must be fulfilled in equilibrium, i.e., $c_2 = \tilde{c}_2$, which generates

$$c_2 = \tilde{c}_2 = \frac{(2 - \theta)(4 + \theta)}{16 - 3\theta^2}.$$

The firms' equilibrium profits are as follows:

$$\Pi_1 = \frac{(4 - \theta)^2(4 - \theta^2)}{2(16 - 3\theta^2)^2}, \;\; \Pi_2 = \frac{(2 - \theta)^2(4 + \theta)^2}{2(16 - 3\theta^2)^2},$$

$$\pi_1 = \frac{(4 - \theta)^2}{(16 - 3\theta^2)^2}, \;\; \pi_2 = \frac{(2 - \theta)^2(4 + \theta)^2}{4(16 - 3\theta^2)^2}.$$

appendix for detailed analysis.

Equilibrium Disclosure Strategies

Given the above analysis, we summarize the manufacturers' equilibrium profits in the subgames in Table 1. In Figure 3, we illustrate the manufacturers' equilibrium profits, where π^{D} (π^{ND}) denotes a manufacturer's profit when both manufacturers choose disclosure (nondisclosure) and where $\pi^{D,ND}$ ($\pi^{ND,D}$) denotes a manufacturer's profit when one manufacturer chooses disclosure (nondisclosure) while the other manufacturer chooses nondisclosure (disclosure).

		Manufacturer 2	
		D	ND
Manufacturer 1	D	$\left(\frac{4}{(4-\theta)^2(2+\theta)^2}, \frac{4}{(4-\theta)^2(2+\theta)^2}\right)$	$\left(\frac{(4-\theta)^2}{(16-3\theta^2)^2}, \frac{(2-\theta)^2(4+\theta)^2}{4(16-3\theta^2)^2}\right)$
	ND	$\left(\frac{(2-\theta)^2(4+\theta)^2}{4(16-3\theta^2)^2}, \frac{(4-\theta)^2}{(16-3\theta^2)^2}\right)$	$\left(\frac{1}{(4+\theta)^2}, \frac{1}{(4+\theta)^2}\right)$

Table 1: Payoff matrix (independent suppliers, quantity competition)

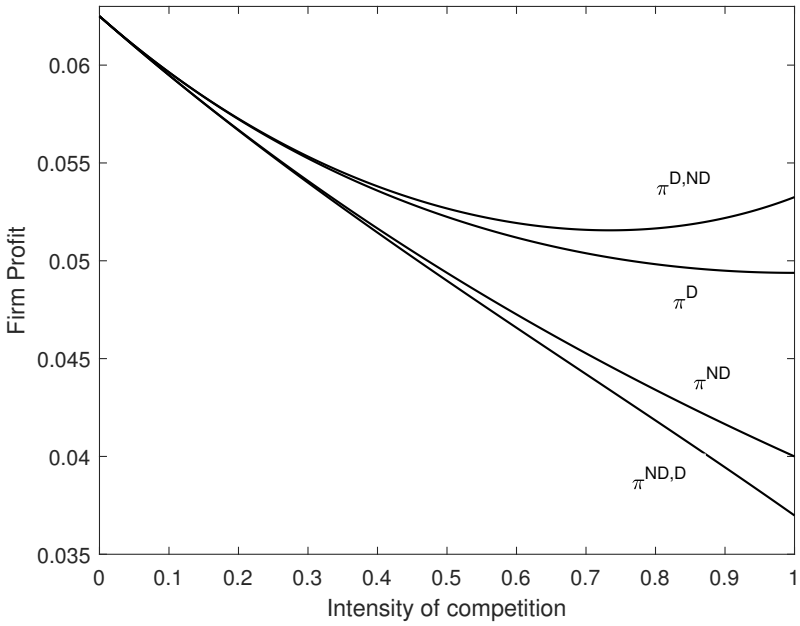


Figure 3: The manufacturers' profits under different scenarios

Proposition 1 below addresses the manufacturers' equilibrium disclosure policies.

Proposition 1 *Suppose that the manufacturers source from independent suppliers and that they compete on quantity. When $\theta > 0$, there exists a unique subgame-perfect equilibrium, in which both manufacturers choose disclosure ($\alpha_1 = \alpha_2 = D$). Compared with the scenario in which neither manufacturer discloses, the manufacturers are better off when they both disclose.*

Proposition 1 suggests that, in a unique equilibrium, both manufacturers choose to disclose their cost information. This finding is in line with a standard view in the cost disclosure literature, which states that firms disclose their (exogenous) costs under quantity competition (Li, 1985; Gal-Or, 1986; Shapiro, 1986; Darrough, 1993). However, in our current model, the costs are endogenously given and there is no cost uncertainty; thus, the conventional rationale for cost disclosure no longer applies. Why, then, do the manufacturers prefer disclosure to nondisclosure?

To shed light on the underlying forces at work, consider first the case in which manufacturer 1 chooses disclosure ($\alpha_1 = D$). We now examine the trade-off that supplier 1 makes between profit margins and purchase quantities when setting its input price c_1. Suppose that supplier 1 slightly increases its input price c_1. Such a price increase exerts two effects on the downstream manufacturers. First, the high procurement cost discourages manufacturer 1 from procuring from supplier 1, i.e., q_1 decreases. Second, observing that manufacturer 1 faces a higher cost, manufacturer 2 understands that it enjoys a competitive advantage and, by the rule of strategic substitutes, it is more willing to offer products to the market to capture a greater market share, i.e., q_2 increases (see Figure 4 for an illustration). In anticipation of this increase in q_2, manufacturer 1 is forced to cut its output q_1 even more sharply. Both the former direct effect and the latter strategic effect reduce supplier 1's demand and injure its profit.

Next, suppose that manufacturer 1 chooses to withhold its cost information. In this case, the direct effect persists but the strategic effect disappears: as manufacturer 2 does not observe c_1, it does not respond to it either (i.e., $\frac{\partial q_2}{\partial c_1} = 0$). In other words, supplier 1 can no longer use its input price c_1 to sway manufacturer 2's behavior. Now, supplier 1 can increase c_1 without worrying about inducing the (negative) strategic effect. As such, supplier 1 is more willing to charge manufacturer 1 a higher price c_1, enjoying a higher profit margin and losing less demand.

From the foregoing analysis we see that manufacturer 1's commitment to disclosure allows it to secure a lower procurement cost from supplier 1 and consequently to benefit from the cost sav-

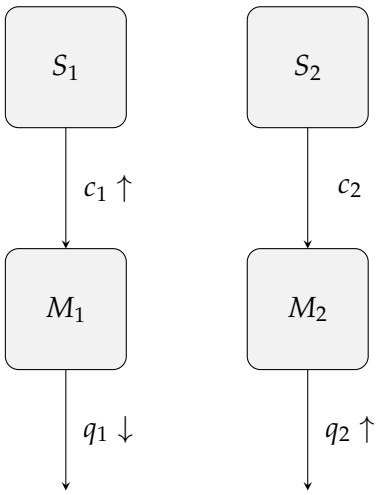


Figure 4: The effect of an increase in c_1 when manufacturer 1 discloses (quantity competition).

ings. Manufacturer 2 also has reasons to prefer disclosure over nondisclosure. Thus, there exists a unique equilibrium in which both manufacturers choose disclosure. Note that in the current model, the manufacturers strategically use their disclosure decisions to affect the upstream suppliers' behavior and their respective procurement costs. This effect is not studied in research on cost disclosure.

4.2 Independent Suppliers and Price Competition

Consider next a scenario in which the manufacturers source from independent suppliers and compete on price. As before, to solve for the manufacturers' equilibrium disclosure strategies, we consider three subgames: (1) both manufacturers choose disclosure; (2) neither manufacturer chooses disclosure; and (3) the manufacturers adopt asymmetric disclosure policies. The analysis of the subgames is analogous to that presented in Section 4.1 and appears in full in the appendix.

We present the manufacturers' payoff matrix in the following table.

The following proposition follows immediately from Table 2.

Proposition 2 *Suppose that the manufacturers source from independent suppliers and that they compete on price. When $\theta > 0$, there exists a unique subgame-perfect equilibrium, in which neither manufacturer chooses disclosure ($\alpha_1 = \alpha_2 = ND$). Compared with the scenario in which both manufacturers disclose, the manufacturers are better off when neither of them discloses.*

		Manufacturer 2: D	Manufacturer 2: ND
Manufacturer 1	D	$\left(\frac{(2-\theta^2)^2}{(4-\theta-2\theta^2)^2(2-\theta)^2}, \frac{(2-\theta^2)^2}{(4-\theta-2\theta^2)^2(2-\theta)^2}\right)$	$\left(\frac{(4+3\theta)^2(2-\theta^2)^2}{4(16-3\theta^2(5-\theta^2))^2}, \frac{(2+\theta)^2(4+\theta-2\theta^2)^2}{4(16-3\theta^2(5-\theta^2))^2}\right)$
	ND	$\left(\frac{(2+\theta)^2(4+\theta-2\theta^2)^2}{4(16-3\theta^2(5-\theta^2))^2}, \frac{(4+3\theta)^2(2-\theta^2)^2}{4(16-3\theta^2(5-\theta^2))^2}\right)$	$\left(\frac{1}{(4-3\theta)^2}, \frac{1}{(4-3\theta)^2}\right)$

Table 2: Payoff matrix (independent suppliers, price competition)

While Proposition 1 states that both manufacturers will disclose under quantity competition, Proposition 2 finds that the opposite is true when the manufacturers compete on price. The reasons for this are as follows.

Again, consider first a case in which manufacturer 1 chooses disclosure ($\alpha_1 = D$). Suppose that supplier 1 slightly increases its input price c_1. Such a price increase will, again, exert two effects on the downstream manufacturers. First, to offset the effect of the higher procurement cost, manufacturer 1 will charge consumers a higher price. This will reduce manufacturer 1's demand for the input. Second, observing that manufacturer 1 faces a higher cost, manufacturer 2 will realize that the competition from manufacturer 1 is weakened, and respond by charging consumers a higher price p_2 (see Figure 5 for an illustration). An increase in p_2, however, will increase manufacturer 1's demand and encourage it to procure more from supplier 1 (i.e., $\frac{\partial D_1}{\partial p_2} > 0$). While the former direct effect hurts supplier 1, the latter strategic effect benefits the supplier, which makes a trade-off between the two effects in setting its input price.

Next, consider the case in which manufacturer 1 chooses to withhold its cost information. Now, the direct effect persists whereas the strategic effect disappears: as manufacturer 2 does not observe c_1, it does not respond to it either (i.e., $\frac{\partial p_2}{\partial c_1} = 0$). In this case, when supplier 1 increases c_1, it no longer benefits from the (positive) strategic effect. In other words, supplier 1 is reluctant to charge manufacturer 1 a higher price c_1, as it will benefit less from doing so.

By the foregoing logic, a commitment to nondisclosure by manufacturer 1 allows it to secure a lower procurement cost from supplier 1, which is self-evidently to manufacturer 1's benefit. (Note that a lower cost c_1 also intensifies market competition, which hurts manufacturer 1; however, this effect is immaterial compared with manufacturer 1's gain from the lowered procurement costs.) Likewise, manufacturer 2 has reasons to prefer nondisclosure to disclosure. Thus, there exists a

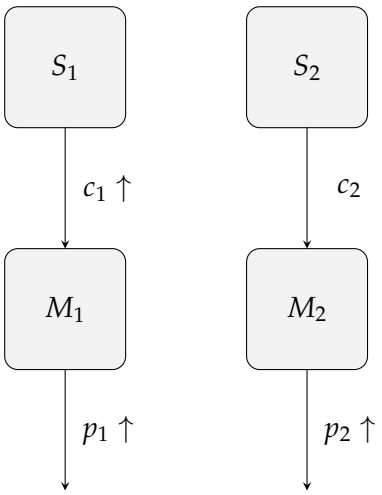


Figure 5: The effect of an increase in c_1 when manufacturer 1 discloses (price competition).

unique equilibrium in which both firms choose nondisclosure.

Interestingly, we find that the manufacturers adopt different disclosure policies under different types of competition (i.e., they choose disclosure under quantity competition but nondisclosure under price competition). The reason for this reversal is well documented in the literature on cost disclosure: quantities are strategic substitutes while prices are strategic complements. Thus, under quantity (price) competition, a higher cost decreases (increases) a manufacturer's output (price), encouraging the rival manufacturer to increase (decrease) its output (price), which results in fiercer (weaker) competition. It is this difference in competitive response that produces the different cost disclosure decisions.

4.3 Common Supplier and Quantity Competition

In this section, we consider a scenario in which the manufacturers source from a common supplier and engage in quantity competition. As with the past scenarios, we adopt passive beliefs when one or more manufacturers choose nondisclosure. (In Section 5.2, we consider wary beliefs and show that our results remain robust under this alternative belief system.) We solve for the different subgame equilibria in the appendix and present the manufacturers' payoff matrix in the following table.

The following proposition follows immediately from Table 3.

Proposition 3 *Suppose that the manufacturers source from a common supplier and that they compete on*

		Manufacturer 2	
		D	ND
Manufacturer 1	D	$\left(\frac{1}{4(2+\theta)^2}, \frac{1}{4(2+\theta)^2}\right)$	$\left(\frac{1}{4(2+\theta)^2}, \frac{(4+\theta)^2}{64(2+\theta)^2}\right)$
	ND	$\left(\frac{(4+\theta)^2}{64(2+\theta)^2}, \frac{1}{4(2+\theta)^2}\right)$	$\left(\frac{1}{(4+\theta)^2}, \frac{1}{(4+\theta)^2}\right)$

Table 3: Payoff matrix (common supplier, quantity competition)

quantity. For any $\theta > 0$, there exists a unique subgame-perfect equilibrium, in which neither manufacturer discloses. Compared with the scenario in which both manufacturers disclose, the manufacturers are better off when neither of them discloses.

As can be seen from Proposition 3, the manufacturers' disclosure incentives are radically different when they source from a common supplier. Proposition 1 suggests that, under quantity competition, both manufacturers choose disclosure when sourcing from independent suppliers, Proposition 3 shows that the opposite is true when they source from a common supplier. This result is also in contrast with the standard view in the literature that firms should disclose their (exogenous) costs under quantity competition.

To understand the intuition in this scenario, consider again the effect of an increase in c_1. When manufacturer 1 chooses disclosure (i.e., $\alpha_1 = D$), such a cost increase has two effects on the downstream manufacturers: first, manufacturer 1, faced with a higher cost, procures less from the supplier, i.e., q_1 decreases; second, manufacturer 2 anticipates that manufacturer 1 will offer fewer products to the market and, by the rule of strategic substitutes, is willing to increase its output to capture a greater market share, i.e., q_2 increases. Obviously, the first direct effect reduces the supplier's demand and hurts its profit. Observe that, now, manufacturer 2 also procures from the same supplier; this strategic effect increases the supplier's demand and profit. This differs radically from the case of independent suppliers, in which an increase in q_2 hurts supplier 1. The supplier makes a trade-off between these two effects when setting its input prices.

When manufacturer 1 chooses nondisclosure, however, the second strategic effect vanishes, as manufacturer 2 neither observes c_1 nor responds to it. In this case, an increase in c_1 only hurts the supplier through the direct effect; as a result, the supplier becomes reluctant to charge manufac-

turer 1 a high input price c_1. By committing to nondisclosure, manufacturer 1 secures a lower cost c_1 from the supplier; thus, nondisclosure benefits the manufacturer. The same reasoning applies to manufacturer 2, who also prefers nondisclosure. As a result, in the unique equilibrium, neither manufacturer discloses. This result suggests that the market structure plays an important role in determining manufacturers' disclosure strategies.

4.4 Common Supplier and Price Competition

Last, consider the scenario in which the manufacturers source from a common supplier and engage in price competition. We solve for the different subgame equilibria in the appendix and present the manufacturers' payoff matrix in the following table.

		Manufacturer 2	
		D	ND
Manufacturer 1	D	$\left(\frac{1}{4(2-\theta)^2}, \frac{1}{4(2-\theta)^2}\right)$	$\left(\frac{1}{4(2-\theta)^2}, \frac{(4+\theta-2\theta^2)^2}{4(2-\theta)^2(4-3\theta^2)^2}\right)$
	ND	$\left(\frac{(4+\theta-2\theta^2)^2}{4(2-\theta)^2(4-3\theta^2)^2}, \frac{1}{4(2-\theta)^2}\right)$	$\left(\frac{1}{(4-3\theta)^2}, \frac{1}{(4-3\theta)^2}\right)$

Table 4: Payoff matrix (common supplier, price competition)

The following proposition summarizes the manufacturers' equilibrium disclosure strategies.

Proposition 4 *Suppose that the manufacturers source from a common supplier and that they compete on price. For any $\theta > 0$, there exists a unique subgame-perfect equilibrium, in which neither manufacturer discloses. Compared with the scenario in which both manufacturers disclose, the manufacturers are better off when neither of them discloses.*

Propositions 3 and 4 indicate that manufacturers sourcing from a common supplier always withhold their cost information, regardless of the nature of the competition, as doing so increases their profits.

To understand Proposition 4, assume again that supplier 1 increases its input price c_1. If manufacturer 1 chooses disclosure, the increase in c_1 exerts two effects on the downstream manufacturers' behavior. First, the high cost forces manufacturer 1 to raise its price p_1 and cut its procurement

q_1 from the supplier, an effect that self-evidently hurts the supplier. Second, anticipating that manufacturer 1 will charge a higher price p_1, manufacturer 2 becomes willing to procure more from the supplier.[9] This strategic effect clearly benefits the supplier, as the demand from manufacturer 2 increases.

When manufacturer 1 withholds its cost information, however, the positive strategic effect disappears while the negative direct effect persists. As a result, an increase in c_1 hurts the supplier even more, making it willing to charge manufacturer 1 a lower input price. Therefore, the manufacturer chooses nondisclosure to secure a lower procurement cost. Likewise, manufacturer 2 withholds its cost information, which constitutes the unique equilibrium.

4.5 Discussions and Implications

Above, we characterize the manufacturers' disclosure strategies under different market structures and different types of competition. To facilitate comparison, we summarize the manufacturers' equilibrium disclosure policies for all cases in the following table.

	Quantity Competition	Price Competition
Independent Suppliers	(D, D)	(ND, ND)
Common Supplier	(ND, ND)	(ND, ND)

Table 5: Equilibrium Disclosure Policies

Table 5 shows that when the manufacturers share a supplier or when they compete on price, there exists a unique equilibrium in which neither manufacturer discloses. Only when the manufacturers source from independent suppliers and compete on quantity do they choose to disclose their cost information.

These findings have important implications for firms. First, we find that cost disclosure not only affects market competition, a phenomenon discussed extensively in cost disclosure research, but can also be used strategically to influence upstream suppliers' pricing decisions and hence downstream manufacturers' procurement costs. By committing to disclosing or withholding its cost information, a manufacturer can secure a low procurement cost from its upstream supplier. To

[9] Manufacturer 2 will also charge consumers a higher price p_2 in response to a higher p_1. While a higher p_1 increases manufacturer 2's demand, a higher p_2 decreases its demand. Overall, the first effect dominates and manufacturer 2 is willing to procure more from the supplier.

the best of our knowledge, this novel effect is not covered in any prior studies; the description of it here therefore expands our understanding of cost disclosure. From a theoretical perspective, our analysis also adds to this research by demonstrating that disclosure matters even in the absence of market uncertainty (recall that in our model all costs are deterministic and firms always play pure strategies).

Second, our results suggest that the established view on cost disclosure does not necessarily hold when firms' costs are endogenously determined. According to the standard view in the cost disclosure literature, a firm operating under quantity competition should always disclose its cost information to rival firms, as doing so alleviates market competition and increases the firm's profit. While this finding holds for exogenous costs, our analysis suggests that it does not necessarily hold when dealing with endogenously determined costs. For instance, our model suggests that firms should conceal their procurement costs when they source inputs from the same supplier.

Third, our results may serve as a warning to firms that they should consider various factors when making their cost disclosure decisions, including the nature of the market competition that they operate under (price vs. quantity), the nature of the cost to be disclosed (exogenous vs. endogenous) and the market structure in which they operate (common supplier vs. independent suppliers). As a result, a firm should not treat all of its costs equally when making disclosure decisions: it may want to disclose certain types of cost (e.g., labor costs and procurement costs from certain suppliers) while withholding other types of cost (e.g., procurement costs from other suppliers). This finding also explains why, in practice, firms are transparent about certain costs but remain silent about others.

5 Model Extensions

In this section, we examine three extensions to our model, namely 1) the economic consequences of mandatory (non-)disclosure, 2) the manufacturers' adoption of wary beliefs when receiving an off-equilibrium price from a common upstream supplier, and 3) the effect of a fixed cost to disclose.

5.1 Regulating Cost Disclosure

Antitrust authorities have long raised concerns regarding information transmission between competitors. Certain groups argue that information exchange stabilizes collusion, giving antitrust authorities cause to forbid it among firms (Feuerstein, 2005). In this with this argument, Athey and Bagwell (2001) show that collusion may not be possible without communication on private costs. On the other hand, there may be efficiency gains from information transmission through uncertainty reductions (Feuerstein, 2005). In fact, Kühn (2001) argues that the exchange of cost information is less conducive to collusion and should only be regulated under extreme circumstances.

While the debate ensues, some policymakers have sought to enforce cost transparency through regulations. For instance, in October 1993, the Danish antitrust authority, the Competition Council, began gathering and regularly publishing figures on the transaction prices of two grades of ready-mixed concrete sold by individual firms in three regions of Denmark (Albæk et al., 1997).

Given these contrasting views on cost disclosure, we now consider the implications of disclosure regulations on the equilibrium outcome and consumer welfare. To do so, we compare three regimes: A mandatory disclosure regime under which the manufacturers are mandated to disclose their cost information, a mandatory nondisclosure regime under which the manufacturers are mandated to withhold their cost information, and a voluntary disclosure regime under which the manufacturers have the discretion to make their own disclosure decisions.

We compare the equilibrium outcomes in the three regimes and arrive at the following proposition:

Proposition 5 *Compared to the voluntary disclosure regime, retail prices under a mandatory disclosure regime or a mandatory nondisclosure regime are always (weakly) higher and consumer surplus and social welfare are always (weakly) lower.*

Proposition 5 reveals an interesting finding: Neither a mandatory disclosure nor nondisclosure policy improves consumer welfare when compared to a voluntary disclosure policy. The intuition is as follows: Our work has shown that, under voluntary disclosure, the manufacturers make strategic disclosure decisions to secure low procurement costs from their suppliers, which, in turn, has cascading downstream implications: The manufacturers pass down price cuts to consumers or

put more products on the market, ultimately benefiting consumers. In contrast, both mandatory disclosure and nondisclosure encourage suppliers to set higher input prices, causing retail prices to rise and hurting downstream manufacturers and consumers alike.

Our results, thus, serve as a warning to policymakers: Regulations aimed at increasing and decreasing cost transparency may have unintended negative consequences, and it may be optimal to leave disclosure decisions to the firms themselves.

5.2 Wary Beliefs

In the basic model, we assume that the manufacturers adopt passive beliefs, meaning manufacturer i does not update its belief regarding c_j upon receiving an unexpected offer $c_i \neq c_i^*$ from its supplier (i.e., it always holds the belief that $\tilde{c}_j = c_j^*$). When the manufacturers source from independent suppliers, passive beliefs are reasonable because the contract terms between supplier j and retailer j should not depend on c_i, which is not observed by supplier j when c_j is chosen. However, when both manufacturers source from a common supplier, a supplier who deviates and offers manufacturer i a price $c_i \neq c_i^*$, could plausibly offer manufacturer j an off-equilibrium price as well.

In this section, we consider an alternative belief specification, *wary beliefs*, when the manufacturers source from a common supplier. Initially proposed by McAfee and Schwartz (1994), wary beliefs have been widely used in games of imperfect information (Rey and Vergé, 2004; Gaudin, 2019).

Under wary beliefs, a manufacturer who receives an off-equilibrium contract offer from a common supplier believes that the supplier will adjust its offer to the rival manufacturer to maximize its own profit. And, perhaps most importantly, each manufacturer is convinced that the other manufacturer shares the same belief (McAfee and Schwartz, 1994).

We defer the detailed analysis to the appendix and prove the following proposition:

Proposition 6 *Suppose that the manufacturers source from a common supplier and that they adopt wary beliefs. Under either price or quantity competition, for any $\theta > 0$, there exists a unique subgame-perfect equilibrium, in which neither manufacturer discloses.*

Proposition 6 suggests that our main results are not altered under wary beliefs and that both

manufacturers conceal their cost information in equilibrium. The intuition is familiar: By committing to withholding its cost information, a manufacturer is able to secure a lower procurement cost from the upstream supplier and make a higher profit.

5.3 Costly Disclosure

In the main model, we assume that disclosure is costless (i.e., a manufacturer does not incur any fixed costs in disclosing its cost information). In this section, we extend the analysis and consider a case in which a manufacturer must expend a fixed cost when disclosing its variable cost. For simplicity, we assume that the manufacturers share the same disclosure cost, $s \geq 0$. We solve the model and present the results in the following proposition:

Proposition 7 *Suppose that the manufacturers' disclosure cost is $s \geq 0$. When the manufacturers compete on price or source from a common supplier, they never disclose their costs regardless of the disclosure cost. When the manufacturers source from independent suppliers and compete on quantity, the equilibrium outcome hinges on the disclosure cost:*

- *If $s \leq \underline{s} = \frac{4}{(4-\theta)^2(2+\theta)^2} - \frac{(2-\theta)^2(4+\theta)^2}{4(16-3\theta^2)^2}$, both manufacturers disclose.*
- *If $s \geq \bar{s} = \frac{8\theta^2(8-\theta^2)}{(4+\theta)^2(16-3\theta^2)^2}$, neither manufacturer discloses.*
- *If $\underline{s} < s < \bar{s}$, there exists a symmetric mixed-strategy equilibrium in which each manufacturer discloses with probability λ, where*

$$\lambda = \frac{4(4-\theta)^2(2+\theta)^2(s(4+\theta)^2(16-3\theta^2)^2 - 8\theta^2(8-\theta^2))}{\theta^5(8-\theta^2)(128+48\theta-8\theta^2-\theta^3)}.$$

Proposition 7 shows that a disclosure cost does not change the equilibrium outcome when the manufacturers compete on price or source from the same supplier. Under either condition, the manufacturers conceal their cost information even when disclosure is costless, a result that is only strengthened by a high disclosure cost.

When the manufacturers source from independent suppliers and compete on quantity, however, the disclosure cost does affect the manufacturers' equilibrium disclosure decisions in that they disclose when the cost is not too high. When the disclosure cost is high enough, the benefit

of securing lower procurement costs is outweighed by the expense, and the manufacturers forgo disclosure to save on the disclosure cost.

6 Conclusion

Firms must often determine whether or not to disclose their cost information to other market participants. In practice, firms' disclosure strategies vary, with some disclosing their cost information and others withholding it. Studies on cost disclosure have investigated firms' incentives to disclose their cost information under market competition when such costs are exogenous and uncertain (e.g., determined by stochastic production technology), showing that firms should disclose (conceal) their cost information under quantity (price) competition. And yet, how firms make disclosure decisions on endogenously determined costs (e.g., procurement costs determined by upstream suppliers) has been understudied.

To fill this research gap and understand firms' incentives to disclose their endogenous costs, this paper develops a game-theoretic model in which two manufacturers source inputs from an upstream supplier or suppliers and compete in the consumer market. Our analysis of four alternative scenarios under different types of market competition (i.e., price and quantity competition) and structures (i.e., independent suppliers and a common supplier) generates findings that depart from established views on cost disclosure.

First, we show that manufacturers' cost-disclosure strategies affect not only market competition but also how suppliers set their input prices. As such, a manufacturer can manipulate its own sourcing costs through strategic cost-disclosure decisions. Upstream suppliers must take their downstream manufacturers' cost-disclosure decisions into account when making their pricing decisions. These findings highlight the strategic role of cost disclosure in determining the costs themselves.

Second, our results warn firms to take various factors into consideration when making their cost-disclosure decisions. While previous research states that firms' disclosure policies should depend on the nature of the competition under which they operate (i.e., price vs. quantity competition), our findings indicate that firms should also consider the nature of the costs to be disclosed (i.e., endogenous vs. exogenous) and the market structure under which they operate (i.e., com-

mon supplier vs. independent suppliers). A further suggestion is for firms to not view all their costs equally and, instead, consider disclosing certain types of cost information while remaining silent on others.

Third, our findings suggest that mandatory (non-)disclosure can affect market efficiency through firms' procurement costs. Regulatory authorities must evaluate this strategic effect when implementing disclosure regulations. Interestingly, both mandatory disclosure and nondisclosure policies increase firms' procurement costs and the final product prices, ultimately injuring consumer surplus and social welfare. Therefore, giving firms the discretion to make their disclosure decisions is the most socially efficient policy.

Our analysis provides preliminary insights into firms' disclosure of endogenous costs, a topic that can be extended in several directions. First, the current model focuses exclusively on firms' disclosure of cost information, but it would be of interest to consider firms' incentives to disclose other information insofar as such information can be endogenized. For example, studies on quality disclosure tend to assume that quality is determined randomly by nature (e.g., Guo 2009). One could consider a case in which firms endogenously choose their product quality and make their disclosure decisions accordingly. Second, when analyzing cost disclosure, we focus on its interaction with market competition. However, it is well-established that cost disclosure also affects the equilibrium outcome when consumers or other market participants are concerned about distributional fairness (Guo, 2015). Future research may consider firms' incentives to disclose their endogenous costs when faced with fair-minded consumers. Finally, while our model assumes that suppliers and manufacturers are contracted through linear prices, intriguing insights may be gained by examining firms' disclosure strategies under other types of contracts (e.g., revenue sharing contracts) or when input prices are set through a bargaining process.[10]

[10] Another commonly used vertical contract is a two-part tariff. We find that, if firms are contracted through two-part tariffs, the downstream manufacturers always make zero profits regardless of their disclosure decisions (the suppliers' profits are different). Therefore, any disclosure policy can be sustained as an equilibrium outcome.

A Formal Equilibrium Analysis

A.1 Independent Suppliers and Quantity Competition

A.1.1 Manufacturers' Best Response Functions

Recall that manufacturer i's inverse demand is given by $p_i = 1 - q_i - \theta q_j$. Let $\tilde{c}_i$ be manufacturer j's belief of c_i. Under passive beliefs, $\tilde{c}_i$ satisfies that

$$\tilde{c}_i = \begin{cases} c_i & \text{if manufacturer } i \text{ discloses,} \\ c_i^* & \text{otherwise,} \end{cases}$$

where c_i^* is the equilibrium cost c_i. That is, if manufacturer i discloses its cost information, manufacturer j's belief must be correct. If manufacturer i does not disclose, manufacturer j believes that supplier i has played the equilibrium strategy and charged manufacturer i an equilibrium input price c_i^*.

We next derive the manufacturers' best response functions. We conjecture that the manufacturers' strategy profiles are as follows (which we confirm later):

$$q_1 = \alpha_0 + \alpha_1 c_1 + \alpha_2 \tilde{c}_1 + \alpha_3 \tilde{c}_2, \tag{4}$$

$$q_2 = \beta_0 + \beta_1 c_2 + \beta_2 \tilde{c}_2 + \beta_3 \tilde{c}_1. \tag{5}$$

Note that manufacturer 1 does not always observe c_2 directly. It replaces c_2 with $\tilde{c}_2$ in (5) and forms belief regarding q_2. Under sequential rationality, manufacturer 1's belief of q_2 is given by

$$\tilde{q}_2 = \beta_0 + (\beta_1 + \beta_2)\tilde{c}_2 + \beta_3 \tilde{c}_1. \tag{6}$$

Manufacturer 1 chooses q_1 to maximize its anticipated profit, that is,

$$\pi_1 = (1 - q_1 - \theta \tilde{q}_2 - c_1) q_1.$$

Optimizing manufacturer 1's profit we have

$$q_1 = \frac{1 - c_1 - \theta(\beta_0 + \beta_3 \tilde{c}_1 + (\beta_1 + \beta_2)\tilde{c}_2)}{2}. \tag{7}$$

Comparing (4) with (7), we have

$$\alpha_0 = \frac{1-\theta\beta_0}{2},\ \alpha_1 = -\frac{1}{2},\ \alpha_2 = -\frac{\theta\beta_3}{2},\ \alpha_3 = -\frac{\theta(\beta_1+\beta_2)}{2}. \tag{8}$$

Similarly, for manufacturer 2, we have

$$\beta_0 = \frac{1-\theta\alpha_0}{2},\ \beta_1 = -\frac{1}{2},\ \beta_2 = -\frac{\theta\alpha_3}{2},\ \beta_3 = -\frac{\theta(\alpha_1+\alpha_2)}{2}. \tag{9}$$

Using (8) and (9), we obtain the manufacturers' strategy profiles as follows.

$$\alpha_0 = \beta_0 = \frac{1}{2+\theta},\ \alpha_1 = \beta_1 = -\frac{1}{2},\ \alpha_2 = \beta_2 = -\frac{\theta^2}{2(4-\theta^2)},\ \alpha_3 = \beta_3 = \frac{\theta}{4-\theta^2}.$$

Next, we derive the equilibrium outcome of each subgame.

A.1.2 Both manufacturers disclose

When both manufacturers disclose, information is perfect and we have that $\tilde{c}_1 = c_1$ and $\tilde{c}_2 = c_2$. The analysis is straightforward and is thus omitted.

A.1.3 Neither manufacturer discloses

Now, consider the subgame in which neither manufacturer discloses. In this case, we have $\tilde{c}_1 = c_1^*$ and $\tilde{c}_2 = c_2^*$. Plugging the manufacturers' beliefs into their best response functions, we come up with

$$q_1 = \frac{1}{2+\theta} - \frac{c_1}{2} - \frac{\theta^2}{2(4-\theta^2)} \cdot c_1^* + \frac{\theta}{4-\theta^2} \cdot c_2^*.$$

Supplier 1's profit $\pi_1 = c_1 q_1$ is maximized at $c_1 = c_1^*$. The first-order condition yields that

$$c_1^* = \frac{4-\theta(2-2c_2^*+\theta c_1^*)}{2(4-\theta^2)}.$$

Similarly, we obtain that

$$c_2^* = \frac{4-\theta(2-2c_1^*+\theta c_2^*)}{2(4-\theta^2)}.$$

Solving for c_1^* and c_2^*, we obtain

$$c_1^* = c_2^* = \frac{2}{4+\theta}.$$

The firms' equilibrium profits are

$$\Pi_i = \frac{2}{(4+\theta)^2}, \ \ \pi_i = \frac{1}{(4+\theta)^2}.$$

A.1.4 Asymmetric Disclosure Policies

Assume that manufacturer 1 chooses disclosure while manufacturer chooses nondisclosure. Then, we have $\tilde{c}_1 = c_1$ and $\tilde{c}_2 = c_2^*$. Plugging the manufacturers' belief into their best response functions, we have

$$q_1 = \frac{2 - 2c_1 - \theta + \theta c_2^*}{4 - \theta^2}, \ \ q_2 = \frac{1}{2+\theta} - \frac{c_2}{2} - \frac{\theta^2}{2(4-\theta^2)} \cdot c_2^* + \frac{\theta}{4-\theta^2} \cdot c_1.$$

Supplier i's profit $\pi_i = c_i q_i$ is maximized at $c_i = c_i^*$. The first-order condition yields that

$$c_1^* = \frac{2 - \theta(1 - c_2^*)}{4}, \ \ c_2^* = \frac{8 - \theta(2 + \theta + \theta c_2^*)}{4(4-\theta^2)}.$$

Solving for c_1^* and c_2^*, we come up with

$$c_1^* = \frac{(4-\theta)(2-\theta)(2+\theta)}{32 - 6\theta^2}, \ \ c_2^* = \frac{(2-\theta)(4+\theta)}{16 - 3\theta^2}.$$

The firms' equilibrium profits are

$$\Pi_1 = \frac{(4-\theta)^2(4-\theta^2)}{2(16-3\theta^2)^2}, \ \ \Pi_2 = \frac{(2-\theta)^2(4+\theta)^2}{2(16-3\theta^2)^2},$$

$$\pi_1 = \frac{(4-\theta)^2}{(16-3\theta^2)^2}, \ \ \pi_2 = \frac{(2-\theta)^2(4+\theta)^2}{4(16-3\theta^2)^2}.$$

A.2 Independent Suppliers and Price Competition

In this section, we solve for the equilibrium outcome when the manufacturers compete in price and source from independent suppliers.

A.2.1 Manufacturers' Best Response Functions

Recall that manufacturer i's demand is given by $D_i = 1 - p_i + \theta p_j$. Let $\tilde{c}_i$ be manufacturer j's belief of c_i, which satisfies that

$$\tilde{c}_i = \begin{cases} c_i & \text{if manufacturer } i \text{ discloses,} \\ c_i^* & \text{otherwise,} \end{cases}$$

where c_i^* is the equilibrium cost c_i.

We next derive the manufacturers' best response functions. We conjecture that the manufacturers' strategy profiles are as follows (which we confirm later):

$$p_1 = \alpha_0 + \alpha_1 c_1 + \alpha_2 \tilde{c}_1 + \alpha_3 \tilde{c}_2, \tag{10}$$

$$p_2 = \beta_0 + \beta_1 c_2 + \beta_2 \tilde{c}_2 + \beta_3 \tilde{c}_1. \tag{11}$$

Note that manufacturer 1 does not always observe c_2 directly. It replaces c_2 with $\tilde{c}_2$ in (11) and forms belief regarding p_2. Under sequential rationality, manufacturer 1's belief of q_2 is given by

$$\tilde{p}_2 = \beta_0 + (\beta_1 + \beta_2)\tilde{c}_2 + \beta_3 \tilde{c}_1. \tag{12}$$

Manufacturer 1 chooses p_1 to maximize its anticipated profit, that is,

$$\pi_1 = (1 - p_1 + \theta \tilde{p}_2)(p_1 - c_1).$$

Optimizing manufacturer 1's profit we have

$$p_1 = \frac{1 + c_1 + \theta(\beta_0 + \beta_3 \tilde{c}_1 + (\beta_1 + \beta_2)\tilde{c}_2)}{2}. \tag{13}$$

Comparing (10) with (13), we have

$$\alpha_0 = \frac{1 + \theta\beta_0}{2},\ \alpha_1 = \frac{1}{2},\ \alpha_2 = \frac{\theta\beta_3}{2},\ \alpha_3 = \frac{\theta(\beta_1 + \beta_2)}{2}. \tag{14}$$

Similarly, for manufacturer 2, we have

$$\beta_0 = \frac{1 + \theta\alpha_0}{2},\ \beta_1 = \frac{1}{2},\ \beta_2 = \frac{\theta\alpha_3}{2},\ \beta_3 = \frac{\theta(\alpha_1 + \alpha_2)}{2}. \tag{15}$$

Using (14) and (15), we come up with

$$\alpha_0 = \beta_0 = \frac{1}{2 - \theta},\ \alpha_1 = \beta_1 = \frac{1}{2},\ \alpha_2 = \beta_2 = \frac{\theta^2}{2(4 - \theta^2)},\ \alpha_3 = \beta_3 = \frac{\theta}{4 - \theta^2}.$$

A.2.2 Both manufacturers disclose

When both manufacturers disclose, information is perfect and we have that $\tilde{c}_1 = c_1$ and $\tilde{c}_2 = c_2$. The analysis is straightforward, and the equilibrium outcome is

$$c_i^* = \frac{2+\theta}{4-\theta-2\theta^2}.$$

The firms' equilibrium profits are

$$\Pi_i = \frac{(2+\theta)(2-\theta^2)}{(2-\theta)(4-\theta-2\theta^2)^2}, \quad \pi_i = \frac{(2-\theta^2)^2}{(2-\theta)^2(4-\theta-2\theta^2)^2}.$$

A.2.3 Neither manufacturer discloses

When neither manufacturer discloses, we have $\tilde{c}_1 = c_1^*, \tilde{c}_2 = c_2^*$. Plugging the manufacturers' beliefs into their best response functions, we have

$$p_1 = \frac{1}{2-\theta} + \frac{c_1}{2} + \frac{\theta^2}{2(4-\theta^2)} \cdot c_1^* + \frac{\theta}{4-\theta^2} \cdot c_2^*, \quad \tilde{p}_2 = \frac{1}{2-\theta} + \frac{2}{4-\theta^2} \cdot c_2^* + \frac{\theta}{4-\theta^2} \cdot c_1^*,$$

p_2 and $\tilde{p}_1$ can be obtained similarly.

Supplier 1's profit $\pi_1 = c_1(1 - p_1 + \theta\tilde{p}_2)$ is maximized at $c_1 = c_1^*$, which yields that

$$c_1^* = \frac{4+\theta(2+2c_2^*+\theta c_1^*)}{2(4-\theta^2)}.$$

Similarly, we have

$$c_2^* = \frac{4+\theta(2+2c_1^*+\theta c_2^*)}{2(4-\theta^2)}.$$

Solving for c_1^* and c_2^*, we come up with

$$c_1^* = c_2^* = \frac{2}{4-3\theta}.$$

The firms' equilibrium profits are

$$\Pi_i = \frac{2}{(4-3\theta)^2}, \quad \pi_i = \frac{1}{(4-3\theta)^2}.$$

A.2.4 Asymmetric Disclosure Policies

Assume that manufacturer 1 chooses disclosure while manufacturer chooses nondisclosure. Then, we have $\tilde{c}_1 = c_1$ and $\tilde{c}_2 = c_2^*$. Plugging the manufacturers' beliefs into their best response functions, we have

$$p_1 = \frac{1}{2-\theta} + \frac{2}{4-\theta^2} \cdot c_1 + \frac{\theta}{4-\theta^2} \cdot c_2^*, \;\; p_2 = \frac{1}{2-\theta} + \frac{c_2}{2} + \frac{\theta^2}{2(4-\theta^2)} \cdot c_2^* + \frac{\theta}{4-\theta^2} \cdot c_1,$$

$$\tilde{p}_1 = \frac{1}{2-\theta} + \frac{2}{4-\theta^2} \cdot c_1 + \frac{\theta}{4-\theta^2} \cdot c_2^*, \;\; \tilde{p}_2 = \frac{1}{2-\theta} + \frac{2}{4-\theta^2} \cdot c_2^* + \frac{\theta}{4-\theta^2} \cdot c_1.$$

Supplier i's profit $\pi_i = c_i(1 - p_i + \theta \tilde{p}_j)$ is maximized at $c_i = c_i^*$. The first-order condition yields that

$$c_1^* = \frac{2 + \theta + \theta c_2^*}{4 - 2\theta^2}, \;\; c_2^* = \frac{8 + \theta(6 - \theta(3 + 2\theta - (3 - \theta^2)c_2^*))}{2(8 - 6\theta^2 + \theta^4)}.$$

Solving for c_1^* and c_2^*, we reach the followings.

$$c_1^* = \frac{(2-\theta)(2+\theta)(4+3\theta)}{32 - 6\theta^2(5-\theta^2)}, \;\; c_2^* = \frac{8 + \theta(6 - \theta(3+2\theta))}{16 - 3\theta^2(5-\theta^2)}.$$

The firms' equilibrium profits are

$$\Pi_1 = \frac{(4+3\theta)^2(8 - 6\theta^2 + \theta^4)}{4(16 - 3\theta^2(5-\theta^2))^2}, \;\; \Pi_2 = \frac{(2+\theta)^2(4 + \theta - 2\theta^2)^2}{2(16 - 3\theta^2(5-\theta^2))^2}.$$

$$\pi_1 = \frac{(4+3\theta)^2(2-\theta^2)^2}{4(16 - 3\theta^2(5-\theta^2))^2}, \;\; \pi_2 = \frac{(2+\theta)^2(4 + \theta(1-2\theta))^2}{4(16 - 3\theta^2(5-\theta^2))^2}$$

The manufacturers' profits in the subgames are summarized in Table 2.

A.3 Common Suppliers and Quantity Competition

A.3.1 Both manufacturers disclose

When both manufacturers disclose, information is perfect and we have that $\tilde{c}_1 = c_1$ and $\tilde{c}_2 = c_2$. The analysis is straightforward, and the equilibrium outcome is $c_1^* = c_2^* = \frac{1}{2}$. In equilibrium, the firms' profits are

$$\Pi = \frac{1}{4+2\theta}, \;\; \pi_1 = \pi_2 = \frac{1}{4(2+\theta)^2}.$$

A.3.2 Neither manufacturer discloses

Following the analysis of Section A.1.3, we have

$$q_i = \frac{1}{2+\theta} - \frac{c_i}{2} - \frac{\theta^2}{2(4-\theta^2)} \cdot c_i^* + \frac{\theta}{4-\theta^2} \cdot c_j^*.$$

The supplier's profit is $\Pi = c_1 q_1 + c_2 q_2$, which is maximized at $c_1 = c_1^*$ and $c_2 = c_2^*$. Using the first-order conditions we come up with

$$c_1^* = \frac{4-\theta(2-2c_2^*+\theta c_1^*)}{2(4-\theta^2)}, \;\; c_2^* = \frac{4-\theta(2-2c_1^*+\theta c_2^*)}{2(4-\theta^2)}.$$

Solving for c_1^* and c_2^*, we obtain

$$c_1^* = c_2^* = \frac{2}{4+\theta}.$$

The firms' equilibrium profits are

$$\Pi = \frac{4}{(4+\theta)^2}, \;\; \pi_1 = \pi_2 = \frac{1}{(4+\theta)^2}.$$

A.3.3 Asymmetric disclosure policies

Assume without loss of generality that only manufacturer 1 chooses disclosure. Following the analysis of Section A.1.4, we have

$$q_1 = \frac{2-2c_1-\theta+\theta c_2^*}{4-\theta^2}, \;\; q_2 = \frac{1}{2+\theta} - \frac{c_2}{2} - \frac{\theta^2}{2(4-\theta^2)} \cdot c_2^* + \frac{\theta}{4-\theta^2} \cdot c_1.$$

The supplier's profit is $\Pi = c_1 q_1 + c_2 q_2$, which is maximized at $c_1 = c_1^*$ and $c_2 = c_2^*$. Solving the supplier's profit maximization problem we come up with

$$c_1^* = \frac{16-\theta(4+2(3-\theta)\theta - c_2^*(8-3\theta^2))}{32-10\theta^2}, \;\; c_2^* = \frac{8-\theta(2+\theta+c_2^*\theta)}{16-5\theta^2}.$$

Solving for c_1^* and c_2^*, we obtain

$$c_1^* = \frac{8+4\theta-\theta^2}{8(2+\theta)}, \;\; c_2^* = \tilde{c}_2 = \frac{4+\theta}{8+4\theta}.$$

The firms' equilibrium profits are

$$\Pi = \frac{32+16\theta-\theta^2}{32(2+\theta)^2}, \;\; \pi_1 = \frac{1}{4(2+\theta)^2}, \;\; \pi_2 = \frac{(4+\theta)^2}{64(2+\theta)^2}.$$

The manufacturers' profits in the subgames are summarized in Table 3.

A.4 Common Suppliers and Price Competition

A.4.1 Both manufacturers disclose

When both manufacturers disclose, information is perfect and we have that $\tilde{c}_1 = c_1$ and $\tilde{c}_2 = c_2$. The analysis is straightforward, and the equilibrium outcome is

$$c_1^* = c_2^* = \frac{1}{2-2\theta}.$$

The firms' equilibrium profits are

$$\Pi = \frac{1}{4-6\theta+2\theta^2}, \;\; \pi_1 = \pi_2 = \frac{1}{4(2-\theta)^2}.$$

A.4.2 Neither Manufacturer Discloses

Following the analysis of Section A.2.3, we have

$$p_i = \frac{1}{2-\theta} + \frac{c_i}{2} + \frac{\theta^2}{2(4-\theta^2)} \cdot c_i^* + \frac{\theta}{4-\theta^2} \cdot c_j^*, \;\; \tilde{p}_j = \frac{1}{2-\theta} + \frac{2}{4-\theta^2} \cdot c_j^* + \frac{\theta}{4-\theta^2} \cdot c_i^*.$$

The supplier's profit is $\Pi = \sum_i c_i(1 - p_i + \theta\tilde{p}_j)$, which is maximized at $c_1 = c_1^*$ and $c_2 = c_2^*$. Using the first-order conditions we come up with

$$c_i^* = \frac{4+\theta(2+2c_j^*+\theta c_i^*)}{2(4-\theta^2)}.$$

Solving for c_1^* and c_2^*, we obtain

$$c_1^* = c_2^* = \frac{2}{4-3\theta}.$$

The firms' equilibrium profits are

$$\Pi = \frac{4}{(4-3\theta)^2}, \;\; \pi_1 = \pi_2 = \frac{1}{(4-3\theta)^2}.$$

A.4.3 Asymmetric disclosure policies

Assume without loss of generality that only manufacturer 1 chooses disclosure. Following the analysis of Section A.2.4, we have

$$p_1 = \frac{1}{2-\theta} + \frac{2}{4-\theta^2}\cdot c_1 + \frac{\theta}{4-\theta^2}\cdot c_2^*,\ \ p_2 = \frac{1}{2-\theta} + \frac{c_2}{2} + \frac{\theta^2}{2(4-\theta^2)}\cdot c_2^* + \frac{\theta}{4-\theta^2}\cdot c_1,$$

$$\tilde{p}_1 = \frac{1}{2-\theta} + \frac{2}{4-\theta^2}\cdot c_1 + \frac{\theta}{4-\theta^2}\cdot c_2^*,\ \ \tilde{p}_2 = \frac{1}{2-\theta} + \frac{2}{4-\theta^2}\cdot c_2^* + \frac{\theta}{4-\theta^2}\cdot c_1.$$

The supplier's profit is $\Pi = \sum_i c_i(1 - p_i + \theta\tilde{p}_j)$, which is maximized at

$$c_1^* = \frac{16+\theta(12+8c_2^*-2\theta-(2+c_2^*)\theta^2)}{32-26\theta^2+4\theta^4},\ \ c_2^* = \frac{8+\theta(6-\theta(3+2\theta-(3-\theta^2)c_2^*))}{16-13\theta^2+2\theta^4}.$$

Solving for c_1^* and c_2^*, we obtain

$$c_1^* = \frac{8+(4-3\theta)\theta}{(2-\theta)(4-3\theta^2)},\ \ c_2^* = \tilde{c}_2 = \frac{4+\theta-2\theta^2}{2(2-\theta)(4-3\theta^2)}.$$

The firms' equilibrium profits are

$$\Pi = \frac{64+32\theta-66\theta^2-20\theta^3+17\theta^4}{4(2-\theta)^2(4-3\theta^2)^2},\ \ \pi_1 = \frac{1}{4(2-\theta)^2},\ \ \pi_2 = \frac{(4+\theta-2\theta^2)^2}{4(2-\theta)^2(4-3\theta^2)^2}.$$

The manufacturers' profits in the subgames are summarized in Table 4.

A.5 Analysis under Wary Beliefs

In this section, we analyze the equilibrium outcome when both manufacturers source from a common supplier and adopt wary beliefs.

A.5.1 Common Supplier and Quantity Competition

First, consider a case in which both manufacturers disclose their cost information. In this case, information is perfect and the equilibrium outcome is not affected. Second, consider a case in which neither manufacturer discloses. Suppose that the supplier offers a price c_1 to manufacturer 1. Let $R(c_1)$ denote the optimal price that the supplier charges manufacturer 2, given that manufacturer 1's input price is c_1. Furthermore, let $\tilde{R}(c_1)$ denote manufacturer 1's belief of c_2, given that its own cost is c_1, and let $\Pi(c_1, c_2)$ denote the

supplier's total profit from both manufacturers. Wary beliefs dictate that

$$R(c_1) = \arg\max_{w} \ \Pi(c_1, w). \tag{16}$$

Put differently, the price pair $(c_1, R(c_1))$ maximizes the supplier's profit, given that the supplier charges manufacturer 1 a price c_1. Equation (16) can be translated into

$$R(c_1) = \arg\max_{w} \ c_1 \cdot q_1(c_1, \tilde{R}(c_1)) + w \cdot q_2(w, \tilde{R}(w)). \tag{17}$$

Note that w does not appear on the first term on the right-hand side, and we can rewrite Equation (17) as

$$R(c_1) = \arg\max_{w} \ w \cdot q_2(w, \tilde{R}(w)). \tag{18}$$

It follows immediately from Equation (18) that $R(c_1)$ is independent of c_1. In other words, manufacturer 1 should not update its belief regarding c_2 upon receiving an expected offer from the supplier, and manufacturer 2 must share the same reasoning. In this regard, wary beliefs coincide with passive beliefs, and the equilibrium outcome is not affected.

The situation becomes more complicated when the manufacturers adopt asymmetric disclosure decisions. Assume without loss of generality that only manufacturer 1 discloses. We conjecture that there exists an equilibrium in which manufacturer 1's belief is linear in its cost, denoted by $\tilde{c}_2 = \alpha_0 + \alpha_1 c_1$. It follows that the manufacturers' quantity decisions are

$$q_1 = \frac{2(1-c_1) - \theta + (\alpha_0 + \alpha_1 c_1)\theta}{4-\theta^2}, \ \ q_2 = \frac{4 - (4-\theta^2)c_2 - \theta(2 + \alpha_0\theta - c_1(2-\alpha_1\theta))}{2(4-\theta^2)}.$$

Maximizing the supplier's total profit, we find

$$c_2 = \frac{4 - \theta(2 + \alpha_0\theta - c_1(2-\alpha_1\theta))}{2(4-\theta^2)}.$$

Using the consistency of beliefs (i.e., $\tilde{c}_2 = c_2$ in equilibrium), we obtain

$$\alpha_0 = \frac{4-2\theta}{8-\theta^2}, \ \ \alpha_1 = \frac{2\theta}{8-\theta},$$

and that the equilibrium costs are

$$c_1 = \frac{32 - (8-\theta)\theta^2}{64 - 12\theta^2}, \ \ c_2 = \frac{16 - 4\theta - \theta^2}{32 - 6\theta^2}.$$

The manufacturers' equilibrium profits are

$$\pi_1 = \frac{4(2-\theta)^2}{(16-3\theta^2)^2}, \quad \pi_2 = \frac{(16-4\theta-\theta^2)^2}{16(16-3\theta^2)^2}.$$

We summarize the equilibrium outcome in the following table. It follows immediately that, in equilibrium, neither manufacturer discloses.

		Manufacturer 2	
		D	ND
Manufacturer 1	D	$\left(\frac{1}{4(2+\theta)^2}, \frac{1}{4(2+\theta)^2}\right)$	$\left(\frac{4(2-\theta)^2}{(16-3\theta^2)^2}, \frac{(16-4\theta-\theta^2)^2}{16(16-3\theta^2)^2}\right)$
	ND	$\left(\frac{(16-4\theta-\theta^2)^2}{16(16-3\theta^2)^2}, \frac{4(2-\theta)^2}{(16-3\theta^2)^2}\right)$	$\left(\frac{1}{(4+\theta)^2}, \frac{1}{(4+\theta)^2}\right)$

Table 6: Payoff matrix (common supplier, quantity competition)

A.5.2 Common Supplier and Price Competition

Consider, again, the case in which both manufacturers disclose their cost information. In this case, information is perfect, and the equilibrium outcome is not affected. Then, consider the case in which neither manufacturer discloses. Suppose that the supplier offers a price c_1 to manufacturer 1. Let $R(c_1)$ denote the optimal price that the supplier charges manufacturer 2, given that manufacturer 1's cost is c_1. Furthermore, let $\tilde{R}(c_1)$ denote manufacturer 1's belief of c_2, given that its own cost is c_1, and let $\Pi(c_1, c_2)$ denote the supplier's total profit from both manufacturers. Wary beliefs dictate that

$$R(c_1) = \arg\max_w \ \Pi(c_1, w). \tag{19}$$

That is, the price pair $(c_1, R(c_1))$ maximizes the supplier's profit, given that the supplier charges manufacturer 1 a price c_1. Equation (19) can be translated into

$$R(c_1) = \arg\max_w \ c_1 \cdot q_1(c_1, \tilde{R}(c_1)) + w \cdot q_2(w, \tilde{R}(w)). \tag{20}$$

Note that w does not appear on the first term on the right-hand side, and we can rewrite Equation (20) as

$$R(c_1) = \arg\max_w \ w \cdot q_2(w, \tilde{R}(w)). \tag{21}$$

It follows immediately from Equation (21) that $R(c_1)$ is independent of c_1. In other words, manufacturer 1 should not update its belief regarding c_2 upon receiving an expected offer from the supplier, and manufacturer 2 must share the same reasoning. Wary beliefs, again, coincide with passive beliefs and the equilibrium outcome will not be affected.

As was the case under quantity competition, the situation becomes more complicated when the manufacturers adopt asymmetric disclosure decisions. Assume without loss of generality that only manufacturer 1 discloses. We conjecture that there exists an equilibrium in which manufacturer 1's belief is linear in its cost, denoted by $\tilde{c}_2 = \alpha_0 + \alpha_1 c_1$. It follows that the manufacturers' pricing decisions are

$$p_1 = \frac{2 + 2c_1 + \theta + \alpha_0\theta + c_1\alpha_1\theta}{4 - \theta^2}, \quad p_2 = \frac{4 + c_2(4 - \theta^2) + \theta(2 + \alpha_0\theta + c_1(2 + \alpha_1\theta))}{2(4 - \theta^2)}.$$

Maximizing the supplier's total profit, we find

$$c_2 = \frac{4 + \theta(2 + \alpha_0\theta + c_1(2 + \theta\alpha_1))}{2(4 - \theta^2)}.$$

Using the consistency of beliefs, i.e., $\tilde{c}_2 = c_2$ in equilibrium, we obtain

$$\alpha_0 = \frac{4 + 2\theta}{8 - 3\theta^2}, \quad \alpha_1 = \frac{2\theta}{8 - 3\theta},$$

and that the equilibrium costs are

$$c_1 = \frac{32 + 32\theta - 8\theta^2 - 9\theta^3}{64 - 76\theta^2 + 18\theta^4}, \quad c_2 = \frac{16 + 12\theta - 9\theta^2 - 6\theta^3}{32 - 38\theta^2 + 9\theta^4}.$$

The manufacturers' equilibrium profits are

$$\pi_1 = \frac{(16 + 8\theta - 16\theta^2 - 9\theta^3)^2}{4(32 - 38\theta^2 + 9\theta^4)^2}, \quad \pi_2 = \frac{(16 + 12\theta - 9\theta^2 - 6\theta^3)^2}{4(32 - 38\theta^2 + 9\theta^4)^2}.$$

We summarize the equilibrium outcome in the following table. It follows immediately that in equilibrium, neither manufacturer discloses.

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		Manufacturer 2	
		D	ND
Manufacturer 1	D	$\left(\frac{1}{4(2-\theta)^2}, \frac{1}{4(2-\theta)^2}\right)$	$\left(\frac{(16+8\theta-16\theta^2-9\theta^3)^2}{4(32-38\theta^2+9\theta^4)^2}, \frac{(16+12\theta-9\theta^2-6\theta^3)^2}{4(32-38\theta^2+9\theta^4)^2}\right)$
	ND	$\left(\frac{(16+12\theta-9\theta^2-6\theta^3)^2}{4(32-38\theta^2+9\theta^4)^2}, \frac{(16+8\theta-16\theta^2-9\theta^3)^2}{4(32-38\theta^2+9\theta^4)^2}\right)$	$\left(\frac{1}{(4-3\theta)^2}, \frac{1}{(4-3\theta)^2}\right)$

Table 7: Payoff matrix (common supplier, price competition)

References

Albæk, S., Møllgaard, P., and Overgaard, P.B. 1997. Government-assisted oligopoly coordination? A concrete case. *Journal of Industrial Economics*, 45(4), 429–443.

Allender, W. J., Liaukonyte, J., Nasser, S., and Richards, T. J. 2021. Price fairness and strategic obfuscation. *Marketing Science*, 40(1), 122–146.

Athey, S. and Bagwell, K., 2001. Optimal collusion with private information. *RAND Journal of Economics*, 428–465.

Bearden, W.O., Carlson, J.P. and Hardesty, D.M., 2003. Using invoice price information to frame advertised offers. *Journal of Business Research*, 56(5), 355–366.

Carroll, G., 2015. Robustness and linear contracts. *American Economic Review*, 105(2), 536–563.

Chen, F., 2003. Information sharing and supply chain coordination. *Handbooks in operations research and management science*, 11, 341–421.

Cui, T., Raju, J. S., and Zhang, Z. J. 2007. Fairness and channel coordination. *Management Science*, 53(8), 1303–1314.

Darrough, M.N., 1993. Disclosure policy and competition: Cournot vs. Bertrand. *The Accounting Review*, 68(3), 534–561.

Einhorn, E. and Ziv, A., 2008. Intertemporal dynamics of corporate voluntary disclosures. *Journal of Accounting Research*, 46(3), 567–589.

Feuerstein, S., 2005. Collusion in industrial economics – a survey. *Journal of Industry, Competition and Trade*, 5(3), 163–198.

Fried, D., 1984. Incentives for information production and disclosure in a duopolistic environment. *Quarterly Journal of Economics*, 99(2), 367–381.

Gal-Or, E., 1985. Information sharing in oligopoly. *Econometrica*, 53(2), 329–343.

Gal-Or, E., 1986. Information transmission – Cournot and Bertrand equilibria. *Review of Economic Studies*, 53(1), 85–92.

Gal-Or, E., Geylani, T. and Dukes, A.J., 2008. Information sharing in a channel with partially informed retailers. *Marketing Science*, 27(4), 642–658.

Ganuza, J.J. and Jansen, J., 2013. Too much information sharing? Welfare effects of sharing acquired cost information in oligopoly. *Journal of Industrial Economics*, 61(4), 845–876.

Gaudin, G., 2019. Vertical relations, opportunism, and welfare. *RAND Journal of Economics*, 50(2), 342–358.

Graham, J.R., Harvey, C.R. and Rajgopal, S., 2005. The economic implications of corporate financial reporting. *Journal of Accounting and Economics*, 40(1-3), 3–73.

Grossman, S.J., 1981. The informational role of warranties and private disclosure about product quality. *Journal of Law and Economics*, 24(3), 461–483.

Guo, L., 2009. Quality disclosure formats in a distribution channel. *Management Science*, 55(9), 1513–1526.

Guo, L., 2015. Inequity aversion and fair selling. *Journal of Marketing Research*, 52(1), 77–89.

Guo, L., 2020. Upstream exploitation and strategic disclosure. *Marketing Science*, 39(5), 923–938.

Guo, L., 2021. Blockchain and price transparency in supply chains. Working paper, the Chinese University of Hong Kong.

Guo, L. and Iyer, G., 2010. Information acquisition and sharing in a vertical relationship. *Marketing Science*, 29(3), 483–506.

Guo, L. and Zhao, Y., 2009. Voluntary quality disclosure and market interaction. *Marketing Science*, 28(3), 488–501.

Hajihashemi, B., Sayedi, A., and Shulman, J. D. 2022. The perils of personalized pricing with network effects. *Marketing Science*, 41(3), 477–500.

Hart, O., and Tirole, J. 1990. Vertical integration and market foreclosure, *Brookings Papers on Economic Activity*, 205–76.

Ho, T. H., and Zhang, J. 2008. Designing pricing contracts for boundedly rational customers: Does the framing of the fixed fee matter? *Management Science*, 54(4), 686–700.

Inderst, R. and Ottaviani, M., 2012. Competition through commissions and kickbacks. *American Economic Review*, 102(2), 780–809.

Janssen, M. and Shelegia, S., 2015. Consumer search and double marginalization. *American Economic Review*, 105(6), 1683–1710.

Jiang, B., Tian, L., Xu, Y. and Zhang, F., 2016. To share or not to share: Demand forecast sharing in a distribution channel. *Marketing Science*, 35(5), 800–809.

Jiang, B., Sudhir, K. and Zou, T., 2021. Effects of cost-information transparency on intertemporal price discrimination. *Production and Operations Management*, 30(2), 390–401.

Kühn, K.U., 2001. Fighting collusion by regulating communication between firms. *Economic Policy*, 16(32), 168–204.

Lanen, W.N. and Verrecchia, R.E., 1987. Operating decisions and the disclosure of management accounting information. *Journal of Accounting Research*, 25, 165–189.

Lariviere, M.A. and Porteus, E.L. 2001. Selling to the newsvendor: An analysis of price-only contracts. *Manufacturing & Service Operations Management*, 3(4), 293–305.

Li, L., 1985. Cournot oligopoly with information sharing. *RAND Journal of Economics*, 16(4), 521–536.

Li, L., 2002. Information sharing in a supply chain with horizontal competition. *Management Science*, 48(9), 1196–1212.

Li, X., Li, K.J. and Wang, X., 2020. Transparency of behavior-based pricing. *Journal of Marketing Research*, 57(1), 78–99.

Li, X. and Liu, Q. 2021. Contract unobservability and downstream competition. *Manufacturing & Service Operations Management*, 23(6), 1468–1482.

McAfee, R.P. and Schwartz, M., 1994. Opportunism in multilateral vertical contracting: nondiscrimination, exclusivity, and uniformity. *American Economic Review*, 84(1), 210–30.

Milgrom, P.R., 1981. Good news and bad news: Representation theorems and applications. *Bell Journal of Economics*, 12(2), 380–391.

Mittendorf, B., Shin, J. and Yoon, D.H., 2022. Information disclosure policy and its implications: Ratcheting in supply chains. *Journal of Marketing Research*, 59(2) 290–305.

Mohan, B., Buell, R.W. and John, L.K., 2020. Lifting the veil: The benefits of cost transparency. *Marketing Science*, 39(6), 1105–1121.

O'Brien, D.P. and Shaffer, G. 1992, Vertical control with bilateral contracts, *RAND Journal of Economics*, 23(3), 299–308.

Rey, P. and Vergé, T., 2004. Bilateral control with vertical contracts. *RAND Journal of Economics*, 728–746.

Shapiro, C., 1986. Exchange of cost information in oligopoly. *Review of Economic Studies*, 53(3), 433–446.

Singh, N. and Vives, X., 1984. Price and quantity competition in a differentiated duopoly. *Rand Journal of Economics*, 546–554.

Sun, M. and Tyagi, R.K., 2020. Product fit uncertainty and information provision in a distribution channel. *Production and Operations Management*, 29(10), 2381–2402.

Testa, J., Friedman, V., and Paton, E. Everlane's promise of "radical transparency" unravels. *New York Times*, July 26, 2020. https://www.nytimes.com/2020/07/26/fashion/everlane-employees-ethical-clothing.html

Vives, X., 1984. Duopoly information equilibrium: Cournot and Bertrand. *Journal of Economic Theory*, 34(1), 71–94.

Vives, X., 1990. Trade association disclosure rules, incentives to share information, and welfare. *RAND Journal of Economics*, 21(3), 409–430.

Weintraub, A., 2021. Hospitals must now disclose prices. Here's how to interpret them. *Next Avenue* (Feb 15).

Xiong, Y. and Yang, L., 2021. Disclosure, competition, and learning from asset prices. *Journal of Economic Theory*, 197, 105331.

Zhang, J. and Li, K.J., 2021. Quality disclosure under consumer loss aversion. *Management Science*, 67(8), 5052–5069.

Zhu, K., 2002. Information transparency in electronic marketplaces: Why data transparency may hinder the adoption of B2B exchanges. *Electronic Markets*, 12(2), 92–99.

Zhu, K., 2004. Information transparency of business-to-business electronic markets: A game-theoretic analysis. *Management Science*, 50(5), 670–685.