Public Disclosures in the Presence of Suppliers and Competitors

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Abstract

Firms' reluctance at times to publicly disclose financial information is often attributed to concern that the information may be used against them by self-interested outside parties. These outside parties may interact with the firm in the horizontal realm (e.g., retail competitors) or in the vertical arena (e.g., wholesale suppliers). This paper is built on the premise that fully understanding the strategic consequences of disclosure requires one to jointly consider horizontal and vertical relationships. When both rivals and suppliers are accounted for, we identify a consistent message – lower intra-industry correlation in product demand favors disclosure. Unlike disclosure determinants derived in previous work primarily considering supply markets or retail markets alone, this result is shown to be robust to modeling variations.
1. Introduction

A firm's decision to publicly release relevant financial information is a nuanced one. The decision is made particularly difficult given the diversity of observers. One widely held view posits that a key force working against information sharing is that the information will be used in self-interest by other strategic players in the marketplace. Not unexpectedly, strategic interplay is more subtle with multiple information users, making identifying and quantifying the nature of proprietary costs and benefits of disclosure a delicate exercise.

With these concerns in mind, this paper revisits the incentives for public disclosures by considering how the joint presence of strategic players in the supply and retail markets can affect preferred disclosure policy. Stated succinctly, the results suggest that in the presence of multi-faceted strategic interplay, a low degree of intra-industry correlation in product demand is a key underlying determinant of a firm's desire to disclose its information.

To elaborate on the model, we consider a circumstance where a firm is privy to information relevant to its demand that may also be informative of the demand of its competitors. Further, both the firm and its competitors rely on a supplier for a key input. The question we ask is whether the firm prefers to publicly disclose its information in light of the fact that it will be strategically used both by the supplier and competitors.

One force working against disclosure is that when the firm reveals high demand, the supplier will seek to exploit such demand by boosting its wholesale price. While this also means that a lower wholesale price will accompany lower demand, this supply market tradeoff is hardly in the firm's best interest since it hurts (benefits) the firm in circumstances when it can potentially reap the most (least) profits. Additionally, a retail market force also works against disclosure when high demand for the firm is indicative of
high demand for competitors – in this case, revelation of good news emboldens competitors, eroding the firm's profit.

The offsetting forces that may point to disclosure being worthwhile also arise in both the supply and retail realms. In the retail market, if high demand for the firm is not predictive of similarly high demand for competitors, disclosure serves as an indirect means of implementing cooperation between the firm and its rivals. That is, when the firm discloses high demand on its part, it also communicates a strong posture to competitors which, in turn, forces them to back away in competition. On the other hand, when the firm discloses low demand on its part, it communicates that it will back away and allow competitors to take the lead. This give-and-take leads to lower competition and higher expected profits for the firms.

In the supply market, while disclosure of high demand leads the supplier to raise its wholesale price all else equal, the effect can be more subtle. First, any increase in wholesale price is also borne by the other input buyers, here the firm's rivals, meaning the increase may not be overly harmful. Second, the supplier's chosen price reflects an averaging of the demand environments of all its customers. If high demand for the firm is indicative of lower demand for others, this feature may even translate into disclosure of high demand for the firm leading to lower wholesale prices. Though the reverse occurs when the firm's demand is low, recall, the firm's primary concern is with obtaining favorable pricing when its own demand is steep.

Taken together, these basic supply and retail market forces suggest that disclosure is advantageous in circumstances where (i) it is effective in promoting tacit cooperation (lower intra-industry demand correlation), (ii) tacit cooperation is particularly valuable (less product differentiation), (iii) supplier pricing does not move in tandem with the firm's demand information (lower intra-industry demand correlation), and (iv) supplier pricing repercussions impact multiple buyers (less market concentration). These four forces together clearly give rise to the implication that lower intra-industry correlation, less
product differentiation, and less market concentration are potentially key factors promoting public disclosure.

Before concluding these factors decisively favor disclosure, the paper considers some notable modeling variations in both the retail and supply realms. In particular, in the retail realm, we consider how results are affected if the information observed by the firm is cost-relevant rather than demand-relevant, and if the retail market is characterized by Bertrand rather than Cournot competition. In the supply realm, we examine the effects if the supply market permits price discrimination, and if the supplier also serves as a retail competitor. Each of these modeling variations introduces key practicalities to the analysis. More importantly, each variation speaks to the robustness of the conclusions. After all, previous research on disclosure has shown that these modeling variations can disable or even reverse the conclusions one obtains about disclosure (e.g., Gal Or 1985, 1986; Darrough 1993).

As we demonstrate, when one considers the joint presence of supply market and competitive effects of disclosure, the underlying results are notably insensitive to these modeling variations. To be sure, each variation adds an new consideration to the analysis and can even disable one or more of the forces at work (as summarized in (i) - (iv) above). Nonetheless, the primary conclusion that lower intra-industry correlation favors disclosure persists in all cases. The reason underlying this robust feature is the fact that forces previously identified in (i) and (iii) work in concert. In particular, lower intra-industry demand correlation fosters beneficial give-and-take with rivals in the retail market while also yielding wholesale price concessions in the supply market.

Given the robust nature of some but not all of the determinants of disclosure we identify when both the supply market and retail market are in play, the paper's results provide some guidance to empirical assessment of proprietary costs of disclosure. Survey results (Graham et al. 2005) and anecdotal evidence generally support the intuitive notion that strategic considerations favor more opacity. Despite this, there is surprisingly little
large-sample empirical support for this connection. Our analysis suggests additional empirical proxies that may be fruitful. A more meaningful discussion of this subject can be provided after detailing the formal results, and so we return to the issue of empirical implications in the penultimate section of the paper.

The remainder of this paper proceeds as follows. Section 2 discusses the related literature. Section 3 presents the basic model of disclosure under retail and supply market pressures. Section 4 presents the results: 4.1 examines the strategic outcome in the absence of disclosure; 4.2 examines the outcome with disclosure; 4.3 considers the preferred disclosure policy; 4.4 considers modeling variations, their effects on the results, and empirical implications. Finally, section 5 concludes.

2. Related Literature

The present analysis is a complement to and extension of the extant literature on strategic effects of information release that spans several disciplines. Beginning with Gal-Or (1985; 1986) in economics and Darrough (1993) in accounting, a vast literature has examined the efficacy of disclosure in the presence of retail market competitors. While this literature has often provided seemingly contradictory views on the proprietary costs and benefits of disclosure, excellent efforts at synthesizing and generalizing the varied perspectives have been undertaken, most notably in Raith (1996) and Bagnoli and Watts (2015).

Raith (1996) provides a general model that includes previous studies as special cases and concludes that the form of retail competition (price or quantity) and the nature of the information (private-value or common-value) are critical factors in identifying the attractiveness of disclosure. Bagnoli and Watts (2015) further extend this view to consider cases where the information in question is more pertinent to the rival than it is the firm that holds it. Among other things, they show that consideration of such "competitive intelligence" stands to further alter prevailing views of the net competitive effects of
disclosure. The present analysis seeks to extend the canon of existing studies to include the presence of a supply market. Though notably complicating the intricacies of strategic interplay, the joint inclusion of supply and retail markets opens the door to a previously elusive unifying theme – regardless of the modeling choice, lower intra-industry correlation in demand points to disclosure being a more likely equilibrium outcome.

Since the inclusion of supply markets represents the novel consideration herein, it is worth asking whether looking at supply markets alone (absent retail competition) could provide related insights. Interestingly, this research question too has a storied past. In particular, research in marketing, operations, and supply chains has extensively examined the consequences of disclosure on supply market conditions and pricing. Though models here too vary, a few themes are noteworthy. On one hand, shared information can be useful in aspects of supply chain interactions that are inherently cooperative in nature. That is, disclosure can help better manage supplier priorities and inventory scheduling, thereby providing efficiency that can trickle down all levels of the supply chain (e.g., Cachon and Fisher 2000; Gavirneni et al. 1999; Lee et al. 2000). As an example, detailed sales data disclosed by a retailer enables a manufacturer to reduce inventory costs by lowering inventory holdings and streamlining logistics processes.

On the other hand, information that is used strategically (the focus herein) generally proves harmful for the discloser. Notably, the decision to disclose information pertinent to underlying retail profitability can lead suppliers to squeeze retailer margins (e.g., He et al. 2008; Narayanan and Raman 2004). As Arya et al. (2016) demonstrate, this feature may favor uniform pricing regulations as means of protecting retailers from supplier information exploitation, which can promote both information gathering and dissemination. An added concern is that any information shared with a supplier in confidence creates problems of information leakage that may have other strategic reverberations (Li 2002).

As elaborated on in Li and Zhang (2008), addressing consequences of information leakage to retailers is distinct from the question of whether to make the information directly
available to the public. A key distinction in the present analysis (relative to existing studies) is that we presume one firm's public disclosure about its own demand can (i) inform a supplier of the firm's demand; (ii) inform competitors of the firm's strategy; and (iii) inform competitors of their own demand. By presuming each firm has no uncertainty about its own circumstance, Li (2002) and Li and Zhang (2008) preclude the role in (iii) above. As we will see in the ensuing analysis, (iii) proves critical in our setting, even being the linchpin for ensuring the results are robust to both the nature of competition and degree of price discrimination in the supply market.

Given the contribution here is rooted in joint consideration of supply and retail market consequences of disclosure, the analysis is perhaps most closely related to the results in Zhang (2002). In the case of perfectly correlated intra-industry demand, Zhang (2002) provides the key insight that a firm will be unwilling to voluntarily release demand-relevant information in the presence of a supplier and competitor but may be willing to take part in mutual disclosure facilitated by side payments. In a sense, the present analysis extends this line of inquiry to the case of imperfect intra-industry demand correlation. In doing so, we note that voluntary information release too may be an equilibrium, but only if intra-industry correlation in demand is sufficiently low.

3. Model

A firm, denoted firm 0, faces competition from \( n, n \geq 1 \), Cournot rivals. We index the rival firm by \( i \), and denote the set of rival firms by \( N, N = \{1, \ldots, n\} \). Each firm relies on a monopolist supplier, \( S \), for a key input. The supplier produces the input at unit cost \( c \) and sells the input to the market at its established wholesale price \( w \). Upon procuring inputs from the supplier, each firm competes in the final good (retail) market. Retail demand is captured by the standard linear (inverse) demand function

\[
p_j = \alpha_j - q_j - \gamma \sum_{k \neq j} q_k, \quad j = 0, \ldots, n,
\]

where \( p_j \) and \( q_j \) reflect the retail price and quantity
for firm $j$, $\alpha_j$ is firm $j$'s demand intercept, and $\gamma \in (0,1)$ reflects the degree of product
differentiation.

At the outset, consumer demand for the firms' products is uncertain. In particular,
the demand intercept for firm 0 is $\alpha_0 = a + \tilde{\delta}$, where $a$ is the expected demand and
$\tilde{\delta} \in [\delta, \bar{\delta}]$ is a mean zero noise term with variance $\sigma^2$. As is standard, throughout the
analysis we assume $a$ is sufficiently large to ensure nonnegative quantities and prices and
nontrivial participation of all firms in the retail market. The demand intercept for rival firm
$i, i \in \mathcal{N}$, is $\alpha_i = a + r\tilde{\delta}$, where $r \in [-1,1]$ reflects the degree of spillover (correlation) in
firm 0's demand and that of its rivals. The case of $r < 0$ reflects circumstances where an
increase in demand for firm 0's product is connected with an offsetting decrease in demand
for its rivals. An example is variation in consumer preferences for different brands: when
consumers develop a preference for one company's brand (say Apple products), they
necessarily do so at the expense of demand for other brands (say Dell). On the other hand,
$r > 0$ reflects positively related demand in that an increase in demand for firm 0's product
is also indicative of added demand for rivals. An example here is consumer preferences for
particular types of products: when more consumers seek out smartphones, all phone
producers (say Apple and Samsung) see an uptick in demand.

The focus of this paper is on disclosure of the firm's demand information in light of
strategic consequences in both the supply and retail markets. To capture that consideration,
say firm 0 observes $\delta$ (the realized value of $\tilde{\delta}$), and can upfront establish a policy of
whether or not to disclose it publicly. Fully cognizant that such a disclosure may impact
both supplier pricing and rival behavior, the question we ask is what is firm 0's preferred
disclosure policy?

In the analysis that follows, we examine subgame perfect equilibria by working
backwards in the game to determine outcomes. The timeline of events for the setting is
summarized in Figure 1.
Firm 0 establishes disclosure policy. Firm 0 observes $\delta$ and discloses according to policy. Supplier $S$ sets the prevailing wholesale price, $w$. Firms choose retail quantities $q_j, j = 0, \ldots, n$. Retail demand is satisfied, and profits are realized.

Figure 1: Timeline

4. Results

To identify firm 0’s preferred disclosure policy, we will first identify the wholesale and retail equilibria both with and without disclosure. Comparing equilibria then reveals the optimal disclosure policy.

4.1. Equilibrium under no disclosure

In the absence of disclosure, the equilibrium outcome is determined as follows. Working backwards, for a given wholesale price, observed $\delta$, and Cournot conjecture of firm $i$’s quantity, denoted $\tilde{q}_i$, firm 0 chooses its quantity to solve:

$$\max_{q_0} \left[ a + \delta - q_0 - \gamma \sum_{i \in N} \tilde{q}_i \right] q_0 - wq_0. \quad (1)$$

The first-order condition of (1) reveals firm 0’s reaction function, $q_0(\tilde{q}_i, i \in N; \delta) = \frac{1}{2} \left[ a + \delta - w - \gamma \sum_{i \in N} \tilde{q}_i \right]$. Firm $i, i \in N$, not aware of $\delta$, chooses its quantity to solve its expected profit as in (2), where $\tilde{q}_0(\delta)$ reflects firm $i$’s Cournot conjecture of firm 0’s quantity for a given $\delta$ and $N_{-i}$ is the set $N$ without the element $i$.

$$\max_{q_i} E_\delta \left[ a + r\delta - q_i - \gamma \tilde{q}_0(\delta) - \gamma \sum_{j \in N_{-i}} \tilde{q}_j \right] q_i - wq_i \right), \quad i \in N. \quad (2)$$

The first-order condition of (2) reveals firm $i$’s reaction function, $q_i(\tilde{q}_0(\delta), \tilde{q}_j, j \in N_{-i}) = \frac{1}{2} \left[ a - w - \gamma E \tilde{q}_0(\delta) - \gamma \sum_{j \in N_{-i}} \tilde{q}_j \right]$. Jointly solving the reaction functions of each firm yields the equilibrium quantities as a function of the wholesale price in the absence of disclosure, denoted $q_0^\phi(w; \delta)$ and $q_i^\phi(w)$, with the superscript $\phi$ reflecting no disclosure.
\[ q^\phi_0(w; \delta) = \frac{a-w}{2 + \gamma n} + \frac{\delta}{2}; \text{ and} \]

\[ q^\phi_i(w) = \frac{a-w}{2 + \gamma n}, \quad i \in \mathbb{N}. \]  

(3)

The retail quantities in (3) reflect some intuitive features. First, the greater the expected demand (captured by \(a\)) or the lower the prevailing wholesale price (\(w\)), the higher the quantities for each firm. Further, the more the number of competitors (\(n\)) or the greater the substitutability in products (\(\gamma\)), the lower the equilibrium quantities for each firm. This reflects that the more other firms can meet consumer demands, the less any one firm will offer. Finally, for firm 0, the greater the demand shock, the greater the quantities chosen so as to meet consumer demand. And, since the other firms are unaware of this demand shock, they simply consider its expected value, i.e., \(q^\phi_i(w) = E_\delta \{q^\phi_0(w; \delta)\}\).

Interestingly, the degree to which the demand shock affects firm 0's demand exceeds the degree by which \(a\) does, i.e., \(\frac{\partial q^\phi_0(w; \delta)}{\partial \delta} > \frac{\partial q^\phi_0(w; \delta)}{\partial a}\). This feature reflects that while greater \(a\) encourages all firms to rush to meet greater consumer demand, only firm 0 is in a position to boost its quantity to meet demand changes unobserved by others.

The quantities in (3) represent the induced demand functions for the supplier, which sets its wholesale price to solve (4):

\[
\text{Max}_w \quad E_\delta \left\{ [w-c] \left[ q^\phi_0(w; \delta) + \sum_{i \in \mathbb{N}} q^\phi_i(w) \right] \right\}. \tag{4}
\]

The first-order condition of (4) reveals the wholesale price set by the supplier in the absence of disclosure, \(w = w^\phi = c + [a - c] / 2\). Intuitively, the greater the demand (\(a\)) or production cost (\(c\)) for the product, the higher the price charged by the supplier. Using this in \(q^\phi_0(w; \delta)\) and \(q^\phi_i(w)\), then, reveals the equilibrium outcome without disclosure, as summarized in Proposition 1. (Proofs are provided in the appendix.)
PROPOSITION 1. In the absence of disclosure, the equilibrium entails:

(i) \( w = w^\phi = c + \frac{a-c}{2} \);
(ii) \( q_0 = q_0^\phi(\delta) = \frac{a-c}{2[2+\gamma n]} + \frac{\delta}{2} ; \) and
(iii) \( q_i = q_i^\phi = \frac{a-c}{2[2+\gamma n]} \) for \( i \in N \).

Given this baseline outcome, we now consider the consequence of disclosure for both wholesale and retail behavior.

4.2. EQUILIBRIUM UNDER DISCLOSURE

With disclosure, the information set for firm 0 is precisely as without disclosure. Thus, for a given wholesale price, observed \( \delta \), and Cournot conjecture of firm \( i \)'s quantity, firm 0 chooses its quantity to solve (1) as before, again yielding a reaction function \( q_0(\tilde{q}_i, i \in N; \delta) = \frac{1}{2} a + \delta - w - \gamma \sum \tilde{q}_i \). With disclosure, firm \( i, i \in N \), too is aware of \( \delta \), and thus chooses its quantity in a symmetric fashion. To be complete, firm \( i \)'s quantity solves (5).

\[
\text{Max}_{q_i} \left[ a + r\delta - q_i - \gamma \tilde{q}_0 - \gamma \sum_{j \in N_{-i}} \tilde{q}_j \right] q_i - wq_i, \quad i \in N. \tag{5}
\]

The first-order condition of (5) reveals firm \( i \)'s reaction function, \( q_i(\tilde{q}_0, \tilde{q}_j, j \in N_{-i}; \delta) = \frac{1}{2} a + r\delta - w - \gamma \tilde{q}_0 - \gamma \sum_{j \in N_{-i}} \tilde{q}_j \). Jointly solving the reactions functions of each firm yields the equilibrium quantities as a function of the wholesale price, denoted \( q_0^d(w; \delta) \) and \( q_i^d(w; \delta) \), with the superscript \( d \) reflecting disclosure.

\[
q_0^d(w; \delta) = q_0^\phi(w; \delta) - \frac{\gamma n \delta [2r - \gamma]}{2[2 - \gamma][2 + \gamma n]} ; \quad \text{and}
q_i^d(w; \delta) = q_i^\phi(w) + \frac{\delta [2r - \gamma]}{[2 - \gamma][2 + \gamma n]} , \quad i \in N. \tag{6}
\]
Note the retail quantities in (6) are as those in the no disclosure case in (3), with some key adjustments. For competitor $i, i \in N$, disclosure has two effects. First, disclosure of $\delta$ directly conveys information about firm $i$'s demand, and higher (lower) demand means greater (lesser) quantities are in order. The extent of this direct information conveyance is roughly captured by the spillover $r$. Second, disclosure also conveys information about firm 0's competitive posture. The degree to which this conveyance of competitive position alters firm $i$'s own choice is roughly captured by the degree of competitive intensity, $\gamma$. As for how disclosure affects firm 0, there is no direct effect, since firm 0 knows the demand parameters regardless of whether or not it chooses to disclose them. But, the indirect effect vis-a-vis competitive posturing is present, as reflected in the term $\frac{\gamma n \delta [2r - \gamma]}{2[2 - \gamma][2 + \gamma n]}$. Intuitively, the more the information released serves to boost (shrink) the quantity of rival $i$, the weaker (stronger) firm 0's competitive posture.

The quantities in (6) represent the induced demand functions for the supplier. Under disclosure, the supplier too knows $\delta$ and thus sets its wholesale price to solve (7):

$$\text{Max}_w \left[ w - c \right] \left[ q^d_0(w;\delta) + \sum_{i \in N} q^d_i(w;\delta) \right].$$

(7)

The first-order condition of (7) reveals the supplier's wholesale price as a function of the disclosed $\delta$: $w = w^d(\delta) = c + [a - c]/2 + \delta[1 + rn]/[2(1 + n)]$. In effect, the wholesale price is as before, except it now reflects the realized value of $\delta$. The greater is $\delta$, the more is the induced demand from firm 0 and thus the higher is the wholesale price. That said, the degree to which $\delta$ affects the wholesale price depends on the average effect it has on all of the retailers' demands. In other words, it is clear that both with and without disclosure, an increase in the demand intercept increases $w$ by a multiple of $1/2$. Given this, one can think of an increase in $\delta$ as affecting the average demand intercept of all $n+1$ firms by $[1 + rn]/[1 + n]$ – recall, the information spillover only impacts the $n$ rivals by the $r$-factor. Thus, an increase in $\delta$ under disclosure increases $w$ by a factor of $[1/2][1 + rn]/[1 + n]$. 
Using the equilibrium wholesale price under disclosure in $q_0^d(w;\delta)$ and $q_i^d(w;\delta)$ reveals the equilibrium outcome with disclosure, as summarized in Proposition 2.

**Proposition 2.** With disclosure, the equilibrium entails:

(i) $w = w^d(\delta) = c + \frac{a - c}{2} + \frac{\delta[1+rn]}{2[1+n]}$;

(ii) $q_0 = q_0^d(\delta) = \frac{a - c}{2[2 + \gamma n]} + \frac{\delta[2 + 2n(2-r) - \gamma(1 - 2n^2(1-r) + rn)]}{2[2 + \gamma n][2 - \gamma][1+n]}$; and

(iii) $q_i = q_i^d(\delta) = q_0^d(\delta) - \frac{\delta[1-r]}{2-\gamma}$ for $i \in N$.

With supply market and retail market equilibria under each disclosure regime in tow, we now compare firm 0's profit under each to establish its preferred disclosure policy.

### 4.3. Optimal Disclosure Policy

To determine the net effect of disclosure on firm 0, let us consider both the retail and wholesale consequences. First, holding the wholesale price constant, (6) confirms the net retail effect of disclosure. Each competitor takes a retail posture more tailored to the demand environment, as well as one that is more responsive to the other firms' behavior. This means that for positive (negative) values of $r$, each rival is inclined to produce more (less) quantities as $\delta$ increases: the direct effect of disclosure tied to the spillover is reflected by $r$. However, it also means that each rival is aware of firm 0's more aggressive posture at higher $\delta$ values which makes the rival inclined to produce less: the indirect effect of disclosure tied to retail competition is reflected by $\gamma$. The net effect is that disclosure of a higher $\delta$ increases each rival's quantity if and only if the spillover direct effect exceeds the competition indirect effect as succinctly represented by the condition $2r - \gamma > 0$, or $r > \gamma / 2$. Given the convexity in payoffs, this effect turns out to be the determinant of whether or not to disclose: the firm seeks to disclose if disclosing a high $\delta$-value is
accompanied with lower quantities by rivals (e.g., Bagnoli and Watts 2015). Stated another way, if the firms could make products at cost \( c \) (rather than procure them from a strategic supplier), the disclosure policy would be determined exclusively by the net retail market effect in which case the optimal policy would entail disclosure if and only if \( r < \frac{\gamma}{2} \). In effect, from a retail perspective, disclosure is attractive for firm 0 if it convinces the rivals to soften their competitive stance when firm 0 most wants them to, suggesting disclosure is useful when \( r \) is small and/or \( \gamma \) is large.

As for the wholesale consequences, a comparison of Propositions 1 and 2 reveals that \( w^d(\delta) = w^\phi + \frac{\delta[1 + rn]}{2[1 + n]} \). In effect, the supplier's prevailing wholesale price is tailored to the average demand conditions of its customers. Generally speaking, firm 0 is hurt by the supplier's price tracking its own demand, since that would mean periods of high demand (where profit potential is greatest) are accompanied by excessive wholesale price. The extent to which such wholesale price tracking occurs, however, depends on both \( r \) and \( n \). The greater \( r \), the more the demands of the supplier's various constituents move in tandem and, thus, the greater the tracking. However, for low values of \( r \), the supplier's price is not very sensitive to firm 0's information and this cost of disclosure is minimized. Furthermore, for negative values of \( r \), the supplier's price can move in the opposite direction to firm 0's information and, thus, there are supply market upsides to disclosure. In particular, when good news for firm 0 is bad news for the other firms, the result is wholesale price concessions precisely when they are most beneficial for firm 0 (in periods of steep demand). How these considerations are manifest naturally depends also on how many rivals make up the supplier's customer base. For large \( n \), the supplier becomes more concerned with the rivals in pricing and less concerned with tracking firm 0's demand circumstance. In such an event, supply market benefits of disclosure are more likely.

The above intuition suggests that once supply market and retail market consequences are jointly considered, disclosure is preferred when \( r \) is small, \( n \) is large, and/or \( \gamma \) is large. It is this intuition we now formalize. Using equilibrium values from
Proposition 1 in firm 0's profit expression in (1) and taking expectations, yields expected profit under no disclosure, denoted $\Pi_0^\phi$, as in (8).

$$\Pi_0^\phi = E_\delta \left\{ a + \delta - q_0^\phi(\delta) - \gamma \sum_{i \in N} q_i^\phi(\delta) - w^\phi q_0^\phi(\delta) \right\} = \left( \frac{a - c}{2[2 + \gamma n]} \right)^2 + \frac{\sigma^2}{4}. \tag{8}$$

Similarly, using values from Proposition 2 in (1) and taking expectations yields expected profit under disclosure, denoted $\Pi_0^d$, as in (9).

$$\Pi_0^d = E_\delta \left\{ a + \delta - q_0^d(\delta) - \gamma \sum_{i \in N} q_i^d(\delta) - w^d(\delta)q_0^d(\delta) \right\} = \left( \frac{a - c}{2[2 + \gamma n]} \right)^2 + \sigma^2 \left( \frac{2 + 2n[2 - r] - \gamma[1 - 2n^2(1 - r) + rn]}{2[2 + \gamma n][2 - \gamma][1 + n]} \right)^2. \tag{9}$$

Comparing $\Pi_0^\phi$ and $\Pi_0^d$ in (8) and (9), respectively, reveals that disclosure is preferred if and only if $r$ is sufficiently small, as summarized in Proposition 3.

**Proposition 3.** The optimal policy entails disclosure if and only if $r < r^*(n, \gamma)$, where 

$$r^*(n, \gamma) = \frac{\gamma^2 n[n + 1] + \gamma - 2}{n[2\gamma n + \gamma + 2]}.$$

The intuition provided above for the competing effects of disclosure in the joint presence of retail and wholesale markets isolates three key factors: correlation in market demand ($r$), market size/concentration ($n$), and product differentiation ($\gamma$). Proposition 3 provides evidence consistent with the first of the three factors being critical. Before we consider the role of each of the others, a bit more on the role of intra-industry demand correlation ($r$) is in order. The effect of correlation is two-fold. First, less (greater) correlation means that information release leads firm 0's rival to choose quantities that are less (more) closely aligned with its own. Second, less (greater) correlation means that the supplier's wholesale price tracks firm 0's demand less (more) closely. Each effect points to lower $r$ being associated with disclosure, as reflected in the $r$-cutoff. As confirmed in parts (i) and (iii) of the next corollary, the cutoff is interior in nature – for $r = -1$ ($r = 1$), disclosure (no disclosure) is sure to be optimal.
Corollary 1.

(i) With perfect negative correlation in demand \( r = -1 \), disclosure is optimal.

(ii) With independent (i.e., private-value) demand \( r = 0 \), disclosure is optimal if and only if
\[
\begin{align*}
n > \left[ \sqrt{8 - 4\gamma + \gamma^2} - \gamma \right] / 2\gamma.
\end{align*}
\]

(iii) With perfect positive correlation (i.e., common-value) demand \( r = 1 \), no disclosure is optimal.

Besides demonstrating the interior nature of the \( r \)-cutoff, the corollary also presents the two most commonly-modeled information scenarios as special cases. When the information learned by firm 0 pertains only to its own demand (private-value information in (ii)), disclosure has a competitive upside, but a supply-side cost of having the wholesale price track its demand. Since the degree of this supply side cost is lowered by greater \( n \), disclosure is preferred for sufficiently large \( n \). In contrast, when the information learned by firm 0 is about industry-wide demand that applies to all firms equally (common-value information in (iii)), disclosure has a competitive downside and a supply-side cost that can no longer be reduced by pooling with multiple (now identical) buyers. Since both factors work against disclosure, no disclosure is preferred for all \( n \). The second key feature mentioned above is the degree of market size/concentration \( n \). The next corollary confirms its effect on the efficacy of disclosure.

Corollary 2.

(i) Less retail concentration increases disclosure, i.e., \( r^*(n, \gamma) \) is increasing in \( n \).

(ii) At the limit of concentration \( (n \rightarrow \infty) \), disclosure is optimal if and only if \( r < \gamma / 2 \).

As alluded to before, less market concentration (greater \( n \)) is beneficial in terms of supply-side effects of disclosure in that it helps shift wholesale price changes away from simply tracking firm 0's disclosed demand. In fact, as the market approaches perfect concentration \( (n \rightarrow \infty) \), competitive concerns are all that remains. As shown before,
determining the net effect of disclosure on a competitor (ignoring supply effects) entails a simple comparison of \( r \) and \( \gamma / 2 \), precisely as in Corollary 2(ii). The broader point of the corollary is that both lower correlation and lower concentration work to favor disclosure.

The third key feature mentioned above is the extent of product differentiation (\( \gamma \)). The next corollary confirms its effect on the desirability of disclosure.

**COROLLARY 3.** Less product differentiation increases the propensity to disclose, i.e.,

\[ r^*(n, \gamma) \text{ is increasing in } \gamma. \]

The consequence of \( \gamma \) is most clear in that it exclusively resides in the retail realm. That is, given competitive benefits of disclosure are weighed against supply market costs, greater values of \( \gamma \) magnify the importance of competitive benefits. For this reason, higher \( \gamma \)-values correspond to more disclosure. Taken together, Proposition 3 and its corollaries demonstrate that the determinants of disclosure are three-pronged: (i) the less the intra-industry correlation in demand (smaller \( r \)), (ii) the less the retail market concentration (greater \( n \)), and (iii) the less product differentiation (greater \( \gamma \)) in a given industry, the more attractive is disclosure. These features are shown in Figure 2, which plots the disclosure policy as a function of \( r \) and \( \gamma \) at varied levels of market concentration (\( n \)).
Despite the clear and monotonic relation between disclosure and these underlying model characteristics, the question of robustness lingers. It is this issue we examine next.

4.4. MODEL VARIATIONS

In this section, we will examine key variants of the model to consider which, if any, forces persist in a variety of circumstances. Besides providing important robustness checks, these variants also set the stage for a modest discussion of empirical implications.

4.4.1. RETAIL MARKET VARIATION

We begin with perhaps the most common source of criticism of models of proprietary costs of disclosure, that they are sensitive to presumed retail market conditions.
**Demand vs. Cost Information**

A commonly-held view about the competitive effects of disclosure is that any conclusions derived about demand-relevant information are reversed if the information is instead cost-relevant. As it turns out, this is a misconception rooted in the usual modeling of demand information as being common-value and cost information being private-value in nature. Recent work (e.g., Bagnoli and Watts 2015), has stressed that it is the common-value vs. private-value distinction, not the demand vs. cost distinction, that often proves critical.

The same is true in this paper. After all, in our setting, one can interpret each firm's demand intercept, $\alpha_i$, as being net of downstream cost (see Singh and Vives 1984). Thus, the private information observed by firm 0, $\delta$, could be demand-specific, cost-specific, or relevant both to cost and demand. The key is not whether the information is about demand or cost, but how the information spills over to the demand/cost environment of others. To this end, the parameter $r$ provides a general representation of the information environment that encompasses both common-value information ($r = 1$) and private-value information ($r = 0$) as special cases. And, the result that $r$ is the critical factor in determining disclosure persists regardless of whether the information itself is demand-relevant, cost-relevant, or both.

**Cournot vs. Bertrand Competition**

A second criticism often levied against research on competitive consequences of disclosure is that the results are highly sensitive to the distinction between Cournot and Bertrand competition. Intuitively, with Cournot competition, quantities are strategic substitutes, so if disclosure reveals good news and a concomitant aggressive posture to competitors, it gets them to back away. With Bertrand competition, prices are strategic complements, so if disclosure reveals a particular competitive posture, it only encourages
competitors to respond in kind. As a result, what before was a competitive upside (downside) of disclosure becomes a competitive downside (upside) under Bertrand. For this reason, while private-value \((r = 0)\) is typically associated with disclosure under Cournot, it is common-value information \((r = 1)\) associated with disclosure under Bertrand. This thinking then suggests that the result that a sufficiently low \(r\) favors disclosure would be reversed if retail competition were instead characterized by Bertrand competition.

Though the above thinking is true when retail competition is viewed in isolation, it turns out not to be the case when supply market and retail market effects are considered jointly. Relegating details to the appendix, the following proposition confirms that the basic tension underlying a preference for disclosure persists under Bertrand competition ("B" denotes the outcomes in the Bertrand game).

**PROPOSITION 4.** There exists a \(r^B(n, \gamma) < r^*(n, \gamma)\) such that under Bertrand competition, firm 0's optimal policy entails disclosure if and only if \(r < r^B(n, \gamma)\).

To get a feel for the result, recall that disclosure has both supply market and retail market consequences. With Bertrand, the retail effects are reversed in that higher \(r\) favors more disclosure. Consistent with this thinking, when \(w = c\) (so strategic supply is a non issue), disclosure is preferred in the Bertrand game if and only if \(r > \frac{\gamma[1 - \gamma + \gamma n]}{2 + 2\gamma[n - 1] + \gamma^2 n}\). Contrasting this result with that in Proposition 4 indicates that the presence of strategic supplier has a radical impact in the Bertrand game – disclosure is favored in the lower tail rather than upper tail of \(r\)-values. Thus, rather than derailing our base Cournot result, as it would if only retail markets were in play, the Bertrand analysis further reinforces it, a feature driven by supply side effects.

In terms of these supply-side effects, higher levels of \(r\) entail the supplier charging prices that more closely track firm 0's demand environment under disclosure. Consistent with Li and Zhang (2008) and Zhang (2002), the supply-side concerns are paramount
when the information is of common value \( (r = 1) \), and thus no disclosure is preferred in that case. Expanding that view beyond the common-value case, for small values of \( r \), the supply side cost of disclosure becomes a supply-side benefit since good news for the firm represents bad news for others. And, for this reason, supplier price may move opposite to firm 0’s demand under disclosure. As a result, despite the demand-side downside, disclosure is still preferred for a lower-tail of \( r \)-values. However, since under Cournot low \( r \) is a boon to disclosure for both retail and supply reasons whereas under Bertrand it is only helpful in the supply realm, the \( r \)-cutoff is more stringent under Bertrand \( (r^B(n, \gamma) < r^*(n, \gamma)) \).

Though the importance of low levels of intra-industry correlation is a critical determinant of disclosure in both the Bertrand and Cournot cases, this is not to say the comparative statics all remain. After all, when disclosure is preferred under Bertrand, this is despite a clear cost from a competitive perspective. For this reason, less differentiation (higher \( \gamma \) ) intensifies the downside of disclosure and reduces its desirability, i.e., \( r^B(n, \gamma) \) is decreasing in \( \gamma \). As market concentration decreases (higher \( n \)), two offsetting effects arise. On one hand, competition becomes more critical and thus disclosure becomes less attractive. On the other hand, the supplier's price is more reflective of competitors' demands and less reflective of the disclosing firm's and, thus, the supply market upside of disclosure becomes more pronounced. Due to these two-fold and opposite effects, \( r^B(n, \gamma) \) is non-monotonic in \( n \). In short, while the effects of market concentration and product differentiation on the efficacy of disclosure are sensitive to the nature of retail market concentration, the essential tension, captured by intra-industry correlation, is not.

4.4.2. SUPPLY MARKET VARIATION

The critical role played by the supply market in the analysis herein also necessitates we consider how variation in supply market assumptions may alter the conclusions.
Supply Market Price Discrimination

The maintained assumption thus far is that the supplier sets a single wholesale price that applies to all of its customers. This assumption is made to reflect the prevailing regulations in place (in particular, the Robinson-Patman act) which preclude third-degree price discrimination in input markets. Even in the absence of regulatory oversight, the assumption of a single (linear) price is perhaps most descriptive, since any firm receiving a more favorable price than any others would have an incentive to procure additional units at that price and then re-sell them to the others at a price slightly below what the supplier is charging them. A firm would be willing to do this since the discount would have minor effects on the firm in competition, but would introduce the potential for substantial profit via sales to rivals. The only way for the supplier to avoid such wholesale competition from its own customers, then, is to charge a uniform price (for more on this, see, e.g., Tirole 1994).

All that said, unfettered supplier price discrimination does have the potential to alter the results. In the context of cost estimation, Arya et al. (2016) demonstrate that uniform pricing regulation enhances incentives to gather and disseminate relevant information. The same forces in that context are likely to influence disclosure here as well. In particular, if firm 0 opts to disclose its information, the wholesale price reaction under uniform pricing reflected an averaging of all of the supplier's customers. If, instead, the supplier were able to charge different prices to different firms, this suggests another cost of disclosure. When the firm discloses good news for itself, the supplier price is not only more responsive to that information but the price increase is also isolated to that firm (that is, the wholesale price increase is not equally shared). For this reason, we now revisit the analysis under the presumption that the supplier is able to credibly charge different prices to each firm, i.e., it employs price discrimination.
In this case of price discrimination, without disclosure the equilibrium is precisely as in Proposition 1. After all, from an uninformed supplier's perspective the buyers are identical, so it is immaterial whether or not it is permitted to price discriminate. With disclosure, however, the outcome is impacted since the informed supplier charges more to the more profitable firm.

Relegating details to the appendix, the disclosure equilibrium with price discrimination entails \( \bar{w}_0 = \bar{w}^d_0(\delta) = c + \frac{a-c}{2} + \frac{\delta}{2} \) and \( \bar{w}_i = \bar{w}^d_i(\delta) = c + \frac{a-c}{2} + \frac{\delta r}{2} \) for \( i \in N \) (here, the "−" indicates price discrimination). Note that the wholesale prices are now tailored to the firms' demand environments: an increase in \( \delta \) affects firm 0 at a magnitude of 1/2, whereas it affects other firms at a magnitude of \( r/2 \). Intuitively, the previously derived uniform wholesale price, \( w^d(\delta) \), is a simple average of the wholesale price that would be charged to the firms separately, i.e., \( w^d(\delta) = \frac{1}{n+1} \sum_{i=0}^{n} \bar{w}^d_i(\delta) \). The question, then, is how such fine tuned prices alter the desirability of disclosure. Recall that the benefits and costs of disclosure arise in both the retail and supply realm. With price discrimination in play in the supply market, the supply market effect is unequivocally a cost of disclosure since firm 0's wholesale price is tailored directly to its disclosed information. Not only that, the retail market benefits are less pronounced, since targeted wholesale prices are set so as to boost competition (and undermine tacit cooperation): a retail firm with lower (higher) demand will receive more (less) favorable pricing so as to put competitors on a more level playing field.

Despite the additional downsides, disclosure can however still be preferred, and this preference is again driven by \( r \), as presented in Proposition 5.

**Proposition 5.** There exists a \( \overline{r}(n, \gamma) < r^*(n, \gamma) \) such that when the supplier can price discriminate, firm 0's optimal policy entails disclosure if and only if \( r < \overline{r}(n, \gamma) \).

The result in Proposition 5 confirms that the result in Arya et al. (2016) that uniform pricing can promote disclosure extends to the case of demand information (as
evidenced by $\bar{r}(n, \gamma) < r^*(n, \gamma)$). Importantly, the result also confirms that the essential forces of interest here persist even in the presence of input market price discrimination. As a final variation, we next consider how interdependency in the supply and retail markets can complicate the strategic effects of disclosure.

*The Supplier as a Competitor*

In the analysis thus far, we have examined how the joint presence of input markets and output markets influences disclosure. In doing so, we have considered markets that consist of independent parties. However, in many circumstances, there is more entanglement in markets, in that sellers in supply markets may also be competitors in retail markets. For example, manufacturers often rely on independent retailers to distribute their products but also compete with these retailers by setting up their own outlet stores or catalog sales. Perhaps more widespread is the joint use of independent retailers and direct-to-consumer online sales arms. In each case, the supplier actually serves as one of the retail competitors. And, research has found that such entanglements can notably alter the incentives of the firms (e.g., Arya and Mittendorf 2013). We now consider how such a circumstance can affect the desirability of disclosure, again relegating details to the appendix.

If the supplier serves as one of the retailers, it's arm has a clear advantage in retail competition since it internalizes marginal cost ($c$) not wholesale price ($w$) when making decisions. This alone puts the other retailers in a position of being less willing to procure inputs. Seeking to balance wholesale and retail profits, then, the supplier is forced to reduce its wholesale price to its customers so as to boost their purchases. This price reduction is evidenced in the wholesale price even absent disclosure, $\hat{w}^\phi$ (the "^\wedge" reflects the outcome when the supplier is one of the $n$ rivals):

$$\hat{w}^\phi = w^\phi - \left[\frac{a - c}{2} - \frac{(1 - \gamma)\gamma^2 n}{8 + 4\gamma(n - 1) - 3\gamma^2 n}\right].$$
The key question is how this new feature of balancing profits on multiple fronts is affected by disclosure. In particular, with disclosure, the supplier wants to tailor wholesale price to the demand environment (the previous consideration) and reduce wholesale price to boost demand (the new consideration). As before, the tailoring of wholesale price to the disclosing firm's demand environment stands to undercut the firm's desire to disclose. Recall, however, since it entails some averaging of demand environments, the wholesale price adjustment is both muted and shared among the rivals. However, when the supplier is one of the rivals, the extent to which the price adjustment is muted is reduced (the averaging is among \( n \), not \( n+1 \) firms), and the supplier is exempt from the shared adjustment (it internalizes \( c \) regardless). For this reason, the supplier not only exploits the disclosed information in the wholesale market, it also exploits the information in the retail market more than the other competitors.

As a result, while the key forces continue to remain, forward integration by a supplier in the retail realm means that disclosure is, all else equal, less desirable to firm 0.

PROPOSITION 6. There exists a \( \hat{r}(n,\gamma) < r^*(n,\gamma) \) such that when the supplier is also a retail rival, firm 0's optimal policy entails disclosure if and only if \( r < \hat{r}(n,\gamma) \).

Taken together, the results in this section suggest a remarkably robust underlying theme, a consistency rooted in the fact that disclosure has effects in multiple markets. The empirical implications of these results are discussed next.

4.4.3. EMPIRICAL IMPLICATIONS

As deftly synthesized in Beyer et al. (2010) and Berger (2011), the notion that firms may (or may not) be reluctant to disclosure information publicly due to proprietary considerations has been one that has been somewhat elusive to demonstrate empirically. Theoretical guidance too has been elusive since studies in this realm have provided varied (sometimes even contradictory) views as to how best to measure these proprietary
considerations. By examining proprietary effects of disclosure in the joint presence of vertical and horizontal relationships, this paper may provide some novel implications in this regard.

The primary measure of the proprietary cost of disclosure employed in empirical analyses is market concentration, be it an index approximated using the sample of publicly traded firms included in Compustat or a measure gleaned from Census data (Berger 2011). While questions remain about the ideal measures of concentration, our paper suggests a perhaps more disconcerting issue. Though lower concentration is typically viewed as being consistent with a pronounced proprietary cost of disclosure (competition is critical), our results suggest a confounding factor. Even if less concentration is indicative of more competitive concerns, it can actually favor disclosure when the strategic atmosphere consists of both supply and retail participants. This is evidenced by $r^*(n, \gamma)$ being increasing in $n$. That said, this conclusion is sensitive to the underlying nature of competition in the retail market. As seen in Section 4.4.1, under Bertrand competition, this comparative static does not persist. For these reasons, the degree of market concentration may not be the most effective means of capturing the effect/magnitude of competitive pressures affecting disclosure policy. Or, if one insists on using concentration as a measure, controlling for the nature of competition in a given industry is critical.

A second measure of proprietary costs of disclosure worth noting is product differentiation. Among other things, Karuna (2011) makes use of a product differentiation measure to demonstrate a nonmonotonic relation between competition and disclosure. Before one concludes this evidence is contradictory to the proprietary cost hypothesis (to his credit, Karuna (2011) is careful not to jump to such a conclusion), one should consider the underlying connection between product differentiation and competitive consequences of disclosure. As this paper demonstrates, joint consideration of supply and retail markets suggests an equivocal connection between the two. And it may be this feature, not the absence of strategic considerations, that gives rise to a nonmonotonic relationship measured
in the cross-section, particularly if the nature of competition varies across industries (after all, \( r^*(n, \gamma) \) is increasing in \( \gamma \) whereas \( r^B(n, \gamma) \) is decreasing in \( \gamma \)).

All this said, our goal is not to criticize existing empirical proxies for proprietary costs/benefits of disclosure. Instead, the point is to see what proxies may be most robust to model variation. The consistency of the results in Propositions 3, 4, 5, and 6 suggests information spillover (\( r \)) is a candidate. Roughly stated, the robust result herein is that in industries where uncertainty essentially entails an inter-firm demand transfer (good news for one is bad news for another), disclosure tends to be beneficial in toto. In industries where market conditions are such that "a rising tide lifts all boats" (good news for one is good news for all), however, disclosure tends to come with sizable proprietary costs. More precisely, the proposed new proxy for proprietary costs of disclosure, \( r \), captures the degree of intra-industry correlation in demand. This is not to say that empirical measures of this concept are nonexistent (see, e.g., Foster 1981; Han et al. 1989), just that they have not to our knowledge been put to work to measure the extent of proprietary costs of disclosure in empirical tests.

5. Conclusion

Academics and practitioners have long debated how strategic considerations may alter a firm's desire to publicly disclose pertinent financial information. Fear (or hope) that an outside party will use the information to a discloser's detriment (benefit) permeates most discussions about disclosure policies and practices. Despite the unanimity with which the importance of strategic interplay on disclosure choice is accepted, there is little consensus on the determinants of the net consequence of strategic effects. This paper revisits traditional models of strategic effects of disclosure by considering both horizontal (competitive) and vertical (supply) strategic participants. Besides integrating seemingly disparate literatures on supply and retail market consequences of disclosure, the paper also
provides some guidance to empirical studies seeking to identify when proprietary costs (or benefits) of disclosure are most likely to arise.

By honing in on the joint presence of strategic supply and retail markets in evaluating strategic effects of disclosure, this paper excludes other observers of disclosures. Further research could integrate other key information observers such as equity investors, debtholders, or even consumers to gain insight on how these parties' interactions can further alter disclosure practices. In addition, the present analysis demonstrates how the degree of retail competition can alter disclosure policy in the presence of external input supply. This approach entailed traditional models of monopoly supply. That said, moving beyond traditional modeling of monopoly supply to vary the degree of supply market competition and/or concentration may also provide new insights and thus represents another promising avenue for future research.
Appendix

Proof of Proposition 1. In the absence of disclosure, for a given wholesale price $w$, the problem for firm 0 and for firm $i$, $i \in N$, is presented in (A1) and (A2) respectively:

$$\text{Max}_{q_0} \left[ a + \delta - q_0 - \gamma \sum_{i \in N} q_i \right] - wq_0. \quad (A1)$$

$$\text{Max}_{q_i} E_\delta \left\{ [a + r \delta - q_i - \gamma q_0 - \gamma \sum_{j \in N \setminus i} q_j]q_i - wq_i \right\}, \ i \in N. \quad (A2)$$

Jointly solving the first-order conditions of (A1) and (A2) reveals the equilibrium quantities in (A3), where "$\phi$" denotes the no disclosure outcomes:

$$q_0^\phi (w; \delta) = \frac{a - w}{2 + \gamma n} + \frac{\delta}{2} \quad \text{and} \quad q_i^\phi (w) = \frac{a - w}{2 + \gamma n}, \ i \in N. \quad (A3)$$

Using (A3), the supplier's problem under no disclosure is:

$$\text{Max}_{w} E_\delta \left\{ [w - c][q_0^\phi (w; \delta) + \sum_{i \in N} q_i^\phi (w)] \right\}. \quad (A4)$$

The first-order condition of (A4) reveals $w = w^\phi$. From (A3), $q_0^\phi (w^\phi; \delta) = q_0^\phi (\delta)$ and $q_i^\phi (w^\phi) = q_i^\phi$. A sufficiently large $a$ ensures that the wholesale price and retail quantities are each nonnegative. This completes the proof of Proposition 1. ■

Proof of Proposition 2. Under disclosure, (A2) is replaced by (A5):

$$\text{Max}_{q_i} \left[ a + r \delta - q_i - \gamma q_0 - \gamma \sum_{j \in N \setminus i} q_j \right]q_i - wq_i, \ i \in N. \quad (A5)$$

Jointly solving the first-order conditions of (A1) and (A5) reveals the equilibrium quantities in (A6), where "$d$" denotes the disclosure outcomes:

$$q_0^d (w; \delta) = \frac{a - w}{2 + \gamma n} + \frac{\delta[2 + \gamma (n(1 - r) - 1)]}{[2 - \gamma][2 + \gamma n]} \quad \text{and}$$

$$q_i^d (w; \delta) = \frac{a - w}{2 + \gamma n} + \frac{\delta[2r - \gamma]}{[2 - \gamma][2 + \gamma n]}, \ i \in N. \quad (A6)$$

Using (A6), the supplier's problem under disclosure is:

$$\text{Max}_{w} [w - c][q_0^d (w; \delta) + \sum_{i \in N} q_i^d (w)]. \quad (A7)$$
The first-order condition of (A7) reveals \( w = w^d(\delta) \). From (A6), \( q_0^d(w^d(\delta); \delta) = q_0^d(\delta) \) and \( q_i^d(w^d(\delta); \delta) = q_i^d(\delta) \). A sufficiently large \( a \) again ensures that the wholesale price and retail quantities are each nonnegative. This completes the proof of Proposition 2.

**Proof of Proposition 3.** Using the solution from Proposition 1 (Proposition 2) in (A1) yields firm 0's profit under no disclosure (disclosure). Taking expectation with respect to \( \delta \), and noting \( E_\delta{\{\delta}\} = 0 \) and \( E_\delta{\{\delta^2}\} = \sigma^2 \), yields expected profit for firm 0 under each disclosure regime:

\[
\begin{align*}
\Pi_0^\phi &= \left( \frac{a - c}{2[2 + \gamma n]} \right)^2 + \frac{\sigma^2}{4} \\
\Pi_0^d &= \left( \frac{a - c}{2[2 + \gamma n]} \right)^2 + \sigma^2 \left( \frac{[2 + 2n(2 - r) - \gamma(1 - 2n^2(1 - r) + rn)]}{2[2 + \gamma n][2 - \gamma][1 + n]} \right)^2.
\end{align*}
\]  

(A8)

From (A8), the sign of \( \Pi_0^d - \Pi_0^\phi \) is the same as that of the term \( T(r) \) given below:

\[ T(r) = \frac{2 + 2n[2 - r] - \gamma[1 - 2n^2(1 - r) + rn]}{2[2 + \gamma n][2 - \gamma][1 + n]} - 1. \]  

(A9)

From (A9), \( dT(r) / dr < 0 \), \( T(-1) > 0 \), and \( T(1) < 0 \). Hence, there exists a unique \( r \)-value in (-1,1) that solves \( T(r) = 0 \). This value is \( r^*(n, \gamma) = \frac{\gamma^2 n[n + 1] + \gamma - 2}{n[2\gamma n + \gamma + 2]} \), and disclosure is preferred if and only if \( r < r^*(n, \gamma) \). This completes the proof of Proposition 3.

**Proof of Corollary 1.**

(i) Substituting \( r = -1 \) in (A9) yields:

\[ T(-1) = \frac{\gamma^2 n[n + 1] + \gamma[2n^2 + n + 1] + 2[n - 1]}{2 + \gamma n[2 - \gamma][1 + n]}. \]

From the above, \( T(-1) > 0 \), so \( \Pi_0^d - \Pi_0^\phi > 0 \).

(ii) Substituting \( r = 0 \) in (A9) yields:

\[ T(0) = \frac{\gamma^2 n[1 + n] + \gamma - 2}{2 + \gamma n[2 - \gamma][1 + n]}. \]
Disclosure is preferred if an only if $T(0) > 0$. From above, this implies 

$$n > \left[ \sqrt{8 - 4\gamma + \gamma^2} - \gamma \right] / [2\gamma].$$

(iii) Substituting $r = 1$ in (A9) yields:

$$T(1) = -\frac{1 + \gamma n}{2 + \gamma n}.$$ 

From the above, $T(1) < 0$, so $\Pi_0^d - \Pi_0^\phi < 0$. This complete the proof of Corollary 1.

**Proof of Corollary 2.**

(i) Taking the derivative of $r^*(n, \gamma)$ in Proposition 3 with respect to $n$ yields the result in part (i):

$$\frac{\partial r^*(n, \gamma)}{\partial n} = \frac{[2 - \gamma][\gamma n(\gamma n + 4) + \gamma + 2]}{n^2[2\gamma n + \gamma + 2]^2} > 0.$$ 

(ii) The limit of $r^*(n, \gamma)$ in Proposition 3 as $n \to \infty$ equals $\gamma / 2$, the result in part (ii).

This complete the proof of Corollary 2.

**Proof of Corollary 3.** The proof follows immediately by taking the derivative of $r^*(n, \gamma)$ with respect to $\gamma$ as noted below:

$$\frac{\partial r^*(n, \gamma)}{\partial \gamma} = \frac{[n + 1][\gamma^2 n(2n + 1) + 4(\gamma n + 1)]}{n[2\gamma n + \gamma + 2]^2} > 0.$$ 

This complete the proof of Corollary 3.

**Proof of Proposition 4.**

The equilibrium outcomes are derived using the same backward induction process as in the base setting except for the fact that the strategic variable for the firms are retail prices (not quantities) in the Bertrand game. Rather than detail the induction process, we merely summarize the resulting equilibrium (denoted by "$B")).

**Under no disclosure:**

(a) $w^B = w^{B\phi} = c + [a - c] / 2$;
\[\begin{align*}
\text{(b) } p_0^B &= p_0^{B\phi}(\delta) = \frac{a[1-\gamma]}{2 + \gamma[n-2]} + \frac{[a + c][1 + \gamma(n-1)]}{2[2 + \gamma(n-2)]} + \frac{\delta[1-\gamma + \gamma n(1-r)]}{2[1 + \gamma(n-1)]}, \\
\text{(c) } p_i^B &= p_i^{B\phi} = \frac{a[1-\gamma]}{2 + \gamma[n-2]} + \frac{[a + c][1 + \gamma(n-1)]}{2[2 + \gamma(n-2)]} \text{ for } i \in N.
\end{align*}\]

Under disclosure:

\[\begin{align*}
\text{(a) } w^B &= w^{Bd} = c + \frac{a-c}{2} + \frac{\delta[1+rn]}{2[1+n]}; \\
\text{(b) } p_0^B &= p_0^{Bd}(\delta) = \frac{a[1-\gamma]}{2 + \gamma[n-2]} + \frac{[a + c][1 + \gamma(n-1)]}{2[2 + \gamma(n-2)]} + \\
&\quad \frac{\delta[\gamma^2(3 + 2n^3 + n(3r-7) - n^2(2 + 3r)) + \gamma(-9 + n(4 - 5r) + 2n^2(3 + r)) + 6 + 2n(2 + r)]}{2[1+n][2 + \gamma(n-2)][2 + \gamma(2n-1)]} \\
\text{(b) } p_i^B &= p_i^{Bd}(\delta) = \frac{a[1-\gamma]}{2 + \gamma[n-2]} + \frac{[a + c][1 + \gamma(n-1)]}{2[2 + \gamma(n-2)]} + \\
&\quad \frac{\delta[\gamma^2(3 + rn^2(2n-5) - n(3 + r)) + \gamma(-5 + n(2 - 3r) + 4r(2n^2-1)) + 2 + 2r(2 + 3n)]}{2[1+n][2 + \gamma(n-2)][2 + \gamma(2n-1)]}.
\end{align*}\]

Using the above solutions, firm 0’s expected profit under no disclosure and disclosure equal:

\[\begin{align*}
\Pi_0^{B\phi} &= \frac{(a-c)^2[1-\gamma][1 + \gamma(n-1)]}{4[2 + \gamma(n-2)]^2[1 + \gamma n]} + \frac{\sigma^2[1-\gamma + \gamma n(1-r)]^2}{4[1-\gamma][1 + \gamma(n-1)][1 + \gamma n]} \quad \text{and} \\
\Pi_0^{Bd} &= \frac{(a-c)^2[1-\gamma][1 + \gamma(n-1)]}{4[2 + \gamma(n-2)]^2[1 + \gamma n]} + \\
&\quad \frac{\sigma^2[1 + \gamma(n-1)]Z}{4[1-\gamma][2 + \gamma(n-2)]^2[1 + n]^2[1 + \gamma n][2 + \gamma(2n-1)]^2}, \text{ where} \\
Z &= [-2 + \gamma^2(-1 + n(2 - r) + 2n^2(2 - r) - 2n^3(1 - r)) - 2n(2 - r) + \gamma(3 + n(2 - r) - n^2(6 - 4r))]^2.
\end{align*}\]

Solving \(\Pi_0^{Bd} - \Pi_0^{B\phi} = 0\) yields either (a) a unique \(r\)-root in \((-1,1)\) or (b) no root in \((-1,1)\). In the former case, \(r^B(n,\gamma)\) is the unique interior root, denoted \(A\); in the latter case, \(\Pi_0^{Bd} - \Pi_0^{B\phi} < 0\). This defines \(r^B(n,\gamma)\) as noted below, with disclosure optimal if and only if \(r < r^B(n,\gamma)\).
\[ r^B(n, \gamma) = A, \text{ if } -1 < A \leq 1, \]
\[ = -1, \text{ otherwise,} \]

where
\[ A = \frac{\gamma^3[-1 + 2n - 2n^2 + n^3] + \gamma^2[4 - 6n + 3n^2] + \gamma[-5 + 4n] + 2}{n(\gamma^3[1 - 4n + n^2] + \gamma^2[-6 + 7n] + \gamma[7 - 2n] - 2)}. \]

Clearly, \( r^B(n, \gamma) < r^*(n, \gamma) \) when \( r^B(n, \gamma) = -1 \) since \( r^*(n, \gamma) > -1 \). When \( r^B(n, \gamma) = A \), so \(-1 < A \leq 1\), tedious calculations verify that \( r^B(n, \gamma) < r^*(n, \gamma) \). This completes the proof of Proposition 4. \[\blacksquare\]

**Proof of Proposition 5.** In the absence of disclosure, the equilibrium is as in Proposition 1 – from the uninformed supplier's perspective the buyers are identical, so it is immaterial whether or not it is permitted to price discriminate. With disclosure, the same backward induction process as in section 3.2 applies except that the supplier is permitted to set different prices for each buyer. Rather than repeat this exercise, we merely summarize the disclosure equilibrium (with "−" denoting the outcomes under price discrimination):

\(\begin{align*}
(a) & \quad \bar{w}_0 = \bar{w}_0^d(\delta) = c + \frac{a - c}{2} + \frac{\delta}{2}; \quad \bar{w}_i = \bar{w}_i^d(\delta) = c + \frac{a - c}{2} + \frac{r\delta}{2} \quad \text{for } i \in N; \\
(b) & \quad \bar{q}_0 = \bar{q}_0^d(\delta) = \frac{a - c}{2[2 + \gamma n]} + \frac{\delta[2 + \gamma(n(1-r) - 1)]}{2[2 + \gamma n][2 - \gamma]}; \quad \text{and} \\
(c) & \quad \bar{q}_i = \bar{q}_i^d(\delta) = \bar{q}_0^d(\delta) - \frac{\delta[1-r]}{2[2 - \gamma]} \quad \text{for } i \in N.
\end{align*}\)

Under the above solutions with price discrimination, firm 0's expected profit under no disclosure and disclosure equals:

\[
\Pi^\phi_0 = \left(\frac{a - c}{2[2 + \gamma n]}\right)^2 + \frac{\sigma^2}{4} \quad \text{and} \quad \Pi^d_0 = \left(\frac{a - c}{2[2 + \gamma n]}\right)^2 + \sigma^2\left(\frac{2 + \gamma(n(1-r) - 1)}{2[2 + \gamma n][2 - \gamma]}\right)^2. \quad (A10)
\]

From (A10), the sign of \( \Pi^d_0 - \Pi^\phi_0 \) is the same as that of \( T(r) \) given below:

\[
T(r) = \frac{2 - \gamma + \gamma n[1-r]}{[2 + \gamma n][2 - \gamma]} - 1. \quad (A11)
\]
From (A11), \( d\bar{T}(r)/dr < 0 \) and \( T(1) < 0 \). Also, \( \bar{T}(-1) > 0 \) if and only if \( n > [2 - \gamma]/\gamma^2 \). Thus, for such \( n \)-values, there exists a unique \( r \)-value in \((-1,1)\) that solves \( \bar{T}(r) = 0 \). For \( n \leq [2 - \gamma]/\gamma^2 \), \( \bar{T}(r) < 0 \), i.e., no disclosure is the optimal policy. This defines \( \bar{r}(n,\gamma) \) as noted below, with disclosure optimal if and only if \( r < \bar{r}(n,\gamma) \).

\[
\bar{r}(n,\gamma) = B, \text{ if } -1 < B \leq 1,
\]

\[
= -1, \text{ otherwise},
\]

where \( B = \frac{-2 - \gamma + \gamma n[1 - \gamma]}{\gamma n} \).

Clearly, \( \bar{r}(n,\gamma) < r^*(n,\gamma) \) when \( \bar{r}(n,\gamma) = -1 \) since \( r^*(n,\gamma) > -1 \). When \( \bar{r}(n,\gamma) = B \), the difference in the two \( r \)-cutoffs is as follows:

\[
\bar{r}(n,\gamma) - r^*(n,\gamma) = \frac{[2 - \gamma][\gamma^2 n^2 + 3\gamma n + 2]}{\gamma n[2\gamma n + \gamma + 2]} < 0.
\]

This completes the proof of Proposition 5.

**Proof of Proposition 6.**

The equilibrium outcomes are derived using the same backward induction process as in the base setting except for the fact that firm \( n \) sets an input price for all buyers while itself acquiring inputs at cost. Rather than detail the induction process, we merely summarize the resulting equilibrium (denoted by "^\#").

**Under no disclosure:**

(a) \( \hat{w} = \hat{w}^\phi = c + \left[ \frac{a - c}{2} \right] \left[ 1 - \frac{(1 - \gamma)\gamma^2 n}{8 + 4\gamma(n-1) - 3\gamma^2 n} \right] \); 

(b) \( \hat{q}_0 = \hat{q}_0^\phi(\delta) = \frac{2[a - c][1 - \gamma]}{8 + 4\gamma[n-1] - 3\gamma^2 n} + \frac{\delta}{2} \); 

(c) \( \hat{q}_n = \hat{q}_n^\phi = \frac{[a - c][2 - \gamma][4 + \gamma n]}{2[8 + 4\gamma(n-1) - 3\gamma^2 n]} \); and

\( \hat{q}_i = \hat{q}_i^\phi = \frac{2[a - c][1 - \gamma]}{8 + 4\gamma[n-1] - 3\gamma^2 n} \) for \( i \in N - n \).

**Under disclosure:**
\[ \hat{w} = \hat{\omega}^d(\delta) = c + \frac{[a - c][2 - \gamma][4 + (2 - \gamma)\gamma n]}{2[8 + 4\gamma(n - 1) - 3\gamma^2 n]} + \frac{\delta[4(2 - \gamma + (1 - \gamma)\gamma n) + r(8(n - 1) + \gamma((2 - \gamma)n - 2))]}{2n[8 + 4\gamma(n - 1) - 3\gamma^2 n]} \]

(b) \[ \hat{q}_0 = \hat{q}_0^d(\delta) = \frac{a - c}{2 + \gamma n} - \frac{2[\hat{\omega}^d(\delta) - c]}{2 - \gamma}[2 + \gamma n] + \frac{\delta[2 + \gamma(n(1 - r) - 1)]}{[2 - \gamma][2 + \gamma n]} \]

(c) \[ \hat{q}_n = \hat{q}_n^d(\delta) = \frac{a - c}{2 + \gamma n} + \frac{\gamma n[\hat{\omega}^d(\delta) - c]}{2 - \gamma}[2 + \gamma n] + \frac{\delta[2r - \gamma]}{[2 - \gamma][2 + \gamma n]} \] and
\[ \hat{q}_i = \hat{q}_i^d(\delta) = \frac{a - c}{2 + \gamma n} - \frac{2[\hat{\omega}^d(\delta) - c]}{2 - \gamma}[2 + \gamma n] + \frac{\delta[2r - \gamma]}{[2 - \gamma][2 + \gamma n]} \] for \( i \in N_n \).

Using the above solutions, firm 0's expected profit under no disclosure and disclosure equal:

\[ \hat{\Pi}_0^\phi = \left( \frac{2[a - c][1 - \gamma]}{8 + 4\gamma(n - 1) - 3\gamma^2 n} \right)^2 + \frac{\sigma^2}{4} \quad \text{and} \quad \hat{\Pi}_0^d = \left( \frac{2[a - c][1 - \gamma]}{8 + 4\gamma(n - 1) - 3\gamma^2 n} \right)^2 + \frac{\sigma^2}{4} \left( \frac{4[2n - 1] + \gamma^2 n[3 - 3n(1 - r) + r]}{2 - \gamma} \right)^2 - \frac{4[2n - 1] + \gamma^2 n[3 - 3n(1 - r) - r - 4r(n - 1) - 2\gamma n(4 - 2n(1 - r) - r - 1 + r)]}{2 - \gamma} \right)^2. \]

Solving \( \hat{\Pi}_0^d - \hat{\Pi}_0^\phi = 0 \) yields either (a) a unique \( r \)-root in \((-1, 1)\) or (b) no root in \((-1, 1)\). In the former case, \( \hat{r}(n, \gamma) \) is the unique interior root, denoted \( C \); in the latter case, \( \hat{\Pi}_0^d - \hat{\Pi}_0^\phi < 0 \). This defines \( \hat{r}(n, \gamma) \), with disclosure optimal if and only if \( r < \hat{r}(n, \gamma) \).

\[ \hat{r}(n, \gamma) = C, \quad \text{if} \quad -1 < C \leq 1, \quad -1, \quad \text{otherwise}, \]

where \( C = \frac{\gamma^2 n[3\gamma n - 2(1 + 2n)] + 4[2 - \gamma]}{2\gamma^2 n[3n - 1] - \gamma[4 - 4n + 8n^2] - 8[n - 1]} \).

Clearly, \( \hat{r}(n, \gamma) < r^*(n, \gamma) \) when \( \hat{r}(n, \gamma) = -1 \) since \( r^*(n, \gamma) > -1 \). When \( \hat{r}(n, \gamma) = C \), it is easy to verify that \( \hat{r}(n, \gamma) < r^*(n, \gamma) \). This completes the proof of Proposition 6.


