Information Disclosure Policy and Its Implications: Ratcheting in Supply Chains

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Abstract

This paper studies implications of the ratchet effect arising in supply chain relationships. The ratchet effect occurs when a retailer feels compelled to modify his investments to hide positive prospects to restrain future wholesale price hikes. In a two-period supply chain interactions, we demonstrate that such an endogenous ratchet effect can have multi-faceted reverberations. We consider two regimes – mandatory information disclosure and no information disclosure. Under no information disclosure, we demonstrate that the conventional wisdom about ratcheting is incomplete in that it fails to consider the supplier’s endogenous response. Under no information disclosure, the manufacturer can use deep discounts of initial wholesale prices to convince the retailer to focus on its short-run profits rather than long-run pricing concerns. These deep discounts not only encourage mutually beneficial investments but also alleviate double-marginalization inefficiencies along the supply chain. We compare those results to the mandatory information disclosure case. We show that such mandatory disclosure can reduce the total channel efficiency compared to the case without information disclosure, where the manufacturer can strategically mitigate the ratcheting problem. Thus, our model presents not only a scenario where ratcheting concerns are endogenous but also one where such ratcheting concerns result in socially beneficial responses.

Key Words: ratcheting, information disclosure, supply chain, and pricing

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Introduction

Supply chains exhibit a curious mixture of collaboration and self-interest. This mixture gives rise to firms working toward a common goal while simultaneously taking actions to shield themselves from one another’s exploitation, and information issues invariably play a key role. A commonly discussed example is the automobile industry in which dealers demonstrate a reluctance to share detailed demand projections with manufacturers, fearing that it would be used to squeeze margins rather than to coordinate behavior. These themes repeat across many industries, including appliances, clothing, electronics, and medicine (Narayanan and Raman 2004). The fundamental concern that can dissuade transparency is that manufacturers cannot resist the temptation to use favorable profitability news to squeeze retailer margins in hopes of extracting their “fair share” by raising input prices, knowing that their buyers’ willingness to pay is higher. Theoretical work has also examined these information sharing issues in depth, and it is now well recognized that concerns about self-interested manufacturer reactions may keep retailers from fully sharing information at their disposal (e.g., Li 2002; He et al. 2008; Guo and Iyer 2010).

While a primary emphasis in this realm is a retailer’s voluntary private disclosure choice, a notable practical consideration is that aggregate profitability information is often publicly known and thus manufacturers may infer information from retailer profits even if that information is not intentionally and privately conveyed. As a result, the retailer may take actions out of fear of a “ratchet effect” – in order to reduce opportunistic response from the manufacturer, the retailer may take real actions to conceal future prospects conveyed by high accounting profits. This too is much more than a theoretical possibility: broad based empirical evidence has demonstrated that positive earnings news of retailers is viewed as a sign their manufacturers will extract future profits from the relationship (e.g., Pandit et al. 2011).

In this research, we present a simple model to examine manufacturer opportunistic behavior and retailers’ incentives to take actions that limit manufacturers’ inferences from revealed performance (the “ratchet effect”). In particular, we demonstrate the implications of different
information disclosure policies on firms’ and consumers’ welfare using a stylized model with a two-period interaction between a privately informed retailer and its manufacturer. The retailer’s private information is indicative of both underlying profitability and the associated efficacy of additional investment by the retailer (for example, various sales promotions and in-store demonstrations, etc.). After one period of interaction, the retailer’s overall profit information is revealed and the manufacturer modifies its prevailing input price based on that public information. Opportunistic behavior by the manufacturer is evident—very high earnings reveal strong product demand to the manufacturer who, in turn, finds it optimal to raise its wholesale price as a means of extracting a portion of the boosted demand.

We demonstrate that the retailer, cognizant of the risk of this ratchet effect, may seek to sidestep otherwise profitable investments. In effect, limiting investments mutes initial successes and thereby serves a “signal-jamming” role.\(^1\) This notion that a firm may adjust its investment behavior to alter others’ inferences is more than a theoretical possibility; in practical terms, it is consistent with the broader view that firms often engage in “real” earnings management to influence perceptions and that this is an important consideration when accounting regulations expand information available to outsiders to include underlying details. For example, the Statement of Financial Accounting Standards No. 131 (a set of regulatory reporting requirements) mandates public disclosure of firms’ segment profitability, and the disclosure naturally reveals a retailer’s market information to a manufacturer.\(^2\) The benefits and costs of these mandatory reporting requirements are controversial. In particular, the real costs of mandatory reporting have recently received attention from both researchers and practitioners (Leuz and Wysocki 2016, Goldstein and Yang 2017). One of the real costs is that investors’ efforts to acquire information is demotivated, and therefore a firm’s investment decision becomes inefficient (Jayaraman and Wu 2019). Moreover, many firms who objected to expanded requirements to publicly disclose segment profitability cited concerns that outside parties would use the infor-

\(^1\) Here, we focus on a particular response to the ratchet effect, which is manifested as jamming the market demand information through forgoing a profitable investment opportunity. That is “signal-jamming.”

\(^2\) There are other important financial reporting requirements that stipulate the mandatory disclosure of components of a firm’s private information such as Statement of Financial Accounting Standards No. 47 and Statement of Financial Accounting Standards No. 144.
nation opportunistically—that disclosing parties would not sit idly by but rather change their way of business to avoid such consequences (Street et al. 2000, Ettredge et al. 2002, Botosan et al. 2008, Arya et al. 2010).

The conventional view of such signal-jamming efforts is that they come with harmful real effects, as this response to the threat of ratcheting can collectively undercut supply chain efficiency. Our setting is consistent with this view in that the retailer’s incentive to bypass investment undermines supply chain profitability, all else being equal. However, we also demonstrate that all else is not equal. To elaborate, we show that a manufacturer may opt to dissuade signal-jamming underinvestment by lowering its initial wholesale price, in effect creating a retailer tradeoff between current profitability (via boosted investments) and future profitability (via ensuing boosts in wholesale prices). The end result is that the retailer’s concern about manufacturer opportunistic behavior may actually lead to lower wholesale prices than would arise otherwise. Further, it is not just the existence of ratcheting in equilibrium but also the mere threat of ratcheting which proves critical in determining how inferences from profit disclosures affect supply chain behaviors.

In light of this feature, we examine a common regulatory proposal to address ratcheting: mandatory disclosure of the underlying demand information rather than just the accounting profit. We explicitly compare the total channel efficiency both with and without mandatory disclosures. One may expect that mandatory disclosure enhances supply chain efficiency by reducing the retailer’s incentive to signal jam, but our results demonstrate that mandatory disclosure can ultimately lead to lower channel efficiency compared to the case of no disclosure. Rather than forcing a retailer to disclose the information, permitting a retailer to withhold it, and making him disclose only overall profit, may increase the supply chain efficiency because a manufacturer provides a wholesale price discount to elicit the retailer’s true underlying market information. This reduces double-marginalization, and thereby, the total supply chain efficiency is enhanced. Perhaps more surprisingly, we even find that no disclosure can improve the total channel efficiency above and beyond the level that complete pre-commitment to wholesale pricing can achieve. The retailer’s temptation to reduce investment gives it a strategic weapon
in its interaction with the manufacturer without commitment power, and this weapon, in turn, convinces the manufacturer to cut its chosen wholesale price as a means of disarming the retailer. The lower wholesale price, in turn, reduces double-marginalization and, thereby, increases the total supply chain efficiency and achieves the Pareto efficiency gain.

To this end, our model not only presents a scenario where ratcheting concerns are endogenous, but also one where it can be socially optimal to permit firms to withhold forward-looking information and only disclose realized profits. Though accounting reports based on GAAP (Generally Accepted Accounting Principles) are often criticized for providing only aggregate and backward-looking information when decision-makers may find forward-looking forecasts more relevant, our results suggest this may be a feature and not a bug of the current regime.

**Literature Review**

This paper lies at the intersection of research examining information sharing in supply chains and research examining incentives to alter behavior so as to limit third-party inference and ratcheting behavior in other contexts. On the first front, many papers mainly focus on the effect of information sharing on supply chain efficiency (Cachon and Fisher 2000, and Lee et al. 2000). Such shared information can help the manufacturer achieve operational efficiency through improved inventory management (Cachon and Fisher 2000) or order logistics in procurement (Lee et al. 2000). Despite these potential benefits from information sharing, the existing literature also points out that strategic retailer behavior may prevent it from fully sharing its proprietary information with other channel members (Li 2002, He et al. 2008, Guo 2009, Guo and Iyer 2010, Mittendorf et al. 2013). Sharing forward-looking demand information, for example, may put a retailer at a disadvantage by allowing the manufacturer to tailor its wholesale price to squeeze retail margins by adjusting to the particulars of the market demand situation (Narayanan and Raman 2004, Arya and Mittendorf 2013).

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3While the emphasis in these papers is on retailer information sharing, others have examined circumstances wherein manufacturers hold private information (Gal-Or et al. 2008, Guo and Iyer 2010, Jiang 2016).
The divergent preference for information sharing between the manufacturer and the retailer is not unique to ratcheting. Jiang et al. (2016) examine a setting where a manufacturer owns better information about market demand than does a retailer: a manufacturer decides whether to share information with a retailer by considering the impact of the information on the retailer’s pricing in the final market. The authors find that, when the manufacturer and the retailer are risk neutral, the retailer prefers no information sharing while the manufacturer prefers information sharing. The key difference between their work and our paper is that in our setting, a retailer possesses better information than does a manufacturer. Also, this paper focuses on a dynamic game showing a manufacturer’s opportunistic choices of wholesale prices over time and a retailer’s signal-jamming activity, while Jiang et al. (2016) consider a single period. Finally, we show that the manufacturer’s dynamic pricing induces a retailer to reveal truthful information by mitigating the double marginalization problem.

Recently, researchers have examined how such information sharing incentives can be distorted in various market conditions such as in the presence of horizontal competition (Li 2002), uncertainty of information acquisition (Guo 2009), supplier information acquisition (Guo and Iyer 2010), or demand-enhancing investment from the manufacturer (Mittendorf et al. 2013). In various scenarios, all of these papers have focused on the issue of information induced distortions in supply chains. Similar incentives are at play in our work except that the information revelation does not arise through direct disclosure but rather through manufacturer inference from (observable) profit reports. Not having the flexibility to withhold such information from the manufacturer, the retailer is instead forced to alter its behavior so as to affect the manufacturer’s learning or inferences about market information. It is this effect that provides a connection to the wider literature on signal-jamming.

Starting with Holmstrom (1982), Fudenberg and Tirole (1986), and Stein (1989), research on “signal-jamming” has demonstrated the incentives of individuals and firms to take actions with the sole intent of influencing the inferences others make from observed outcomes.4 Such

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4For marketing context such as advertising, several papers study the issue of signal-jamming (Shapiro 2006, Shin 2005, Grunewald and Kräkel 2017).
signaling effects have been shown in supply chains, in the context of conveying information to suppliers through observed inventory levels (Zhang et al. 2010). In an empirical setting closely related to our study, Raman and Shahrur (2008) find that customers and suppliers manage earnings to influence the other party’s inference about their financial status and thereby to induce more relation-specific investments in supply chains. Based on the results, they suggest another venue for future research in which customers and suppliers may manipulate even real activities, as shown in Roychowdhury (2006), to motivate more investments. Consistent with these notions permeating extant literature, our paper shows that a retailer can manipulate a real activity (investment decision) to affect a manufacturer’s inference about market demand to obtain a favorable subsequent wholesale price. That is, in this paper, we demonstrate that profit disclosures can also have an information-signaling role when supply chain firms engage in dynamic relationships and that this signaling role can alter retailer investment for demand-enhancing activities such as promotion, in-store demonstrations, and advertising.

In particular, the retailer’s signal-jamming activity in our setting is rooted in a manufacturer’s opportunistic behaviors which result in a higher wholesale price in the next period. In this sense, our model is also closely aligned with research examining concerns of ratcheting that can arise in collaborative interactions, be they supply chains, joint ventures, or employment relationships (e.g., Weitzman 1980, Freixas et al. 1985, Bouwens and Kroos 2011, Misra and Nair 2011). Strategic behaviors based on the revealed information normally aim to extract higher rent from the other party but they often cause unintended strategic responses in the dynamic relationship.\footnote{Even in the firm-customer relationship, firms can use the revealed information from the customer’s past purchase for price discrimination (Villas-Boas 2004, Shin and Sudhir 2010).} For example, if agents anticipate that high performance in the current period will increase both the principal’s expectation and future target, they have less incentive to exert high effort in the current period (Weitzman 1980). This strategic response to the “ratchet effect,” by which an agent modifies his/her actions in the current period to alter incentives of other agents in future periods, is well established in several areas of marketing and economics, such as workforce management (Weitzman 1980, Misra and Nair 2011, Bouwens

As in the previous literature, the present study also examines the ratcheting issue but with a different implication. The setting in this paper focuses on the ratcheting behavior in a supply chain, and it shows that the ratcheting problem can actually prove helpful in strained supply chain relationships. Ratcheting helps enhance supply chain efficiency by compelling a manufacturer to take actions to elicit market information from a retailer worried about the other party’s opportunistic behaviors—in this case, the tool at the manufacturer’s disposal, an initial wholesale price discount, is one that alleviates supply chain frictions. Importantly, we demonstrate that in the context of supply chain ratcheting, manufacturers themselves can take action to preempt a retailer’s defenses against opportunistic behaviors. We also show that such manufacturer responses to the threat of ratcheting can actually lead to signal-jamming concerns being the productive force to improve the efficiency of the supply chain, rather than being a detriment to it, as conventional wisdom suggests.

Model Setup

We consider a two-period model between a manufacturer (she) and a retailer (he) in a supply chain. The market demand in period $t$ is captured by the following linear demand function, which is in line with previous research (Arya et al. 2007, Guo 2009, Li 2002, Mittendorf et al. 2013, and Li et al. 2014)\(^6\)

$$D_t = a + e_t \cdot \theta - p_t$$

\[= q_t - p_t,\]  

\(^6\)One can consider alternative specifications such as $D_t = a + \theta + \lambda e_t \cdot \theta - p_t$, where $\theta$ not only interacts with the retailer effort, but also affects demand directly. Even in this nonlinear demand specification, the primary premise of the setting remains as long as the manufacturer cannot infer the market condition ($\theta$) perfectly due to the unobservability of the retailer’s efforts. Our main results do not depend on a particular demand specification, but the key is the endogenous market demand and the unobservability of the retailer’s effort.
where $a > 0$ is a basic market demand, $p_t$ is the (observable) chosen retail price in period $t$, $q_t = a + e_t \cdot \theta$ is the “realized” market size, and $e_t \in \{0,1\}$ is the retailer’s marketing effort that can enhance the market demand such as promotions, in-store service, or advertising (e.g., Xia and Gilbert 2007, Mittendorf et al. 2013). Therefore, the total demand is endogenous and determined by the retailer’s demand-enhancing effort, which itself is unobservable to the manufacturer. This reflects the practical reality that retail prices are observable and accounting reports reveal overall profitability information such as sales and revenues ($D_t$), but it is hard to observe the counterfactual of potential demand and/or the retailer’s underlying marketing efforts such as luring customers to the stores with various sales efforts that buttressed those overall results. That is, the model reflects current generally accepted accounting principles (GAAP) that entail disclosure of top-line financial performance (e.g., profits and revenue) but not disaggregated forward-looking information which makes up these performance figures (e.g., investment efforts, or forecasts in particular markets).

The market potential $\theta$ is either high or low, $\theta = \{\theta_L, \theta_H\}$, where $\theta_H = d > \theta_L = 0$ without loss of generality. The size of $d$, $d \in [0,a]$, is known to both the retailer and manufacturer. We assume that only the retailer learns the true state of market potential $\theta$ (i.e., whether it is a high potential or low potential market) because of his proximity to the final consumers and his operational experience in that market. For simplicity, we presume the market potential possibilities are equally likely ex ante, i.e., $\Pr(\theta = \theta_H) = \Pr(\theta = \theta_L) = \frac{1}{2}$. After the manufacturer observes the realized retailer profitability (i.e., demand, $D_1$) in period one, she updates her belief about the market potential in period two. Here, the manufacturer’s posterior belief is denoted by $\tilde{\mu}(D_1)$.

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7For “$e_t$”, we use the expressions “effort” and “investment” interchangeably.

8The current $\theta_L = 0$ assumption helps us to understand the main forces behind the results and intuition with the least complexity. Nevertheless, we can show that our main results still hold when $\theta_L > 0$ which imposes significant computational burden without adding new insight.

9One can consider another scenario when the manufacturer has the market information, but not the retailer (for example, Jiang et al. 2016). In this case, a manufacturer would charge a contingent wholesale price based on her demand forecast. Therefore, a retailer’s inefficient investment decision (i.e., signal-jamming activity) will disappear because there is no benefit of foregoing the investment. However, we believe that in most situations, the retailer possesses the market demand information due to his proximity to the final consumers, and our paper focuses on such realistic situations.

10The manufacturer can observe the retail price $p_1$ as well as the market demand $D_1$, and thus, can perfectly
Also, the retailer incurs a fixed cost \( c \geq 0 \) for engaging in demand-enhancing activities: \( C(e_t = 1) = c \) and \( C(e_t = 0) = 0 \). We assume that \( c \leq \frac{ad}{4} \) to ensure that investment under high market conditions is preferred by the retailer absent information effects (otherwise, there is no investment irrespective of market condition \( \theta \)).

The retailer’s investment strategy is defined as follows: for a given \( \theta \), he chooses an effort level, \( e_t = 1 \) or \( e_t = 0 \). When the market potential is high (\( \theta = \theta_H \)), the retailer can enhance the demand by expanding his promotional effort (\( e_t = 1 \)). On the other hand, a manufacturer’s strategy is to charge a periodic wholesale price, \( w_t \geq 0 \), in order to maximize her profit for a given market demand \( D_t \). Table 1 summarizes a retailer’s strategy corresponding to the realized retail demand.\(^{11}\)

The profit functions of two parties are as follows:

\[
\Pi^M = \sum_t w_t D_t; \tag{2}
\]

\[
\Pi^R = \sum_t (p_t - w_t)D_t - c \cdot e_t.
\]

Both the retailer and manufacturer are strategic and forward-looking, and thus they maxim-

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\(^{11}\)We assume that \( c \) and \( d \) are known because they are not stochastic. The uncertain term, \( \theta \), is presumed to be unobservable. This uncertain term is private information because only retailers have direct access to end-consumer data, e.g., by using the data collection technology based on scanner system and online data processing in channels (Fisher et al. 1994). This distinction (non-stochastic terms and underlying distributions are common knowledge but realizations of stochastic demand is privately observed) is largely intended to most simply capture the notion that a retailer may have more knowledge about consumers than its supplier, and that realized profits may reveal some of that knowledge.
mize their expected total profit over two periods. The model examines the two-period repeated game with demand uncertainty, in which market potential is unknown to the manufacturer a priori.

The timing of the game is as follows. First, at $t = 0$ before the game starts, a retailer learns information about the market potential ($\theta$). Second, at $t = 1$, a manufacturer first sets a wholesale price ($w_1$) based on her belief about the market potential. Then, the retailer decides how much effort to put in ($e_1$) for enhancing the market demand for that period: he can enhance the demand by exerting his promotional effort ($e_1 = 1$). Also, the retailer decides how much to charge in the market ($p_1$), and then the ensuing demand and profits are realized for period 1. Next, after the first-period demand is realized and observed, the manufacturer updates her beliefs about the market potential and sets her period 2 wholesale price ($w_2$) and the retailer decides how much effort to put in ($e_2$) and the prevailing retail price ($p_2$).

Regarding the information structure in the game, at the beginning of period 1, only the retailer knows about the market potential ($\theta$), while this information is unknown to a manufacturer. The manufacturer has the prior belief, $\Pr(\theta = \theta_H) = \Pr(\theta = \theta_L) = \frac{1}{2}$. At the start of period 2, the manufacturer updates her belief based on the realized demand in period 1 and her presumption of the retailer’s investment strategy, denoted $\tilde{\mu}(D_1) = \Pr(\theta = \theta_H | D_1)$, which we abbreviate to $\tilde{\mu}$. The sequence of events is summarized in Figure 1. Using this setup, we identify the Perfect Bayesian Equilibria (PBE) of the game and their implications.

Figure 1: Timing of the game
Benchmark I: Full Commitment

We first examine the benchmark where the manufacturer commits in advance to her two-period pricing structure, thereby ensuring that inference from first-period profitability has no impact on subsequent interactions. This commitment case serves as a useful benchmark to assess how dynamic pricing under ratcheting concerns affects parties in the supply chain as well as the overall supply channel efficiency and social welfare. To derive the equilibrium in this case, we work backward in the game, starting with the retailer’s pricing (and investment) decision in period 2. Given this presumption and the fact that the maximum wholesale price a manufacturer would rationally charge in either period is $\frac{a+d}{2}$, the retailer’s terminal investment decision is $e_2 = 1$ ($e_2 = 0$) if $\theta = \theta_H$ (if $\theta = \theta_L$).

The retailer chooses its price in period 2 then by solving

\[ \max_{p_2} \Pi^R \equiv (p_1 - w_1)D_1 - c \cdot e_1 + (p_2 - w_2)(q_2 - p_2) - c \cdot e_2, \]

which yields $p_2 = \frac{q_2 + w_2}{2}$, where $q_2 = a + d$ when $\theta = \theta_H$ (with price denoted $p_{2H}$) and $q_2 = a$ when $\theta = \theta_L$ (with price denoted $p_{2L}$).

Since $w_1$ and $w_2$ are fixed under commitment when the retailer chooses his first-period investment and price, it is straightforward to confirm that the retailer’s period 1 investment and pricing choices precisely mirror those in period 2, i.e., when $\theta = \theta_H$, $e_1 = 1$ and $p_1 = \frac{a+d+w_1}{2}$, and when $\theta = \theta_L$, $e_1 = 0$ and $p_1 = \frac{a+w_1}{2}$. Taking this induced retailer behavior into account, the manufacturer sets wholesale prices to maximize her total expected profit at the outset of the game:

\[ \max_{w_1, w_2} \mathbb{E}_\theta[\Pi^M] = \frac{1}{2} \left[ w_1 \left( a + d - \frac{a+d+w_1}{2} \right) + w_2 \left( a + d - \frac{a+d+w_2}{2} \right) \right] + \frac{1}{2} \left[ w_1 \left( a - \frac{a+w_1}{2} \right) + w_2 \left( a - \frac{a+w_2}{2} \right) \right]. \]

The first-order condition reveals the manufacturer’s benchmark wholesale prices: $w_1 =$

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12The role of commitment is well-documented in the literature (Stokey 1979, Hart and Tirole 1988, and Villas-Boas 2004). In a durable-good context, Stokey (1979) shows that when firms can commit to the time path of prices, the monopolist commits to having the same price in all periods, which ends up being the static monopoly price. Hart and Tirole (1988) show that the same conclusion applies when the firm can engage in behavior-based price discrimination: the optimal policy is to forgo the ability to price discriminate and simply charge the static monopoly price in every period. Villas-Boas (2004) shows that the result also applies when there are overlapping generations of consumers.
w_2 = \bar{w} = \frac{a+d/2}{2}. We summarize the benchmark findings in the following lemma. In the lemma, the superscript $C$ denotes the commitment case.

Lemma 1. When the manufacturer precommits to two-period wholesale pricing (where “C” denotes “commitment”):

1. Wholesale prices, retailer investments, and retail prices are: $w_t^C = \bar{w} = \frac{a+d/2}{2}$; $e_t^{CH} = 1$, $e_t^{CL} = 0$; $p_t^{CH} = \frac{1}{8}(6a + 5d)$, $p_t^{CL} = \frac{1}{8}(6a + d)$, for $t = 1, 2$.

2. Expected profits for Manufacturer and Retailer are: $E_\theta[\Pi^{MC}] = \frac{(2a+d)^2}{16}$ and $E_\theta[\Pi^{RC}] = \frac{4a^2+4ad+5d^2}{32} - c$.

The benchmark case offers some intuitive results. First and foremost, second-period wholesale price does not vary when first-period retailer demand is high – the benchmark is by design one without concerns of ratcheting. Second, the wholesale prices in each period reflect the manufacturer’s ex-ante assessment of expected retail demand. Equilibrium retail prices, in turn, reflect this. Even when demand turns out to be low, prices are higher when manufacturer ex-ante expectations are higher since that is when wholesale prices are higher: $p_t^{CH}$ and $p_t^{CL}$ are each increasing in $d$. With this benchmark in tow, we now consider the outcome under the second benchmark of mandatory disclosure, wherein the manufacturer sets her prevailing price at the beginning of each period and there are no issues of retailer signal jamming realized profits since the underlying demand information is publicly disclosed.

**Benchmark II: Mandatory Disclosure**

Here, we consider the equilibrium outcome under sequential strategic play with mandatory information disclosure of underlying demand information ($\theta$). In particular, when the retailer is compelled to directly disclose his private information about demand, the interactions in the two periods effectively separate and while ratcheting of expectations arises, it is not driven by realized period one profits but instead by the disclosed underlying demand information. In particular, under high demand ($\theta = \theta_H$), the disclosure requirement mitigates any retailer
incentive to distort his investment decision in period 1 because the released true demand information would allow the manufacturer to adjust a wholesale price in period 2 regardless of the retailer’s investment decision in period 1. In this circumstance, the retailer makes an investment whenever a high demand is realized, knowing that there will not be reverberations from this choice in period 2.

More precisely, working backwards in the game, consider first the retailer’s pricing (and investment) decision in period 2. The retailer’s terminal investment decision is \( e_2 = 1 \) \( (e_2 = 0) \) if \( \theta = \theta_H \) \( (\theta = \theta_L) \). Under mandatory information disclosure, the market information will be revealed at the outset of period 2, and thus, the manufacturer would choose the optimal wholesale prices for the given market potential \( \theta \). That is, the manufacturer’s second period wholesale pricing decision reflects the true demand in the mandatory disclosure because she does not have an ability to credibly commit otherwise. Thus, \( w_2(\theta = \theta_H) = w_{2H} = \arg\max_{w_2} (a + d - p_2H)w_2 = \frac{a + d}{2} \) and \( w_2(\theta = \theta_L) = w_{2L} = \arg\max_{w_2} (a - p_2L)w_2 = \frac{a}{2} \). In this case, the retailer’s preferred retail prices in period 1 if \( \theta = \theta_H \) and \( \theta = \theta_L \) solve:

\[
\max_{p_1} \Pi^R_{\theta_H}(\theta_H) \equiv (p_1 - w_1)(a + d - p_1) - c + (p_{2H} - w_2)(a + d - p_{2H}) - c, \quad (4)
\]

\[
\max_{p_1} \Pi^R_{\theta_L}(\theta_L) \equiv (p_1 - w_1)(a - p_1) + (p_{2L} - w_2)(a - p_{2L}). \quad (5)
\]

The first-order conditions of (4) and (5) yield \( p_{1H}^M(w_1) = \frac{a + d + w_1}{2} \) if \( \theta = \theta_H \) and \( p_{1L}^M(w_1) = \frac{a + w_1}{2} \) if \( \theta = \theta_L \) (the superscript “M” denotes mandatory information disclosure). Note that in this scenario, the price cannot serve as a signal since the retailer is aware that private market potential information will be revealed regardless of the chosen retail price. The retailer simply chooses the price that maximizes first-period profits. In the first period, the manufacturer sets the wholesale price \( w_1 \) to maximize her total expected profit as the following:

\[
\max_{w_1} \mathbb{E}_\theta[\Pi^M] = \frac{1}{2} \left[ w_1 \left( a + d - \frac{a + d + w_1}{2} \right) + w_{2H} \left( a + d - \frac{a + d + w_2H}{2} \right) \right]
\]

\[
+ \frac{1}{2} \left[ w_1 \left( a - \frac{a + w_1}{2} \right) + w_{2L} \left( a - \frac{a + w_2L}{2} \right) \right]
\]

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With the looming disclosure, the equilibrium wholesale price emanating from (6) is familiar: 
\[ w_1^M = \bar{w} = \frac{a+d/2}{2}. \] 
The equilibrium outcomes under the mandatory information disclosure are summarized in Lemma 2.

**Lemma 2.** Under mandatory information disclosure (where “M” denotes “mandatory information disclosure”)

1. Wholesale prices, retailer investments, and retail prices are: 
   \[ w_1^M = \bar{w}; \quad w_2^{MH} = \frac{a+d}{2}, \quad w_2^{ML} = \frac{a}{2}; \quad e_{iH}^M = 1, \quad e_{iL}^M = 0; \quad p_{1H}^M = \frac{1}{8}(6a + 5d), \quad p_{1L}^M = \frac{1}{8}(6a + d) \text{ and } p_{2H}^M = \frac{3}{4}(a + d), \quad p_{2L}^M = \frac{3a}{4}. \]

2. Expected profits for Manufacturer and Retailer are: 
   \[ \mathbb{E}_\theta[\Pi^{MM}] = \frac{8a^2 + 8ad + 7d^2}{32}, \quad \text{and } \mathbb{E}_\theta[\Pi^{RM}] = \frac{8a^2 + 8ad + 7d^2}{64} - c. \]

As seen in this lemma, regulation that forces the retailer to disclose true underlying demand information at the end of period 1 dissuades any investment distortions to reduce inference from profit realizations. However, the revealed truthful information does allow the manufacturer to charge a wholesale price contingent on realized market demand.

**Endogenous Ratcheting**

We now address the equilibrium outcome when there is no disclosure of the underlying demand information, and thus the manufacturer must instead rely on inference from revealed retailer profit. Working backward in the game, consider the manufacturer’s period 2 opportunistic behavior based on the revealed demand information. Upon observing high retail profit (i.e., one that given the retail price can only arise when \( \theta = \theta_H \) and \( e_1 = 1 \), the manufacturer knows with certainty that \( \theta = \theta_H \)). The result is a high period 2 wholesale price just as with mandatory disclosure, i.e., 
\[ w_2(\theta = \theta_H) = w_{2H} = \arg\max_{w_2} (a + d - p_{2H})w_2 = \frac{a+d}{2}. \]

Upon observing lower profit, the manufacturer cannot directly infer \( \theta \). It could either indicate \( \theta = \theta_L \) or it could be \( \theta = \theta_H \) with \( e_1 = 0 \). As a result, the manufacturer *imperfectly* updates her prior beliefs about the market condition \( \theta \in \{\theta_L, \theta_H\} \). Denote the manufacturer belief in this case by \( \tilde{\mu} \), where \( \tilde{\mu} \) is assured to be no more than \( \frac{1}{2} \) (low realized profit cannot
feasibly lead to a heightened belief about the demand environment). Given this belief, the manufacturer’s period 2 price given low realized profit is

\[ w_{2L}(\tilde{\mu}) = \arg\max_{w_2} \tilde{\mu}(a + d - p_{2H})w_2 + (1 - \tilde{\mu})(a - p_{2L})w_2 = \frac{a + \tilde{\mu}d}{2}. \]  

Comparing \( w_{2H} \) and \( w_{2L} \) confirms that \( w_{2H} > w_{2L} \). In other words, high initial profits invariably ratchet expectations and thereby ratchet pricing. This endogenous ratcheting is, of course, anticipated by the retailer who can then adjust initial investments to attempt to influence beliefs and pricing.

In particular, when the retailer observes \( \theta = \theta_L \), the investment decision (and the ensuing pricing choice) is straightforward – since investment cannot alter demand, its only effect is to induce a cost so \( e_1 = 0 \) and, thus, price is \( p_1 = \frac{a + w_1}{2} \). When market potential is high, on the other hand, the retailer is inclined to make an investment and choose \( p_1 = \frac{a + d + w_1}{2} \), all else being equal. However, another option is to forgo the investment opportunity and set \( p_1 = \frac{a + w_1}{2} \) and thus conceal the favorable market condition (signal-jamming) to avoid the manufacturer’s strategic exploitation of that information to charge a high second-period wholesale price. Permitting the possibility of a mixed-strategy, denote the retailer’s probability of choosing the investment and high profit option by \( \beta \). In other words, \( \beta \) is the probability the retailer makes a (truth-telling) investment given the true state \( \theta = \theta_H \). With a probability \( 1 - \beta \), the retailer makes no investment to conceal his market condition. Figure 2 shows the game structure with endogenous ratcheting case.

For any given initial choice of \( w_1 \), a Perfect Bayesian Equilibrium (PBE) outcome can then be defined as a \( \beta \) and \( \tilde{\mu} \) such that: (i) \( \beta \) is an optimal choice for the retailer given the ensuing prices that come from \( \tilde{\mu} \); and (ii) \( \tilde{\mu} \) is a rational expectation given the retailer’s strategy. That is, the posterior belief for the manufacturer is following the Bayes’ Rule:

\[ \tilde{\mu} = \frac{\frac{1 - \beta}{2} + \frac{1}{2}}{1 - \beta + \frac{1}{2}} = \frac{1 - \beta}{2 - \beta}. \]
Consider first the possibility of a fully separating equilibrium, i.e., \( \beta = 1 \). For this to be an equilibrium, it must be the case that even for \( \tilde{\mu} = 0 \) (i.e., the belief the manufacturer will hold if retailer deviates by choosing \( e_1 = 0 \) when \( \theta = \theta_H \)), the retailer nonetheless prefers an investment in period one to instead bypassing investment and mimicking \( \theta = \theta_L \) to secure a lower period 2 wholesale price. This is satisfied if:

\[
\begin{align*}
(\frac{a + d + w_1}{2} - w_1)(a + d - \frac{a + d + w_1}{2}) - c + (\frac{a + d + w_{2H}}{2} - w_{2H})(a + d - \frac{a + d + w_{2H}}{2}) - c & \\
(\frac{a + w_1}{2} - w_1)(a - \frac{a + w_1}{2}) + (\frac{a + d + w_{2L}}{2} - w_{2L})(a + d - \frac{a + d + w_{2L}}{2}) - c
\end{align*}
\]

Note from the above condition (9) that the main consequences of investment are: (i) incurring cost \( c \); (ii) boosting period 1 demand/profit; and (iii) inducing higher period 2 wholesale price. Using the expressions for \( w_{2H} \) and \( w_{2L} \) with \( \beta = 1 \) in equation (7) reveals a separating equilibrium can arise when \( w_1 \leq \frac{1}{8}(6a + d - \frac{16c}{d}) = w_1^* \). Intuitively, for low values of \( w_1 \), the possible period-one profit advantage from investing outweighs any period-two advantage from mimicking a low-type and, thereby, encourages full revelation.

Now consider the other extreme, a fully pooling equilibrium. That is the case of \( \beta = 0 \), in which the retailer is inclined to forego initial investment so as to not tip his hand to the manufacturer. For this to be an equilibrium, it must be the case that for \( \tilde{\mu} = \frac{1}{2} \) (i.e., the
belief the manufacturer will hold from equation (8) with \( \beta = 0 \), the retailer in a favorable environment prefers skipping an investment in period one to secure the lower period 2 wholesale price that reflects an averaging of types. This is satisfied if:

\[
\left( \frac{a + w_1}{2} - w_1 \right) (a - \frac{a + w_1}{2}) + \left( \frac{a + d + w_{2L}}{2} - w_{2L} \right) (a + d - \frac{a + d + w_{2L}}{2}) - c \geq \tag{10}
\]

Using the expressions for \( w_{2H} \) and \( w_{2L} \) with \( \beta = 0 \) in equation (7) reveals a pooling equilibrium can arise when \( w_1 \geq \frac{1}{8} \left( 7a + \frac{11d}{4} - \frac{16c}{d} \right) = w_1^p \). Intuitively, for very high values of \( w_1 \), any temptation to deviate from the pooling equilibrium and invest in period one demand is tempered since the profits from investment are limited due to the high wholesale price. Also, it is clear that \( w_1^s < w_1^p \).

For intermediate values of \( w_1 \in [w_1^s, w_1^p] \), then, no pure strategy equilibrium exists. Instead, the equilibrium entails a partially-separating outcome, where \( \beta \in [0, 1] \). In particular, the semi-separating equilibrium is defined as the \( \beta \) value that solves the following indifference condition:

\[
\left( \frac{a + w_1}{2} - w_1 \right) (a - \frac{a + w_1}{2}) + \left( \frac{a + d + w_{2L}}{2} - w_{2L} \right) (a + d - \frac{a + d + w_{2L}}{2}) - c = \tag{11}
\]

When the market potential is high \( (\theta = \theta_H) \), for the retailer to mix between exerting an effort \( (e_1 = 1) \) and no effort \( (e_1 = 0) \), it must be the case that the expected payoff from either case should be the same. This is the indifference condition for the existence of semi-separating equilibrium. Using \( \mu = \frac{1-\beta}{2-\beta} \) in equation (8), and solving equation (11) reveals that the semi-separating equilibrium entails

\[
\beta^* = \frac{2a + 3d - 2\sqrt{a^2 - 16c + 10ad + 5d^2 - 8dw_1}}{a + d - \sqrt{a^2 - 16c + 10ad + 5d^2 - 8dw_1}} = \frac{2a + 3d - 2\varphi(w_1)}{a + d - \varphi(w_1)}, \tag{12}
\]

where \( \varphi(w_1) = \sqrt{a^2 - 16c + 10ad + 5d^2 - 8dw_1} \).
Figure 3: Equilibrium regions and investment probabilities

Note that at \( w_1^a = \frac{1}{8} \left( 6a + d - \frac{16c}{d} \right) \), \( \beta^* = 1 \) and at \( w_1^p = \frac{1}{8} \left( 7a + \frac{11d}{4} - \frac{16c}{d} \right) \), \( \beta^* = 0 \). Furthermore, for interior values of \( w_1 \in [w_1^a, w_1^p] \), \( \beta^* \) is decreasing in \( w_1 \): \( \frac{\partial \beta^*}{\partial w_1} = -\frac{4d^2}{\varphi(w_1)(a+d-\varphi(w_1))^2} < 0 \).

Therefore, it confirms the existence of a semi-separating equilibrium for intermediate values of \( w_1 \). The following proposition uses these results to provide the conditions under which any of three types of equilibrium – fully-separating; partially-separating; or pooling – can arise as the unique outcome.

**Proposition 1.** For a given initial wholesale price, \( w_1 \), the equilibrium outcome of the retailer-manufacturer game is as follows:

1. For \( w_1 \leq w_1^a = \frac{1}{8} \left( 6a + d - \frac{16c}{d} \right) \), the equilibrium entails full information revelation through the retailer’s investment choice, i.e., \( \beta = 1 \).

2. For \( w_1^a < w_1 < w_1^p = \frac{1}{8} \left( 7a + \frac{11d}{4} - \frac{16c}{d} \right) \), the equilibrium entails signal jamming through a retailer mixed-strategy investment choice, in particular \( \beta^* = \frac{2a + 3d - 2\varphi(w_1)}{a + d - \varphi(w_1)} \).

3. For \( w_1 \geq w_1^p \), the equilibrium entails signal jamming through a retailer bypassing initial investment, i.e., \( \beta = 0 \).

Figure 3 provides a graphical depiction of the results in Proposition 1 and illustrates the three regions for the different types of equilibria.
In summary, the firm’s early performance can have an information-signaling role within a supply chain, and the signaling role of the performance can alter the retailer’s incentives to engage in profitable demand-enhancing investments. In effect, the retailer’s decision to forego investment can serve as a “signal-jamming” that hinders the manufacturer’s inference about the market demand. These results demonstrate the possibility of ratcheting of expectations (and, thus, wholesale prices) can lead the retailer to take real actions to curb its consequences (as in the semi-separating and pooling equilibrium cases). We next consider the manufacturer’s endogenous response in light of these incentives. While intuition may suggest that the retailer may have a harmful incentive to withhold demand information by foregoing his investment opportunity in the first period in order to avoid the manufacturer’s strategic choice of wholesale prices in the second period, a savvy manufacturer may opt to stave off such behavior with a sufficiently low initial wholesale price.

Dynamic Wholesale Pricing

Endogenous ratcheting suggests a key inefficiency that can arise from underlying demand information being learned indirectly from realized profit rather than directly from mandatory disclosure – a retailer may choose to forego profitable investment in order to signal-jam the inference from accounting profit. To get a sense for how this can arise, consider the outcome if a naive manufacturer simply uses the initial wholesale price under the presumption of mandatory disclosure, where \( w_1^M = \bar{w} = \frac{a+d/2}{2} \).

Reviewing the results in Proposition 1, this wholesale price can conceivably induce a separating equilibrium, semi-separating equilibrium, or pooling equilibrium, depending on the value of \( c \). For example, when \( w_1 \leq w_1^s = \frac{1}{8} \left(6a + d - \frac{16c}{d}\right) \), the full separating equilibrium is an equilibrium outcome. Given the wholesale price \( w_1^M = \bar{w} = \frac{2a+d}{4} \), this condition translates into \( w_1 = \bar{w} = \frac{2a+d}{4} \leq w_1^s = \frac{1}{8} \left(6a + d - \frac{16c}{d}\right) \Leftrightarrow c \leq \frac{d(2a-d)}{16} \equiv c^* \). Therefore, for \( c \leq \frac{d(2a-d)}{16} \), it becomes that \( \bar{w} \leq w_1^s \). Thus, the retailer benefit of investment is so compelling that she is willing to invest even though it means a hike in wholesale price will ensue. On the other
Figure 4: Equilibrium regions as a function of $w_1$ and $c$.

hand, if $c > \frac{d(2a-d)}{16}$, we have $\bar{w} > w_1^s$ and thus, the naive manufacturer will be disappointed to learn that her chosen wholesale price induces costly signal jamming by the retailer (i.e., semi-separating or pooling depending on the value of $c$). This same consideration plays out for any other value of $w_1$ as well. Given a choice of $w_1$, low values of $c$ cement full information revelation via the investment choice whereas high values of $c$ induce signal jamming by the retailer. This tradeoff is depicted graphically in Figure 4. The grey area under the line $w_1^s = \frac{1}{8} \left( 6a + d - \frac{16c}{d} \right)$ represents the parameter space for the separating equilibrium, the red area above the line $w_1^p = \frac{1}{8} \left( 7a + \frac{11d}{4} - \frac{16c}{d} \right)$ represents the parameter space for pooling area. Also, the white area between these two lines represents the area for semi-separating equilibrium.

The question that remains is under what conditions the manufacturer will choose a $w_1$ that induces full information revelation even if $\bar{w}$ does not do the trick. To elaborate, as noted above, full information revelation and corresponding optimal wholesale price $w_1 = \bar{w}$ comes for “free” for low $c$-values, i.e., $c \leq \frac{d(2a-d)}{16}$. As can be seen in Figure 4, even for $c$-values above $\frac{d(2a-d)}{16}$, the manufacturer can choose to move $w_1$ below $\bar{w}$ in order to ensure the separating equilibrium. The minimum deviation that ensures this is, in fact, $w_1 = w_1^s$. As it turns out, as long as $c$ is not too large, such a haircut in $w_1$ proves optimal, as confirmed in the next
proposition.

**Proposition 2.** The manufacturer optimally chooses an initial wholesale price to ensure voluntary information revelation (that is the separating equilibrium), if and only if \( c \leq c^{**} \equiv \frac{d(2a-d)}{16} + \frac{d^2(a+d)}{4(a+3d)} \). In this case, \( w_1 = \bar{w} \) if \( c \leq c^{*} \equiv \frac{d(2a-d)}{16} \) and \( w_1 = w_1^s \), otherwise.

*Proof.* See Appendix.

The proposition shows that a manufacturer opts to dissuade signal-jamming from a retailer by offering a sufficiently low first-period wholesale price as an enticement. This entails a lower wholesale price than chosen under the mandatory disclosure benchmark when \( c > \frac{d(2a-d)}{16} \). This circumstance reflects optimal what we refer to as “dynamic pricing discounts” - a lower initial wholesale price than benchmarks would prescribe in order to create an added incentive for first-period investment.

More precisely, using the wholesale prices in Proposition 2 in comparison to pricing under mandatory disclosure, we can derive that the dynamic wholesale price discount is:

\[
\Delta w = w_1^M - w_1^P = \frac{1}{8d} \left(16c + d^2 - 2ad\right).
\] (13)

**Proposition 3.** The price discount \((\Delta w)\) decreases in the size of base demand \((a)\) and the size of market potential \((d)\), but increases in the cost of investment \((c)\): \(\frac{\partial \Delta w}{\partial a} < 0\), \(\frac{\partial \Delta w}{\partial d} < 0\), \(\frac{\partial \Delta w}{\partial c} > 0\).

*Proof.* See Appendix.

Intuitively, the proposition confirms that the price discount put in place to entice a separating equilibrium is one that encourages investment – the more intrinsically attractive investment is (higher \(a\), higher \(d\), or lower \(c\)), the less of a discount is needed to get such voluntary compliance from the retailer.

The equilibrium outcomes under dynamic wholesale pricing discounts are summarized in Proposition 4.
Proposition 4. For \( c \in (c^*, c^{**}) \) (where \( c^* \equiv \frac{d(2a-d)}{16}, c^{**} \equiv \frac{d(2a-d)}{16} + \frac{d^2(a+d)}{4(a+3d)} \)), the equilibrium entails dynamic wholesale pricing discounts (where “D” denotes “dynamic pricing”). The equilibrium outcome is:

1. Wholesale prices are: \( w_1 = w_1^D = w_s^* \); \( w_2^H = \frac{a+d}{2}, w_2^L = \frac{a}{2} \).

2. Retailer investments and retail prices are: \( e_1^D = 1, e_1^D = 0 \); \( p_1^H = \frac{14ad + 9d^2 - 16c}{16d}, p_1^L = \frac{3a}{4} \), for \( t = 1, 2 \).

3. Expected profits for Manufacturer and Retailer are:
   \[
   E_\theta[\Pi^{MD}] = \frac{7a^2}{32} + \frac{ac}{8d} + \frac{9ad}{32} + \frac{11d^2}{128} - \frac{2c^2}{d^2} - \frac{c}{4}, \\
   E_\theta[\Pi^{RD}] = \frac{5a^2}{64} - \frac{5c}{8} + \frac{c^2}{d^2} + \frac{ac}{4d} + \frac{7ad}{64} + \frac{33d^2}{256}.
   \]

Channel Efficiency

In this section, we show that when a dynamic wholesale pricing discounts (endogenous manufacturer concessions) constitute the chosen equilibrium outcome, it can increase the channel efficiency above and beyond the levels of channel efficiency attainable from either benchmark case. Therefore, our results suggest that public policy may allow retailers to withhold their private demand information and parties may be permitted to adjust pricing over time to meet demand conditions, because the dynamic interactions surrounding the ratchet effect can actually work to enhance the total supply channel efficiency.

Comparison: Without information disclosure vs with information disclosure

First we compare the results of a dynamic wholesale pricing approach (where there is no information disclosure) with the mandatory information disclosure case. Mandatory information disclosure represents the natural knee-jerk reaction to concerns of gaming information inference from accounting disclosures. As the next proposition confirms, the knee-jerk regulatory reaction fails to take into account the positive endogenous strategic response to these concerns.
Proposition 5. For \( c \in (c^*, c^{**}) \), a mandatory information disclosure policy decreases supply channel efficiency: \( \mathbb{E}_\theta[\Pi^{MD}] + \mathbb{E}_\theta[\Pi^{RD}] > \mathbb{E}_\theta[\Pi^{MM}] + \mathbb{E}_\theta[\Pi^{RM}] \). Further, a mandatory information disclosure increases (decreases) a manufacturer’s (a retailer’s) profit: \( \mathbb{E}_\theta[\Pi^{MD}] \leq \mathbb{E}_\theta[\Pi^{MM}] \) \( (\mathbb{E}_\theta[\Pi^{RD}] \geq \mathbb{E}_\theta[\Pi^{RM}] \).

Proof. See Appendix.

The result suggests that the retailer’s temptation to reduce investment gives him a strategic weapon in the interaction with the manufacturer, and this weapon, in turn, convinces the manufacturer to lower her chosen wholesale price as a means of disarming the retailer. Rather than the threat of ratcheting manifesting as costly signal-jamming, it instead manifests as beneficial wholesale price cuts.

To elaborate, a natural reaction to concerns of costly signal-jamming is to propose mandatory disclosure of the underlying information, in this case, forward-looking demand information. Unlike the lay belief about the efficiency of such a policy, the regulation which mandates the disclosure of more information may alleviate information differences between supply chain members but not necessarily improve the underlying supply channel efficiency when we consider the firms’ real decisions such as investment and pricing. Moreover, permitting a retailer to withhold the market information and making him disclose only the realized market information may increase the supply chain efficiency because a manufacturer more actively provides such a concession (e.g., price discount) to elicit the market information on her own, thereby increasing the supply chain efficiency.

Comparison: Dynamic wholesale pricing vs. Commitment

Next, we evaluate the supply chain efficiency gain from the dynamic pricing equilibrium by comparing it to the case of the commitment for the circumstance in which unfettered pricing results in dynamic pricing adjustments.

Proposition 6. When \( c \in (\zeta, \bar{c}) \) (where \( c^* \leq \zeta \equiv \frac{d(4\sqrt{a^2+ad+d^2}-(2a+3d))}{16} \) and \( \bar{c} \equiv \frac{d(2a+d)}{16} \leq c^{**} \)), supply chain efficiency under the dynamic pricing equilibrium is greater than that of
commitment case: \( E_\theta [\Pi^{MD}] + E_\theta [\Pi^{RD}] > E_\theta [\Pi^{MC}] + E_\theta [\Pi^{RC}] \). Further, under this condition, both the manufacturer and retailer are better off under the dynamic pricing equilibrium than commitment case: \( E_\theta [\Pi^{MD}] > E_\theta [\Pi^{MC}] \) and \( E_\theta [\Pi^{RD}] > E_\theta [\Pi^{RC}] \).

**Proof.** See Appendix.

This result is a stark contrast to a conventional wisdom that the ratchet effect creates perverse inefficiencies. The proposition implies that the retailer’s concerns for the manufacturer’s opportunistic behaviors, and ensuing strategic response to shield his demand information (which seemingly hurts the channel efficiency), can be a blessing in disguise. In fact, it can increase supply chain efficiency even more than the commitment case. Though signal-jamming appears a threat to efficiency, it turns out to be one that is off-equilibrium. As such, the dynamic pricing outcome gets the best of both worlds: information-relevant profitability figures along with a reduction in double-marginalization brought about by the threat of signal-jamming. The retailer’s threat of signal-jamming disciplines the manufacturer to lower the first-period retail price below the level of commitment case, thereby alleviating the double-marginalization problem in the supply chain.

For the retailer, the primary benefit of dynamic pricing relative to pre-commitment comes from its ability to reduce double-marginalization. For the manufacturer, being forced to set a lower initial wholesale price turns out to be worthwhile since dynamic pricing also permits circumstance-contingent pricing in period 2. This give-and-take means that not only is efficiency enhanced relative to pre-commitment, this enhanced efficiency can naturally take the form of Pareto gains.

**Two-Part Tariff Contracts**

The setting studied herein considers supply chain ratcheting arising under short-term linear wholesale pricing arrangements. Besides presenting the most succinct case of supply chain inefficiencies, this formulation also reflects the empirical regularity of such simple linear contracts
In this subsection, we digress to discuss the importance of this stylized contractual presumption on the results.

If one were to expand the contractual arrangement to entail a full commitment to a general, profit-contingent long-term contract, ratcheting is a non-issue. After all, the well-known Revelation Principle (Myerson 1979) demonstrates that under such unlimited contracting and commitment, any equilibrium outcome can be replicated under a fully revealing direct-revelation mechanism, i.e., one in which a firm can credibly commit not to ratchet expectations. A necessary condition for ratcheting to be a pressing issue, then, is some form of contractual incompleteness. Though our setting reflected such incompleteness in the form of dynamic linear contracts, the critical feature is that the manufacturer cannot fully pre-commit to how she will respond to information learned after the first period. It is that inability to commit that fosters ratcheting concerns. Knowing the manufacturer will respond to information revelation in self-interest, the retailer is prone to signal-jamming in order to manage the information environment and the manufacturer’s exploitation thereof.

To see how the forces play out in another contractual environment, consider the case in which the buyer can offer successive menus of two-part tariff contracts, where the fixed-fee and (nonnegative) marginal tariff are denoted $F$ and $t$, respectively. In effect, this translates our game of signaling under simple contracts to one of adverse selection under a wider selection of contracts. A typical view is that two-part tariffs overcome contractual inefficiencies in supply chains and thereby achieve first-best outcomes. However, with information asymmetry, even this is not necessarily the case. The retailer’s private information creates two considerations relative to the first-best. First, as is typical in adverse selection settings, the manufacturer is willing to introduce an inefficiency to limit retailer information rents. Here, this takes the form of a nonzero marginal tariff that results in rationed production. Second, the two-period nature of the game introduces the key feature of our setting that the seller’s fear of ratcheting requires a first-period concession in order to induce investment since such investment undercuts information advantage. Interestingly, these two features work in opposite directions: while a one-shot adverse selection game would stipulate high marginal tariffs to overcome information
rents, the concessions needed to assuage ratcheting fears take the form of reduced tariffs. More precisely, the next proposition demonstrates the adverse selection inefficiencies of marginal tariffs above marginal cost (seen in the mandatory disclosure case of part (1)), the endogenous concessions that arise under the threat of ratcheting (part (2)), and the ensuing efficiency benefits of dynamic pricing (part (3)).

**Proposition 7.** With successive two-part tariff contract menus

1. Under mandatory disclosure, the optimal first-period contract entails $F = F_L = \frac{1}{4}(a - d)^2$ and $t = t_L = d$ when $\theta = \theta_L$, and $F = F_H = \frac{1}{4}(a^2 + 2d^2)$ and $t = t_H = 0$ when $\theta = \theta_H$. The second-period contracts entail $t = 0$ and fixed fees to extract the full surplus.

2. Under dynamic pricing without disclosure, the optimal first-period contract entails a fully separating equilibrium in which $F = \frac{1}{4}a^2$, $t = 0$ and the retailer invests when $\theta = \theta_H$ but does not invest when $\theta = \theta_L$. The second-period contracts entail $t = 0$ and fixed fees to extract the full surplus.

3. Supply channel efficiency is greater under dynamic pricing than under mandatory disclosure.

**Proof.** See Appendix.

Intuitively, with mandatory disclosure after the first period, the optimal initial contract takes the form of a fully-revealing mechanism in which the manufacturer offers a menu of contracts from which the retailer can choose: when $\theta = \theta_L$, the contract choice entails a marginal tariff of $d$ whereas it is 0 when $\theta = \theta_H$. This contract exhibits the usual adverse selection features of (i) production distortions for one type (here, a marginal tariff above zero when $\theta = \theta_L$) and information rents for the other type (when $\theta = \theta_H$). In other words, the fixed fee in Proposition 7-(1) permits a high-type retailer to retain some profit (information rents) when investing. And, to limit such profit concessions the manufacturer sets an above-cost tariff to dissuade a high-type retailer from mimicking a low-type retailer.
As in our primary setup, the dynamic game again brings concerns of ratcheting: if the retailer reveals its type in period 1, it stands to lose out on potential information rents from the contract that would be offered in the presence of information asymmetry in the second period. After all, as shown in part (1) of the proposition, revelation of information at the end of period 1 ensures the entire surplus will be extracted by the manufacturer in period 2. The threat of ratcheting, in turn, makes it more difficult for the manufacturer to elicit information about retailer type in the first-period contract. Just as in the case of simple linear contracts, the manufacturer is forced to make concessions in the first period to assuage ratcheting concerns. In this case, the remedy is quite stark: knowing a retailer facing \( \theta = \theta_H \) can mimic \( \theta = \theta_L \) by refusing investment and creating a wide-open space for exploiting gains from investment in the subsequent period, the manufacturer must provide that wide-open space in the first period in order to ensure it can at least extract the gains from investment in period 2. This takes the form of treating the retailer as if \( \theta = \theta_L \) and permitting it to walk away with the added profits from investment in the first period.

In other words, concessions to ease concerns of ratcheting persist in the case of menus of (successive) two-part tariff contracts, and they effectively take the form of the parties agreeing to take turns reaping the benefits from investment. This détente of sorts opens the door to supply chain gains that could not accrue if mandatory disclosure were in place.

Many other contractual arrangements are possible, and each would introduce a new consideration and alter equilibrium outcomes. The goal here is not to identify the ideal or most practical contractual arrangement. Rather, the point is to identify that the primary forces are robust to contractual form provided there remains a degree of contractual incompleteness. It is a manufacturer’s inability to fully commit to how she will respond to learning new information – not how that is manifest in specific contractual arrangements – that is the key feature that can give rise to ratcheting, signal-jamming, and welfare-enhancing manufacturer concessions.
Conclusion

Long-term relationships not subject to long-term contractual commitments often expose themselves to concerns about ratcheting. This paper presents a simple model of such a commonly discussed concern in the context of supply chain relationships. By examining dynamic supply chain interactions, we not only demonstrate that ratcheting is a legitimate concern among repeated buyer-supplier relationships, but we also show that such relationships may introduce a natural solution to the conflict, one that alleviates another source of conflict in the channel. In particular, in order to assuage a retailer’s fears of opportunistic ratcheting of input pricing, a manufacturer may offer initial price concessions. These price concessions, in turn, reduce double marginalization and promote greater supply chain efficiency. The end result is that not only can ratcheting concerns be naturally addressed by supply chain partners, but they may actually prove to be a salve in strained supply chains.

Thus, our results suggest that a manufacturer may rationally consider a wholesale price which coordinates a supply chain rather than the one that maximizes its own short-term profit. The lower wholesale price may appear as suboptimal in the short-run, but it actually can enhance the manufacturer’s profit in the long-run as well as the supply chain efficiency by inducing the retailer to make an efficient investment decision, thereby communicating the demand information to the manufacturer. This endogenous give-and-take, in turn, can provide some justification for the absence of regulations requiring disclosure of forward-looking financial information.

A key driver of both the concern of ratcheting and the parties’ reactions to it in this setting is the inter-temporal correlation in demand that gives rise to backward looking profit figures potentially revealing future conditions. Absent such correlation, the forces of interest would be moot. Other limitations are the chosen contractual forms (i.e., linear wholesale pricing), and the simple monopoly framework. Future work may examine how ratcheting concerns and a retailer’s natural desire to “signal jam” his profit reports influence supply chain interactions when competitors, at both the wholesale level and retail level are also key
strategic observers. It may also consider how such signal-jamming is influenced by the degree of aggregation inherent in reported profits, i.e., whether the natural aggregation of profit obtained from various industries or geographical markets could complement or substitute for a retailer’s incentive to tailor investment choices to influence outside inference from profit disclosures and how this, in turn, can affect prevailing manufacturer prices.
Appendix

Proof of Proposition 2

Proof. First, if $c \leq \frac{d(2a-d)}{16}$, $w_1 = \bar{w} = \frac{2a+d}{4} \leq \bar{w}_1^* = \frac{1}{8}(6a+d - \frac{16c}{d})$ and $w_1 = \bar{w}$ ensures voluntary information revelation by satisfying the (IC) constraint in equation (9). On the other hand, if $c > \frac{d(2a-d)}{16}$, $\bar{w} = \frac{2a+d}{4} > \bar{w}_1^* = \frac{1}{8}(6a+d - \frac{16c}{d})$, a manufacturer has to choose $w_1 = w_1^* = \frac{1}{8}(6a+d - \frac{16c}{d})$ which satisfies equation (9) while inducing the retailer’s information disclosure and minimizing distortion of wholesale price between $\bar{w}$ and $w_1$.

Second, we show the condition under which a manufacturer’s profit under the separating equilibrium with dynamic pricing is greater than those under both semi-separating equilibrium and pooling equilibrium. The manufacturer profit under dynamic pricing with $w_1^* = \frac{1}{8}(6a+d - \frac{16c}{d})$ is as follows:

$$E_{\theta}[\Pi^{MD}] = \frac{1}{128} \left( 28a^2 - 32c - \frac{256c^2}{d^2} + \frac{64ac}{d} + 36ad + 11d^2 \right).$$

Also, by using equation (11), the equilibrium wholesale price under semi-separating equilibrium is $w_1 = \frac{1}{8}(2a(\bar{\mu} + 3) - (d(\bar{\mu} - 4)\bar{\mu}) + d) - \frac{2c}{d}$ with $\bar{\mu} = \frac{1-\beta}{2-\beta}$. Using this equilibrium wholesale price, the manufacturer’s expected profit under semi-separating equilibrium can be expressed as a function of $\beta$, denoted $E_{\theta}[\Pi^{MS}; \beta]$. Taking the derivative of $E_{\theta}[\Pi^{MD}] - E_{\theta}[\Pi^{MS}; \beta]$ with respect to $c$ yields:

$$\frac{\partial}{\partial c} \left( E_{\theta}[\Pi^{MD}] - E_{\theta}[\Pi^{MS}; \beta] \right) = - \frac{(1-\beta)(2a(2-\beta)+d(15-11\beta+2\beta^2))}{4d(2-\beta)^2} < 0.$$  

Hence, for greater values of $c$, there can exist a $\beta < 1$ for which the semi-separating outcome is preferred to the separating equilibrium.

Also, we take the first derivative of $E_{\theta}[\Pi^{MD}] - E_{\theta}[\Pi^{MS}; \beta]$ with respect to $\beta$:

$$\frac{\partial}{\partial \beta} \left( E_{\theta}[\Pi^{MD}] - E_{\theta}[\Pi^{MS}] \right) = \frac{1}{32} \left( \frac{16ac-4a^2d-4ad^2+16cd^2-3d^3}{(2-\beta)^2d} + \frac{2(a^2+8c+d^2)}{(2-\beta)^2} - 4(d(2a + d) - 4c) + \frac{3d(a+d)}{(2-\beta)^4} + \frac{d^2}{(2-\beta)^3} \right).$$
We first find a sufficient condition $c^{**}$ such that \[ \frac{\partial (E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}])}{\partial \beta(\beta - 1)} < 0 \] when $\beta = 1$. By plugging in $\beta = 1$;

\[
\frac{\partial (E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}])}{\partial \beta(\beta - 1)} = \frac{48cd+16ac-2a^2d-9ad^2-d^3}{32d} < 0 \iff c \leq \frac{d(2a-d)}{16} + \frac{d^2(a+d)}{4(a+3d)} = c^{**}.
\]

Next, we demonstrate that the separating equilibrium under dynamic pricing is strictly preferred by the manufacturer for $c \in (c^*, c^{**})$. First, we note that the lowest value of $E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}; \beta]$ arises as $c \to c^{**}$ since $\frac{\partial (E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}; \beta])}{\partial c} < 0$ for any $\beta \in [0, 1]$. Then, we only need to show that $E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}; \beta] < 0$ for all $\beta \in [0, 1]$ when evaluated at $c = c^{**}$. Plugging in $c = c^{**}$ to the profit expressions and taking the derivative with respect to $\beta$ yields:

\[
\frac{\partial}{\partial \beta} \left( E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}; \beta] \right) |_{c=c^{**}} = -\frac{(1-\beta)(2a^2(2-\beta)^2 + (2-\beta)(97-6\beta^2 + 42\beta^2 - 107\beta)a^2d + (19\beta^4 - 171\beta^3 + 594\beta^2 - 945\beta + 579)a^2d^2 + (11\beta^4 - 99\beta^3 + 349\beta^2 - 572\beta + 367)d^2)}{32(2-\beta)^2(a+3d)} < 0.
\]

Given the difference is decreasing in $\beta$, the manufacturer’s preference for the separating equilibrium is confirmed by noting that $E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}; \beta = 1] = 0$. Hence, for $c \in (c^*, c^{**})$, $E_\theta[\Pi^{MD}] - E_\theta[\Pi^{MS}; \beta] > 0$ for any $\beta < 1$; thus, the manufacturer strictly prefers $w_1 = w_1^s = \frac{1}{8}(6a + d - \frac{16c}{d})$ to any $w_1$ that induces a semi-separating equilibrium.

Finally, we compare the manufacturer profit under the induced separating equilibrium with the profit under the pooling equilibrium (i.e., $\beta = 0$). When $c \leq c^{**}$, $w_1 = w_1^p = \frac{1}{8} \left( 7a + \frac{11d}{4} - \frac{16c}{d} \right) > \frac{a}{2}$ and $w_1^p$ maximizes the pooling equilibrium profit and then:

\[
E_\theta[\Pi^{MP}(w_1 = w_1^p)] = \frac{368a^2-8ad-57d^2}{2048} + \frac{1}{16}c \left( \frac{12a}{d} + 11 \right) - \frac{2c^2}{d^2}.
\]

If we compare the two profits:

\[
E_\theta[\Pi^{MD}(w_1 = w_1^s)] - E_\theta[\Pi^{MP}(w_1 = w_1^p)] = \frac{80(a^2-24c)d+584ad^2+233d^3-512ac}{2048d},
\]
which is positive if \( c \leq c^* \) and the difference is decreasing in \( c \). Therefore, if \( c \leq c^* \), the manufacturer’s profit is greater under the separating equilibrium with dynamic pricing than the profit under the pooling equilibrium. In sum, the separating equilibrium with dynamic pricing is preferred to both the profit under the semi-separating equilibrium and the profit under the pooling equilibrium when \( c \in (c^*,c^{**}) \).

\[ \square \]

**Proof of Proposition 3**

*Proof.* It is obvious that \( \frac{\partial \Delta w}{\partial a} = -\frac{1}{4} < 0 \), \( \frac{\partial \Delta w}{\partial d} = \frac{d^2 - 16c}{8d^2} < 0 \) when \( c \geq \frac{1}{16}d^2 \). Under the region where \( \frac{d(2a-d)}{16} \leq c \), we have \( \frac{d^2}{16} \leq c \) because \( a > d \). Finally, \( \frac{\partial \Delta w}{\partial c} = \frac{2}{d} > 0 \).

\[ \square \]

**Proof of Proposition 5**

*Proof.* \( \mathbb{E}_\theta[\Pi^{MD} + \mathbb{E}_\theta[\Pi^{RD}] - \{ \mathbb{E}_\theta[\Pi^{MM} + \mathbb{E}_\theta[\Pi^{RM}] \} = \frac{(d(2a-d)-16c)(d(10a+3d)-16c)}{256d^2} > 0 \) if \( c > \frac{(2a-d)d}{16} \). Furthermore, \( \mathbb{E}_\theta[\Pi^{MD}] - \mathbb{E}_\theta[\Pi^{MM}] = \frac{(d(2a-d)-16c)^2}{128d^2} < 0 \); \( \mathbb{E}_\theta[\Pi^{RD}] - \mathbb{E}_\theta[\Pi^{RM}] = \frac{(16c-d(2a-d))(16c+d(6a+5d))}{256d^2} > 0 \) if \( c > \frac{(2a-d)d}{16} \).

\[ \square \]

**Proof of Proposition 6**

*Proof.* \( \mathbb{E}_\theta[\Pi^{MD}] + \mathbb{E}_\theta[\Pi^{RD}] \) = \( \frac{19a^2}{64} + \frac{3ac}{4d} + \frac{25ad}{64} + \frac{55d^2}{256} - \frac{7c}{8} - \frac{c^2}{2d} \) and \( \mathbb{E}_\theta[\Pi^{MC}] + \mathbb{E}_\theta[\Pi^{RC}] = \frac{3a(a+d)}{8} + \frac{7d^2}{32} - c \). If we compare the supply chain efficiency under the dynamic pricing equilibrium and that under commitment, \( \mathbb{E}_\theta[\Pi^{MD}] + \mathbb{E}_\theta[\Pi^{RD}] > \mathbb{E}_\theta[\Pi^{MC}] + \mathbb{E}_\theta[\Pi^{RC}] \) when \( c \in \left( \frac{d(2a-d)}{16}, \frac{d(2a-d)+d^2}{4(a+3d)} \right) \). Also, \( \mathbb{E}_\theta[\Pi^{MD}] - \mathbb{E}_\theta[\Pi^{MC}] = \frac{(d(2a-d)-16c)(d(3d-2a)+16c)}{128d^2} > 0 \) when \( c \in \left( \frac{d(2a-d)}{16}, \frac{d(2a-d)+d^2}{4(a+3d)} \right) \). \( \mathbb{E}_\theta[\Pi^{RD}] - \mathbb{E}_\theta[\Pi^{RC}] = \frac{ac}{4d} + \frac{c^2}{2d^2} - \frac{3a^2}{64} + \frac{2c^2}{8} - \frac{ad}{64} - \frac{7d^2}{256} > 0 \) when \( c \in \left( \frac{d(2a-d)}{16}, \frac{d(2a-d)+d^2}{4(a+3d)} \right) \).

Note that after a few algebraic steps, we can confirm \( \xi \equiv \frac{d(4\sqrt{a^2+ad+d^2}-(2a+3d))}{16} > \frac{d(6a+d-4\sqrt{a(a+d)})}{16} \) and \( \xi \equiv \frac{d(4\sqrt{a^2+ad+d^2}-(2a+3d))}{16} > c^* \equiv \frac{d(2a-d)}{16} \). Further, \( c^{**} \equiv \frac{d(2a-d)}{16} + \frac{d^2(a+d)}{4(a+3d)} > \tilde{c} \equiv \frac{d(2a+d)}{16} \).

This confirms that \( c^* < \xi \) and \( \xi < c^{**} \). Therefore, when \( c \in (\xi,\tilde{c}) \), \( \mathbb{E}_\theta[\Pi^{MD}] + \mathbb{E}_\theta[\Pi^{RD}] > \mathbb{E}_\theta[\Pi^{MC}] + \mathbb{E}_\theta[\Pi^{RC}] \), \( \mathbb{E}_\theta[\Pi^{MD}] > \mathbb{E}_\theta[\Pi^{MC}] \), and \( \mathbb{E}_\theta[\Pi^{RD}] > \mathbb{E}_\theta[\Pi^{RC}] \).

\[ \square \]
Proof of Proposition 7

Working backwards in the game, consider first the contractual outcome in period two under two scenarios: (a) period 1 presents a fully-revealing equilibrium; and (b) the period 1 outcome leaves uncertainty about the retailer’s type.

(a) Period 1 presents a fully-revealing equilibrium case: In this case, since the manufacturer knows the retailer’s type, it is straightforward to show that the period 2 contract is written such that the marginal tariff ensures maximum supply chain profit and the fixed fee extracts the entire profit, i.e., when $\theta = \theta_L(\theta = \theta_H)$, $t = 0$ ($t = 0$) and $F = \frac{a^2}{4}$ ($F = \frac{a^2}{4} + \frac{d(2a + d)}{4} - c$).

(b) Period 1 outcome leaves uncertainty about the retailer’s type: In this case, denote the manufacturer’s belief that $\theta = \theta_H$ by $\tilde{\mu}$, where $\tilde{\mu} = \frac{1-\beta}{2-\beta} \leq \frac{1}{2}$ (this is assured given the nature of the information environment – a $\theta_H$-type retailer can mimic a $\theta_L$-type retailer but not vice-versa, so any outcome yielding type-uncertainty necessarily involves an ex-ant post belief not more than the ex ante belief). Given the ability to commit to the contract governing the remainder of the game, it is without loss of generality (Myerson 1979) to consider a menu of contracts that fully reveals retailer type. Denote the menu of contracts by $\{(F_L^2, t_L^2), (F_H^2, t_H^2)\}$. As typical in adverse selection games, the binding constraints will be those that (i) ensure truth-telling when $\theta = \theta_H$ and (ii) ensure participation when $\theta = \theta_L$. (This is readily confirmed by solving the equilibrium dropping the other constraints and showing that the solution satisfies the remaining constraints as well.)

Using these binding constraints to solve for fixed fees, plugging into the manufacturer’s expected second period profit expression, and optimizing marginal tariffs yields $t_L^2 = \frac{d\tilde{\mu}}{1 - \tilde{\mu}}$ and $t_H^2 = 0$, and thereby $F_L^2 = \frac{1}{4} \left[a - \frac{d\tilde{\mu}}{1 - \tilde{\mu}}\right]^2$ and $F_H^2 = \frac{1}{4} \left[a^2 + \frac{2d^2\tilde{\mu}}{1 - \tilde{\mu}}\right]$.

With these period 2 possibilities in place, consider first the period 1 contract under mandatory disclosure. In this regime, period 2 is, by construction, case (a) above regardless of how period 1 plays out. As a result of the deterministic period 2 outcome, the manufacturer’s
problem condenses to a one-period game of commitment and the Revelation Principle can thus be applied consider a fully-revealing equilibrium period 1 contract without loss of generality. Following the logic as in (b) above, with \( \mu = \frac{1}{2} \), confirms the optimal contract in part (i) of the proposition.

Now consider the outcome under dynamic pricing, denoting the menu of contracts \( \{F^1_L, t^1_L\}, \{F^1_H, t^1_H\} \). There are three possibilities for the chosen contract to induce:

(A) The period 1 contract induces full revelation, i.e., the menu ensures truth-telling.

(B) The period 1 contract induces a partially separating equilibrium, i.e., the menu ensures indifference when \( \theta = \theta_H \) in which case the retailer adopts a mixed strategy.

(C) The period 1 contract induces a pooling equilibrium, i.e., the menu provides the same contract to each type and ensures no investment when \( \theta = \theta_H \).

In case (A), we will again examine a simplified game in which only two constraints are in place: (i) when \( \theta = \theta_H \), the retailer will prefer to choose that contract and invest than to mimic \( \theta = \theta_L \) by choosing that contract and not investing; and (ii) when \( \theta = \theta_L \), the retailer’s expected profit from the chosen contract is nonnegative. Given the solution to this relaxed problem, we can readily confirm that the other omitted constraints are satisfied. In this case, if \( \theta = \theta_H \) and the retailer chooses the contract designed for \( \theta = \theta_H \), it gets that contract for period 1. However, it can get the lower fixed fee in period 2 as long as it deviates and opts not to invest in period one, i.e., the fixed fee saving (including the investment cost saving \( c \)) is \( F = \frac{a^2}{4} \) vs. \( F = \frac{a^2}{4} + \frac{d(2a+d)}{4} - c \). Using these binding constraints to solve for fixed fees, plugging into the manufacturer’s expected second period profit expression given full revelation, and optimizing marginal tariffs yields \( t^1_L = 0 \) and \( t^1_H = 0 \), and \( F^1_L = \frac{a^2}{4} \) and \( F^1_H = \frac{a^2}{4} \).

In cases (B) and (C), again consider the preferred period one contract of the manufacturer under a relaxed optimization problem in which only two constraints are in place. If we can demonstrate that case (A) is preferred even under this relaxed game, it is ensured to be preferred to the optimal contractual solution under (B) or (C). Say that when \( \theta = \theta_H \), the
retailer chooses the $\theta = \theta_L$ contract with probability $1 - \beta \in (0, 1)$ corresponds to case (B), and $\beta = 0$ corresponds to case (C). In order for this to be viable, it must again be the case that when $\theta = \theta_H$, the retailer is indifferent between the two contract possibilities. In this case, the ensuing period two contract when the $\theta = \theta_H$ contract is chosen in period one is as in (a); in contrast, the period two contract when the $\theta = \theta_L$ contract and no investment is chosen is as in (b) with $\tilde{\mu} = \frac{1 - \beta}{1 - \frac{a}{2} + \frac{d}{2}} = \frac{1 - \beta}{2 - \beta}$. Using the indifference point for $\theta = \theta_H$ and the participation constraint when $\theta = \theta_L$ into the period one objective function and maximizing with respect to the marginal tariff yields $t_1^L = 0$ and $t_2^2 = 0$, and $F_1^L = \frac{a^2}{4}$ and $F_1^H = \frac{a^2}{4} + \frac{d^2(1 - \beta)}{2}$. Note from the contractual form that this particular contract may not satisfy the additional constraints when they are included. Nonetheless, comparing expected manufacturer profit under contracts in this relaxed game to those under part (A) confirms that expected profit under part (A) is higher for all $\beta \in (0, 1)$ (given $a \geq d$ and $c \leq \frac{ad}{2}$). Since (A) is preferred to the optimal contract in the relaxed game, it is assured to be preferred to the contract that solves the one subject to additional constraints. This confirms part (ii) of the proposition.

Part (iii) of the proposition follows from two observations. First, the second period outcomes are identical under both mandatory disclosure and dynamic pricing. Second, while both cases ensure channel-optimizing (first-best) investment levels in period one, only dynamic pricing prescribes a period one marginal tariff that permits first-best retail pricing.
References


