Don’t Ask, Don’t Tell: Sharing Revenues with a Dishonest Retailer

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When different supply chain parties have private information, some form of information sharing is required to improve supply chain performance. However, it might be difficult to ensure truthful information transfer when firms can benefit from distorting their private information. To investigate the impact of dishonest information transfer, we consider a single-supplier single-retailer supply chain that operates under a contract with a revenue sharing clause, providing the retailer incentive to underreport sales revenues. In practice, suppliers utilize audits based on statistical tools that, for example, compare the retailers’ sales reports and order quantities to limit, but not necessarily eliminate, cheating. We investigate the impact of such limited cheating on the different supply chain constituents. We show that when the retailer can exert sales effort, a supplier might benefit from the retailer’s dishonesty. Our findings also suggest that if the retailer’s negotiation power is high or if retailer effort is effective, the supplier should reduce the retailer’s revenue share and absorb some of the demand risk to increase retailer participation. When facing a less powerful or less capable retailer, the supplier might be better off extracting profitability upfront through a higher wholesale price.

Keywords: supply chain management, supply chain conflict, information sharing, asymmetric information, dishonesty, revenue-sharing contracts

1. Introduction

Supply chains where firms have private information are exposed to inefficiencies due to double marginalization and information asymmetry. The concept of double marginalization is often associated with the problems that arise as individual parties in a supply chain make their decisions following their own individual incentives, which are usually not aligned with the incentives of the overall supply chain. Over the last years, there has been extensive research on supply chain coordination, and different contract formats have been suggested to align the individual incentives in a supply chain. Sharing sales revenues between a seller and a supplier is one possible way to eliminate or at least mitigate the inefficiencies resulting from double marginalization. In a supply chain where a supplier sells a single good to a single (or multiple noncompeting) retailer(s), Cachon and Lariviere (2005) show contracts based on revenue sharing can coordinate the supply chain and induce an arbitrary profit allocation between the firms\(^1\). Sharing of revenues is not only a feature of revenue-sharing contracts but also of franchise contracts, where revenue sharing is implemented through royalty fees.

Inefficiencies due to information asymmetry arise since not all parties in the supply have access to all relevant information. While there has been some research on how to elicit this private knowledge or to induce explicit information sharing, complications arise if firms have the ability and incentives to

\(^1\) In the context of VHS rentals, Gerchak, Cho, and Ray (2006) show that the coordinating revenue-sharing contract does not achieve an arbitrary allocation of profits when the retailer’s tape switching and holding costs are considered.
strategically distort the transferred information. In this paper we study a supply chain where incentives for such information distortion exist. We consider a supply chain setting where revenue is shared between the supplier and the retailer, such that the retailer, who actually collects the revenues, has incentive to underreport them. We focus on the informational dynamics that arise when the retailer’s demand and sales effort are private information.

Under contracts with revenue sharing, the supplier, who cannot observe the revenues being generated, must install the means to monitor revenues to guard himself against dishonest reporting (Varian 2001). However, continuous and perfect monitoring is rarely possible or feasible. Instead, suppliers may conduct random audits of retailers with the hope that such random audits will deter or minimize dishonest reporting. There are now a number of companies (e.g., Audigence, KPMG, etc.), who offer contract compliance services to suppliers to uncover underreporting and noncompliance to contracts. These companies, in addition to performing the actual audit, provide services that help suppliers focus their audit efforts on those companies that are most likely to be underreporting. Using data such as the amount of goods the retailer purchased from the supplier, the location of the retailer, etc., these companies provide an estimate of how much revenue the retailer should generate. If the difference between the estimated and reported revenues is too large, the retailer in question is targeted for an audit. While prohibitive costs and implementation issues are often cited as reasons why audits cannot completely eliminate cheating in practice, Heese and Kemahlioglu Ziya (2014) show that completely eliminating cheating is not in the best interest of the supplier even if auditing is free. In this paper, we analyze a related but different scenario. We focus on a situation where the supplier has formed an expectation regarding how an honest retailer would behave. Any sales reports that do not conform to these expectations result in such dire consequences for the retailer that he always chooses to appear honest and never triggers an audit. In addition, different from Heese and Kemahlioglu Ziya, we assume that the retailer can exert unobservable effort to increase demand.

We consider a stylized supply chain with a single retailer and a single supplier, operating under a contract that stipulates sharing of revenues between them. In each period, the market size of the retailer is either low (with probability $p$) or high (with probability $1-p$), and the probability of low demand can be reduced through retailer effort. While the retailer knows the true value of $p$, the supplier does not. Note that our model of demand information asymmetry is different from and more complex than the one most often used in the literature, where the retailer privately knows whether she will face high or low demand (denoted as the retailer’s type) before she places an order with the supplier. In our model, the retailer only knows the probability with which she will face high or low demand, so infinitely many retailer types are possible. Since the supplier neither knows $p$ nor observes sales, he relies on the retailer’s sales reports to estimate demand. We assume that the supplier is following an auditing strategy that tracks for obvious
inconsistencies between the retailer’s purchasing and sales reporting behavior and will audit her if there are notable inconsistencies (we define the exact mechanism in the following sections).

Our first goal in this paper is to analyze how dishonesty (i.e., underreporting of sales) affects the decisions of the retailer and impacts supplier and supply chain profits. To benchmark the results, we first analyze the behavior of an honest retailer, that is, one who reports sales truthfully, and we address the following questions: How does a dishonest retailer’s order quantity and sales effort differ from that of an honest retailer? How does dishonesty affect the supplier and the supply chain? Not surprisingly, we find that a dishonest retailer orders for the high-demand scenario for a wider range of parameter values than an honest retailer and is more likely to exert sales effort. Underreporting by the retailer never causes a decrease in supply chain profits and sometimes results in an increase. We characterize the parameter regions where the latter happens.

Our second goal is to gain insights with respect to the question of how a supplier should adjust his objectives in contract term negotiations when suspecting the retailer is dishonest. Our intent here is not to design a mechanism that coordinates the channel, but rather to understand how a contract with a revenue sharing clause works in a channel, where the retailer can underreport revenues. Note that under our model of information asymmetry, it would be very difficult for a (Stackelberg) supplier to design a simple contract that coordinates the channel and extracts all profit. For example, two-part tariffs are used to coordinate the supply chain in many different settings, as they allow the supplier to align the incentives through marginal cost pricing and then extract all surplus through a fixed fee (“selling the firm”). In our context however, the supplier does not know the retailer’s demand distribution, so it would be impossible to determine the size of the fixed transfer payment. Designing a contract that elicits truthful demand information (i.e., the value of $p$) from a potentially dishonest retailer is not our objective either. It may be possible to elicit truthful information using a contract that is designed based on the principal-agent framework and mechanism design principles, but such contracts are usually complex to implement and require the supplier to make take-it-or-leave-it offers where, in practice, contract terms are usually determined through negotiations such that the player with the higher bargaining power receives more favorable terms. Our goal is to provide insights regarding favorable contract terms for a supplier, who faces a potentially dishonest retailer. Therefore, given a distribution of bargaining power between the supplier and the retailer (defined as the ratio of retailer margin to supply-chain margin), we derive insights as to what the supplier should aim for in contract negotiations when the retailer is prone to underreporting sales.

Intuition suggests that when the supplier cannot verify sales and the retailer underreports revenues, the supplier might favor a wholesale price-only contract over a revenue-sharing contract to reduce his exposure to cheating. Comparing the supplier’s profits under a wholesale price-only contract that eliminates cheating with those under a revenue-sharing contract that increases his exposure to cheating,
we derive some insight into when a supplier might prefer to absorb either more or less risk. Surprisingly, our results suggest that the supplier will often prefer a revenue-sharing contract, even when facing a dishonest retailer.

Our results have several practical implications. The need to monitor revenues accurately has long been cited as a barrier against the implementation of revenue-sharing contracts. Our results show that this is not necessarily a concern and, as long as blatant cheating can be prevented, leaving some room for underreporting may improve supplier and supply chain profits by aligning the retailer’s decisions with those of the supply chain. We also provide insights for suppliers regarding contract choice when faced with a dishonest retailer. We find that suppliers may be better off using revenue-sharing contracts when the retailer’s bargaining power is high and a wholesale price-only contract if the retailer’s negotiation power is low. We show that there exists an all units quantity discount contract that coordinates the supply chain and which, by design, is not subject to underreporting risk. Hence, intuition might suggest that the supplier would always be better off using that contract over revenue sharing when faced with a dishonest retailer. However, from our numerical study, we observe that the supplier is making at least as much money under a revenue-sharing contract (with limited underreporting) as under the best coordinating quantity discount contract. The managerial implication of this observation, again, is that a revenue-sharing contract that leaves some room for underreporting might be an attractive contract choice for the supplier as long as he is able to prevent blatant cheating.

2. Literature Review
The different constituents of a supply chain have access to different types of information, and there is a wide body of research on the impact of making such information accessible to all supply chain members. When information is easily verifiable, the question most often is how to optimally use that shared information, and under what circumstances such information is most valuable (e.g., Gavirneni, Kapuscinski, & Tayur, 1999; Cachon & Fisher, 2000; Lee, So, & Tang, 2000; Aviv, 2001). However, as is the case in our work, when information is private and difficult or impossible to verify, a key problem is how to induce truthful sharing of this information to begin with. Most of the research on information asymmetry in supply chains focuses on deriving contracts that induce truthful information revelation, some of which use the principal-agent framework and mechanism design principles. There is a broad literature studying information asymmetry regarding different supply chain parameters, the most common being demand and costs (e.g., Corbett & Tang, 1999; Corbett & deGroote, 2000; Ha, 2001). We review the literature studying asymmetric demand information in greater detail since it is this demand information asymmetry that enables the retailer to cheat and report lower revenues. Porteus and Whang (1999) and Cachon and Lariviere (2001) are relevant to our work because they study supply chains where the buyer has private information about demand. In Porteus and Whang (1999) the supplier offers the
contract with the aim of eliciting truthful information while in Cachon and Lariviere (2001) the buyer offers the contract with the aim of signaling that the revealed information is truthful. Variations studied include nonlinear price capacity reservation and advance purchase contracts (Özer & Wei, 2006), quantity-discount contracts (Burnetas, Gilbert, & Smith, 2007), forward and options contracts (Li, Ritchken, & Wang, 2009), commitment-penalty contracts (Gan, Sethi, & Zhou, 2010), and buy-back contracts (Babich, Li, Ritchken, & Wang, 2012). Egri and Vancza (2013) study a supply chain with a single supplier and multiple retailers, where the supplier’s production cost and the retailers’ demand forecasts are private information. They derive the optimal contract based on mechanism design theory and show that it can be implemented through retailers’ paying for vendor managed inventory services. Kostamis and Duenyas (2011) characterize the optimal contract for a supplier who sells to an OEM where the demand and assembly cost of the OEM are unknown to the supplier. This is a two dimensional screening problem and the authors show that the OEM does not always benefit from higher dimensions of information asymmetry but the supply chain does. Oh and Özer (2013) consider a situation where neither the supplier nor the manufacturer have complete knowledge about demand and their forecasts are dynamically evolving. Their work proposes a new approach to solving dynamic mechanism design problems. Simester and Zhang (2014) model a supply chain where the customer faces high or low demand and the firm does not know the demand state. Different from our model, the customer’s willingness to pay depends on the demand state and the effort exerted by sales representatives (in our model, effort reduces the probability of low demand). The authors compare pricing delegation, lobbying and verification as mechanisms to elicit truthful information. While the work by Simester and Zhang (2014) has some common features with our model, our research focus is different. In their paper, unless the firm learns the true demand state, it cannot price the product correctly. Hence, the authors study contracts that elicit truthful information. We, on the other hand, are interested in understanding if/when the supplier can be better off under inaccurate information. Lau and Lau (2001) take a different approach and rather than deriving a menu of contracts that elicit truthful information from the retailer, they model a supplier who offers a contract based on his incomplete demand information and show that the real expected supplier profit may be higher than the perceived expected profit, so the supplier is not necessarily worse off because the retailer has superior demand information. Similar to our approach, Liu and Özer (2010) also refrain from using screening mechanisms to elicit truthful information, but their context and research questions are different. They model a supply chain where the manufacturer introduces a new product and has more information than the retailer. They investigate if simple contracts incentivize the manufacturer to share this information with the retailer. A potential consequence of asymmetric information is information leakage from an informed party to an uninformed one through an

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Burnetas et al. also derive the supplier’s optimal contract based on mechanism design and compare its performance with the all-units and incremental quantity discount contracts, which they argue are easier to operationalize.
intermediary. Anand and Goyal (2009) and Kong, Rajagopalan, and Zhang (2013) study this problem under wholesale-price and revenue-sharing contracts, respectively. Their research questions are different from ours, but, similar to our paper, they mainly focus on the consequences of using a given contract under information asymmetry, rather than on deriving optimal contracts.

A common assumption of the literature on truth-inducing contracts is that a leading party (most often a Stackelberg supplier) with subjective prior beliefs regarding the distribution of retailer types makes a take-it-or-leave-it offer, in an attempt to maximize his own profitability (based on his beliefs). While this setup enables the design of menus of contracts that achieve truthful information revelation and supply chain coordination, it seems to conflict with many observations of practice, where most contracts have much simpler structures than the ones proposed in this body of research, and where firms determine the terms of these contracts through negotiations. Recent experimental research by Kalkanci, Chen, and Erhun (2011) also shows that, in practice, suppliers often are unable to set the parameters of complex contracts optimally and hence, the real profit gains are much lower than the theoretical, anticipated gains. Our paper contributes to this discussion by showing that the supplier does not have to use complex, truth-inducing contracts in order to increase his profits over a wholesale price contract. A two-parameter revenue-sharing contract that leaves some room for misreporting of revenues might be sufficient. In addition, we provide some insights for designing revenue-sharing contracts under demand information asymmetry without assuming that the supplier is the powerful party that can make a take-it-or-leave-it offer. We show that if the retailer’s negotiation power is high or if retailer effort is effective, the supplier’s loss due to his lack of knowledge on the demand distribution might not be substantial. Our paper complements the literature studying contracts that achieve truthful information revelation by showing that untruthful information sharing may be another strategy to explore for increasing supplier and supply chain profits in the presence of information asymmetry.

While much of the supply chain management literature focuses on designing contracts that elicit truthful information sharing, researchers in other fields, for example sharecropping (e.g., de Janvry & Sadoulet, 2007) and tax evasion (see Sandmo (2005) for a review), explicitly study the phenomenon of untruthful information sharing. In sharecropping, the principal (the landowner) rents land to the agent (the renter) and shares output, whose size depends on unobservable renter effort and stochastic environmental factors. This literature identifies conditions where all parties may benefit from underreporting by the renter. Similarly, in the context of taxation the agent has incentive to underreport income to the principal, and much of the literature focuses on designing audit mechanisms to eliminate or limit cheating (e.g., Townsend, 1979; Border & Sobel, 1985; Scotchmer, 1987; Sanchez & Sobel, 1993). These papers are clearly related to our work since we consider a supply chain with a dishonest retailer who provides the supplier with distorted information whenever such untruthful reporting is beneficial. However, the insights from the research on sharecropping and tax evasion do not readily carry over to our supply chain
setting, where the agent (the retailer) not only shares revenues with the principal (the supplier) but also orders inventory. This “ordering” fundamentally changes the problem and the analysis. The agent (the retailer) reveals some information to the principal (the supplier) through her order quantity, which needs to be taken into account when analyzing the reporting behavior of a dishonest retailer.

Like the current paper, Gerchak and Khmelnitsky (2003) and Gerchak, Khmelnitsky, and Robinson (2007) also explicitly consider the possibility that a retailer might provide the supplier with manipulated demand information in the context of revenue sharing. Gerchak and Khmelnitsky (2003) consider a supply chain with a single supplier and a single retailer under a vendor-managed revenue-sharing arrangement. The retailer provides the supplier demand information in terms of sales reports, which the supplier uses to determine the optimal stocking quantity. They show that untruthful behavior by a retailer can eliminate the problem of double marginalization in a decentralized supply chain, thus leading to supply chain coordination. Gerchak et al. (2007) consider the same problem under the assumption that the retailer provides the supplier information about the demand probability distribution, which must be consistent with the retailer’s sales reports. They find that the retailer will cheat the supplier, constructing a (degenerate) demand distribution that leads the supplier to provide the system-optimal inventory level. Whereas Gerchak and Khmelnitsky (2003) and Gerchak et al. (2007) consider a setting with vendor-managed inventory, we study a scenario where the retailer determines her own order quantities. This difference is important because, in our model, the supplier might detect untruthful reporting by comparing the retailer’s order quantities and sales reports.

Heese and Kemahlioglu Ziya (2014) also model a single-supplier single-retailer supply chain where the retailer purchases from the supplier under a revenue-sharing contract. Using a general demand model, they show that it is not optimal for the supplier to completely eliminate cheating through audits even if auditing is free. Given their result, in this paper we do not model the auditing decisions of the supplier explicitly. Instead, we assume that the supplier has formed an expectation regarding how an honest retailer would behave; knowing this and given the dire consequences (e.g., termination of contract) of behaving differently, the retailer always acts rationally and makes sure to appear honest. By definition, this rational behavior allows some underreporting but no blatant cheating. Also different from Heese and Kemahlioglu Ziya (2014), in this paper the retailer can exert costly effort that increases demand, but is unobservable to the supplier. We show that under this new set of assumptions, the supplier can still benefit from retailer cheating and our model allows us to characterize the regions where such benefit would accrue to the supplier. Wu and Babich (2012) study misreporting in a context where a power plant is under contract to sell electricity to a distributor at a fixed price, contingent on the fact that the power plant is operational. If the plant can buy cheap electricity at the spot market, it can report up status even if it is down and sell the distributor electricity bought on the spot market. Even though their context and the
underlying model are significantly different from ours, they also find that misreporting can be beneficial to both parties, as it allocates risk more efficiently.

3. Model Preliminaries
We consider a supply chain with a single supplier and a single retailer, but the insights of our model also apply to the case where the supplier faces multiple independent retailers. The supplier produces a product at per-unit cost $c$, which we normalize to $c = 0$, without loss of generality. The supplier supplies the retailer following a revenue-sharing contract, which stipulates that the retailer pays the supplier a per-unit wholesale price $w$ at the beginning of the period, and then – after sales have been realized – a fixed fraction $1-g$ of the sales revenues. The retailer determines how many products to stock for sale to customers, and collects a per-unit revenue $r$ for each sold product. We assume the product is perishable and a unit left over at the end of the period yields the retailer a salvage value $s$; we follow Chopra and Meindl (2007) and assume that salvage revenues are not shared with the supplier. To exclude trivial parameter settings, we assume $gr > w > s \geq 0$.

We assume that demand is either low ($L$) with probability $p$ or high ($H$) with probability $1-p$. Considering the problem of information management in a supply chain with information asymmetries, Anand and Goyal (2009) make a similar assumption about the support of the intercept in a linear demand function, and they argue that this assumption is necessary in settings with incomplete information, the analysis of which is often mathematically intractable otherwise (cf. page 443). They also cite various studies suggesting that models based on binary and continuous supports often yield very similar insights, and that few, if any, additional insights can be gained by relaxing the assumption of binary support (cf. Milgrom & Roberts, 1982; Laffont & Martimort, 2002; Bolton & Dewatripoint, 2005). Since the retailer can observe demand directly, we assume that she knows the probability of low demand ($p$). The supplier on the other hand can only guess $p$, and he depends on the retailer’s orders and sales reports to derive his estimates. In the following, we will also refer to $p$ as a retailer’s type. Note that our model of information asymmetry is different from and more complex than the approach used in most of the related literature. There are infinitely many different types of retailers, and a retailer’s private information does not entail her demand state, but rather information on the distribution of demand states.

Consider a repeated newsvendor problem (similar to Gerchak et al., 2007). At the start of each period, the retailer determines her order quantity ($H$ or $L$) and whether to exert demand-increasing sales effort. Specifically, in each period the retailer has the option of exerting effort at an expense $A$, and this effort reduces the probability of low demand from $p$ to $p/B$, where $B > 1$. The retailer then observes the state of demand, satisfies demand to the extent possible, and reports demand to the supplier, paying him his fraction of the corresponding sales revenues. Let $\hat{p} \in [0,1]$ denote the long-run proportion of low-demand reports provided by the retailer. The supplier can neither observe demand nor the retailer’s sales,
so the retailer’s reports are his only information about demand. However, the retailer might not always report truthfully, i.e., \( p^* \) is not necessarily equal to the actual probability of low demand faced by the retailer. If she stocked \( H \) and demand turned out to be high, she might (deceptively) report to the supplier that demand had been low, thus cheating the supplier out of part of his just share of sales revenues. We assume that the supplier knows the possible demand scenarios (i.e., the values of \( L \) and \( H \)), but he is uncertain about the retailer’s type, i.e., the probability of either outcome.

Clearly, reporting high sales to the supplier is costly to the retailer since it is associated with a larger transfer payment. On the other hand, the retailer cannot afford to continuously order to meet high demand, while reporting to the supplier that demand was low, as the supplier would suspect cheating if her behavior was obviously inconsistent with that of an honest retailer. This fact forms the basis of the supplier’s auditing strategy. The supplier announces the frequency with which audit reviews will be conducted (in practice such reviews usually coincide with financial review cycles). Over this period of time, the supplier observes \( \hat{p} \), the long-run proportion of low-demand reports provided by the retailer. If, given a history of ordering decisions, \( \hat{p} \) is not consistent with a possible reporting strategy of an honest retailer, the supplier audits the retailer. We formally define and characterize the supplier’s auditing strategy in the following sections.

4. Behavior of An Honest Retailer

In this section we derive the optimal behavior for an honest retailer. We first determine the optimal ordering and sales effort policy and then characterize the reporting of an honest retailer. While an honest retailer by definition reports honestly, this characterization is still needed as a baseline for the supplier’s audit policy.

In our environment with stationary parameters and without inventory holding between periods, the optimal ordering policy must be stationary, and the optimal order quantity will be either \( L \) or \( H \). Clearly, the retailer will never exert effort to increase the likelihood of the high-demand scenario, unless she orders for the high-demand scenario. Using \( Q \) to denote the retailer’s order quantity and \( E \) to denote her effort decision (0 or \( A \)), three possible profit functions need to be distinguished:

\[
\pi_r(Q = L, E = 0) = -wL + grL \quad (1)
\]

\[
\pi_r(Q = H, E = 0) = -wH + p(grL + s(H - L)) + (1 - p)grH \quad (2)
\]

\[
\pi_r(Q = H, E = A) = -wH + \frac{p}{B} (grL + s(H - L)) + \left(1 - \frac{p}{B}\right)grH - A \quad (3)
\]

\footnote{Note that when \( Q = L \), whether demand is \( L \) or \( H \) is irrelevant and the retailer’s profit is \( -wL + grL \), since the maximum the retailer can sell is \( L \) and it is never optimal for the retailer to order \( L \) and exert effort at the same time.}
**Lemma 1:** When characterizing a retailer’s optimal decisions (honest or dishonest), the magnitude of the low-demand realization (L) can be normalized to zero without loss of generality.

Irrespective of the retailer’s ordering, effort, and reporting decisions, she will always sell at least \( L \) units at a per-unit margin of \( gr - w \), that is, she will always have the revenues described in (1). Hence, the retailer needs to decide whether to order an additional \( H - L \) units to be prepared for the high-demand scenario, and if so, whether to exert effort to increase the likelihood of high demand. Hence, in evaluating the associated trade-offs, the retailer only needs to consider the potential additional revenues, and \( L \) can be normalized without any loss of generality. Given Lemma 1, in the following we often focus on the normalized problem (with \( L = 0 \)). Rather than referring to the order quantity decision (\( H \) or \( L \)), we will refer to the retailer’s decision as whether to “participate” (i.e., whether to order for the high-demand scenario \( H \)) or not (i.e., ordering for the low-demand scenario \( L = 0 \)). Note that this normalization is merely for expositional simplicity, and all our results continue to hold otherwise. (Since this normalization does not affect the part of the profit function that depends on the retailer’s reporting strategy, it is also without loss of generality for a dishonest retailer case and hence does not affect the impact of cheating.) This normalization also facilitates the interpretation of our model in the context of digital distribution. In that context, rather than ordering physical products, the firm’s decision is whether to participate (i.e., purchase the right to distribute a product) or not. In this context, the cost \( w \) can be interpreted as a fixed (franchise) fee.

Given the retailer’s type \( p \), the retailer’s optimal strategy can be readily derived from comparing the three profit functions (1)-(3). For simplicity of exposition, define:

\[
\phi \equiv \frac{gr - w}{gr - s}
\]

(4)

\[
\alpha \equiv \frac{AB}{H(B-1)(gr - s)}
\]

(5)

As we will see in Proposition 1, these two thresholds determine whether an honest retailer participates (\( \phi \)) and exerts sales effort (\( \alpha \)).

**Proposition 1** (The optimal ordering and sales effort policy of an honest retailer):

a) \( \phi < \alpha \) : An honest retailer participates if and only if \( p \leq \phi \). She never exerts effort.

b) \( \phi \geq \alpha \) : An honest retailer participates if and only if \( p \leq B\phi - (B-1)\alpha \). She exerts effort if and only if \( \alpha < p \leq B\phi - (B-1)\alpha \). If \( p = \alpha \), an honest retailer is indifferent between exerting effort and not exerting effort.
Since \( \phi < 1 \) by definition, an honest retailer would never consider exerting effort if \( \alpha \geq 1 \). To avoid such trivial scenarios, in the following we focus on scenarios, where an honest retailer could potentially exert effort, that is, for the rest of the paper we assume

\[ \alpha < 1. \tag{6} \]

Consider an integrated supply chain. Since \( c = 0 \), from the supply chain’s perspective it would always be profitable to participate (i.e., to order \( H \)). It is easy to show (cf. Proof of Lemma A1 in the Appendix) that an integrated supply chain would find it profitable to invest in sales effort whenever the probability of the low-demand scenario is higher than \( \frac{gr-s}{r-s} \alpha \); a comparison with the results in Proposition 1 indicates the negative implications of double marginalization in the decentralized supply chain.

Next, we characterize the reporting of an honest retailer. By definition, an honest retailer always reports truthfully. However, we still characterize the reporting by an honest retailer because the auditing strategy of the supplier takes this behavior as a baseline and audits retailers whose reporting is inconsistent with it. Recall that \( \hat{p} \in [0,1] \) denotes the long-run proportion of low-demand reports. An honest retailer of type \( p \) would, by definition, report honestly, so her proportion of low-demand reports \( \hat{p} \) would be either \( p \) or \( \frac{p}{B} \), depending on whether she chose to exert effort or not. Using Proposition 1, we define the set of actions \( \Omega \) (i.e., order quantity \( Q \) and long-run proportion of low-demand reports \( \hat{p} \)) that the supplier could observe from an honest retailer. If \( \phi < \alpha \) then the set of observable actions of an honest retailer is \( \Omega^{\phi<\alpha} = \Omega_L^{\phi<\alpha} \cup \Omega_H^{\phi<\alpha} \), where \( \Omega_L^{\phi<\alpha} = \{(Q, \hat{p})|Q = L, \hat{p} > \phi \} \) and \( \Omega_H^{\phi<\alpha} = \{(Q, \hat{p})|Q = H, \hat{p} \leq \phi \} \). Similarly, if \( \phi \geq \alpha \), then \( \Omega^{\phi\geq\alpha} = \Omega_L^{\phi\geq\alpha} \cup \Omega_H^{\phi\geq\alpha} \), where \( \Omega_L^{\phi\geq\alpha} = \{(Q, \hat{p})|Q = L, \hat{p} > B\phi - (B-1)\alpha \} \) and \( \Omega_H^{\phi\geq\alpha} = \{(Q, \hat{p})|Q = H, \hat{p} \leq \text{MAX} \left( \alpha, \phi - \frac{B-1}{B} \alpha \right) \} \), where the two elements within the maximum operator reflect the fact that a participating honest retailer has the option to exert effort. Taking the two possible cases together, all possible observable actions of an honest retailer are given by

\[ \Omega = \begin{cases} \Omega_L^{\phi<\alpha}, & \text{if } \phi < \alpha \\ \Omega_H^{\phi<\alpha}, & \text{if } \phi \geq \alpha \end{cases}. \tag{7} \]
5. Behavior of a Dishonest Retailer

We start by formally defining the auditing strategy of the supplier as this drives the dishonest retailer’s behavior. With the information available to the supplier, he can correctly determine the set of all possible actions of an honest retailer as given by Equation (7). The supplier tries to detect cheating by identifying inconsistencies between the ordering and reporting of the retailer. An audit is triggered if the retailer’s behavior is not consistent with one that could be observed from an honest retailer (cf. Equation 7). We assume that the retailer is completely informed of the supplier’s auditing strategy. In addition, an audit covers the entire history of reports and the supplier’s sanctions in the event of confirmed cheating are severe. For example, if caught cheating, the retailer might not only have to repay the supplier for the missing share of revenues, but also have to compensate his auditing cost. An example is the audit clause of the contract between Blockbuster and Columbia Tristar Home Video (Contract, 1998). In some cases, fraud might also lead to penalty payments (either contractually agreed on or imposed through litigation), and/or the end of the business relation. The auditing strategy we propose is consistent with how revenues are monitored in the video rental industry with the help of Rentrak software. According to the information on Rentrak’s website (Rentrak, 2008), the software system keeps track of rental and sales transactions and “determines variations from statistical norms for potential audit action.” This implies that as long as the revenues reported through the Rentrak software are consistent with what is expected from a typical store, cheating is not suspected or pursued. Following a similar logic, the management consulting firm Audigence has a tool called Sales Monitoring Dashboard, which takes reported sales data, purchase data (captured by the order quantity in our model) and advertising spend (captured by the effort level in our model, which is unobservable) and calculates expected sales numbers. Locations where the reported sales data exhibits large variations from expected sales numbers over time are singled out for auditing (Audigence, 2013). Knowing how the auditing mechanism works, a dishonest retailer may cheat but never to the extent that would trigger an audit. For the different possible participation and effort decisions, the dishonest retailer’s profit, as a function of her proportion of low-demand reports, is (the profit without participation can again be normalized to 0):

\[
\hat{\pi}_r(Q = L = 0, E = 0, \hat{p}) = 0
\]

\[
\hat{\pi}_r(Q = H, E = 0, \hat{p}) = -wH + psH + (1 - p)rH - (1 - \hat{p})(1 - g)rH
\]

\[
\hat{\pi}_r(Q = H, E = A, \hat{p}) = -wH + \frac{p}{B} sH + \left(1 - \frac{p}{B}\right)rH - A - (1 - \hat{p})(1 - g)rH
\]

The dishonest retailer’s choice of the proportion of low-demand reports then is the result of the following optimization problem.
\[
\max_{\hat{p} \in \Omega} \hat{\pi}_b(\hat{p}) = \text{MAX}(\hat{\pi}_b(Q = L = 0, E = 0, \hat{p}), \hat{\pi}_b(Q = H, E = 0, \hat{p}), \hat{\pi}_b(Q = H, E = A, \hat{p})) \tag{11}
\]

**Lemma 2:** The dishonest retailer’s optimal proportion of low-demand reports is

\[
\hat{p}^* = \begin{cases} 
\phi, & \text{if } \phi < \alpha \\
\alpha, & \text{if } \alpha \leq \phi < \alpha \left( 2 - \frac{1}{B} \right) \\
\phi - \frac{B-1}{B} \alpha, & \text{otherwise.}
\end{cases}
\]

Reporting decisions are only relevant when the retailer orders for the high-demand scenario. The retailer’s reporting has no impact on her expected profits when she orders for the low-demand scenario (or, obviously, when \(L = 0\) and she does not participate), since her order quantity limits her payments to the supplier. When ordering for the high-demand scenario, the retailer’s expected profit from product sales are independent of her reports, which only affect the magnitude of transfer payments to the supplier. Hence, a dishonest retailer reports low demand as long as the condition given in Equation (7) is not violated; this maximum feasible proportion of low-demand reports in characterized in Lemma 2. In other words, independently of the actual demand realizations, the retailer submits low and high demand reports such that the long-run proportion of low-demand reports is as given in Lemma 2.

In the following proposition, we characterize a dishonest retailer’s optimal ordering, sales effort, and reporting strategies. We provide the result with respect to four intervals \(\phi\) may lie in, but we note that these intervals exhaust the whole spectrum of values that \(\phi\) may take in (0, 1), so the result is a complete characterization of a dishonest retailer’s behavior.

**Proposition 2** (The behavior of a dishonest retailer):

\begin{itemize}
  \item[a)] \(\phi < \frac{gr - s}{r - s} \alpha\) : A dishonest retailer participates and reports low demand a fraction \(\phi\) of the periods if and only if \(p \leq \phi\).
  \item[b)] \(\frac{gr - s}{r - s} \alpha \leq \phi < \alpha\) : A dishonest retailer participates and reports low demand a fraction \(\phi\) of the periods if and only if \(p \leq B\phi - (B - 1) \frac{gr - s}{r - s} \alpha\).
  \item[c)] \(\alpha \leq \phi < \left( 2 - \frac{1}{B} \right) \alpha\) : A dishonest retailer participates and reports low demand a fraction \(\alpha\) of the periods if and only if \(p \leq \frac{gr - s}{r - s} (B\phi + \alpha - 2B\alpha) + aB\).
\end{itemize}
d) $\phi \geq \left(2 - \frac{1}{B}\right)\alpha$: A dishonest retailer participates and reports low demand a fraction

$\phi - \frac{B - 1}{B} \alpha$ of the periods if and only if $p \leq B\phi - (B - 1)\alpha$.

In all cases, a participating dishonest retailer exerts effort if and only if $p \geq \frac{gr - s}{r - s} \alpha$.

When $\phi$ is small, similar to the honest retailer, the dishonest retailer participates if and only if the probability of low demand $p$ is less than $\phi$ (cf. Proposition 2, part a). The supplier knows that when $\phi$ is less than $\alpha$, the highest $p$ under which an honest retailer would participate is $\phi$, so the dishonest retailer submits low-demand reports with a proportion that equals $\phi$. When $\phi$ is somewhat higher, but still less than $\alpha$, the dishonest retailer participates as long as $p$ does not exceed $B\phi - (B - 1)\frac{gr - s}{r - s} \alpha$, which is always higher than $\phi$ (cf. part b). Over this range, the dishonest retailer participates for higher $p$ values than the honest retailer would, because she can exert effort, reduce the low-demand probability, but get away with reporting low demand in a fraction $\phi$ of the periods. Similarly, under the conditions given in Proposition 2, part c, the dishonest retailer participates for higher $p$ values than the honest retailer would, because she can exert effort to reduce the probability of low demand and still report low demand a proportion $\alpha$ of the time. Finally, when $\phi$ is sufficiently large (cf. part d), the dishonest retailer participates for the same range of $p$ values as an honest retailer would, but reports low demand in a fraction $\phi - \frac{B - 1}{B} \alpha$ of the periods, which is the probability of low demand above which an effort-exerting honest retailer would never participate.

Interestingly, we see that a dishonest retailer’s sales effort incentives are aligned with those of the supply chain (cf. proof of Lemma A1 in the Appendix). When demand is high, a dishonest retailer that exerts effort can keep all revenues on the additional sales, as it does not report these higher sales to the supplier. As a consequence, a dishonest retailer internalizes the complete benefit of effort, exerting effort in a supply chain optimal fashion.

6. The Impact of Cheating

We determine the impact of cheating on the retailer and the supplier, and we characterize environments where the impact of cheating is most or least pronounced.

Proposition 3 (The impact of cheating):

If a dishonest retailer does not participate, neither does an honest retailer, so both scenarios are identical. Consider the scenarios when a dishonest retailer participates (cf. Proposition 2).

a) Cheating increases supplier profits if only if
i) \( \phi < \alpha \) and \( \phi < p \leq B\phi - (B - 1)\frac{gr - s}{r - s} \alpha \), or

ii) \( \alpha \leq \phi \) and \( B\phi - (B - 1)\alpha < p \leq \frac{gr - s}{r - s} \left( B\phi + \alpha - 2B\alpha \right) + aB \).

b) Cheating increases supply chain profits if supplier profits increase (cf. part a) or if

\[
\frac{gr - s}{r - s} \alpha < p \leq \text{MIN}(\alpha, \phi).
\]

c) Otherwise, whenever a dishonest retailer participates, cheating only affects the transfer payment from the supplier to the retailer, leaving supply chain profits unaffected.

The results in Proposition 3 demonstrate that, surprisingly, cheating by the retailer may increase supplier and supply chain profits, and the proposition completely characterizes the parameter regions where this happens. Cheating may benefit the supply chain if a dishonest retailer participates when an honest retailer would not or if a participating dishonest retailer exerts effort when a participating honest retailer would not. A dishonest retailer needs to report a certain amount of sales to appear honest (cf. Lemma 2), and she keeps only a fraction \( g \) of these reported revenues. However, when demand is high and she underreports demand, she can retain all revenues on sales that exceed this minimum required quantity. Because of this higher marginal revenue under cheating, some retailer types can derive positive expected profit from participation only if they are dishonest. In those cases, a dishonest retailer keeps all the benefits of sales effort for herself, so her sales effort incentives are aligned with those of the supply chain and under the conditions given in Proposition 3, cheating increases overall system profitability.

The supplier can also benefit from the retailer’s dishonesty when the dishonest retailer participates and exerts effort in parameter regions where the honest retailer would not participate. The conditions in Proposition 3, part a, characterize such parameter regions. For retailer types \( p \) below the lower bounds given in parts a.i and a.ii, both honest and the dishonest retailers participate, whereas for types above the upper bounds, neither type of retailer participates. Hence, the supplier benefits from cheating only when the probability of low demand falls in the right range. Since the retailer always (weakly) benefits from cheating, supply chain profits always increase whenever supplier profits increase. In other words, the conditions in part a hold when the probability of low demand is high enough to prevent an honest retailer from participating, whereas a dishonest retailer finds it profitable to participate because she lowers the probability of low demand through exerting effort but reports as if no effort were exerted.

However, there is also a parameter region where supply chain profits increase as a result of cheating, while supplier profits decrease. In the parameter region characterized by Proposition 3, part b, both dishonest and honest retailers participate but only the dishonest retailer exerts effort. The dishonest retailer exerts effort, reduces the low-demand probability and increases her own and supply chain profits. However, recall that a dishonest retailer reports like the honest retailer type with the lowest probability of
high demand that would still participate. In other words, in this parameter region, the dishonest retailer mimics a retailer with higher probability of low demand, thus hurting the supplier.

7. **Insights with respect to Desirable Contract Terms**

The majority of the extant research on supply chain contracting considers the scenario where the supplier sets contract terms as Stackelberg leader. However, this is not realistic for many if not most supply chain environments, where contract terms are set through mutual negotiations. While there has been some research with focus on the details of such negotiations (e.g., Nagarajan & Bassok, 2008), given the specifics of the contract form (revenue sharing) and the potential of dishonest reporting in our case, we abstract from the details of such a process here. Rather, similar to the notion in Cachon (2004), we take the retailer’s fraction of the supply chain margin as a measure of her bargaining power and assume that it is fixed. Define the retailer’s bargaining power as follows.

\[
N = \frac{gr - w}{r}
\]

For any given value of \(N\), we consider the supplier’s and the retailer’s preferences with respect to the relative magnitudes of the two contract parameters (higher wholesale price coupled with higher retailer revenue share or lower wholesale price coupled with a lower retailer revenue share), deriving insights into the individual preferences regarding the distribution of risk and responsibility in the supply chain. We derive the supplier’s optimal contracts for the two canonical cases of an honest and a dishonest retailer and we compare these contracts to gain insights into how a supplier should adjust his objectives in contract negotiations when he suspects that the retailer might underreport. If the supplier is uncertain with respect to whether he faces an honest or a dishonest retailer, the optimal contract adjustments due to dishonesty will be in the same direction as they would be if the supplier knew that the retailer was dishonest, though they might be less pronounced, depending on the likelihood that the supplier associates with facing a dishonest retailer. Also note that our model and our results easily apply to the case where a supplier designs a single contract for multiple retailers, some of which might be dishonest. In either case, we assume that the supplier offers a single contract, rather than a menu of contracts. While there has been wide research on the design of contracts that induce information revelation through self-selection, designing such a contract would be very difficult in this context with two levels of potential information asymmetry (retailer type and degree of honesty). Complex menus of contracts may also be difficult to administer, and most firms in practice use simple and identical contracts to regulate relations with many different retailers or franchisees. For example, McDonald’s uses the same franchise contract with all its franchisees, even though these franchisees differ widely in terms of restaurant and market characteristics (Kaufmann & Lafontaine, 1994). In addition, contract terms, especially the revenue share parameter, tend to remain remarkably stable over time, so there is empirical evidence that suppliers do not change
contract terms over time to gather information about the retailers they are working with (Bhattacharyya & Lafontaine, 1995).

We first derive insights regarding preferred contract terms for given (known) values of \( p \). We then step back and evaluate how these insights can help the supplier in negotiating contract terms when facing a dishonest retailer, even if he does not know her type (\( p \)).

For a fixed distribution of bargaining power between the supplier and the retailer, it can be shown that the low-demand realization can be normalized to zero without any loss of generality when considering the supplier’s preferences, too.

**Lemma 3**: For given negotiation power \( (N) \), when characterizing the supplier’s contract preferences, the magnitude of the low-demand realization \( (L) \) can be normalized to zero, without loss of generality.

**Proposition 4** (The retailer’s contract preferences): For given negotiation power \( (N) \), both an honest and a dishonest retailer prefer (strictly, if participating) contracts with lower wholesale price \((w)\) and lower retailer revenue share \((g)\).

**Proposition 5** (The supplier’s contract preferences): For given negotiation power \( (N) \) and facing a participating retailer (honest or dishonest), the supplier strictly prefers contracts with higher wholesale price \((w)\) and higher retailer revenue share \((g)\).

The results of Propositions 4 and 5 illustrate the conflict between the retailer’s and the supplier’s contract preferences. For a given level of bargaining power, the retailer prefers contracts with lower wholesale prices and retailer revenue shares, whereas the supplier is better off under contracts with higher wholesale prices and revenue shares. Payments transferred through the wholesale price are risk-free, whereas the transfers based on the revenue sharing part of the contract are subject to demand uncertainty. This finding is hence not surprising, as both parties prefer to increase (decrease) their revenues (costs) that are not subject to demand uncertainty.

However, note that the characterization of the supplier’s contract preferences in Proposition 5 assumes retailer participation, which might not hold for high wholesale prices and retailer revenue shares. Hence the supplier should be careful when negotiating the contract terms. We next provide some insights on the supplier’s preferences with regard to the revenue share \( g \), which in turn determines the value of \( w \) due to the fixed bargaining power. We first assume that the supplier knows the retailer’s type \( (p) \). Building on these results, we then derive insights into the supplier’s optimal strategy when negotiating with a retailer of unknown type. Define:

\[
\bar{N} \equiv \frac{AB}{Hr(B-1)}
\]  

(13)

The assumption \( \alpha < 1 \) (cf. Equation 6) implies that:
\[ N < 1 - \frac{s}{r} \]  

For expositional simplicity also define:

\[ g_a(p) \equiv \frac{N}{p} + \frac{s}{r} \]  

(15)

\[ g_c^h(p) \equiv \frac{N}{p} + \frac{s}{r} \]  

(16)

\[ g_b(p) = \frac{NH(r - s)B}{Hp(r - s) + AB} + \frac{s}{r} \]  

(17)

\[ g_c(p) = \frac{AB^2(r - s)}{rH(B - 1)(p(r - s) - BNr) + rAB(2B - 1)} + \frac{s}{r} \]  

(18)

\[ g_d(p) = \frac{BN}{p} - \frac{AB}{Hpr} + \frac{s}{r} \]  

(19)

**Proposition 6** (The supplier’s optimal contract – facing an honest retailer):

For given negotiation power \((N)\) and retailer type \((p)\):

a) If \(N < \bar{N}\), the supplier’s optimal contract satisfies \(g^*(p) = \min\{1, g_a(p)\}\).

b) If \(N \geq \bar{N}\), the supplier’s optimal contract satisfies \(g^*(p) = \min\{1, g_c^h(p)\}\).

**Proposition 7** (The supplier’s optimal contract – facing a dishonest retailer):

For given negotiation power \((N)\) and retailer type \((p)\):

a) If \(N < \bar{N}\), the supplier’s optimal contract satisfies

\[
\hat{g}_s^h(p) = \begin{cases} 
1, & \text{if } p \leq \frac{r}{r-s}N \\
g_a(p), & \text{if } \frac{r}{r-s}N < p < \frac{r}{r-s}\bar{N} \\
g_b(p), & \text{if } \frac{r}{r-s}\bar{N} \leq p
\end{cases}
\]

b) If \(N \geq \bar{N}\), the supplier’s optimal contract satisfies
A comparison of the results in Propositions 6 and 7 provides insights into how a retailer’s dishonesty affects the supplier’s optimal contract terms. It can be shown that \( g^*_h(p) < 1 \iff p > \frac{r}{r-s} N \) (cf. Lemma A3 in the Appendix), so we see that for relatively low values of \( p \) (with \( p \leq \frac{r}{r-s} N \)) a wholesale price-only contract is optimal for both an honest and a dishonest retailer. However, for higher values of \( p \), the supplier should try to offer a dishonest retailer a contract with a higher revenue share. For fixed negotiation powers, this implies a higher wholesale price such that the supplier extracts more profit upfront and thus reduces his exposure to cheating. Then, the results from Proposition 3 imply that the supplier can be better off, if the retailer cheats, even if the supplier sets the optimal contract assuming an honest retailer (cf. Lemma A4 in the Appendix). The supplier benefits as cheating leads a dishonest retailer to participate whereas an honest retailer would not. Considering the intervals where the supplier uses a higher revenue share when facing a dishonest retailer than he would when facing an honest retailer, interestingly it can be shown that the absolute magnitude of the increase in the optimal retailer revenue share becomes more pronounced as the retailer’s bargaining power increases (cf. Lemma A5 in the Appendix). A more powerful retailer can extract more additional profit from cheating, allowing the supplier to charge more money upfront without jeopardizing participation.

Figures 1 and 2 schematically illustrate the results of Propositions 6 and 7. Specifically, we plot the supplier’s preferred contract terms when facing an honest or a dishonest retailer for the case where the retailer’s bargaining power is low (i.e., \( N < \overline{N} \)) or high (i.e., \( N \geq \overline{N} \)), respectively. (In Figure 2, we consider the case where \( N < (2-1/B)\overline{N} \). The illustration for the alternate case is identical, except that the optimal retailer revenue share for a dishonest retailer is determined by \( g_d(p) \) rather than \( g_c(p) \).)
Figure 1: Optimal retailer revenue shares for $N < \bar{N}$

Figure 2: Optimal retailer revenue shares for $\bar{N} \leq N < \left(2 - 1/B\right)\bar{N}$
Propositions 6 and 7 define the supplier’s preferred contract terms when facing an honest or a dishonest retailer, assuming the retailer’s type $p$ is known to the supplier. More generally these findings suggest that the supplier might benefit from using a wholesale price-only contract if the retailer is more likely to face high demand (i.e., if $p$ is low). Then retailer participation is not an issue, and the supplier should increase the retailer’s revenue share to maximize his profits (cf. Proposition 5). If, on the other hand, the retailer is more likely to face low demand, the supplier might be better off negotiating a revenue-sharing contract to improve participation. In the following, based on the findings in Proposition 7, we aim to derive structural insights into the supplier’s optimal contract terms when facing a dishonest retailer, without assuming knowledge of the retailer’s type.

It follows directly from Proposition 7 that, when facing a dishonest retailer, the supplier’s optimal contract lies between the wholesale price-only contract (with $g = 1$) and the revenue-sharing contract that maximizes participation (with $g = \hat{g}^*_s (1)$), where the specific form of the contract depends on the retailer’s negotiation power. While it is not possible to determine the specific optimal contract without additional information on the distribution of retailer types, we can derive some insights by comparing the supplier’s profits at these two limiting contracts. When comparing these contracts, the supplier needs to trade-off the impact on revenues (subject to retailer participation) versus the probability that the retailer is of a participating type. Using a contract with a maximum revenue share of $g = 1$ (i.e., a wholesale price-only contract) increases revenues (for a participating retailer) when compared to choosing a lower revenue share of $g = \hat{g}^*_s (1) < 1$, but some retailer types (with $p > \frac{r}{r - s} N$ if $N < \bar{N}$ and with $p > \frac{r}{r - s} (BN - (B - 1)N)$ otherwise) will not participate under a wholesale price-only contract.

The normalization $L = 0$ (cf. Lemmas 1 and 3) implies zero profits if the retailer does not participate. A dishonest retailer’s reporting strategy is defined in Lemma 2. When facing a dishonest retailer who participates and submits a proportion $\hat{p}$ of low-demand reports, the supplier’s profit as a function of $g$ equals

$$\hat{\pi}_s (g) = (1 - N)rH - (1 - g)rH\hat{p}.$$  \hspace{1cm} (20)

Hence, when moving to a wholesale price-only contract, if the retailer participates, the supplier’s revenue increases by $\hat{\pi}_s (1) - \hat{\pi}_s (\hat{g}^*_s (1))$, but the supplier loses revenue of $\hat{\pi}_s (\hat{g}^*_s (1))$ if the retailer no longer participates. In the following, we derive insights with respect to how the magnitude of this potential upside of using higher revenue shares relates to the potential loss of revenue due to the retailer types who cease to participate. Specifically, we consider the ratio of $\hat{\pi}_s (1) - \hat{\pi}_s (\hat{g}^*_s (1))$ to $\hat{\pi}_s (\hat{g}^*_s (1))$, a
characterization of which provides insights into when the potential upside of increasing the revenue share is large compared to the potential downside, and vice versa. Define

\[
\chi = \frac{\hat{\pi}_S(1) - \hat{\pi}_S(\hat{g}_S^*(1))}{\hat{\pi}_S(\hat{g}_S^*(1))}
\]  

(21)

The numerator of this ratio captures the difference between the profits that a supplier obtains when using a contract that ensures retailer participation and the profit that he receives if he uses a wholesale price-only contract and the retailer participates. The denominator of the ratio reflects the profits that the supplier loses when the retailer does not participate under the wholesale price-only contract. The premise of our ensuing discussion is that, other things being equal, a larger ratio suggests that a wholesale price-only contract is more attractive, whereas a smaller ratio suggests that the supplier should extract some profitability through revenue sharing. The definition of \( \chi \) and hence the results in Proposition 8 are given for the dishonest retailer case since our main interest is in providing insights for the supplier when he faces a dishonest retailer.

**Proposition 8:** The ratio \( \chi \) decreases in the retailer’s negotiation power \( (N) \) and it increases as the retailer’s sales effort becomes less effective (i.e., as \( A \) increases or \( B \) decreases). It increases in the per-unit revenue \( (r) \) if and only if \( \frac{N}{r} > \frac{s}{B-1} \), and it decreases in the per-unit salvage value. It decreases as the difference between the two demand realizations \( (H-L) \) increases.

Proposition 8 suggests that a wholesale price-only contract might be more attractive if the retailer has limited negotiation power, whereas a revenue-sharing contract is preferable when the retailer has substantial negotiation power. A dishonest retailer will often participate under a contract with a higher retailer revenue share than an honest retailer does (cf. Propositions 6 and 7). The magnitude by which the retailer revenue share can be increased for a dishonest retailer increases in the retailer’s bargaining power (cf. Lemma A5 in the Appendix). Hence, when facing a powerful retailer, the supplier might be able to negotiate a fairly high retailer revenue share under a revenue-sharing contract and still guarantee participation. Given fixed bargaining powers, a higher retailer revenue share corresponds to a higher wholesale price, implying that, compared to a wholesale price-only contract, the supplier might not sacrifice too much revenue per participating retailer, even if he signs a revenue-sharing contract to increase retailer participation. Hence the supplier is more likely to prefer a revenue-sharing contract when the retailer’s bargaining power is high and a wholesale price-only contract if her negotiation power is low.

Recall that a wholesale price-only contract maximizes the supplier’s per-retailer revenue (conditional on participation), whereas the benefit of a revenue-sharing contract is that it increases participation. Under a wholesale price-only contract the supplier obtains all revenues at the beginning of the period, so...
his profits are independent of the demand realization and the retailer’s sales effort decisions. However, under this contract only retailer types that are likely to face high demand participate. A retailer that exerts effort is less profitable if such effort is less effective and is not likely to participate. Hence, to entice such a retailer to participate, under a revenue-sharing contract the supplier needs to agree to a contract with a low retailer revenue share and a low whole wholesale price, reducing his revenue per participating retailer. Other things being equal, it might thus be more appealing for the supplier to use a wholesale price-only contract and collect revenues upfront if sales effort is not very effective.

For a given allocation of negotiation power between the retailer and the supplier, a revenue-sharing contract reduces the retailer’s exposure to risk, and thus might improve participation. Increased participation through revenue sharing is particularly attractive to the supplier if it leads to a significant increase in the retailer’s order quantity, that is, if the difference between the two demand scenarios \((H-L)\) is large.

Proposition 8 also provides insights regarding when information on \(p\) is more valuable. The ratio \(\chi\) could be interpreted as the worst-case loss that the supplier will incur due to lack of information on \(p\). When \(\chi\) is small, the real loss, that is, the loss incurred when the supplier is forced to use the contract that guarantees participation of all retailer types as opposed to his optimal contract, is also small. Hence under the conditions that imply a small \(\chi\), the supplier’s gain from having more accurate information on \(p\) will be limited. He can simply set \(g = \hat{g}_{s}(1)\) and the difference between realized and theoretically optimal profits will be small.

8. Extensions

In this extension section we consider the questions of how opportunistic retailer reporting affects supply chain efficiency and whether it can lead to supply chain coordination (Section 8.1), and how a revenue-sharing contract with an opportunistic retailer compares to other widely-used types of contracts, namely a wholesale price contract and a coordinating all-unit quantity discount (Section 8.2). Given the consideration of a supply chain perspective, to prevent trivial and nonsensical scenarios, throughout this section we assume that there is no positive salvage value, that is \(s=0\).

8.1. Revenue sharing, cheating and supply chain coordination

Up to this point in the paper, we have analyzed a supply chain that operates under a revenue-sharing contract and compared settings with honest and dishonest reporting. We characterized when the supplier and the supply chain benefit from cheating. In this section, we explore when revenue-sharing contracts that leave some room for cheating lead to supply chain coordination and result in first-best supply chain profits.
With the normalization of base profits to 0 (given $L=0$), under $Q=H$, the supply chain obtains (additional) profits of $(1-p)rH$ or $(1-p/B)rH-A$, depending on whether sales effort is exerted or not. Since $p \leq 1$, the maximum of these two values is always positive, implying that participation (with $Q=H$) is optimal from a supply chain perspective; comparing the two expressions reveals that it is optimal to exert effort if and only if $p \geq g\alpha$. As demonstrated in Proposition 2, conditional on participation, the dishonest retailer’s effort decision is characterized by the same threshold, so the dishonest retailer makes supply chain-optimal effort decisions. Hence, the maximum channel profit is reached whenever the dishonest retailer participates ($Q=H$). It is thus sufficient to characterize settings where the dishonest retailer participates; clearly all (additional) profits are lost when the retailer finds participation unattractive. The conditions in Proposition 2 directly provide such a characterization.

Next, we numerically illustrate these conditions to characterize settings where channel profits are maximized. We normalize $H$ and $r$ to 1; the effects of $H$ and $r$ are straightforward and consistent with the following insights. As in Figures 1 and 2, we illustrate the settings with retailer participation by varying $p$ (horizontally, between 0 and 1) and $g$ (vertically, between 0 and 14), for different combinations of the other parameters ($A$, $B$, and $w$). We follow a simple full-factorial design, varying $A$ and $w$ in [0.2, 0.5] and $B$ in [2,5], leading to the eight scenarios given in Table 1.

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</table>

Table 1: Scenarios for illustration of settings with retailer participation

The eight frames of Figure 3 illustrate the settings with participation. We indicate which of the four regimes (a, b, c, or d) from Proposition 2 applies, though distinction of these regimes is not relevant when only concerned with the question of participation (and thus maximal channel profit).

\footnote{Note that our model is only defined for values of $g$ that are sufficiently large to ensure a positive $\phi$ (cf. definition in Equation 4) and to satisfy constraint in Equation (6).}
Based on these numerical experiments, we observe that retailer participation is more likely in settings with a lower wholesale price (comparing the first row with the second) and when it is more attractive to exert sales effort, that is, when such effort has lower cost or higher efficiency (going from left to right in each row). Interestingly, we find that participation is optimal in a large percentage of the studied cases, implying that supply chain coordination can often be achieved in the presence of retailer dishonesty.

8.2. Comparison of revenue-sharing contracts with wholesale-price and quantity-discount contracts
In this section, we benchmark the performance of revenue-sharing contracts that allow for limited cheating against two widely used contracts: (1) a wholesale-price contract, and (2) a coordinating quantity-discount contract. Throughout this numeric comparison, the parameters of all contracts are set to maximize supplier profits.

Under symmetric information, Cachon and Lariviere (2005) show that, when the retailer has the ability to exert demand enhancing sales effort, revenue-sharing contracts no longer can coordinate the supply chain, whereas an all-units discount scheme can. From Section 8.1, we know that revenue-sharing contracts that allow limited cheating improve the performance of the supply chain and sometimes even lead to coordination. Under asymmetric information and unobservable sales, the discount scheme proposed by Cachon and Lariviere does not apply to our setting, but we are able to derive the following all-unit discount contract that coordinates the supply chain under the assumptions of our paper.5

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5 In line with the rest of the paper, we provide the supplier's optimal schedule for $c=0$. The results for the general case are available from the authors upon request.
**Proposition 9:** The supplier’s optimal coordinating all-unit discount schedule is

\[ w(Q) = \begin{cases} \frac{r}{w}, & \text{if } Q = L, \\ \frac{w}{r}, & \text{if } Q = H, \end{cases} \]

where

\[ w = \left( 1 - \frac{H - L}{BH} \right) r - \frac{A}{H}. \]

This contract yields supplier profits of

\[ \pi_s = \overline{w} H = r \left( H - \frac{H - L}{B} \right) - A. \]

Using Proposition 9 and numerically determining the supplier’s optimal contract parameters for the wholesale-price contract and the revenue-sharing contract, we conduct a numerical study to compare the performances of wholesale price, revenue sharing and quantity discount contracts. To evaluate the supplier’s expected profits under information asymmetry, we assume a uniform (prior) distribution of retailer types on [0, 1]. While the value of \( L \) does not affect the optimal decisions of a dishonest retailer under revenue sharing (i.e., the case we have considered thus far), it does affect the relative profitability when compared to other contract forms, so we consider different non-zero \( L \) values; we also normalize \( H = 1 \) without affecting the generality of the obtained insights. Table 2 provides the parameter values and results for 16 scenarios, which are representative of the insights obtained in a wider study.

Out of the 16 instances in Table 2, the wholesale price contract achieves coordination in four cases while the revenue-sharing contract achieves coordination in six. In all but the four cases where both the wholesale price contract and the revenue-sharing contract lead to coordination, the efficiency of the revenue-sharing contract is significantly higher. Interestingly, the supplier’s profit under the revenue-sharing contract always is at least as high as that under either the wholesale-price contract or the quantity discount. These observations provide further support for the attractiveness of revenue-sharing contracts in practice, where retailers might have some room for underreporting their sales revenues. Not only can retailer underreporting improve supplier profits compared to the case with honest reporting, but using a revenue-sharing contract in such a setting might also outperform wholesale-price contracts and supply chain coordinating quantity discounts.
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Table 2: Comparison of Contracts
9. Discussion & Conclusion

Unless sales can be perfectly monitored, contracts that stipulate revenue sharing, by design, give retailers incentive to underreport revenues. In this paper, we show that if the amount of “cheating” can be kept at bay, dishonest reporting of revenues may increase supplier and supply chain profits. When the retailer underreports, at the margin she keeps all revenues on a sale and therefore exerts effort like an integrated supply chain would. However the retailer cannot cheat blatantly and must, on average, report sales as if she were honest. This upper bound on the amount of cheating might also allow the supplier to benefit from cheating.

Our analysis provides some guidelines for suppliers as they design revenue-sharing contracts in situations where they do not know the demand the retailer faces. We fix the retailer’s negotiation power and consider two limiting contracts: the wholesale price-only contract and a revenue-sharing contract with a share parameter under which all retailer types participate. If the retailer’s negotiation power is high or if retailer effort is effective, the difference in the supplier’s profits under these two contracts is minor, so the supplier should reduce the retailer’s revenue share and absorb some of the demand risk to increase retailer participation. When these conditions hold, the supplier’s loss due to his lack of knowledge on the demand distribution might not be substantial. On the other hand, when facing a less powerful retailer with less effective sales effort capabilities, the supplier might be better off increasing the retailer’s revenue share, thus extracting higher profits upfront through a higher wholesale price.

We find that dishonest reporting under a revenue-sharing contract aligns the retailer’s sales effort incentives with those of the supply chain, but it is important to note that “misreporting by the retailer” is not the only means to achieve this result. Taylor (2002) and Cachon and Lariviere (2005) propose contracts that coordinate the retailer’s sales effort, but these contracts are significantly more complex than the revenue-sharing contract analyzed in this paper and it is hard to find examples of such contracts being implemented in industry. Similarly the supplier may design a complex menu of contracts that elicit the true demand distribution of the retailer, but again such a contract will be very hard to implement, especially if the supplier cannot tell if retailers are honest or dishonest. This might explain why companies like Columbia Tristar Home Video stick to simpler contracts like revenue sharing and allow some misreporting; a contract between Columbia and Blockbuster specifies that Columbia will seek damages only if misreporting is higher that 10% of actual revenues.

Our analysis and findings are based on a stylized model with several simplifying assumptions. We assume that units leftover at the end of each period are salvaged. If the retailer could hold inventory, varying order quantities would reveal additional information to the supplier, making it difficult for the retailer to cheat. Our focus lies on understanding the impact of dishonesty, and inaccurate reporting is more likely to be of concern in product categories where revenues are not as directly linked to the number of units purchased from the supplier, and thus not easily inferable by him. Dishonest reporting would be
facilitated in settings where a single unit of product or a single franchise fee can give rise to varying amounts of revenues. For example, cheating would be difficult to detect in settings where a single physical product is repeatedly rented or where a certain distribution permission or franchise engagement allows a repeated and unverifiable generation of revenues (e.g., video rentals, digital distribution of media or software). Our assumption of perishable inventory is not restrictive if inventory either has a very short life-cycle or if franchise agreements and associated contract fees are renewed periodically. Coincidentally, contracts with revenue-sharing clauses are prevalent in many of these product categories.

To facilitate mathematical tractability, our assumptions with respect to demand and sales effort are simplistic. We assume a demand distribution with binary support. While there are settings where revenue uncertainty is indeed binary (like in the context considered in Wu and Babich 2012), this two-point distribution is clearly an abstraction of settings where demand realizations could take many different values. However, this assumption is fairly common in research involving information asymmetry and there is wide evidence that relaxing this assumption usually does not generate any significantly different or new insights. Also note that we do not make any assumptions with respect to the distribution of retailer types, giving rise to very general ex ante demand distributions from the supplier’s perspective. If retailer types \( p \) are distributed according to a probability distribution function \( f(p) \), then the probability with which demand equals to \( x \) (with \( L \leq x \leq H \)) equals \( f\left(\frac{(H-x)}{(H-L)}\right)\). Similarly, our assumption of a two-point effort model (effort or no effort) is clearly an abstraction from reality. It could be interesting to attempt a generalization of our results to more complex demand and sales effort functions. However, while we believe that the underlying logical structure (and thus structural insights) would not be substantially affected by assuming a more general discrete distribution, the resulting size of the strategic space would likely render analysis mathematically intractable.

We assume that the supplier has complete knowledge about the efficiency of the retailer’s sales effort (i.e., the values of parameters \( A \) and \( B \)). In the absence of any information regarding \( A \) and \( B \), the supplier cannot characterize the behavior of an honest retailer and it cannot establish any bounds on the dishonest retailer’s reporting. This would allow the retailer to underreport revenues in every period. In practice, suppliers may not have complete information regarding the efficiency of their retailers’ sales effort efficiency, but complete lack of information is unlikely, too. It seems plausible to assume that suppliers have at least some vague idea, which could be captured in the form of a distribution. Bounds on this distribution then could allow the supplier to impose limits on the retailer’s reporting behavior. The added uncertainty increases ambiguity and more often than not will shift benefits from the supplier to the retailer, but the structural insights derived in the paper still apply. A more detailed analysis of the benchmark setting where the supplier has insufficient knowledge to characterize the honest retailer’s behavior could be an interesting venue for future research, as could be the development of mechanisms to extract profit in those settings.
In motivating our steady-state solution approach, we assume that both the supplier and the retailer are non-strategic. At the outset of a contract relation, a strategic supplier could continuously alter the contract terms to observe the retailer’s responses and derive information about her type. Similarly, a strategic retailer then could mimic another retailer type in an effort to manipulate the supplier’s (final) contract decisions. Determining the resulting equilibrium (and whether it exists) is not the focus of this paper, but it might present an interesting avenue for future research.

Finally, in this paper, motivated by empirical observations that complex contracts may be hard to implement in practice, we have not utilized mechanism design to derive the optimal contract that would allow the supplier to extract complete information from the retailer. Instead, we focused on a simple, frequently-used contract and showed that cheating by the retailer is not necessarily detrimental to the supplier or the supply chain. Deriving the optimal contract using mechanism design and comparing the insights would be a possible research problem.

References


