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Supply Chain Performance with Target-Oriented Firms

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Problem definition: We study a supply chain in which a supplier sets the wholesale price and a retailer responds with an order quantity. Both the two firms can be either risk-neutral—maximizing the expected profit—or target-oriented, which is to maximize her/his ability to reach a target profit.

Academic/Practical relevance: Our work not only sheds light on the benefit/loss of trading with target-oriented decision makers, but also adds new knowledge to the supply chain coordination literature.

Methodology: We provide a strong support for firms' target-based preference and the linear target formation model through a survey as well as analyzing company data. With the firms' target-oriented behavior evaluated by a CVaR-satisficing measure, we apply a game theoretical framework to investigate how the target-based preference affects supply chain performance.

Results: A firm, be it a supplier or a retailer, is always hurt by its target-based preference, but can benefit from its trading partner's target-based preference. A risk-neutral supplier, for example, can sometimes reap the whole supply chain's profit if the retailer is target-oriented; and a target-oriented supplier always performs better with a target-oriented retailer than a risk-neutral one. Furthermore, a target-oriented retailer or/and supplier can help alleviate the double marginalization effect, and with a specific target can help the supply chain achieve the same efficiency level as in a risk-neutral centralized system, with just a wholesale price contract. Another important finding is that if both firms are target-oriented, then the supply chain can have a higher expected profit under a decentralized system than a centralized one. This contrasts to the case when both firms are risk-neutral. We also investigate the role of outside option and retailer type misidentification, and find that both can alleviate the retailer's disadvantage of being target-oriented.

Managerial insights: i) the target-based preference can be exploited by the trading partner and hence a firm should adopt the target-oriented decision criterion with caution; ii) a target-oriented retailer can explore strategies such as revealing his outside option or hiding his target-based preference in order to be less manipulated; iii) whether a firm (and the supply chain) can benefit from its trading partner's target-based preference often depends on how ambitious the trading partner (and the firm itself if it is target-oriented) sets the target; iv) target-based preference of one or both firms can help the supply chain reach the first-best efficiency; and v) when both firms are target-oriented, decentralization can be preferred to centralization.

Key words: target-oriented, target models, supply chain performance, wholesale price contract

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1. Introduction

People in complex situations rarely take into full consideration of the complexity; they often accept the first option that ensures the attainment of certain targets (Simon 1955). We refer to them as target-oriented decision makers. Indeed, target attaining is a prevalent phenomenon in practice. According to the U.S. Office of Energy Efficiency & Renewable Energy, “big box retailers and other investor-owned firms have very specific profit targets that must be reached to meet corporate and investor requirements” (U.S. Department of Energy 2012). Correspondingly, in our survey of 74 EMBA students, 94.6% of the participants reported that their companies set profit targets in every accounting period. Managers determine the level of unit sales or revenues needed not only to cover a firm’s costs but also to attain its profit targets (Farris et al. 2010, p106). Missing a profit or revenue target can have a significantly adverse impact on a firm’s stock price and hence investor sentiment. Amazon, for example, experienced a more than 12% drop in its stock price after it reported weaker than expected Q4 earnings in 2015 (Lieberman 2016).

Managers are found to be more concerned about achieving targets also because this is often linked to their performance (Brown and Tang 2006). In a survey of 194 senior managers, for example, 71% responded that they found “target revenue” or “target profit” metric very useful (Farris et al. 2010, p13). Payne et al. (1980, 1981) also found that when making investment decisions, managers rarely invest in projects that are likely to miss the target rate of return. As such, for managers, risk can be viewed as the prospect of not achieving the target rate of return (Mao 1970).

Targets can significantly steer firms’ operational decisions (Shinkle 2012). A Canada-based retailer, for example, implemented a goal-oriented decision support system developed by Pourshahid et al. (2014). The system recommends various operation strategies such as order quantities for groceries to meet multiple criteria such as target profit. At the individual-level, with a daily target of earnings in mind, cab drivers in New York City go home early when they earn more on rainy, busy days; but make long hours to reach their target on hot summer days when they earn less (Camerer et al. 1997).

Despite the prevalence of target-oriented decision making in practice, the literature in this area is scarce. There is a stream of research that discusses target-oriented utility (e.g., Bordley and LiCalzi 2000, Bordley and Kirkwood 2004, Diecidue and Van De Ven 2008, etc.). Recently, Brown and Sim (2009) and Brown et al. (2012) incorporate a target into decision makers’ preference by proposing a class of satisficing/aspirational measures that evaluate the ability of a random outcome beating a target. None of these works, however, study the role of a target in Operations Management (OM) decisions. The OM field has been relatively silent on this. Among the limited literature, Lau (1980) solves the problem of a newsvendor maximizing the probability of the random profit attaining a target, which is further explored under an inventory competition setting in Shi et al.

(2011). Lim and Wang (2017) propose a target-oriented robust optimization approach to solve a multiproduct, multiperiod inventory management problem. They aim to find a policy to maximize all the uncertainty sets such that the total cost is lower than a prespecified cost target, and find that a static decision rule is optimal for an approximate formulation of the problem. Chen et al. (2015) incorporate a target into the newsvendor problem by adopting the CVaR-satisficing measure and the entropic satisficing measure. They show that with the target being linearly dependent on the profit margin, a target-oriented newsvendor will over-order low-profit products and under-order high-profit products. All these works are focused on the decision making at a single stage without investigating the impact of a firm's target-based preference on supply chain performance.

To fill the void, we study in this paper how a target-oriented retailer or/and supplier affects the performance, *specifically, the profitability of a supply chain*. We consider a supply chain with one supplier and one retailer, who trade on a wholesale price contract. Both the two firms can either be risk-neutral or target-oriented. A risk-neutral supplier¹ (retailer) decides the wholesale price (order quantity) to maximize her (his) expected profit, whereas a target-oriented supplier (retailer) sets the wholesale price (order quantity) to maximize the ability to achieve her (his) profit target. We examine and compare four different compositions of supply chain, and aim to understand i) how the two parties make their optimal decisions under different settings; ii) how the two parties' performances are affected by the target-based preference; iii) whether the supply chain will benefit from having a target-oriented (as opposed to a risk-neutral) retailer or/and supplier; and iv) how outside option and retailer type misidentification will affect the role of the target-based preference.

A common measure to characterize a decision maker's target-based preference is the probability attainment measure, which evaluates the probability that a target is attained (see for example Lau 1980, Shi et al. 2011, Brown and Tang 2006). This measure, however, is computationally intractable and also does not take into account the level of shortfall from the target. As such, similar to Chen et al. (2015), we adopt the CVaR satisficing measure (Brown and Sim 2009, Brown et al. 2012) to represent the firms' target-based preference. For example, a target-oriented retailer's objective is to select an order quantity to maximize the CVaR satisficing measure, which evaluates the ability of his random profit achieving a target.

In the setting where a risk-neutral supplier faces a target-oriented retailer, with a linear target formation model where the retailer's target is linearly dependent on his profit margin, we find that compared to trading with a risk-neutral retailer, the supplier can sometimes benefit from having a target-oriented retailer and in some cases, she can reap the whole supply chain's profit. The

¹ As can be seen later, the supplier in our decentralized model faces no randomness. Nevertheless, we still call it "risk-neutral" when she is not target-oriented, in parallel to the naming of risk-neutral retailer. Similarly, we sometimes refer to this type of supplier's profit as expected profit for ease of exposition.

retailer, on the other hand, is always worse off being target-oriented. We also find that the whole supply chain can perform better with a target-oriented retailer and surprisingly, it can sometimes reach the same efficiency level as in a centralized system when the retailer has a specific target. When the supplier is the target-oriented, similar results hold except that now the supplier and the supply chain *always* perform better with a target-oriented retailer than a risk-neutral one.

We also find that regardless the retailer's type, a target-oriented supplier always performs worse than a risk-neutral supplier. The retailer and the supply chain can sometimes benefit from having a target-oriented supplier, which depends on how ambitious the supplier or/and the retailer sets the target. In other words, a target-oriented supplier can also help alleviate the effect of double marginalization and improve the supply chain performance, and with a specific target she can help the supply chain reach the same efficiency level as the risk-neutral centralized system.

It has long been acknowledged in the supply chain contract literature (see Cachon 2003 for a comprehensive survey) that, a wholesale price contract cannot coordinate the chain. Our results, however, suggest that the opposite can be true if the one or both firms are target-oriented.

Another interesting finding is that when both firms are target-oriented, then the supply chain can sometimes have a higher order quantity and a higher system profit if it is decentralized than centralized. This is in direct contrast to a risk-neutral system, where the centralized supply chain always performs better than a decentralized one with both firms being risk-neutral.

We also extend the model to the scenarios when the retailer has an outside option and when the retailer's type is misidentified. We find that the retailer's outside option helps alleviate the retailer's disadvantage of being target-oriented. Furthermore, while the risk-neutral supplier is always worse off if she misidentifies the retailer's type, a target-oriented retailer benefits from the supplier mistaking him as risk-neutral. A risk-neutral retailer, however, is always hurt by being misidentified as target-oriented. Similar results hold if the supplier is target-oriented except that now the supplier can also benefit from misidentifying the retailer's type.

To the best of our knowledge, this is the first paper that investigates the performance of a supply chain with target-oriented firms. The most closely related literature, Chen et al. (2015), only studies a single firm's target-oriented decision making. By analyzing supply chains with one or both firms being target-oriented, we are able to offer important guidelines to managers: i) the target-based preference can be exploited by the trading partner and hence a firm should adopt the target-oriented decision criterion with caution; ii) a target-oriented retailer can explore strategies such as revealing his outside option or hiding his target-based preference in order to be less manipulated; iii) whether a firm and the supply chain can benefit from its trading partner's target-based preference often depends on how ambitious the trading partner (and the firm itself if it is target-oriented) sets

the target; and iv) when both firms are target-oriented, decentralization can have a better system performance than centralization.

Our paper further differentiates with Chen et al. (2015) in that we provide a stronger support for firms' target-based preference and the linear target formation model through a survey as well as analyzing company data. This enhances the applicability of our model. Our work not only sheds light on the benefit/loss of trading with a target-oriented firm, but also adds new knowledge to the supply chain coordination literature. It can also potentially help unfold a new research direction in the supply chain management field on target-based decision making.

The rest of the paper is organized as follows. We start by discussing in Section 2 the choice of measures characterizing the target-oriented behavior as well as the target formation model. In Section 3, we describe the supply chain setup and the models. Section 4 provides the analytical results for four settings, followed by the comparisons of these settings in Section 5. We then discuss two methods in Section 6 to mitigate the disadvantages of the retailer being target-oriented. A comprehensive numerical study is presented in Section 7 to demonstrate the robustness of our results with respect to demand distributions. We conclude the paper in Section 8. All the proofs appear in the Online Appendix.

2. Measuring Target-Based Preference

In this section, we discuss the choice of the measure to characterize a decision maker's target-based preference. Specifically, we introduce two measures—probability attainment measure and CVaR-Satisficing Measure (CSM)—and illustrate why the latter is a better choice.

Consider a decision maker who makes a decision on $y \in \mathcal{Y}$, where $\mathcal{Y}$ is a set of all feasible candidates. This decision results in a random utility of $V(y; D)$, which is associated with a random variable D that follows a probability distribution $\mathbb{P}$. The decision maker aims to achieve a utility target τ . The target is attained if and only if $V(y; d) - \tau \geq 0$, where d is a realization of D . Since $V(y; D)$ is random, we need to evaluate the ability of this random utility achieving the target. An intuitive measure for evaluating this ability is the following Probability Attainment Measure.

2.1. Probability Attainment Measure

The decision maker can evaluate the probability of his random utility achieving the target τ as

$$\hat{\rho}_\tau(V(y; D)) \triangleq \mathbb{P}((V(y; D) - \tau) \geq 0),$$

where we call $\hat{\rho}_\tau$ the probability attainment measure. To maximize the probability of achieving the target, a target-oriented decision maker maximizes this measure with respect to y :

$$\max_{y \in \mathcal{Y}} \hat{\rho}_\tau(V(y; D)).$$

This measure is adopted in Lau (1980), Lau and Lau (1999), Shi et al. (2011) to study the newsvendor problem. Despite being intuitive, the probability attainment measure has drawbacks from both the analytical and modeling perspectives. It is well-known that this measure is non-convex (Ahmed and Shapiro 2008). The lack of any form of structural convexity leads to analytical intractability. This measure is also behaviorally crude. It fails to take into account the magnitude of shortfall from the target and can evaluate a catastrophic event and a mild violation, occurring with the same low probability, equally.

REMARK 1. Along the line of probability attainment, one may also propose to maximize the expected utility while treating the probability attainment as a constraint, i.e.,

$$\begin{aligned} \max \quad & \mathbb{E}[V(y; D)] \\ \text{s.t.} \quad & \mathbb{P}((V(y; D) - \tau) \geq 0) \geq \delta \\ & y \in \mathcal{Y}, \end{aligned}$$

where $\delta \in [0, 1]$. This is a chance constrained problem, which is notorious to deal with. Inheriting the drawbacks of the probability attainment measure, this problem has also been shown to be NP-hard even in the most basic setting where $V(y; D)$ is affine in y and D (Luedtke et al. 2010).

2.2. CVaR-Satisficing Measure

We now define and explain the *CVaR-satisficing measure* (CSM), which was first introduced in Brown and Sim (2009), and also discuss its superiority over the probability attainment measure.

DEFINITION 1. Given a target τ , the CVaR-satisficing measure of the random utility $V(y; D)$ is defined as

$$\rho_\tau(V(y; D)) = \begin{cases} \sup \{ \eta \in (-1, 1) : \text{CVaR}_\eta(V(y; D) - \tau) \geq 0 \}, & \text{if feasible,} \\ -1, & \text{otherwise,} \end{cases}$$

where the conditional value-at-risk of the random utility, $\text{CVaR}_\eta(V)$, is defined as

$$\text{CVaR}_\eta(V) = \begin{cases} \mathbb{E}[V | V \leq q_{1-\eta}(V)], & \text{if } \eta \in [0, 1], \\ \mathbb{E}[V | V \geq q_{-\eta}(V)], & \text{if } \eta \in (-1, 0). \end{cases}$$

Here, $q_\eta(V)$ is the unique η -quantile of V , i.e., $\text{Prob}(V \leq q_\eta(V)) = \eta$.

As can be seen, the CSM is another measure that evaluates the ability of the random utility attaining a target. Because of the translation invariance property of CVaR (Pflug 2000), we can rewrite $\text{CVaR}_\eta(V(y; D) - \tau) \geq 0$ as $\text{CVaR}_\eta(V(y; D)) \geq \tau$. As such, the CSM can be written as

$$\rho_\tau(V(y; D)) = \begin{cases} \sup \{ \eta \in (-1, 1) : \text{CVaR}_\eta(V(y; D)) \geq \tau \}, & \text{if feasible,} \\ -1, & \text{otherwise,} \end{cases} \quad (1)$$

Different than the probability attainment measure that focuses on the probability of a shortfall, CSM takes into account the magnitude of loss, an characteristics that is more behaviorally consistent with decision making. We briefly discuss CSM as follows. More details can be found in Brown and Sim (2009) and Chen et al. (2015).

Note that the CVaR defined here is an extended version of its classic definition in Rockafellar and Uryasev (2000), where η can take values of only between 0 and 1 and so $\text{CVaR}_\eta(V)$ measures the expectation over the worst $(1 - \eta)$ case realizations. In the extended version, however, η can also take the negative values between -1 and 0 , such that $\text{CVaR}_\eta(V)$ measures the expectation over the best $(1 + \eta)$ case realizations. Figure 1 illustrates the extended definition of CVaR_η assuming V is normally distributed.

Figure 1 Illustration for CVaR

As can be seen in equation (1), with the extended definition of CVaR, the largest η such that the CVaR of a random utility V attains the target τ is defined as the *CVaR-satisficing measure*, $\rho_\tau(V)$. We further illustrate $\rho_\tau(V)$ in Figure 2 with a specific example. Suppose when $\eta = 0.1$ and $\eta = 0.3$, both $\text{CVaR}_{0.1}(V)$ and $\text{CVaR}_{0.3}(V)$ are greater than the target τ , and when $\eta = 0.7$, $\text{CVaR}_{0.7}(V)$ equals τ . Since $\text{CVaR}_\eta(V)$ decreases with η , we know that $\text{CVaR}_\eta(V) < \tau$ for any $\eta > 0.7$. Therefore, the largest η such that $\text{CVaR}_\eta(V)$ attains the target τ is 0.7 , i.e., $\rho_\tau(V) = 0.7$. From the definition, we can see that a random utility with a higher CSM has a higher target-attaining ability. This is because a higher CSM implies that the utility can achieve the target even if it realizes in a less optimistic region.

Figure 2 Illustration for CVaR-satisficing measure

In summary, CSM properly factors in the level of shortfall from the target. It also enjoys good structural properties such as monotonicity and characterizes a mix of both convex and concave preferences. Because of this, it can address some of the well-known paradoxes, such as Allais' Paradox and Ellsberg Paradox, as shown in Online Appendix E.

We hence adopt the CSM to model the preference of a target-oriented decision maker, whose problem is to decide y to maximize the CSM of the random utility:

$$\max_{y \in \mathcal{Y}} \rho_{\tau}(V(y; D)). \quad (2)$$

Note that when the decision maker faces no randomness², that is, D assumes its nominal value D_0 and $\eta \equiv 1$, then Problem (2) is reduced to the following feasibility problem:

$$\begin{aligned} \max \quad & 1 \\ \text{s.t.} \quad & V(y; D_0) \geq \tau; \\ & y \in \mathcal{Y}. \end{aligned} \quad (3)$$

2.3. Target Formation Model

Before we move to describe and analyze the problem, we first discuss a firm's profit target formation model. There has been limited research on how decision makers set their targets. Kőszegi and Rabin (2006) suggest that people often form their targets according to some simple heuristics. One intuitive heuristic is to set the target to be linearly dependent on the profit margin, which is adopted by Chen et al. (2015). This heuristic is in line with the widely adopted textbook formula to set the profit target in the cost-volume-profit analysis, where the target is equal to the product of the units of sales and the marginal profit, subtracted by the total fixed cost (Hansen and Mowen 2014, p831). As another supporting evidence for this heuristic, firms often adjust their profit target when their profit margin or sales changes (e.g., BBC 2012, Aureliano 2018).

To further examine the applicability of the linear target formation model as well as our target-oriented decision framework, we conducted a survey for 74 EMBA students in a top Asian university. We relegate the details of the survey to Online Appendix C and summarize the survey results as follows. The 74 respondents come from a number of countries, including USA, China, Singapore, Australia, France, India, Japan, etc. They have different industry backgrounds such as manufacturing, oil & gas, fast-moving consumer goods (FMCC), healthcare, information technology, etc; and hold various managerial positions such as CEO, director, general manager, sales manager, vice president, etc. Among the 74 respondents, 70 (94.6%) confirmed that the companies they were working for set target profits in every accounting period, and 58 (78.4%) of them had the experience of setting target profits. 61 (82.4%) participants responded that all else being equal, they would set up a higher (lower) target profit if the profit margin increases (decreases). Furthermore, 60 (81.1%) of them believed that

$$\text{Target profit} = \text{Forecasted sales} \times (\text{Unit selling price} - \text{Unit cost}) - \text{Operating cost}$$

² Note that a decision maker facing no randomness can still be target-oriented for various reasons, such as the effort to search for the profit maximizing solution is considerably high or driven by the corporate culture of goal-setting.

was a reasonable proxy for setting the target profit. As can be seen later, in our problem setting the operating cost is irrelevant, which can be considered as sunk cost, see for example, Lariviere and Porteus (2001), Chen et al. (2009). We hence adopt the linear target model $\tau = \alpha m$, where α is a positive number that, for example, can be a firm's subjective estimation related to the demand and m is the profit margin for each unit of product. Hereinafter, for ease of exposition, we often refer to α as subjective estimation of demand.

Figure 3 Forecasted Pre-tax Profit v.s. Profit Margin

In addition to the supporting evidences for the linear target model as stated above, we take one step further and analyze the data for top nine crude oil & gas companies in the U.S.A. to examine the validity of the model. We picked the crude oil & gas companies as they have a relatively simple product mix, which makes the analysis more feasible. All the data were obtained from WRDS (Wharton Research Data Services); the details of the data set can be found in Online Appendix D. For all the nine companies, we extracted from the IBES database the quarterly forecast of the pre-tax profit between 2003 and 2019 and make it as a proxy for the target profit³. We also exported each company's cost and revenue data from Compustat to approximate the profit margin⁴ for a barrel of oil. As an example, Figure 3 displays the forecasted pre-tax profits for Exxon Mobil (left) and Occidental (right) w.r.p. to their profit margins. It suggests that the target profit is highly dependent on the profit margin. This is validated by the regression results after we ran the linear regression for the model $\tau = \alpha m$ for each company. The detailed regression results can be found in Table D.2 in Online Appendix D. Together with the survey result, the data analysis lends the support for the linear target formation model, which we will adopt for our analysis. We recognize, however, there can be other target formation heuristics and our results hence are only applicable to the firms who adopt the linear target formation model.

³ All the nine firms are publicly traded firms. We believe that analysts' profit forecast is a good proxy for the target profit, as a public firm would strive to meet the forecast; missing the forecasted profit can result in a significant loss.

⁴ Note that in our data analysis, we treated each company as if their business was entirely in the crude oil sector. Despite being imperfect, this approximation serves the purpose, as oil accounts for a significant portion of these companies' business. For example, for Occidental, oil and gas segments accounts for 72.85% of the total revenue in the second quarter of 2019. On average, sales from oil accounts for 90.5% of the total revenue in that segment each day, as shown in Table D.1 in Online Appendix D.

3. Problem Description

Consider a supply chain with one supplier and one retailer. The supplier produces a product at a marginal cost c and decides the wholesale price, w , to be charged to the retailer. The retailer sells the product to end-customers at a fixed price p . To avoid triviality, we assume that $c \leq w \leq p$. The retailer faces a random demand D which, without loss of generality, is assumed to be continuously distributed with a *c.d.f.* $F(\cdot)$ and a log-concave *p.d.f.* $f(\cdot)$ ⁵. We also assume that any unsatisfied demand will be lost and the salvage value for unsold items is zero. As such, the retailer's profit is $V(y; D) = p \min\{D, y\} - wy$, where y is his order quantity. In this paper, we focus on the case where the supplier acts as a Stackelberg leader and quotes the wholesale price, and the retailer reacts with an order quantity. Both firms can be either risk-neutral, denoted by "N"—a setting where the decision maker will maximize his/her (expected) profit—or target-oriented, denoted by "T". Hence, there is a total of four possible settings: "NN", "NT", "TN", and "TT", where the first letter represents the supplier's type and the second letter the retailer's. In each setting, all parameters are assumed to be common knowledge for both parties.

3.1. The Supplier's Problem

A *risk-neutral supplier* decides the wholesale price, w , to maximize her profit. Given the retailer's order quantity y , the supplier's problem can be written as:

$$\max_{c \leq w \leq p} \pi_n^s(w) = (w - c)y. \quad (4)$$

Throughout the paper, we use the superscripts s and r to represent the supplier and the retailer, respectively. We also use the subscripts n and t to respectively denote the types—risk-neutral and target-oriented.

A *target-oriented supplier*, on the contrary, evaluates his ability to achieve the target τ^s , given the retailer's order quantity y . Since there is no randomness in the target-oriented supplier's profit, as illustrated in (3), she solves the following feasibility problem:

$$\begin{aligned} \max \quad & 1 \\ \text{s.t.} \quad & (w - c)y \geq \tau^s; \\ & c \leq w \leq p. \end{aligned}$$

In solving this problem, we assume that the supplier will choose the largest wholesale price such that her target profit is achieved, i.e., a target-oriented supplier solves the following problem:

$$\begin{aligned} \max \quad & w \\ \text{s.t.} \quad & (w - c)y \geq \tau^s; \\ & c \leq w \leq p. \end{aligned} \quad (5)$$

This is plausible as among all the feasible wholesale prices, the largest one provides the highest profit margin that she can obtain and hence the highest target profit, which guarantees a largest lower-bound of her actual profit.

⁵ Most commonly assumed distributions (such as the uniform, normal, exponential, power, etc.) are log-concave (Bagnoli and Bergstrom 2005).

3.2. Retailer's Problem

Given the supplier's wholesale price, w , a *risk-neutral retailer* decides the order quantity y to maximize his expected profit, that is,

$$\max_{y \geq 0} \mathbb{E}[V(y; D)], \quad (6)$$

while a *target-oriented retailer* maximizes the target-attaining ability of his random profit. As discussed in Section 2 and following Chen et al. (2015), we adopt the *CVaR-safisficing measure* (CSM), $\rho_{\tau^r}(V(y; D))$, to evaluate this ability. The target-oriented retailer's problem is hence to decide the order quantity y to maximize the CSM of the random profit:

$$\max_{y \geq 0} \rho_{\tau^r}(V(y; D)). \quad (7)$$

4. Analysis

The analysis proceeds in the following order. Subsections 4.1 to 4.4 present the results of settings “NN,” “NT,” “TN,” and “TT,” respectively. For settings “NN” and “TT,” we discuss both a centralized system and a decentralized one. Wherever applicable, subscripts “nn”, “nt”, “tn”, and “tt” are used in notations to indicate the association with corresponding settings.

4.1. Setting 1: “NN”

In this section, we analyze the setting where both firms are risk-neutral, and study both a decentralized supply chain and a centralized system. Hereinafter, we will often refer the latter as risk-neutral centralized system.

Centralized Supply Chain

In a centralized supply chain, the optimal order quantity is determined to maximize the expected total supply chain profit. It is obtained by solving the following problem:

$$\max_{y \geq 0} \Pi_{nn}^c(y) = p\mathbb{E}[\min(y, D)] - cy. \quad (8)$$

Here, the superscript c represents the centralized supply chain. The optimal order quantity is calculated to be $y_{nn}^{c*} = F^{-1}(\xi^c)$, where $\xi^c = \frac{p-c}{p}$ is the critical fractile or system profit margin. Specifically, if the demand D is uniformly distributed in $[a, a+b]$, where a and b are non-negative, then the optimal order quantity y_{nn}^{c*} , and the maximum supply chain profit Π_{nn}^{c*} are given by

$$y_{nn}^{c*} = \frac{p(a+b) - bc}{p}, \quad \Pi_{nn}^{c*} = \frac{[p(a+b) - bc]^2}{2bp} - \frac{pa^2}{2b}.$$

Note that the optimal profit in this centralized system is the first-best solution a supply chain can achieve. We will later evaluate the system's performance in other settings against this benchmark.

Decentralized Supply Chain

In a decentralized supply chain, the supplier obtains the optimal wholesale price w by solving Problem (4), and the retailer responds with an order quantity through solving Problem (6).

We can use a standard backward induction to solve the problem. For a given wholesale price w , the retailer solves for his optimal order quantity $y_{nn}(w)$, expecting which, the supplier will decide the wholesale price to maximize her profit $\pi_{nn}^s(w) = (w - c)y_{nn}(w)$. Note that if the demand distribution is log-concave with a finite support, it has an increasing generalized failure rate (Banciu and Mirchandani 2013), so that the the supplier's profit function is uni-modal (Lariviere and Porteus 2001). That is, the optimal quantity y_{nn}^* satisfies $F(y_{nn}^*) + y_{nn}^*f(y_{nn}^*) = \xi^c$, and the optimal wholesale price is $p(1 - F(y_{nn}^*))$. In particular, if the demand is uniformly distributed, we find that if $\frac{b}{a} > \frac{1}{\xi^c}$ ⁶, then the optimal order quantity and wholesale price are given as follows:

$$w_{nn}^* = \frac{p(a+b) + bc}{2b}, \quad y_{nn}^* = \frac{p(a+b) - bc}{2p}; \quad (9)$$

and the optimal profits for the supplier and the retailer, respectively, can be calculated to be:

$$\pi_{nn}^{s*} = \frac{[p(a+b) - bc]^2}{4bp}, \quad \pi_{nn}^{r*} = \frac{[p(a+b) - bc]^2}{8bp} - \frac{pa^2}{2b}. \quad (10)$$

4.2. Setting 2: “NT”

In this section, we analyze the supply chain with a risk-neutral supplier and a target-oriented retailer with $\tau^r = \alpha^r(p - w)$, and identify the optimal decisions and profits. We first show that the retailer's optimal CSM is always non-positive.

PROPOSITION 1. $\rho_{nt}^* \leq 0$.⁷

Note that a positive (negative) CSM suggests that the decision maker is focused on the worst-case (best-case) profit realization. Proposition 1 shows that the supplier will set a wholesale price such that the retailer always focuses on the best-case profit realization. In other words, the retailer is driven to be more aggressive in making the quantity decision in order to reach the target.

For tractability reason and to facilitate the comparison of profits, hereinafter, when the retailer is target-oriented (i.e., under both the “NT” and “TT” settings), unless otherwise specified, we will focus on the case where the demand is uniformly distributed in $[a, a + b]$. (In Online Appendix B, we prove that our results also hold for the Exponential distribution. We also numerically demonstrate the robustness of our results with respect to different distributions in Section 7.)

Let $\alpha_{nt}^{r1} = \frac{3p(a+b) - \sqrt{p^2(a+b)^2 + 4pb^2(p+c)}}{4p}$, $\alpha_{nt}^{r2} = \frac{(p-c)(a+b)}{3p-c}$, $w_{nt}^1 = \sqrt{\frac{2p(p+c)(a+b-\alpha^r)}{a+b-2\alpha^r}} - p$, $\rho_{nt}^1 = -1 + \frac{1}{b}\sqrt{\frac{2p(a+b-\alpha^r)(a+b-2\alpha^r)}{p+c}}$, and $y_{nt}^1 = \sqrt{\frac{2p(a+b-\alpha^r)(a+b-2\alpha^r)}{p+c}} - (a+b-2\alpha^r)$. Also let ϵ be an infinitely small positive number. We have the two firms' optimal decisions in Proposition 2.

⁶ If $\frac{b}{a} \leq \frac{1}{\xi^c}$, then $w_{nn}^* = p$ and $y_{nn}^* = a$. The supplier's and the retailer's profits are $\pi_{nn}^{r*} = 0$ and $\pi_{nn}^{s*} = (p - c)a$, respectively.

⁷ Hereinafter, we remove τ^r in the notation ρ , and replace it with subscripts such as “nt” to reflect the setting.

PROPOSITION 2. *The supplier's optimal wholesale price, w_{nt}^* , and the retailer's optimal order quantity, y_{nt}^* , are given as follows.*

1. *When $\frac{b}{a} \leq \frac{2}{\xi^c}$, $w_{nt}^* = p - \epsilon$, $y_{nt}^* = \alpha^r - \epsilon$, for all $\alpha^r \in [a, a + b]$.*
2. *When $\frac{b}{a} > \frac{2}{\xi^c}$, the optimal decisions are:*

$$\begin{cases} w_{nt}^* = \frac{p(2a+b-2\alpha^r)}{b}, & y_{nt}^* = 2\alpha^r - a, & \text{if } \alpha^r \in [a, \alpha_{nt}^{r1}); \\ w_{nt}^* = w_{nt}^1, & y_{nt}^* = y_{nt}^1, & \text{if } \alpha^r \in [\alpha_{nt}^{r1}, \alpha_{nt}^{r2}); \\ w_{nt}^* = p - \epsilon, & y_{nt}^* = \alpha^r - \epsilon, & \text{if } \alpha^r \in [\alpha_{nt}^{r2}, a + b]. \end{cases}$$

Proposition 2 shows that the optimal policies are affected by $\frac{b}{a}$, which measures the demand variability. We can see that when the demand variability is low, the supplier will set up the wholesale price to be approaching to p , enabling her to keep almost all the supply chain profit. This is because, with a lower demand variability, the retailer's target-attaining ability is less sensitive to the order quantity and hence the wholesale price. As such, the supplier can take the advantage and charge a wholesale price to the highest possible. Note that the supplier, however, will avert from setting the wholesale price to be equal to the retail price because with $w = p$, the retailer will order an amount (anywhere between 0 and a) less than he would if $w = p - \epsilon$. The observation that the supplier reaps almost all the supply chain profit when the demand variability is low echoes that in the risk-neutral case, as shown in Section 4.1. The range of the demand variability for this to happen, however, is much smaller in the risk-neutral case.

We further observe that the optimal decisions vary with α^r when the demand variability is high ($\frac{b}{a} > \frac{2}{\xi^c}$). For a clear illustration, we summarize in Table 1 the optimal decisions and the retailer's optimal satisficing measure in this scenario. We can see that the retailer's optimal value of the CVaR-satisficing measure, ρ_{nt}^* , decreases with α^r and is always non-positive.

Table 1 Optimal Decisions and Satisficing Measure when $\frac{b}{a} > \frac{2}{\xi^c}$

α^r	ρ_{nt}^*	y_{nt}^*	w_{nt}^*
$[a, \alpha_{nt}^{r1})$	0	$2\alpha^r - a$	$\frac{p(2a+b-2\alpha^r)}{b}$
$[\alpha_{nt}^{r1}, \alpha_{nt}^{r2})$	ρ_1	y_{nt}^1	w_{nt}^1
$[\alpha_{nt}^{r2}, a + b]$	$\frac{a-\alpha^r}{b} + \epsilon$	$\alpha^r - \epsilon$	$p - \epsilon$

We further examine the optimal wholesale price w_{nt}^* with respect to α^r .

COROLLARY 1. *When $\frac{b}{a} > \frac{2}{\xi^c}$, the optimal wholesale price w_{nt}^* first decreases and then increases with α^r , and is approaching to the retail price p from α_{nt}^{r2} onwards.*

The reason is probably as follows. Chen et al. (2015) show that there exists a threshold value $\zeta = \frac{2(\alpha^r - a)}{b}$ such that if the critical fractile $\xi = \frac{p-w}{p}$, which represents the retailer's profit margin, is larger than ζ , then the retailer will under-order and otherwise, he will over-order. A small α^r implies a low ζ . In this case, the retailer will treat the product as a high-profit product and under-order. Hence, to incentivize the retailer to order more, the supplier will reduce her wholesale price. When α^r increases, ζ becomes larger and the retailer is more likely to consider the product to be a low-profit product and over-order. The supplier will take advantage of the retailer's over-ordering behavior and increase the wholesale price (to reduce the profit margin) to further motivate the retailer to order more. When α^r is large enough, i.e., $\alpha^r \geq \alpha_{nt}^2$, the supplier can set up her wholesale price approaching to the retail price and reap all the supply chain profit.

4.3. Setting 3: "TN"

In this section, we discuss the scenario with a risk-neutral retailer and a target-oriented supplier, whose profit target is $\tau^s = \alpha^s(w - c)$. For ease of exposition, we refer to α^s as the supplier's subjective estimation of demand (order quantity from the retailer). The supplier solves Problem (5) to decide w . With the risk-neutral retailer's response as in Section 4.1, we have the following proposition.

PROPOSITION 3. *If $\alpha^s \leq F^{-1}(\xi^c)$, then for any general demand distribution, the supplier's optimal wholesale price and the retailer's optimal order quantity are respectively given as*

$$w_{tn}^* = p(1 - F(\alpha^s)), y_{tn}^* = \alpha^s.^8$$

Specifically, if the demand is uniformly distributed in $[a, a + b]$ and $\alpha^s \leq b\xi^c + a$, then

$$w_{tn}^* = \frac{p}{b}(a + b - \alpha^s), y_{tn}^* = \alpha^s.$$

Otherwise, if $\alpha^s > F^{-1}(\xi^c)$, the supplier will not offer the contract.

Proposition 3 shows that the supplier will set up her wholesale price such that retailer's order quantity is exactly her subjective estimation of demand, if this estimation is less than or equal to the order quantity in the risk-neutral centralized system. It is evident that the optimal wholesale price decreases with α^s . This is because a larger α^s indicates a higher target, and in order to attain her target, the supplier reduces her wholesale price such that the retailer will order more. If the estimation is larger than $F^{-1}(\xi^c)$, the wholesale price would have to be less than c for the retailer to order α^s , resulting a negative profit for the supplier. Hence, the supplier will not offer the contract.

⁸ Note that when $\alpha^s = F^{-1}(\xi^c)$, we have $w_{tn}^* = p(1 - F(\alpha^s)) + \epsilon = c + \epsilon$, $y_{tn}^* = \alpha^s - \epsilon$. We present the proposition in the current form for conciseness.

4.4. Setting 4: “TT”

Similar to the setting “NN,” in this section we will also investigate both a centralized system and a decentralized one under “TT.”

Decentralized system We have explored a target-oriented retailer’s response in the “NT” setting. Now if the supplier is also target-oriented, we have the following proposition to characterize the system equilibrium.

PROPOSITION 4. *If the demand is uniformly distributed in $[a, a + b]$ and $\alpha^s \leq 2\alpha^r - a$, then the supplier’s optimal wholesale price and the retailer’s optimal order quantity are given as*

$$w_{tt}^* = \begin{cases} p - \epsilon & \text{if } a \leq \alpha^s < \alpha^r \\ \frac{p(a+b-\alpha^s)}{a+b-2\alpha^r+\alpha^s} & \text{if } \alpha^r \leq \alpha^s \leq 2\alpha^r - a \end{cases}, \quad y_{tt}^* = \begin{cases} \alpha^r - \epsilon & \text{if } a \leq \alpha^s < \alpha^r \\ \alpha^s & \text{if } \alpha^r \leq \alpha^s \leq 2\alpha^r - a \end{cases}.$$

Otherwise, if $\alpha^s > 2\alpha^r - a$, then the supplier will not offer the contract.

Proposition 4 shows that when both firms are target-oriented, if the supplier’s subjective estimation of demand is lower than the retailer’s, the supplier takes advantage of the retailer’s over-ordering behavior and charges a wholesale price approaching to the retail price to push the retailer to order more than the supplier’s estimation, which guarantees her target attainment. When the supplier’s estimation of demand is higher than that of the retailer (but still moderate, i.e., $\alpha^s \leq 2\alpha^r - a$), the supplier will set up a wholesale price such that the retailer will order exactly the supplier’s estimation. When the supplier is too optimistic about the demand (i.e., $\alpha^s > 2\alpha^r - a$), the retailer’s order quantity is not high enough for her to reach the target and so she will not offer the contract.

Centralized system Under the “TT” setting, we also briefly discuss an integrated target-oriented supply chain with a target profit of $\tau^c = \alpha^c(p - c)$. Note that now the supplier solves Problem (2) as she faces the demand uncertainty directly. The optimal order quantity can be obtained by following the same procedure as in the target-oriented retailer’s problem.

PROPOSITION 5. *If the demand is uniformly distributed in $[a, a + b]$ and $a \leq \alpha^c \leq a + b$, then the optimal order quantity for the centralized system is*

$$y_{tt}^{c*} = \begin{cases} 2\alpha^c - a & \text{if } a \leq \alpha^c < \frac{b(p-c)}{2p} + a \\ \frac{(p-c)(a+b)+2c\alpha^c}{p+c} & \text{if } \frac{b(p-c)}{2p} + a \leq \alpha^c \leq a + b \end{cases}.$$

In a centralized target-oriented system, the optimal order quantity increases with α^c and hence increases with target τ_c . Corollary 2 compares the order quantity and the expected profit of the target-oriented centralized system with those of the corresponding decentralized one.

COROLLARY 2. *If the demand is uniformly distributed in $[a, a + b]$, $\alpha^c = \alpha^s$, and $\alpha^s \leq 2\alpha^r - a$ for any given α^r , we have*

1. there exists an α_{tt}^{s1} such that $y_{tt}^* \geq y_{tt}^{c*}$ if $\alpha^s \leq \alpha_{tt}^{s1}$, and $y_{tt}^* \leq y_{tt}^{c*}$ if $\alpha^s \geq \alpha_{tt}^{s1}$.
2. there exists α_{tt}^{sc1} and α_{tt}^{sc2} such that $\Pi_{tt}^* \leq \Pi_{tt}^{c*}$ if $\alpha_{tt}^{sc1} \leq \alpha^s \leq \alpha_{tt}^{sc2}$, and $\Pi_{tt}^* \geq \Pi_{tt}^{c*}$ if $\alpha^s \leq \alpha_{tt}^{sc1}$ or $\alpha^s \geq \alpha_{tt}^{sc2}$. In particular, if $\alpha^r = b\xi^c + a$, $\Pi_{tt}^* \geq \Pi_{tt}^{c*}$.

We remark that in Corollary 2, we assume the supplier's subjective estimation of demand remains the same under a centralized system as that under a decentralized one, i.e., $\alpha^s = \alpha^c$, on the assumption that no extra information will be added to change the supplier's estimation. Recall that in the “NN” setting, the optimal order quantity in a centralized system is always higher than that of the decentralized one. In the “TT” setting, however, this is not the case. When α^s is smaller (larger) than a threshold, the order quantity in the decentralized system is higher (smaller) than that in the centralized system. This is probably because when α^s is relatively small (e.g., $\alpha^s < \alpha^r$), the supplier in the decentralized system will incentivize the retailer to order more, whereas the centralized system with a small target will be conservative and orders a quantity that is potentially smaller than that in the decentralized system. When α^s is large, in the decentralized system the retailer orders exactly the α^s . In a centralized system, a big α^s leads the supplier to be more aggressive and orders more than that in the decentralized system.

On the expected profit, the well established fact (under “NN”) that a centralized system always has a higher expected profit than that of a decentralized system no longer holds under “TT”. Specifically, there exists a range such that when α^s falls beyond (within) this range, the centralized system has a lower (higher) expected profit than the decentralized one. (In particular, when the retailer's estimation of demand is equal to the optimal order quantity in the risk-neutral centralized system, the decentralized system will always perform better.) This is because when α^s is small (large), the centralized system has a small (large) order quantity that is even lower (higher) than that of the decentralized system. This results in a higher expected profit for the decentralized system, due to the concave nature of the system profit function. When α^s is moderate, the order quantity in the centralized system is at a medium level, which enables it to perform better.

5. Comparisons

In this section, we compare the optimal decisions and supply chain performance among the four settings. *By performance, we refer to the expected profit, as we would like to understand how the target-based preference will affect the profitability of the firms as well as the supply chain.* Specifically, for each given type of supplier (retailer), we compare the scenarios of having a risk-neutral retailer (supplier) and a target-oriented retailer (supplier). There is hence a total of four cases. In what follows, we use subscript $i \in \{I, II, III, IV\}$ to denote case i .

5.1. Case I – “NN” v.s. “NT”

This section focuses on a supply chain with a risk-neutral supplier and compares the alternatives of her facing a risk-neutral retailer and a target-oriented one. For conciseness, we drop “risk-neutral” in front of “supplier”. Similar treatments apply to other three cases of comparisons.

PROPOSITION 6. *Comparing the optimal optimal decisions under “NN” and “NT”, we have*

1. $w_{nt}^* > w_{nn}^*$, i.e., the supplier sets a higher wholesale price for a target-oriented retailer than for a risk-neutral one;
2. for the order quantities,
 - (a) there exists a threshold α_I^{r1} such that $y_{nt}^* \leq y_{nn}^*$ if $\alpha^r \leq \alpha_I^{r1}$, and $y_{nt}^* > y_{nn}^*$ if $\alpha^r > \alpha_I^{r1}$;
 - (b) there exists a threshold α_I^{rc1} such that $y_{nt}^* \leq y_{nn}^{c*}$ if $\alpha^r \leq \alpha_I^{rc1}$, and $y_{nt}^* > y_{nn}^{c*}$ if $\alpha^r > \alpha_I^{rc1}$.

Since Chen et al. (2015) shows that a retailer with a higher target will order more, one may expect that when the retailer’s target is high, the supplier would charge a lower wholesale price so that the retailer would order more than if he were risk-neutral. Nevertheless, Part 1 of Proposition 6 suggests that this is not the case. Rather, the supplier always sets up a higher price when she is with a target-oriented retailer than with a risk-neutral one. The reason is that a lower profit margin will drive the retailer to more likely consider the product as a low-profit one and over-order it, which is beneficial for the supplier. The second part of Proposition 6 suggests that when α^r is small, a target-oriented retailer’s order quantity will be smaller than that of a risk-neutral retailer as well as that of a centralized system. The opposite holds when α^r is large. A small (large) α^r suggests a less (more) ambitious target, which can result in an order quantity less (more) than that for a risk-neutral retailer and for a centralized system as well.

Supply Chain Performance We compare the performance of the supply chain with a target-oriented retailer to that in the “NN” setting. This will help us understand whether it will be beneficial for the supplier and the supply chain to have a target-oriented retailer.

PROPOSITION 7. *Comparing the retailer’s and the supplier’s profits under “NN” and “NT”, we have*

1. a target-oriented retailer always performs worse than a risk-neutral retailer, i.e., $\pi_{nt}^* < \pi_{nn}^*$.
2. π_{nt}^{s*} increases with α^r , and there exists an $\hat{\alpha}_I^r$ such that $\pi_{nt}^{s*} \leq \pi_{nn}^{s*}$ if $\alpha^r \leq \hat{\alpha}_I^r$, and $\pi_{nt}^{s*} > \pi_{nn}^{s*}$ if $\alpha^r > \hat{\alpha}_I^r$.

As shown in Proposition 6, the supplier will set a higher wholesale price for a target-oriented retailer. It therefore follows that a target-oriented retailer will have a lower expected profit than a risk-neutral retailer, whose goal is to maximize his expected profit. For the supplier, however, Proposition 7 shows that she can be better off with a target-oriented retailer when α^r is large, and

worse off otherwise. This is because, although the supplier with a target-oriented retailer always has a higher profit margin, as can be seen in Proposition 6, the order quantity of the target-oriented retailer is smaller than that of the risk-neutral retailer when α^r is small. This can result in a lower expected profit for the supplier. When the value of α^r passes a threshold, a higher order quantity from the target-oriented retailer together with a higher profit margin can make the supplier outperform the case with a risk-neutral retailer.

Proposition 7 suggests that the retailer's target-based preference can be exploited by the supplier. Hence, the retailer should adopt this decision criterion with caution and consider strategies that can alleviate him from being manipulated. As shown in Section 6 later, the retailer can adopt strategies such as revealing his outside option or hiding his target-based preference to the supplier.

Let $\Pi_{nt}^* = \pi_{nt}^{s*} + \pi_{nt}^{r*}$ and $\Pi_{nn}^* = \pi_{nn}^{s*} + \pi_{nn}^{r*}$ be the total supply chain profit with a target-oriented retailer and that with a risk-neutral retailer, respectively. We have the following proposition.

PROPOSITION 8. *Comparing the supply chain profits under “NN” and “NT,” we have:*

1. *there exist two thresholds $\bar{\alpha}_I^{r1}$ and $\bar{\alpha}_I^{r2}$ such that $\Pi_{nt}^* \leq \Pi_{nn}^*$ if $\alpha^r \leq \bar{\alpha}_I^{r1}$ or $\alpha^r \geq \bar{\alpha}_I^{r2}$; and if $\alpha^r \in (\bar{\alpha}_I^{r1}, \bar{\alpha}_I^{r2})$, then $\Pi_{nt}^* \geq \Pi_{nn}^*$;*
2. *Π_{nt}^* is concave in α^r for $\alpha^r \in [\bar{\alpha}_I^{r1}, a+b]$ and achieve its maximum at $\alpha^r = b\xi^c + a$;*
3. *when $\alpha^r = b\xi^c + a$, $\Pi_{nt}^* = \Pi_{nn}^*$, i.e., the supply chain's profit under NT is the same as that for a risk-neutral centralized system.*

Proposition 8 suggests that the supply chain with a target-oriented retailer can outperform the one with a risk-neutral retailer when α^r is moderately large. This is because when α^r is very small, the supplier either is hurt or benefits insignificantly from having a target-oriented retailer and when α^r is very large, the retailer's loss is substantial. In both cases, the supplier's benefit cannot compensate the retailer's loss. When α^r is moderately large, the supplier's benefit more than compensates the retailer's loss and hence the whole supply chain performance improves. Note that here α^r can represent the retailer's subjective estimation of demand. Proposition 8 suggests that either a too ambitious (α^r is very large) or too conservative (α^r is too small) retailer will undermine the supply chain efficiency. In other words, when α^r is moderate, the double marginalization effect can be alleviated.

It is well known that the double marginalization contributes to the profit gap between a centralized and a decentralized system (Spengler 1950). Our results indicate that a target-oriented retailer can naturally help reduce the double marginalization effect and increase the supply chain efficiency. A large body of supply chain contract literature (see Cachon 2003 for a comprehensive survey) suggests that the wholesale price contract cannot coordinate a supply chain. Part 3 of Proposition 8 shows that this is only part of the story. With a target-oriented retailer, the supply chain can,

Figure 4 Profit Comparison

under a wholesale price contract, achieve the same efficiency level as a centralized system when the retailer has a specific α^r .

Propositions 7 and 8 indicate that for a range of values for α^r , the supplier and the supply chain can perform better with a target-oriented retailer than with a risk-neutral one. To gain a better understanding on the extent to which this benefit can be, we numerically investigate a scenario with $p = 10$, $c = 4$, and $D \sim U[1, 100]$. Figure 4 shows that the supplier and the supply chain will benefit from having a target-oriented retailer when α^r is greater than 16 and in the region of $[30.2, 90.6]$, respectively. The supply chain with a target-oriented retailer has the same efficiency level as a centralized system when $\alpha^r = 60.4$. Note that compared to the maximum demand 100, these threshold values (16, 30.2, and 60.4) of α^r are not unrealistically large, which makes the applicable targets reasonable and practical.

5.2. Case II – “TN” v.s. “TT”

What happens when a target-oriented supplier faces either a risk-neutral retailer or a target-oriented retailer? We answer this question by comparing settings “TN” and “TT” in this section.

PROPOSITION 9. *Comparing the optimal decisions under “TN” and “TT”, we have*

1. $w_{tn}^* \leq w_{tt}^*$, i.e., a target-oriented supplier sets a lower wholesale price for a risk-neutral retailer than for a target-oriented one;
2. for the order quantities,
 - (a) $y_{tn}^* \leq y_{tt}^*$, i.e., a risk-neutral retailer will order less than a target-oriented one;
 - (b) $y_{tn}^* \leq y_{tt}^{c*}$ if $\alpha^c = \alpha^s$.

Similar to part 1 in Proposition 6, a target-oriented supplier will quote a higher wholesale price when she faces a target-oriented retailer than a risk-neutral retailer. Different than part 2 in Proposition 6, now the target-oriented retailer always orders more than a risk-neutral retailer,

regardless what value α^r takes. This is probably because compared to a risk-neutral supplier, a target-oriented supplier is more focused on incentivizing the retailer to order enough to help her achieve the target. With a target-oriented retailer, the supplier is able to more easily manipulate through the wholesale price to have a larger order quantity to achieve her goal. Similarly, the centralized system under “TT” will have an order quantity no smaller than that of a risk-neutral retailer to a target-oriented supplier, as shown in Proposition 9, because the former has a better control over the ordering decision to attain the target.

Supply Chain Performance The following proposition compares the two firms’ profits under “TN” and “TT.”

PROPOSITION 10. *Comparing the retailer’s and the supplier’s profits under “TN” and “TT,” we have*

1. *a risk-neutral retailer always performs better than a target-oriented retailer, i.e., $\pi_{tn}^{r*} \geq \pi_{tt}^{r*}$.*
2. *a target-oriented supplier always benefits from having a target-oriented retailer, i.e., $\pi_{tn}^{s*} \leq \pi_{tt}^{s*}$.*

Proposition 10 echos Proposition 7 but differs in that now the supplier is always better off with a target-oriented retailer. This makes trading with a target-oriented retailer more attractive to a target-oriented supplier than a risk-neutral supplier.

PROPOSITION 11. *Comparing the supply chain profits under “TN” and “TT,” we have*

1. $\Pi_{tn}^* \leq \Pi_{tt}^*$;
2. Π_{tn}^* is concave in α^s for $\alpha^s \in [a, b\xi^c + a]$ and achieves its maximum at $\alpha^s = b\xi^c + a$;
3. when $\alpha^s = b\xi^c + a$, $\Pi_{tn}^* = \Pi_{tt}^* = \Pi_{nn}^*$.

Proposition 11 suggests that given the supplier is target-oriented, the supply chain with a target-oriented retailer always outperforms the one with a risk-neutral retailer. Although a target-oriented retailer performs worse than the risk-neutral one, the supplier gains much more with a target-oriented retailer which can more than compensate the loss of the former. Fundamentally, under “TT” the retailer’s target-based preference drives him to order more and hence leads to a better system performance. Part 2 of Proposition 11 follows immediately from Proposition 3, since the order quantity under the setting “TN” is equal to α^s . And when α^s is equal to the order quantity in the risk-neutral centralized system, both systems under “TT” and “TN” have an order quantity of α^s and achieve the first-best system performance, as is also shown in Proposition 11.

5.3. Case III - “NN” v.s. “TN”

Now we consider the case where the retailer is risk-neutral, and the supplier can be either risk-neutral or target-oriented. The results in this section hold for any general distribution. Proposition 12 below compares the the optimal decisions.

PROPOSITION 12. *Comparing the optimal wholesale prices and order quantities under “TN” and “NN,” there exists a threshold α_{III}^s such that $w_{tn}^* \geq w_{nn}^*$ and $y_{tn}^* \leq y_{nn}^*$ if $\alpha^s \leq \alpha_{III}^s$, and $w_{tn}^* < w_{nn}^*$ and $y_{tn}^* > y_{nn}^*$ if $\alpha^s > \alpha_{III}^s$.*

Proposition 12 holds because when α^s is large, the target-oriented supplier has a more ambitious target. So she will set a low wholesale price to incentivize the retailer to order a high quantity that is potentially larger than that under “NN.” The opposite holds when α^s is small.

Supply Chain Performance We now compare the profits under the “TN” and “NN” settings to see the impact of the supplier’s target-based preference on herself, the retailer, and the system.

PROPOSITION 13. *Comparing the retailer’s and the supplier’s profits under “TN” and “NN,” we have*

1. π_{tn}^{r*} increases with α^s , and there exists an α_{III}^s such that $\pi_{tn}^{r*} \leq \pi_{nn}^{r*}$ if $\alpha^s \leq \alpha_{III}^s$, and $\pi_{tn}^{r*} > \pi_{nn}^{r*}$ if $\alpha^s > \alpha_{III}^s$.
2. a target-oriented supplier always performs worse than a risk-neutral supplier in terms of the expected profit, i.e., $\pi_{tn}^{s*} \leq \pi_{nn}^{s*}$.

We can see that a target-oriented supplier always has a lower expected profit than a risk-neutral supplier. This is because the latter maximizes the expected profit. The retailer benefits from having a target-oriented supplier with a high estimation of demand, as she will charge a lower wholesale price, which induces a higher order quantity. This can also benefit the whole system, as shown in the following proposition.

PROPOSITION 14. *Comparing the supply chain profits under “TN” and “NN,” we have*

1. there exists a threshold α_{III}^s such that $\Pi_{tn}^* \leq \Pi_{nn}^*$ if $\alpha^s \leq \alpha_{III}^s$, and $\Pi_{tn}^* > \Pi_{nn}^*$ if $\alpha^s > \alpha_{III}^s$.
2. when $\alpha^s = F^{-1}(\xi^c)$, $\Pi_{tn}^* = \Pi_{nn}^{c*}$, i.e., the supply chain’s profit is the same as that for a risk-neutral centralized system.

Although the supplier is always worse off being target-oriented, the whole system benefits from her target-based preference when her estimation of the demand is high. Similar to the “NT” setting, now a target-oriented supplier can help reduce the double marginalization effect and increase the supply chain efficiency. Furthermore, when α^s coincides with the order quantity of the centralized system under “NN,” the supply chain can achieve the same efficiency level as the centralized system.

5.4. Case IV – “NT” v.s. “TT”

This section focuses on a supply chain with a target-oriented retailer and compares the scenarios of him trading with a risk-neutral supplier and a target-oriented one.

PROPOSITION 15. *Comparing the optimal decisions under settings “NT” and “TT,” we have*

1. if $a \leq \alpha^r < \alpha_{nt}^{r1}$, then $w_{nt}^* \leq w_{tt}^*$, $y_{nt}^* \geq y_{tt}^*$, and $\rho_{nt}^* \geq \rho_{tt}^*$;
2. if $\alpha_{nt}^{r1} \leq \alpha^r < \alpha_{nt}^{r2}$, we have
 - (a) if $a \leq \alpha^s \leq y_{nt}^1$, then $w_{nt}^* \leq w_{tt}^*$, $y_{nt}^* \geq y_{tt}^*$, and $\rho_{nt}^* \geq \rho_{tt}^*$,
 - (b) if $y_{nt}^1 \leq \alpha^s \leq 2\alpha^r - a$, then $w_{nt}^* \geq w_{tt}^*$, $y_{nt}^* \leq y_{tt}^*$, and $\rho_{nt}^* \leq \rho_{tt}^*$;
3. if $\alpha_{nt}^{r2} \leq \alpha^r \leq a + b$, then $w_{nt}^* \geq w_{tt}^*$, $y_{nt}^* \leq y_{tt}^*$, and $\rho_{nt}^* \leq \rho_{tt}^*$;

Proposition 15 suggests that when α^r is small (large), a risk-neutral supplier sets up a lower (higher) wholesale price than a target-oriented supplier, resulting in higher (lower) order quantity. This is because a retailer with a small α^r is conservative in ordering; in order to incentivize the retailer to order more, both the risk-neutral and target-oriented supplier would quote a small wholesale price. However, the risk-neutral supplier will be more aggressive in reducing the wholesale price as he maximizes the profit, whereas the target-oriented supplier just needs the retailer to order enough so that she can reach her target. When α^r is large, the retailer is aggressive in ordering. Both types of suppliers would take advantage of this over-ordering behavior through increasing the wholesale price, with the risk-neutral supplier being more aggressive in doing so. This is probably because now the profit margin plays a more important role in profitability than the order quantity. When α^r takes a medium value, a small α^s ($< y_{nt}^1$) drives the target-oriented supplier to quote a higher wholesale price to push the retailer to order approaching to α^r , which is smaller than y_{nt}^1 , the order quantity with a risk-neutral supplier. If α^s is relatively large ($> y_{nt}^1$), then the target-oriented supplier would quote a relatively small wholesale price to induce the retailer to order exactly α^s , which is greater than y_{nt}^1 . We also observe from Proposition 15 that whether a target-oriented retailer can have a better ability to attain the target (a higher CSM) with a risk-neutral or a target-oriented supplier is consistent with whether the order quantity is higher under a risk-neutral or a target-oriented retailer.

Supply Chain Performance We now compare the profits of the two firms and the supply chain under settings “NT” and “TT.”

PROPOSITION 16. *Comparing the retailer’s and the supplier’s profits under settings “NT” and “TT,” we have*

1. if $a \leq \alpha^r < \alpha_{nt}^{r1}$, then $\pi_{nt}^{r*} \geq \pi_{tt}^{r*}$ and $\pi_{nt}^{s*} \geq \pi_{tt}^{s*}$;
2. if $\alpha_{nt}^{r1} \leq \alpha^r < \alpha_{nt}^{r2}$, we have
 - (a) if $a \leq \alpha^s < \alpha^r$, then $\pi_{nt}^{r*} \geq \pi_{tt}^{r*}$ and $\pi_{nt}^{s*} \geq \pi_{tt}^{s*}$;
 - (b) if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, then $\pi_{nt}^{s*} \geq \pi_{tt}^{s*}$.
3. if $\alpha_{nt}^{r2} \leq \alpha^r \leq a + b$, then $\pi_{nt}^{r*} \leq \pi_{tt}^{r*}$ and $\pi_{nt}^{s*} \geq \pi_{tt}^{s*}$;

Propositions 16 suggests that when facing a target-oriented retailer, a supplier is always hurt by being target-oriented, as her objective is to attain the profit target but not to maximize the expected profit. The retailer, on the other hand, can benefit from the supplier being target-oriented when his target is large. This is because when the retailer's target is large, compared to a risk-neutral supplier, a target-oriented one will be less aggressive in increasing the wholesale price, which benefits the retailer.

PROPOSITION 17. *Comparing the supply chain profits under the settings “NT” and “TT” setting, we have:*

1. *if $a \leq \alpha^r < \alpha_{nt}^{r1}$, then $\Pi_{nt}^* \geq \Pi_{tt}^*$;*
2. *if $\alpha_{nt}^{r1} \leq \alpha^r < \alpha_{nt}^{r2}$, we have*
 - (a) *if $a \leq \alpha^s < y_{nt}^1$ or $\min\{2(a+b) - y_{nt}^1 - 2bc/p, 2\alpha^r - a\} \leq \alpha^s \leq 2\alpha^r - a$, then $\Pi_{nt}^* \geq \Pi_{tt}^*$;*
 - (b) *if $y_{nt}^1 \leq \alpha^s < \min\{2(a+b) - y_{nt}^1 - 2bc/p, 2\alpha^r - a\}$, then $\Pi_{nt}^* \leq \Pi_{tt}^*$.*
3. *if $\alpha_{nt}^{r2} \leq \alpha^r \leq a+b$, we have*
 - (a) *if $a \leq \alpha^s < \min\{2(a+b) - \alpha^r - 2bc/p, 2\alpha^r - a\}$, then $\Pi_{nt}^* \leq \Pi_{tt}^*$;*
 - (b) *if $\min\{2(a+b) - y_{nt}^1 - 2bc/p, 2\alpha^r - a\} \leq \alpha^s \leq 2\alpha^r - a$, then $\Pi_{nt}^* \geq \Pi_{tt}^*$.*

We observe in Proposition 17 that the supply chain will perform better with a target-oriented supplier than a risk-neutral one when i) α^r is moderate and α^s is relatively large but still less than a threshold or ii), when α^r is large and α^s is below a threshold. This is because in the former case, a large α^s will drive the target-oriented supplier to quite a relatively small wholesale price to incentivize the retailer to order exactly α^s , which is greater than the order quantity with a risk-neutral supplier. This can benefit the whole supply chain. When α^s is beyond the threshold, however, the order quantity will be too high, which hurts the supply chain. In the latter case with a large α^r , compared to the risk-neutral supplier, the target-oriented supplier is less aggressive in increasing the wholesale price, resulting a higher order quantity that can benefit the supply chain. Nevertheless, if α^s is beyond a threshold, the high order quantity, which is essentially α^s , can hurt the supply chain.

For ease of reference, we summarize the results of all these comparisons in Table 2.

6. Outside Option and retailer type misidentification

So far, we have shown that a firm, be it the supplier or the retailer, is always hurt by the target-based preference, regardless whether the trading partner is target-oriented or risk-neutral. Since the retailer has to react to the supplier's decision, which puts him in a weak position, in this section we explore two scenarios—i) the retailer has an outside option and ii), the retailer's type (target-oriented versus risk-neutral) is being misidentified—and show that they can potentially help mitigate the retailer's disadvantage of being target-oriented.

Table 2 A summary of comparison results

	NN	TN	NN	NT
	v.s.	v.s.	v.s.	v.s.
	NT	TT	TN	TT
Wholesale price	$\leq$	$\leq$	$\leq\geq$	$\leq\geq$
Order quantity	$\leq\geq$	$\leq$	$\leq\geq$	$\leq\geq$
Retailer's profit	$\geq$	$\geq$	$\leq\geq$	$\leq\geq$
Supplier's profit	$\leq\geq$	$\leq$	$\geq$	$\geq$
Supply chain profit	$\leq\geq$	$\leq$	$\leq\geq$	$\leq\geq$

“ $\geq$ ($\leq$)” means the former is greater (smaller) than the latter and “ $\leq\geq$ ” means the former could be either greater or smaller than the latter

6.1. Retailer with an Outside Option

In practice, it can happen that the retailer has an outside option, that is, there exists an alternative supplier, with whom the retailer's ability to achieve the target is maximized at $\bar{\eta}$. As such, $\bar{\eta}$ becomes the lower bound for the satisficing measure the retailer seeks for. The retailer's problem then becomes $\max_{y \geq 0, \eta \geq \bar{\eta}} \rho_{\tau}(V(y; D))$. Solving this problem, we can obtain both the order quantity y and η as functions of the wholesale price w .

Risk-Neutral Supplier Anticipating the retailer's response, the risk-neutral supplier will find an optimal wholesale price to maximize her profit conditioning on the retailer accepting the contract. This implies that the wholesale price must be such that $\eta(w) \geq \bar{\eta}$. Hence, the supplier's problem becomes

$$\begin{aligned} \max \quad & (w - c)y(w) \\ \text{s.t.} \quad & c \leq w \leq p \\ & \eta(w) \geq \bar{\eta} \end{aligned}$$

Let $w_o = p[b(1 - \bar{\eta}) - 2(\alpha^r - a)]/(b(1 + \bar{\eta}))$, $w_o^1 = p - 2p(\alpha^r - a)/(b(1 - \bar{\eta}))$, $w_o^2 = p - 2p(\alpha^r - a)/b$, $\xi_o \triangleq 3/2 - (b - a)/(b(1 + \bar{\eta})^2)$, and $\alpha_{nt}^{r2o} = [3(a + b) - \sqrt{(a + b)^2 + 4b^2(1 + \bar{\eta})^2(p + c)/p}]/4$, $\pi_o^{s2}(w_{nt}^1) = -2\sqrt{2p(p + c)(a + b - \alpha^r)(a + b - 2\alpha^r)} + (3p + c)(a + b - 2\alpha^r) + 2p\alpha^r$, $w_o^1 = p - 2p(\alpha^r - a)/(b(1 - \bar{\eta}))$, $w_o^2 = p - 2p(\alpha^r - a)/b$, $\pi_o^{s1}(w_o^1) \triangleq [p - c - 2p(\alpha^r - a)/(b(1 - \bar{\eta}))](2\alpha^r - a)$ and $\pi_o^{s1}(w_o^2) \triangleq [p - c - 2p(\alpha^r - a)/b](2\alpha^r - a)$, the following proposition summarizes the optimal decisions.

PROPOSITION 18. *If the retailer has an outside option with a guaranteed satisficing measure of $\bar{\eta}$, the risk-neutral supplier's optimal wholesale price, w_{nt}^* , and the retailer's optimal order quantity, y_{nt}^* , are given as follows.*

1. If $\bar{\eta} \leq -\frac{\alpha^r - a}{b}$, w_{nt}^* and y_{nt}^* are the same as those in Proposition 2.
2. When $-\frac{\alpha^r - a}{b} < \bar{\eta} \leq 0$,
 - (a) if $\xi^c \leq \xi_o$, then $w_{nt}^* = w_o$ if $\pi_o^{s2}(w_o) \geq \pi_o^{s1}(w_o^2)$; otherwise, $w_{nt}^* = w_o^2$;

(b) if $\xi^c > \xi_o$, then

$$\begin{cases} w_{nt}^* = \frac{p(2a+b-2\alpha^r)}{b}, & y_{nt}^* = 2\alpha^r - a, & \text{if } \alpha^r \in [a, \alpha_{nt}^{r1}); \\ w_{nt}^* = w_{nt}^1, & y_{nt}^* = y_{nt}^1, & \text{if } \alpha^r \in [\alpha_{nt}^{r1}, \alpha_{nt}^{r2o}); \\ w_{nt}^* = w_o, & y_{nt}^* = b\bar{\eta} + 2(\alpha^r - a) + \frac{b\alpha^r}{a+b-\alpha^r}, & \text{if } \alpha^r \in [\alpha_{nt}^{r2o}, a+b]. \end{cases}$$

3. When $\bar{\eta} > 0$,

(a) if $\xi^c \leq \xi_o$, then $w_{nt}^* = w_o$ and $y_{nt}^* = b\bar{\eta} + 2(\alpha^r - a) + \frac{b\alpha^r}{a+b-\alpha^r}$;

(b) if $\xi^c > \xi_o$, $w_{nt}^* = w_{nt}^1$, $y_{nt}^* = y_{nt}^1$ if $\pi_o^{s2}(w_{nt}^1) \geq \pi_o^{s1}(w_o^1)$; otherwise, $w_{nt}^* = w_o^1$.

Proposition 18 shows that if the retailer's outside option is unattractive ($\bar{\eta}$ is very low), then the supplier will adopt the same strategy as if the retailer has no outside options. When $\bar{\eta}$ is above a threshold, however, in order to keep the retailer in the game, the supplier will modify her strategy such that the wholesale price never approaches to p and is always an interior solution. As such, the outside option alleviates the retailer's disadvantage of being target-oriented.

Target-oriented Supplier If the supplier is target-oriented, her problem then becomes

$$\begin{aligned} & \max w \\ & \text{s.t. } c \leq w \leq p; \\ & (w - c)y(w) \geq \tau^s; \\ & \eta(w) \geq \bar{\eta}. \end{aligned}$$

The following proposition summarizes the optimal decisions for both the supplier and the retailer.

PROPOSITION 19. *If the retailer has an outside option with a guaranteed satisfying measure of $\bar{\eta}$, the target-oriented supplier's optimal wholesale price, w_{nt}^* , and the retailer's optimal order quantity, y_{nt}^* , are given as follows.*

1. If $\bar{\eta} \leq \frac{\alpha^s - 2\alpha^r + a}{b}$, w_{nt}^* and y_{nt}^* are the same as those in Proposition 4.
2. When $\frac{\alpha^s - 2\alpha^r + a}{b} < \bar{\eta} \leq -\frac{\alpha^r - a}{b}$, then $w_{nt}^* = p - \epsilon$ and $y_{nt}^* = \alpha^r - \epsilon$;
3. If $-\frac{\alpha^r - a}{b} < \bar{\eta} \leq 0$, then $w_{nt}^* = w_o$ and $y_{nt}^* = b\bar{\eta} + 2(\alpha^r - a) + \frac{b\alpha^r}{a+b-\alpha^r}$.
4. If $\bar{\eta} > 0$, the supplier's problem is not feasible.

From Proposition 19, we can see that if the retailer's outside option is such that $\bar{\eta} > 0$, then no contract will be offered by the supplier. When $\bar{\eta}$ is negative and greater than a threshold, then the target-oriented supplier will reduce her wholesale price (i.e., $w_o \leq w_{nt}^*$, as shown in the proof of the proposition), which is beneficial for the retailer.

6.2. retailer type misidentification

We have analyzed the impact of a target-oriented retailer based on the assumption that the supplier has full knowledge of the retailer being target-oriented. In practice, however, this may not be the case. We now study how retailer type misidentification—the supplier misidentifying the retailer's type—affects the supply chain performance. There are two scenarios: i) the supplier believes the

retailer to be risk-neutral but the retailer is target-oriented; and ii) the supplier mistakes the risk-neutral retailer as target-oriented. We discuss these two scenarios for both when the supplier is target-oriented and risk-neutral, and use the tilde sign to denote the results under retailer type misidentification.

retailer type misidentification when the supplier is risk-neutral For the first scenario where the supplier mistakes a target-oriented retailer as risk-neutral, she will set her wholesale price to be w_{nn}^* , and the retailer responds according to Lemma 1 (see Online Appendix A). Let $\alpha_{nt}^3 = \frac{p(b+3a)-bc}{4p}$, we summarize in Proposition 20 the optimal decisions and compare the profits with those under the case without retailer type misidentification.

PROPOSITION 20. *If the supplier mistakes a target-oriented retailer as risk-neutral, then:*

1. $\tilde{w}_{nt}^* = w_{nn}^*$;
2. *the retailer's optimal order quantity is*

$$\tilde{y}_{nt}^* = \begin{cases} 2\alpha^r - a, & \text{if } a \leq \alpha^r < \alpha_{nt}^3, \\ \frac{2bp(a+b)-(pa+pb+bc)(a+b-2\alpha^r)}{pa+3pb+bc}, & \text{if } \alpha_{nt}^3 \leq \alpha^r \leq a+b; \end{cases}$$

and $\tilde{y}_{nt}^ \geq y_{nt}^*$;*

3. *the supplier is hurt by the retailer type misidentification, i.e., $\tilde{\pi}_{nt}^{s*} \leq \pi_{nt}^{s*}$;*
4. *the retailer benefits from the retailer type misidentification, i.e., $\tilde{\pi}_{nt}^{r*} \geq \pi_{nt}^{r*}$;*
5. *when $\alpha^r = \alpha_{nt}^3$, the retailer's profit and the supply chain's profit are the same as those when the retailer is risk-neutral and correctly identified so, i.e., $\tilde{\pi}_{nt}^{r*} = \pi_{nn}^{r*}$ and $\tilde{\Pi}_{nt}^* = \Pi_{nn}^*$,*
6. *the supply chain can obtain the same profit as that for a risk-neutral centralized system, i.e., $\tilde{\Pi}_{nt}^* = \Pi_{nn}^{c*}$, if $\alpha^r = \frac{2p^2(a+b)^2-pbc(b-a)-b^2c^2}{2p(pa+pb+bc)}$.*

Proposition 20 shows that when the supplier mistakes the target-oriented retailer to be risk-neutral, the wholesale price is lower than that if the retailer type is accurately identified. Correspondingly, the retailer's order quantity is higher, as according to Lemma 1, it is non-increasing with the wholesale price. We also observe that the supplier is hurt by the retailer type misidentification, whereas the retailer benefits from it; and if $\alpha^r = \alpha_{nt}^3$, he can even retain the same expected profit as that when he is risk-neutral. This suggests that by incorrectly identifying the retailer's type, the supplier will benefit less, if any, from having a target-oriented retailer. On the other hand, a target-oriented retailer can hide his type information to gain from it. Furthermore, the last part of Proposition 20 suggests that a target-oriented retailer, even if being mistaken as risk-neutral, can still help eliminate the double marginalization effect and increase the supply chain efficiency.

We now move to the second scenario where the retailer is risk-neutral but the supplier mistakes him to be target-oriented. In this case, the supplier would set the wholesale price to be w_{nt}^* , but the retailer responds as a risk-neutral one would. We summarize in Proposition 21 the optimal decisions and compare the profits with those when the retailer is accurately identified to be risk-neutral.

PROPOSITION 21. *If the supplier mistakes a risk-neutral retailer as target-oriented, then:*

1. $\tilde{w}_{nn}^* = w_{nt}^*$;
2. *the retailer's optimal order quantity is*

$$\tilde{y}_{nn}^* = \begin{cases} 2\alpha^r - a & \text{if } a \leq \alpha^r < \alpha_{nt}^{r1}, \\ a + b - \frac{w_{nt}^1 b}{p} & \text{if } \alpha_{nt}^{r1} \leq \alpha^r < \alpha_{nt}^{r2}, \\ a & \text{if } \alpha_{nt}^{r2} \leq \alpha^r \leq a + b; \end{cases}$$

3. *Both the supplier, the retailer, and hence the supply chain are worse off with retailer type misidentification, i.e., $\tilde{\pi}_{nn}^{r*} \leq \pi_{nn}^{r*}$, $\tilde{\pi}_{nn}^{s*} \leq \pi_{nn}^{s*}$, and $\tilde{\Pi}_{nn}^* \leq \Pi_{nn}^*$;*

When the supplier mistakenly identifies the risk-neutral retailer to be target-oriented, she will set up a wholesale price that deviates from the equilibrium with a risk-neutral retailer. The retailer, however, will still respond with a risk-neutral objective. As such, both the supplier and the retailer are worse off, and so is the supply chain.

Retailer type misidentification when the supplier is target-oriented Similarly, the target-oriented supplier may mistakenly treat a target-oriented retailer as risk-neutral, or a risk-neutral retailer as target-oriented. In the former case, the supplier sets her wholesale price as w_{tn}^* , whereas the retailer orders according to Lemma 1. We summarize in Proposition 22 the optimal decisions and compare the profits with those under the case without retailer type misidentification.

PROPOSITION 22. *If the target-oriented supplier mistakes the target-oriented retailer to be risk-neutral and $\alpha^s \leq a + b - bc/p$, let $\mathcal{S}_0 = \{(\alpha^r, \alpha^s) : a \leq \alpha^s \leq 2\alpha^r - a; \alpha^s \leq a + b - bc/p; a \leq \alpha^r \leq a + b\}$, $\mathcal{S}_1 = \{(\alpha^r, \alpha^s) : p(a + b)^2 - bc(a + b) + \alpha^r(bc - 2ap - 3bp) - \alpha^s p(a + b - 2\alpha^r) \leq 0; \alpha^s \leq \alpha^r\}$, $\mathcal{S}_2 = \{(\alpha^r, \alpha^s) : p(a + b)^2 - bc(a + b) + 2\alpha^r(bc - ap - bp) - \alpha^s(bc + 2bp + ap - 2\alpha^r p) \leq 0; \alpha^s \geq \alpha^r\}$, $\mathcal{S}_3 = \{(\alpha^r, \alpha^s) : p(a + b)(3a + 4b) - 2bc(2b + a) - p\alpha^r(3a + 4b) + \alpha^s(2bc - 3ap - 3bp + 3\alpha^r p) \leq 0; \alpha^s \leq \alpha^r\}$, and $\mathcal{S}_4 = \{(\alpha^r, \alpha^s) : p(a + b)(3a + 4b - 2\alpha^r) - 2bc(2b + a) + \alpha^s(2bc - 4ap - 5bp + 2\alpha^r p) + (\alpha^s)^2 p \leq 0; \alpha^s \geq \alpha^r\}$. We then have:*

1. $\tilde{w}_{tt}^* = w_{tn}^* \leq w_{tt}^*$;
2. *the retailer's optimal order quantity is $\tilde{y}_{tt}^* = \frac{(p - w_{tn}^*)(a + b) + 2w_{tn}^* \alpha^r}{p + w_{tn}^*} \geq y_{tt}^*$;*
3. *the supplier is hurt by the retailer type misidentification i.e., $\tilde{\pi}_{tt}^{s*} \leq \pi_{tt}^{s*}$ if $(\alpha^r, \alpha^s) \in (\mathcal{S}_1 \cup \mathcal{S}_2) \cap \mathcal{S}_0$; otherwise, the supplier benefits from the retailer type misidentification;*
4. *the retailer always benefits from the retailer type misidentification, i.e., $\tilde{\pi}_{tt}^{r*} \geq \pi_{tt}^{r*}$;*
5. *the supply chain is hurt by the retailer type misidentification i.e., $\tilde{\Pi}_{tt}^* \leq \Pi_{tt}^*$ if $(\alpha^r, \alpha^s) \in (\mathcal{S}_3 \cup \mathcal{S}_4) \cap \mathcal{S}_0$; otherwise, the supply chain benefits from the retailer type misidentification.*

Similar to the case where a risk-neutral supplier mistakes the target-oriented retailer to be risk-neutral, Proposition 22 shows that a target-oriented supplier also sets up a lower wholesale price

under retailer type misidentification, resulting in a higher order quantity. As a result, the retailer always benefits from the type misidentification. More interestingly, the supplier, as well as the supply chain, can also sometimes be better-off when the retailer's type is misidentified.

For the second scenario where the supplier mistakes the risk-neutral retailer for a target-oriented one, the supplier quotes a wholesale price w_{tt}^* , but the retailer places an order as a risk-neutral one would. We summarize in Proposition 23 the optimal decisions and compare the profits with those when the retailer is accurately identified to be risk-neutral.

PROPOSITION 23. *If the target-oriented supplier mistakes a risk-neutral retailer to be target-oriented, then we have:*

1. $\tilde{w}_{tn}^* = w_{tt}^* \geq w_{tn}^*$;
2. *the retailer's optimal order quantity is $\tilde{y}_{tn}^* = a + b - \frac{b}{p}w_{tt}^*$ and $\tilde{y}_{tn}^* \leq y_{tn}^*$.*
3. *The supplier is worse off with retailer type misidentification if $\alpha^s \leq \alpha_{III}^s$, i.e., $\tilde{\pi}_{tn}^{s*} \leq \pi_{tn}^{s*}$; she benefits from retailer type misidentification if $\alpha_{III}^s \leq \alpha^s < \alpha^r$ and $\xi^c \leq \frac{a}{b}$.*
4. *Both the retailer and the supply chain are worse off with retailer type misidentification, i.e., $\tilde{\pi}_{tn}^{r*} \leq \pi_{tn}^{r*}$ and $\tilde{\Pi}_{tn}^* \leq \Pi_{tn}^*$;*

When the target-oriented supplier mistakes a risk-neutral retailer to be target-oriented, similar to the case when the supplier is risk-neutral, the wholesale price (order quantity) in equilibrium is higher (lower) than that without retailer type misidentification, resulting in a lower expected profit for the retailer and the whole chain. Interestingly, different than the scenario when the supplier is risk-neutral, the target-oriented supplier can sometimes benefit from the retailer type misidentification.

7. Robustness check

In this section, we will conduct a numerical study to check the robustness of our results with respect to different demand distributions. For conciseness, we only present the results under “NT” and its comparison with the “NN” setting. Interested readers can contact the authors for the results on other settings. We study five types of commonly encountered demand distributions, including Uniform, truncated Normal, Gamma, Log-Normal, and Weibull distributions.

Let $\theta = \frac{\pi_{nt}^{s*} - \pi_{nn}^{s*}}{\pi_{nn}^{s*}}$ denote the supplier's performance gap between having a target-oriented retailer and a risk-neutral retailer, and $\Theta = \frac{\Pi_{nt}^* - \Pi_{nn}^*}{\Pi_{nn}^*}$ the supply chain's performance gap.

To evaluate the impact of the demand distribution, we look at the scenario where all the distributions have the same mean and standard deviations. For ease of exposition, we report the results for the case of $p = 10$, $c = 4$, the mean equal to 50, and the standard deviation equal to 28.29. We note that the observations with other parameters are similar. Figure 5 shows the optimal decisions

Figure 5 Optimal Decisions and Profits under Different Distributions

and expected profits for each of the five distributions under the case with a target-oriented retailer. We can see that they display the same pattern under all the five distributions. Furthermore, Figure 6 shows that there exist threshold values of α^r such that the supplier and the supply chain benefit from having a target-oriented retailer. These observations are consistent with our theoretical results and suggest that our findings are robust with respect to demand distributions.

Figure 6 Performance Gaps under Different Distributions

While the optimal decisions and performance metrics display the same pattern for all the five demand distributions, we do observe from Figure 6 that the supplier benefits the most from having

a target-oriented retailer when the demand is uniformly distributed, and the least with a Log-Normal distribution of the demand. The higher standardized moments of the distributions such as skewness and kurtosis can be a contributing factor to this difference.

8. Conclusions

In this paper, we study a supply chain with one supplier and one retailer. Both the supplier and the retailer can either be risk-neutral or target-oriented. We aim to investigate the impact of firms' target-based preferences on the optimal decisions and supply chain performance. Assuming the target is linearly dependent on the profit margin, we find that regardless the supplier's type, i) the supplier sets a higher wholesale price for a target-oriented retailer than for a risk-neutral one; and ii) the retailer is always hurt by his target-based preference. Furthermore, if the supplier is risk-neutral, i) the supplier can *sometimes* benefit from working with a target-oriented retailer; and ii) a target-oriented retailer can help reduce and even eliminate the double-marginalization effect and improve the supply chain efficiency. If the supplier is target-oriented, both the supplier and the supply chain are *always* better off with a target-oriented retailer, who can also sometimes help eliminate the double marginalization effect with a specific target.

We also find that regardless the retailer's type, a supplier is always hurt by her target-based preference. The retailer (being it target-oriented or risk-neutral) as well as the supply chain can sometimes perform better with a target-oriented supplier than a risk-neutral one, which depends on how ambitious the supplier or (and) retailer sets the target. In other words, a target-oriented supplier can also help alleviate the effect of double marginalization to improve the supply chain performance. Furthermore, a supply chain with a target-oriented supplier can sometimes reach the same efficiency level as the risk-neutral centralized system when the supplier has a specific target.

Another interesting finding is that comparing a centralized target-oriented system with a decentralized one where both firms are target-oriented, the decentralized system can sometimes have a higher order quantity and achieve a higher system profitability. This is in direct contrast to a risk-neutral system, where a centralized supply chain always performs better than a decentralized one with both firms being risk-neutral.

To the best of our knowledge, our research is the first to analyze the supply chain performance with target-oriented firms. Our results provide important guidelines to managers in a supply chain: i) Being target-oriented can put a firm in a position less favorable or being exploited and as such, it should adopt this decision criterion with caution; ii) in order to be less exploited, a target-oriented retailer can strategically hide his target-based preference or reveal his outside option; iii) whether the supplier (retailer) and the supply chain can benefit from having a target-oriented retailer (supplier) often depends on how ambitious the retailer (supplier) is in setting the target; iv) target-based preference of one or both firms can help the supply chain reach the first-best efficiency; and

v) when both firms are target-oriented, decentralization may be preferred to centralization. We also note that, although our analysis suggests that with a target-oriented retailer (supplier), the supply chain efficiency can be improved and sometimes can reach that in a risk-neutral centralized system, it is often at the cost of the retailer's (supplier's) expected profit.

While our results are only applicable to the scenario of one supplier trading with one retailer in a single period, as a first initiative to explore the impact of the target-based preference on the supply chain performance, our work opens up research opportunities for other problem settings such as competition, multiple locations, multiple periods, etc. While we assume a firm's type is exogenously fixed, it can be worthwhile to investigate the firms' decisions on being target-oriented or risk-neutral at equilibrium. There also remains a question whether there exists a different trading agreement such that the retailer's (supplier's) expected profit, when hurt by his (her) target-based preference, is less negatively affected.

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Online Appendices of “Supply Chain Performance with Target-Oriented Firms”

Due to the page limit, this online appendix only presents the sketches of proofs in Appendix A and important parts of Appendices C and D. A complete version of the online appendix (Appendices A to E) can be found at <https://ssrn.com/abstract=3533746> or obtained by contacting the authors.

Online Appendix A: Proofs of All Propositions

Before we prove Proposition 1, let us first derive the retailer's best response strategy as in Lemma 1.

LEMMA 1. Denote $G_1(\eta, w) = p \int_a^{F^{-1}(\xi - \eta\xi)} u dF(u) - (1 - \eta)\alpha^r(p - w)$, and $G_2(\eta, w) = p \int_{F^{-1}(-\eta)}^{F^{-1}(\xi - \eta(1 - \xi))} u dF(u) - (1 + \eta)\alpha^r(p - w)$, where $\xi = \frac{p-w}{p}$. Also let $\eta_1 = \{\eta \in [0, 1] \text{ s.t. } G_1(\eta, w) = 0\}$, $\eta_2 = \{\eta \in [-1, 0] \text{ s.t. } G_2(\eta, w) = 0\}$, for any given $w \in [c, p]$, and denote $\bar{w} = \{w \in [c, p(1 - F(\alpha^r))] : G_1(0, w) \geq 0\}$. The retailer's order quantity as a function of w , $y(w)$, is given as follows:

$$y(w) = \begin{cases} F^{-1}(\xi - \eta_1\xi) & \text{if } w \leq \bar{w}, \\ F^{-1}(\xi - \eta_2(1 - \xi)) & \text{if } w > \bar{w}. \end{cases}$$

Proof of Lemma 1. According to Proposition 1 in Chen et al. (2015), we have

$$y(\eta, w) = \underset{y \geq 0}{\operatorname{argmax}} \operatorname{CVaR}_\eta(V(y; D)) = \begin{cases} F^{-1}(\xi - \eta\xi) & \text{if } \eta \in [0, 1] \\ F^{-1}(\xi - \eta(1 - \xi)) & \text{if } \eta \in (-1, 0). \end{cases}$$

where $\xi = (p - w)/p$. Substituting $y(\eta, w)$ back into $\operatorname{CVaR}_\eta(V(y; D))$, denote $G_1(\eta, w)$ and $G_2(\eta, w)$ as in the Lemma 1, and let $G(\eta, w) = \begin{cases} G_1(\eta, w) & \text{if } \eta \in [0, 1], \\ G_2(\eta, w) & \text{if } \eta \in (-1, 0), \end{cases}$ where $\tau(w) = \alpha^r(p - w)$ and $\alpha^r > 0$, then Problem (7) is equivalent to $\sup_\eta \eta \text{ s.t. } G(\eta, w) \geq 0$.

It is easy to show that $G_1(\eta, w)$ is convex in η given any $w \in [c, p]$. As for $G_2(\eta, w)$, note that $\frac{\partial^2 G_2(\eta, w)}{\partial \eta^2} = p \left(\frac{(1 - \xi)^2}{f(F^{-1}(\xi - (1 - \xi)\eta))} - \frac{1}{f(F^{-1}(-\eta))} \right)$, and if $f(x)$ is log-concave, then $1 - F(x)$ is also log-concave (Bagnoli and Bergstrom 2005, Theorem 4), so $f(F^{-1}(x))/(1 - x)$ increases with x . We thus have, $(1 - \xi)^2 f(F^{-1}(-\eta)) - f(F^{-1}(\xi - (1 - \xi)\eta)) = (1 - \xi)(1 + \eta) \frac{(1 - \xi)f(F^{-1}(-\eta))}{1 + \eta} - \frac{f(F^{-1}(\xi - (1 - \xi)\eta))}{(1 - \xi)(1 + \eta)} \leq (1 - \xi)(1 + \eta) \frac{f(F^{-1}(\xi - (1 - \xi)\eta))}{(1 - \xi)(1 + \eta)} (-\xi) \leq 0$, where the second last inequality is because $\frac{f(F^{-1}(-\eta))}{1 + \eta} \leq \frac{f(F^{-1}(\xi - (1 - \xi)\eta))}{(1 - \xi)(1 + \eta)}$. As such, $G_2(\eta, w)$ is concave in η given any $w \in [c, p]$. We then can obtain the optimal η , and hence $y(w)$. ■

Proof of Proposition 1. If $w \leq \bar{w}$, that is, $\tau(w) \leq p \int_a^{F^{-1}(\xi)} u dF(u)$, we set $\frac{\partial G_1(\eta_1, w)}{\partial w}$ to be zero so we have $\frac{d\eta_1}{dw} = \frac{(F^{-1}(\xi - \eta_1\xi) - \alpha^r)(1 - \eta_1)}{\tau(w) - (p - w)F^{-1}(\xi - \eta_1\xi)} = -\frac{1 - \eta_1}{p - w} \leq 0$, and thus $y'(w) = \frac{1}{f(F^{-1}(\xi - \eta_1\xi))} \left(-\frac{1}{p}(1 - \eta_1) - \xi \frac{d\eta_1}{dw} \right) = 0$. In this case, the supplier will set the maximum wholesale price such that $\tau(w) \leq p \int_a^{F^{-1}(\xi)} u dF(u)$, that is, $w_{nt}^0 \triangleq \max\{w : G_1(0, w) \geq 0\}$. Moreover, note that $\frac{dG_1(0, w)}{dw} = \alpha^r - F^{-1}(\xi)$, $\frac{d^2 G_1(0, w)}{dw^2} = \frac{1}{p} \frac{1}{f(F^{-1}(\xi))} \geq 0$, therefore, $G_1(0, w)$ is convex in w . Besides, since $G_1(0, 0) > 0$, $G_1(0, p) = 0$, there must exist a maximum w such that $G_1(0, w) = 0$, namely, $G_1(0, w_{nt}^0) = 0$. On the other hand, since there exists a unique η such that $G_1(\eta, w) \geq 0$ given any w , we have $\eta_1 = 0$. Hence, ρ^* is either 0 or attained in $(-1, 0)$, that is $\rho^* \leq 0$. ■

Proof of Proposition 2. According to Lemma 1,

(1) If $a \leq \alpha^r < a + b(p - w)/(2p)$, $\pi_{nt}^s(y(w))$ increases with w , so $w_{nt}^0 = p - 2p(\alpha^r - a)/b$, and $\pi_{nt}^{s1}(w_{nt}^0) = [p - c - 2p(\alpha^r - a)/b](2\alpha^r - a)$.

(2) If $a + b(p - w)/(2p) \leq \alpha^r \leq a + b$, $\pi_{nt}^s(y(w)) = -(p + w)(a + b - 2\alpha^r) - 2p(p + c)(a + b - \alpha^r)/(p + w) + (3p + c)(a + b - 2\alpha^r) + 2p\alpha^r$. If $a + b - 2\alpha^r > 0$, $\pi_{nt}^s(y(w))$ is concave in (c, p) . Solving the FOC gives $w_{nt}^1 = \sqrt{2p(p + c)(a + b - \alpha^r)/(a + b - 2\alpha^r)} - p$. In order to secure $w_{nt}^1 \in (c, p)$, we need $\alpha^r \leq \alpha_{nt}^{r2} \triangleq (p - c)(a + b)/(3p - c)$, otherwise, $w_{nt}^1 = p - \epsilon$. The corresponding optimal profit for supplier when $\alpha^r \leq \alpha_{nt}^{r2}$ is $\pi_{nt}^{s2}(w_{nt}^1) = -2\sqrt{2p(p + c)(a + b - \alpha^r)(a + b - 2\alpha^r)} + (3p + c)(a + b - 2\alpha^r) + 2p\alpha^r$. For $a + b - 2\alpha^r \leq 0$, $\pi_{nt}^s(y(w))$ increases with w , which indicates that $w_{nt}^* = p - \epsilon$, $y_{nt}^* = \alpha^r - \epsilon$, and $\pi_{nt}^s(w_{nt}^*) = (p - c)\alpha^r - \epsilon$. But w_{nt}^* will not be equal to p . In order to make α_{nt}^{r2} no less than a , we need $b/a \geq 2/\xi^c$. For $b/a < 2/\xi^c$, $\alpha_{nt}^{r2} < a$, that is, the supplier will always set up his wholesale price approaching to retailing price p , $w_{nt}^* = p - \epsilon$.

Next, we need to compare $\pi_{nt}^{s1}(w_{nt}^0)$ and $\pi_{nt}^{s2}(w_{nt}^1)$ when $\alpha^r \leq \alpha_{nt}^{r2}$ and $b/a \geq 2/\xi^c$. A simple comparison shows that $\pi_{nt}^{s1}(w_{nt}^0) \geq \pi_{nt}^{s2}(w_{nt}^1)$ if $\alpha^r \leq \alpha_{nt}^{r1}$, otherwise, $\pi_{nt}^{s1}(w_{nt}^0) < \pi_{nt}^{s2}(w_{nt}^1)$, where $\alpha_{nt}^{r1} = [3p(a + b) - \sqrt{p^2(a + b)^2 + 4pb^2(p + c)}]/(4p)$.

Now we prove that w_{nt}^* first decreases and then increases with α^r . When $b/a > 2/\xi^c$, we have 1) For $\alpha^r \in [a, \alpha_{nt}^{r1}]$, $w_{nt}^* = \frac{p(2a + b - 2\alpha^r)}{b}$, which decreases with α^r . 2) For $\alpha^r \in [\alpha_{nt}^{r1}, \alpha_{nt}^{r2}]$, $w_{nt}^* = \sqrt{\frac{2p(p + c)(a + b - \alpha^r)}{(a + b - 2\alpha^r)}} - p = \sqrt{2p(p + c) \left(1 + \frac{1}{(a + b)/\alpha^r - 2}\right)} - p$, which increases with α^r and equals p when $\alpha^r = \alpha_{nt}^{r2}$. 3) For $\alpha^r \in [\alpha_{nt}^{r2}, a + b]$, $w_{nt}^* = p - \epsilon$. Together with the fact that $\frac{p(2a + b - 2\alpha_{nt}^{r1})}{b} = \sqrt{\frac{2p(p + c)(a + b - \alpha_{nt}^{r1})}{(a + b - 2\alpha_{nt}^{r1})}} - p$, we prove the proposition. ■

Proof of Corollary 2. When $\alpha^c = \alpha^s$, we have

$$y_{tt}^{c*} = \begin{cases} 2\alpha^s - a & \text{if } a \leq \alpha^s < b\xi^c/2 + a \\ \frac{(p - c)(a + b) + 2c\alpha^s}{p + c} & \text{if } b\xi^c/2 + a \leq \alpha^s \leq a + b \end{cases}.$$

It is easy to see that $y_{tt}^{c*} \geq \alpha^s$. Hence, $y_{tt}^{c*} \geq y_{tt}^*$ when $\alpha^s \geq \alpha^r$. Now if $\alpha^s \leq \alpha^r < b\xi^c/2 + a$ or $\alpha^s < b\xi^c/2 + a \leq \alpha^r$, we can easily obtain $\alpha_{tt}^{s1} = \frac{\alpha^r + a}{2}$; if $b\xi^c/2 + a \leq \alpha^s < \alpha^r$, we can easily obtain $\alpha_{tt}^{s1} = \frac{\alpha(p + c) - (p - c)(a + b)}{2c}$.

Let $\Pi(y) = (p - c)y - \frac{p}{2b}(y - a)^2$, then $\Pi_{tt}^{c*} = \Pi(y_{tt}^{c*})$ and $\Pi_{tt}^* = \Pi(y_{tt}^*)$. The function Π achieves its maximum—which is Π_{nn}^{c*} —when $y = b\xi^c + a$. It is easy to see that Π_{tt}^{c*} increases in $[a, b\xi^c/2 + a]$ and decreases in $[b\xi^c/2 + a, a + b]$. Besides, if $\alpha^r \leq b\xi^c + a$, Π_{tt}^* is invariant with α^s in $[a, \alpha^r]$, increases in $[\alpha^r, b\xi^c + a]$, and decreases in $[b\xi^c + a, a + b]$.

When $\alpha^r = b\xi^c + a$, we have $\Pi_{tt}^* = \Pi_{nn}^{c*} \geq \Pi_{tt}^{c*}$. It follows that $\Pi_{tt}^* \geq \Pi_{tt}^{c*}$ if $a \leq \alpha^s \leq \alpha^r$. In addition, both Π_{tt}^* and Π_{tt}^{c*} decrease in $[\alpha^r, a + b]$ and $\Pi_{tt}^* = \Pi_{tt}^{c*}$ when $\alpha^s = a + b$. We thus conclude that if $\alpha^r = b\xi^c + a$, $\Pi_{tt}^* \geq \Pi_{tt}^{c*}$. Now when $\alpha^r \neq b\xi^c + a$, it is easy to see that $\alpha_{tt}^{sc1} = \{\alpha^s : 2\alpha^s - a = \alpha^r\}$ and $\alpha_{tt}^{sc2} = \min\{\alpha^s : y_{tt}^* = y_{tt}^{c*}, \alpha^s \geq b\xi^c/2 + a\}$. ■

Proof of Proposition 6. For $0 \leq b/a < 2/\xi^c$, $w_{nt}^* = p - \epsilon$, $y_{nt}^* = \alpha^r - \epsilon$, the proof is trivial. For $0 \leq b/a < 2/\xi^c$: 1) For $\alpha^r \in [a, \alpha_{nt}^{r1}]$, $(2pa + pb - 2p\alpha^r)/b = w_{nt}^* > w_{nn}^* \Leftrightarrow \alpha^r < (pb + 3pa - bc)/(4p)$. $w_{nt}^* > w_{nn}^*$ results from $(pb + 3pa - bc)/(4p) > \alpha_{nt}^{r1}$. $2\alpha^r - a = y_{nt}^* < y_{nn}^* \Leftrightarrow \alpha^r < (pb + 3pa - bc)/(4p)$. Therefore, for $\alpha^r \in [a, \alpha_{nt}^{r1}]$, we have $y_{nt}^* < y_{nn}^*$.

2) For $\alpha^r \in [\alpha_{nt}^{r1}, \alpha_{nt}^{r2}]$, $w_{nt}^* = w_{nt}^1$. w_{nt}^1 is an increasing function of α^r , and substituting α_{nt}^{r1} into w_{nt}^1 we have $p(2a + b - \alpha_{nt}^{r1})/p$, which is larger than w_{nn}^* . Therefore, $w_{nt}^* > w_{nn}^*$.

Next, we prove that for $\alpha^r \in [\alpha_{nt}^{r1}, \alpha_{nt}^{r2}]$, $y_{nt}^* = y_{nt}^1 \leq y_{nn}^*$. Let $\hat{\alpha}_I^r = (a + b) \left(\frac{3}{4} - \sqrt{\frac{1}{16} + \frac{p}{16c}} \right)$, then if $p/c < 3$, $\alpha_{nt}^{r2} < \hat{\alpha}_I^r$, y_{nt}^1 increases in $[\alpha_{nt}^{r1}, \alpha_{nt}^{r2}]$; if $p/c > \frac{2b^2 + 2b\sqrt{b^2 + (a + b)^2}}{(a + b)^2}$, $\alpha_{nt}^{r1} > \hat{\alpha}_I^r$, y_{nt}^1 decrease in $[\alpha_{nt}^{r1}, \alpha_{nt}^{r2}]$; otherwise if $3a < b$, y_{nt}^1 increases in $[\alpha_{nt}^{r1}, \hat{\alpha}_I^r]$, and decreases in $[\hat{\alpha}_I^r, \alpha_{nt}^{r2}]$, and achieves maximum at $\hat{\alpha}_I^r$ with maximum

value $\frac{a+b}{2} \left(\sqrt{\frac{p^2}{c(p+c)}} - \sqrt{\frac{p+c}{c}} + 1 \right) \equiv y_{nt}^1(\hat{\alpha}_I^r)$. For y_{nt}^1 either increases or decreases in $[\alpha_{nt}^{r1}, \alpha_{nt}^{r2}]$, we have proved that $y_{nt}^* = y_{nt}^1 \leq y_{nn}^*$. For others, since $y_{nt}^1(\hat{\alpha}_I^r) - y_{nn}^* = \frac{bc}{2p} + \frac{a+b}{2} \left(\sqrt{\frac{p^2}{c(p+c)}} - \sqrt{\frac{p+c}{c}} + 1 \right) < 0 \Leftrightarrow p^2(a+b)^2 > b^2c(p+c) \Leftrightarrow p/c > \frac{b^2+b\sqrt{b^2+4(a+b)^2}}{2(a+b)^2}$, which is obviously true give that $\frac{b^2+b\sqrt{b^2+4(a+b)^2}}{2(a+b)^2} < 3$.

3) For $\alpha \in [\alpha_{nt}^{r2}, a+b]$, the proof is trivial. ■

LEMMA 2. For $\alpha^r \in (\alpha_{nt}^{r1}, \alpha_{nt}^{r2})$, π_{nt}^{s*} increases with α^r .

Proof of Proposition 7. (1) For $0 \leq b/a < 2/\xi^c$, $\pi_{nt}^{s*} - \pi_{nn}^{s*} \geq 0 \Leftrightarrow \alpha^r \geq \bar{\alpha}_{nt}^2 \triangleq [p(a+b) - bc]^2 / [4bp(p-c)]$.

(2) Let $t_2 = \frac{1}{\xi^c} (1 + \frac{2}{\sqrt{2-\xi^c}})$, then for $2/\xi^c \leq b/a < t_2$, we have $\alpha_{nt}^{r2} < \bar{\alpha}_{nt}^2$. For $\alpha^r \in (\alpha_{nt}^{r1}, \alpha_{nt}^{r2})$, from Lemma 2, we know that π_{nt}^{s*} is an increasing function of α^r . Since we have $\pi_{nt}^{s*} \leq \pi_{nn}^{s*}$ for $\alpha^r \in [\alpha_{nt}^{r2}, \bar{\alpha}_{nt}^2) \cup [a, \alpha_{nt}^{r1})$, we can conclude that if $2/\xi^c \leq b/a < t_2$, $\pi_{nt}^{s*} < \pi_{nn}^{s*}$ for $\alpha^r \in [\alpha_{nt}^{r1}, \alpha_{nt}^{r2})$. Since $\alpha_{nt}^{r2} < \bar{\alpha}_{nt}^2$ and $\pi_{nt}^{s*} - \pi_{nn}^{s*} \geq 0 \Leftrightarrow \alpha^r \geq \bar{\alpha}_{nt}^2 [p(a+b) - bc]^2 / [4bp(p-c)]$ when $\pi_{nt}^{s*} = (p-c)\alpha^r$, then $\pi_{nt}^{s*} < \pi_{nn}^{s*}$ if $\alpha^r < \bar{\alpha}_{nt}^2$ and $\pi_{nt}^{s*} \geq \pi_{nn}^{s*}$ if $\alpha^r \geq \bar{\alpha}_{nt}^2$.

(3) For $b/a \geq t_2$, $\alpha_{nt}^{r2} \geq \bar{\alpha}_{nt}^2$, then $\pi_{nt}^{s*} \geq \pi_{nn}^{s*}$ if $\alpha^r \in [\alpha_{nt}^{r2}, a+b]$. For $\alpha^r \in (\alpha_{nt}^{r1}, \alpha_{nt}^{r2})$, from Lemma 2, there must exist an threshold in $(\alpha_{nt}^{r1}, \alpha_{nt}^{r2})$ before which $\pi_{nt}^{s*} \leq \pi_{nn}^{s*}$ and after which $\pi_{nt}^{s*} \geq \pi_{nn}^{s*}$. ■

Proof of Proposition 8. 1. If $b/a \leq 2/\xi^c$, $\Pi_{nt}^* = (p-c)\alpha^r - p(a-\alpha^r)^2/(2b)$. Let $f(\alpha^r) = \Pi_{nt}^* - \Pi_{nn}^*$, then it is a concave function of α^r and achieves it maximum at $\tilde{\alpha} = (p(a+b) - bc)/p$. Solve the equation $f(\alpha^r) = 0$, we have $\bar{\alpha}_I^{r1} = (p(a+b) - bc)/(2p)$ and $\bar{\alpha}_I^{r2} = 3(p(a+b) - bc)/(2p)$. That is, Π_{nt}^* is less than Π_{nn}^* if and only if $\alpha^r \in [a, \bar{\alpha}_I^{r1}] \cup [\bar{\alpha}_I^{r2}, a+b]$; Π_{nt}^* is more than Π_{nn}^* if and only if $\alpha^r \in [\bar{\alpha}_I^{r1}, \bar{\alpha}_I^{r2}]$.

2. If $b/a > 2/\xi^c$, $\Pi_{nt}^* = (p-c)\alpha^r - p(a-\alpha^r)^2/(2b)$, we have three cases:

(1) For $\alpha^r \in [a, \alpha_{nt}^{r1}]$, $\pi_{nt}^{s*} = (p(a+b) - bc - p(2\alpha^r - a))(2\alpha^r - a)/b$, and we have $\pi_{nt}^{s*} - \pi_{nn}^{s*} = -(3ap - bc - 4\alpha^r p + bp)/(4bp) \leq 0$. We also have $\pi_{nt}^{s*} = p(2\alpha^r - a)^2/(2b) - pa^2/(2b)$. It is less than π_{nn}^{s*} if and only if $2\alpha^r - a < (p(a+b) - bc)/(2p)$, which is true for $\alpha^r \in [a, \alpha_{nt}^{r1}]$. Therefore, $\Pi_{nt}^* < \Pi_{nn}^*$ for $\alpha^r \in [a, \alpha_{nt}^{r1}]$.

(2) For $\alpha^r \in [\alpha_{nt}^{r1}, \alpha_{nt}^{r2}]$, let $g(y) = (p(a+b) - bc)y/b - py^2/(2b) - pa^2/(2b)$, which is a concave function of y and achieves it maximum at y_{nn}^{c*} . It increases in $[0, y_{nn}^{c*}]$. We have proved that $y_{nt}^1 \leq y_{nn}^*$ in the proof of Proposition 6, together with $g(y_{nn}^*) = \Pi_{nn}^*$ and the fact that $g(y)$ increases when $y \in [0, y_{nn}^{c*}]$, we have $\Pi_{nt}^* = g(y_{nt}^1) \leq g(y_{nn}^*) = \Pi_{nn}^*$.

(3) For $\alpha^r \in [\alpha_{nt}^{r2}, a+b]$, $y_{nt}^* = \alpha^r - \epsilon$ and $w_{nt}^* = p - \epsilon$, which is the same as when $b/a \leq 2/\xi^c$. Therefore, Π_{nt}^* is less than Π_{nn}^* if and only if $\alpha^r \in [\alpha_{nt}^{r2}, \bar{\alpha}_I^{r1}] \cup [\bar{\alpha}_I^{r2}, a+b]$; Π_{nt}^* is more than Π_{nn}^* if and only if $\alpha^r \in [\bar{\alpha}_I^{r1}, \bar{\alpha}_I^{r2}]$.

When wholesale price approaches to p , suppliers' and retailer's profit, respectively, approach to $(p-c)\alpha^r$ and $-p(a-\alpha^r)^2/(2b)$. Supply chain total profit is $(p-c)\alpha^r - p(a-\alpha^r)^2/(2b)$. Let it equal the integrated supply chain profit, $(p(a+b) - bc)^2/(2bp) - pa^2/(2b)$, and solve the equation with respect to α^r yields $\alpha^r = (p(a+b) - bc)/(2p)$, which is exactly the centralized order quantity y_{nn}^{c*} . Recall that when w approaches to p , retailer's order quantity approaches to α^r . ■

Proof of Proposition 15. Recall that the optimal strategies under the "NT" setting depends on α^r . Hence, we make the comparisons for different ranges of α^r .

1. When $a \leq \alpha^r < \alpha_{nt}^{r1}$, 1) if $a \leq \alpha^s < \alpha^r$, then $w_{tt}^* = p - \epsilon$ and $y_{tt}^* = \alpha^r$. It directly follows that $w_{tt}^* \geq w_{nt}^*$ and $y_{tt}^* \leq y_{nt}^*$. It is easy to see that $\rho_{tt}^* = -\frac{\alpha^r - a}{b} \leq 0 = \rho_{nt}^*$. 2) if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, then $w_{tt}^* = p \frac{a+b-\alpha^s}{a+b-2\alpha^r+\alpha^s}$ and $y_{tt}^* = \alpha^s$. Note that w_{tt}^* decreases in α^s , as such, $w_{tt}^* \geq p \frac{a+b-(2\alpha^r-a)}{a+b-2\alpha^r+\alpha^r-a} = p \frac{2a+b-2\alpha^r}{b} = w_{nt}^*$ and $y_{tt}^* = \alpha^s \leq 2\alpha^r - a = y_{nt}^*$. While for ρ_{tt}^* , we have $\rho_{tt}^* = \frac{b(\alpha^s - \alpha^r) - (\alpha^r - a)(a+b-2\alpha^r+\alpha^s)}{b(a+b-\alpha^r)}$, which increases with α^s , and thus we have $-\frac{\alpha^r - a}{b} \leq \rho_{tt}^* \leq 0$.

2. When $\alpha_{nt}^{r2} \leq \alpha^r \leq a + b$, 1) if $a \leq \alpha^s < \alpha^r$, then $w_{tt}^* = w_{nt}^* = p - \epsilon$, $y_{tt}^* = w_{nt}^* = \alpha^r$, and $\rho_{tt}^* = \rho_{nt}^* = -\frac{\alpha^r - a}{b}$. 2) if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, then $w_{tt}^* = p \frac{a+b-\alpha^s}{a+b-2\alpha^r+\alpha^s} \leq p - \epsilon = w_{nt}^*$ and $y_{tt}^* = \alpha^s \geq \alpha^r = y_{nt}^*$. Recall that $\rho_{nt}^* = -1 + \frac{1}{b} \sqrt{\frac{2p(a+b-\alpha^r)(a+b-2\alpha^r)}{p+c}}$, which is less than $\rho_{tt}^* = \frac{b(\alpha^s - \alpha^r) - (\alpha^r - a)(a+b-2\alpha^r+\alpha^s)}{b(a+b-\alpha^r)}$ when $\alpha^s \geq \sqrt{\frac{2p(a+b-\alpha^r)(a+b-2\alpha^r)}{p+c}} - (a+b-2\alpha^r) = y_{nt}^1$. From $y_{tt}^* = \alpha^s \geq \alpha^r = y_{nt}^*$, we can obtain that $\rho_{nt}^* \leq \rho_{tt}^*$.
3. When $\alpha_{nt}^{r1} \leq \alpha^r < \alpha_{nt}^{r2}$, 1) if $a \leq \alpha^s < \alpha^r$, then $w_{tt}^* = p - \epsilon \geq w_{nt}^*$. Note that $y_{nt}^* - y_{tt}^* = \sqrt{\frac{2p(a+b-\alpha^r)(a+b-2\alpha^r)}{p+c}} - (a+b-2\alpha^r) - \alpha^r \geq 0$ is equivalent to $(p-c)(a+b) \geq (3p-c)\alpha^r$, that is, $\alpha^r \leq (p-c)(a+b)/(3p-c)$, the right hand side of which is exactly α_{nt}^{r2} . Hence, we have $y_{tt}^* \leq y_{nt}^*$. It is easy to see that $\rho_{tt}^* = -\frac{\alpha^r - a}{b} \leq -1 + \frac{1}{b} \sqrt{\frac{2p(a+b-\alpha^r)(a+b-2\alpha^r)}{p+c}} = \rho_{nt}^*$. 2) if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, recall that $w_{tt}^* = p \frac{a+b-\alpha^s}{a+b-2\alpha^r+\alpha^s}$, $w_{nt}^* = \sqrt{\frac{2p(p+c)(a+b-\alpha^r)}{a+b-2\alpha^r}} - p$, and $y_{tt}^* = \alpha^s$, $y_{nt}^* = \sqrt{\frac{2p(a+b-\alpha^r)(a+b-2\alpha^r)}{p+c}} - (a+b-2\alpha^r)$. Let $\xi_{II}^1 = 2 - \frac{2(a+b-\alpha^r)(a+b-2\alpha^r)}{(a+b-2\alpha^r+\alpha^s)^2}$, it follows that $w_{tt}^* \geq w_{nt}^*$ and $y_{tt}^* \geq y_{nt}^*$ if and only if $\xi^c \geq \xi_{II}^1$ (or equivalently $\alpha^s \geq y_{nt}^1$). Similarly, we have $\rho_{tt}^* \geq \rho_{nt}^*$ if and only if $\alpha^s \geq y_{nt}^1$. ■

Proof of Proposition 16. We also make the comparisons for each range of α^r . 1. When $a \leq \alpha^r < \alpha_{nt}^{r1}$, 1) if $a \leq \alpha^s < \alpha^r$, $\pi_{tt}^{s*} - \pi_{nt}^{s*} = \frac{1}{b}(\alpha^r - a)(4\alpha^r p + bc - 2ap - bp) \leq 0$ for all $a \leq \alpha^r < \alpha_{nt}^{r1}$. Hence, $\pi_{tt}^{s*} \leq \pi_{nt}^{s*}$. Note that $w_{tt}^* = p - \epsilon$, as such, $\pi_{tt}^{r*} = -\frac{p}{2b}(\alpha^r - a)^2$. It directly follows that $\pi_{tt}^{r*} \leq \pi_{nt}^{r*}$. 2) if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, then $\pi_{tt}^{s*} - \pi_{nt}^{s*} = -\frac{2\alpha^r - a - \alpha^s}{b(a+b-2\alpha^r+\alpha^s)}\gamma_1$. We now prove that $\gamma_1 = p(a+b)(2a+b) - bc(a+b) - \alpha^s b(p+c) + 2\alpha^r(bc - 3ap - 2bp) + 4(\alpha^r)^2 p \geq 0$ for all $a \leq \alpha^r < \alpha_{nt}^{r1}$, $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$. Note that γ_1 decreases with α^s , thus $\gamma_1 \geq \gamma_1|_{\alpha^s=2\alpha^r-a} = (\alpha^r - \alpha_{nt}^{r1}) \left(\alpha^r - \frac{3p(a+b) + \sqrt{p^2(a+b)^2 + 4pb^2(p+c)}}{4p} \right) \geq 0$ for all $a \leq \alpha^r < \alpha_{nt}^{r1}$. Therefore, $\pi_{tt}^{s*} \leq \pi_{nt}^{s*}$. Now for the retailer, we have $\pi_{tt}^{r*} - \pi_{nt}^{r*} = \frac{p(2\alpha^r - a - \alpha^s)}{2b(a+b-2\alpha^r+\alpha^s)}\gamma_2$. Note that $\gamma_2 = a(a+b) - \alpha^s(2a+3b) + (\alpha^s)^2 - 2\alpha^r(2a+b) + 4(\alpha^r)^2 \leq (a-5\alpha^r)(a+b-\alpha^r) \leq 0$ for $a \leq \alpha^r < \alpha_{nt}^{r1}$. As such, we have $\pi_{tt}^{r*} \leq \pi_{nt}^{r*}$.

2. When $\alpha_{nt}^{r2} \leq \alpha^r \leq a + b$, 1) if $a \leq \alpha^s < \alpha^r$, it is easy to see that $\pi_{nt}^{s*} = \pi_{tt}^{s*}$ and $\pi_{nt}^{r*} = \pi_{tt}^{r*}$. 2) if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, $\pi_{tt}^{s*} - \pi_{nt}^{s*} = -\frac{\alpha^s - \alpha^r}{a+b-2\alpha^r+\alpha^s}\gamma_3$. Observe that $\gamma_3 = -(a+b)(p-c) + 2\alpha^r(p-c) + \alpha^s(p+c) \geq -(a+b)(p-c) + \alpha^r(3p-c) \geq 0$ for $\alpha_{nt}^{r2} \leq \alpha^r \leq a + b$. Hence, $\pi_{tt}^{s*} \leq \pi_{nt}^{s*}$.

3. When $\alpha_{nt}^{r1} \leq \alpha^r < \alpha_{nt}^{r2}$, 1) if $a \leq \alpha^s < \alpha^r$, then $w_{tt}^* = p - \epsilon \geq w_{nt}^*$. It directly follows that $\pi_{tt}^{r*} \geq \pi_{nt}^{r*}$. For the supplier, we have $\pi_{tt}^{s*} - \pi_{nt}^{s*} = -(a+b)(3p+c) + \alpha^r(5p+c) + 2\sqrt{2p(p+c)(a+b-\alpha^r)(a+b-2\alpha^r)}$. Note here that $8p(p+c)(a+b-\alpha^r)(a+b-2\alpha^r) - ((a+b)(3p+c) - \alpha^r(5p+c))^2 = -(\alpha^r(3p-c) - (a+b)(p-c))^2 \leq 0$, and thus we have $\pi_{tt}^{s*} \leq \pi_{nt}^{s*}$. 2) if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, $\pi_{tt}^{s*} - \pi_{nt}^{s*} = p \frac{(a+b-\alpha^s)\alpha^s}{a+b-2\alpha^r+\alpha^s} - c(a+b-2\alpha^r+\alpha^s) - 3p(a+b) + 4p\alpha^r + 2\sqrt{2p(p+c)(a+b-\alpha^r)(a+b-2\alpha^r)} \leq 0$. ■

Proof of Proposition 17. We also make the comparisons for each range of α^r . Part 1 and Part 3(a) directly follow from Proposition 16. Now for Part 2, that is, when $\alpha_{nt}^{r2} \leq \alpha^r \leq a + b$,

- if $a \leq \alpha^s < \alpha^r$, since $w_{tt}^* = w_{nt}^* = p - \epsilon$ and $y_{tt}^* = w_{nt}^* = \alpha^r$, we thus have $\Pi_{nt}^* = \Pi_{tt}^*$.
- if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, recall that $y_{tt}^* = \alpha^s \geq \alpha^r = y_{nt}^*$, we thus have $\Pi_{tt}^* - \Pi_{nt}^* = \frac{\alpha^s - \alpha^r}{2b} (2p(a+b) - 2bc - p(\alpha^s + \alpha^r))$. It follows that $\Pi_{tt}^* \leq \Pi_{nt}^*$ if $\xi^c \leq \frac{\alpha^r + \alpha^s - 2a}{2b}$ and $\Pi_{tt}^* \geq \Pi_{nt}^*$ if $\xi^c \geq \frac{\alpha^r + \alpha^s - 2a}{2b}$.

For Part 3(b), that is, when $\alpha_{nt}^{r1} \leq \alpha^r < \alpha_{nt}^{r2}$ and $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, recall that $y_{tt}^* = \alpha^s$, $y_{nt}^* = y_{nt}^1$. We then have $\Pi_{tt}^* - \Pi_{nt}^* = \frac{1}{2b}(\alpha^s - y_{nt}^1)(2bp + 2ap - 2bc - p\alpha^s - py_{nt}^1)$. It directly follows that $\Pi_{tt}^* \leq \Pi_{nt}^*$ if $\alpha^s \leq y_{nt}^1$ or $\alpha^s \geq 2(a+b) - y_{nt}^1 - 2bc/p$; and $\Pi_{tt}^* \geq \Pi_{nt}^*$ if $y_{nt}^1 \leq \alpha^s \leq 2(a+b) - y_{nt}^1 - 2bc/p$. ■

Proof of Proposition 18. According to Lemma 1,

(1) If $a \leq \alpha^r < a + b(p-w)/(2p)$, that is, $w < p - 2p(\alpha^r - a)/b$, we have $y(w) = 2\alpha^r - a$, $\eta(w) = 1 - 2p(\alpha^r - a)/(bp - bw)$, and $\pi_{nt}^s(y(w)) = (w-c)(2\alpha^r - a)$. Since $\pi_{nt}^s(y(w))$ increases with w , and on the other

hand, $\eta(w) \geq \bar{\eta}$ if and only if $w \leq p - 2p(\alpha^r - a)/(b(1 - \bar{\eta}))$. Denote $w_o^1 = p - 2p(\alpha^r - a)/(b(1 - \bar{\eta}))$, $w_o^2 = p - 2p(\alpha^r - a)/b$. Then $w_o^{1*} = w_o^1$, if $\bar{\eta} \geq 0$, $w_o^{1*} = w_o^2$ if $\bar{\eta} < 0$, and the corresponding supplier's profit are $\pi_o^{s1}(w_o^1) \triangleq [p - c - 2p(\alpha^r - a)/(b(1 - \bar{\eta}))](2\alpha^r - a)$ and $\pi_o^{s1}(w_o^2) \triangleq [p - c - 2p(\alpha^r - a)/b](2\alpha^r - a)$, respectively.

(2) If $a + b(p - w)/(2p) \leq \alpha^r \leq a + b$, $y(w) = [(p - w)(a + b) + 2\alpha^r w]/(p + w)$, $\pi_s^{t2}(y(w)) \triangleq -(p + w)(a + b - 2\alpha^r) - 2p(p + c)(a + b - \alpha^r)/(p + w) + (3p + c)(a + b - 2\alpha^r) + 2p\alpha^r$, $\eta(w) = [b(p - w) + 2p(a - \alpha^r)]/(bp + bw)$. The condition $\eta(w) \geq \bar{\eta}$ requires $w \leq p[b(1 - \bar{\eta}) - 2(\alpha^r - a)]/(b(1 + \bar{\eta})) \triangleq \bar{w}_{nt}^1$, which is strictly less than p if $\bar{\eta} > -(\alpha^r - a)/b$. As such, if $\bar{\eta} \leq -(\alpha^r - a)/b$, the result remains the same as in Proposition 2. Otherwise,

- If $a + b - 2\alpha^r > 0$, $\pi_{nt}^s(y(w))$ is concave in $(c, \bar{w}_{nt}^1]$. Solving the FOC gives $w_{nt}^1 = \sqrt{2p(p + c)(a + b - \alpha^r)/(a + b - 2\alpha^r)} - p$. In order to secure $w_{nt}^1 \in (c, \bar{w}_{nt}^1]$, we need $\alpha^r \leq \alpha_{nt}^{r2o} \triangleq [3(a + b) - \sqrt{(a + b)^2 + 4b^2(1 + \bar{\eta})^2(p + c)/p}]/4$, otherwise, $w_{nt}^1 = \bar{w}_{nt}^1$. The corresponding optimal profit for supplier when $\alpha^r \leq \alpha_{nt}^{r2o}$ is $\pi_o^{s2}(w_{nt}^1) \triangleq -2\sqrt{2p(p + c)(a + b - \alpha^r)(a + b - 2\alpha^r)} + (3p + c)(a + b - 2\alpha^r) + 2p\alpha^r$.
- For $a + b - 2\alpha^r \leq 0$, $\pi_{nt}^s(y(w))$ increases with w , which indicates that $w_{nt}^* = \bar{w}_{nt}^1$, $y_{nt}^* = b\bar{\eta} + 2(\alpha^r - a) + b\alpha^r/(a + b - \alpha^r)$, and $\pi_s^{t2}(\bar{w}_{nt}^1) \triangleq (\bar{w}_{nt}^1 - c)y(\bar{w}_{nt}^1)$.

In order to make α_{nt}^{r2o} no less than a , we need $\xi^c \geq \xi_o \triangleq 3/2 - (b - a)/(b(1 + \bar{\eta})^2)$. For $\xi^c < \xi_o$, $\alpha_{nt}^{r2o} < a$, we first compare $\pi_o^{s1}(w_{nt}^0)$ and $\pi_o^{s2}(\bar{w}_{nt}^1)$. If $\bar{\eta} \geq 0$, it is not hard to obtain $\bar{w}_{nt}^1 \geq w_{nt}^0$, while at the same time $y(w_{nt}^0) \leq y(\bar{w}_{nt}^1)$. As such, $\pi_o^{s1}(w_{nt}^0) \leq \pi_o^{s2}(\bar{w}_{nt}^1)$. Therefore, if $\bar{\eta} \geq 0$ and $\xi^c < \xi_o$, the supplier will always set $w_{nt}^* = \bar{w}_{nt}^1$. However, when $-(\alpha^r - a)/b \leq \bar{\eta} < 0$, we select the w such that its corresponding profit is higher. That it, $w_{nt}^* = \arg \max\{\pi_o^{s2}(\bar{w}_{nt}^1), \pi_o^{s1}(w_{nt}^0)\}$.

Next, we need to compare $\pi_o^{s1}(w_{nt}^0)$ and $\pi_o^{s2}(w_{nt}^0)$ when $\alpha^r \leq \alpha_{nt}^{20}$ and $\xi^c \geq \xi_o$. If $-(\alpha^r - a)/b \leq \bar{\eta} < 0$, we get the same α_I^{r1} such that $\pi_o^{s1}(w_{nt}^{t1}) \geq \pi_o^{s2}(w_{nt}^0)$ if $\alpha^r \leq \alpha_{nt}^{r1}$, otherwise, $\pi_o^{s1}(w_{nt}^{t1}) < \pi_o^{s2}(w_{nt}^0)$, where $\alpha_I^{r1} = [3p(a + b) - \sqrt{p^2(a + b)^2 + 4pb^2(p + c)}]/(4p)$. Since $\alpha_{nt}^{r2o} - \alpha_{nt}^{r1} \geq 0$, we then the first point under (c).

For the case when $\bar{\eta} \geq 0$, $w_{nt}^* = w_{nt}^1$ if $\pi_o^{s2}(w_{nt}^1) \geq \pi_o^{s1}(w_o^1)$; otherwise, $w_{nt}^* = w_o^1$. ■

Proof of Proposition 19. According to the proof of Proposition 18, we have

(1) If $w < p - 2p(\alpha^r - a)/b$, then $y(w) = 2\alpha^r - a$, and $\eta(w) = 1 - 2p(\alpha^r - a)/(bp - bw)$, so that $\eta(w) \geq \bar{\eta}$ if and only if $w \leq p - 2p(\alpha^r - a)/(b(1 - \bar{\eta}))$.

(2) If $p - 2p(\alpha^r - a)/b \leq w < p$, then $y(w) = [(p - w)(a + b) + 2\alpha^r w]/(p + w)$ and $\eta(w) = [b(p - w) + 2p(a - \alpha^r)]/(bp + bw)$, so that $y(w) \geq \alpha^s$ if and only if $w \leq p(a + b - \alpha^s)/(a + b - 2\alpha^r + \alpha^s)$. Besides, the condition $\eta(w) \geq \bar{\eta}$ requires $w \leq w_o$, which is in the feasible set $[p - 2p(\alpha^r - a)/b, p)$ if and only if $-(\alpha^r - a)/b < \bar{\eta} \leq 0$. Note that $p(a + b - \alpha^s)/(a + b - 2\alpha^r + \alpha^s) \leq p[b(1 - \bar{\eta}) - 2(\alpha^r - a)]/(b(1 + \bar{\eta}))$ if and only if $\bar{\eta} < \frac{\alpha^s - 2\alpha^r + a}{b}$. As such, if $\bar{\eta} < \frac{\alpha^s - 2\alpha^r + a}{b}$, the result remains the same as in Proposition 4.

Now when $a \leq \alpha^s < \alpha^r$, we have $\frac{\alpha^s - 2\alpha^r + a}{b} \leq -\frac{\alpha^r - a}{b}$. Recall that $w_o \leq p$ if and only if $\bar{\eta} \geq -\frac{\alpha^r - a}{b}$. It follows that 1) If $\frac{\alpha^s - 2\alpha^r + a}{b} \leq \bar{\eta} < -\frac{\alpha^r - a}{b}$, then $w_{tt}^* = p - \epsilon$ and $y_{tt}^* = \alpha^r$. 2) If $-\frac{\alpha^r - a}{b} \leq \bar{\eta} \leq 0$, then $w_{tt}^* = w_o$ and $y_{tt}^* = b\bar{\eta} + 2(\alpha^r - a) + \frac{b\alpha^r}{a + b - \alpha^r}$. 3) $\bar{\eta} > 0$, the supplier's problem is not feasible.

Moreover, when $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, 1) If $\frac{\alpha^s - 2\alpha^r + a}{b} \leq \bar{\eta} \leq 0$, then $w_{tt}^* = w_o$ and $y_{tt}^* = b\bar{\eta} + 2(\alpha^r - a) + \frac{b\alpha^r}{a + b - \alpha^r}$. 2) If $\bar{\eta} \geq 0$, the supplier's problem is not feasible.

We now prove that $w_o \leq w_{tt}^*$ when $\bar{\eta} \geq \frac{\alpha^s - 2\alpha^r + a}{b}$. It directly holds when $a \leq \alpha^s \leq \alpha^r$. When $\alpha^r < \alpha^s \leq 2\alpha^r - a$, $w_{tt}^* - w_o = \frac{2p(a + b - \alpha^r)(b\bar{\eta} - 2\alpha^r - a - \alpha^s)}{b(1 + \bar{\eta})(a + b - 2\alpha^r + \alpha^s)} \geq 0$, because $\bar{\eta} \geq \frac{\alpha^s - 2\alpha^r + a}{b}$. ■

Proof of proposition 20. In this case, $\tilde{w}_{nt}^* = w_{nt}^*$ and the corresponding order quantity, $\tilde{y}_{nt}^*$, which is greater than y_{nt}^* because $\tilde{w}_{nt}^* < w_{nt}^*$ and by Lemma 1, order quantity is non-increasing in wholesale price. By the definition of π_{nt}^{s*} , we have $\pi_{nt}^{s*} = \max_w (w - c)y(w)$, where $y(w)$ is in Lemma 1. And w_{nt}^* is the wholesale price such that $(w - c)y(w)$ is maximized. As such, if we set $\tilde{w}_{nt}^* = w_{nn}^* < w_{nt}^*$, then $\tilde{\pi}_{nt}^{s*} = (w_{nn}^* - c)y(w_{nn}^*) < (w_{nt}^* - c)y(w_{nt}^*) = \pi_{nt}^{s*}$. While for the retailer, his expected profit is $\tilde{\pi}_{nt}^{r*} = pE[\min(\tilde{y}_{nt}^*, D)] - \tilde{w}_{nt}^* \tilde{y}_{nt}^* = (p - w_{nn}^*)\tilde{y}_{nt}^* - p\frac{(\tilde{y}_{nt}^*)^2}{2b} + \frac{2ap\tilde{y}_{nt}^* - pa^2}{2b}$, which is greater than π_{nt}^{r*} when $\alpha^r < \alpha_{nt}^{r1}$ because when $\alpha^r \leq \alpha_{nt}^{r1}$, $\tilde{y}_{nt}^* = y_{nt}^* = 2\alpha^r - a$, and at the same time $\tilde{w}_{nt}^* = w_{nn}^* < w_{nt}^*$.

We can prove that $\pi^r(w) = (p - w)y(w) - p\frac{(y(w))^2}{2b} + \frac{2apy(w) - pa^2}{2b}$, where $y(w) = ((p - w)(a + b) + 2\alpha^r w)/(p + w)$, is decreasing in w for $\alpha^r \geq a + p(p - w)/(2p)$, which leads to $\pi^r(\tilde{w}_{nt}^*) > \pi^r(w_{nt}^*)$, that is, $\tilde{\pi}_{nt}^{r*} > \pi_{nt}^{r*}$. However, if $\alpha^r = (p(b + 3a) - bc)/(4p)$, then $\tilde{y}_{nt}^* = y_{nn}^*$, as such, $\tilde{\pi}_{nt}^{r*} = \pi_{nn}^{r*}$ and $\tilde{\Pi}_{nt}^* = \Pi_{nn}^*$. The double marginalization is eliminated when $\tilde{y}_{nt}^* = y_{nn}^*$, that is, when $\alpha^r = \frac{2p^2(a + b)^2 - pbc(b - a) - b^2c^2}{2p(pa + pb + bc)}$. ■

Proof of Proposition 22. Given that $\alpha^s \leq 2\alpha^r - a$, $\tilde{y}_{tt}^* = \frac{(\alpha^s - a)(a + b) + 2\alpha^r(a + b - \alpha^s)}{a + 2b - \alpha^s} \geq \frac{(\alpha^s - a)(a + b) + (\alpha^s + a)(a + b - \alpha^s)}{a + 2b - \alpha^s} = \alpha^s$. Besides, $\frac{(\alpha^s - a)(a + b) + 2\alpha^r(a + b - \alpha^s)}{a + 2b - \alpha^s} - \alpha^r = \frac{(\alpha^s - a)(a + b - \alpha^r)}{a + 2b - \alpha^s} \geq 0$, so $\tilde{y}_{tt}^* \geq y_{tt}^*$.

For the supplier, when $\alpha^s \leq \alpha^r$, $\pi_{tt}^{s*} - \tilde{\pi}_{tt}^{s*} = -\frac{\alpha^s - a}{b(a - \alpha^s + 2b)}(p(a + b)^2 - bc(a + b) + \alpha^r(bc - 2ap - 3bp) - \alpha^s p(a + b - 2\alpha^r))$, so that $\pi_{tt}^{s*} \geq \tilde{\pi}_{tt}^{s*}$ if $p(a + b)^2 - bc(a + b) + \alpha^r(bc - 2ap - 3bp) - \alpha^s p(a + b - 2\alpha^r) \leq 0$.

When $\alpha^s \geq \alpha^r$, we have $\pi_{tt}^{s*} - \tilde{\pi}_{tt}^{s*} = -\frac{(a + b - \alpha^s)(2\alpha^r - a - \alpha^s)}{b(a - \alpha^s + 2b)(a - 2\alpha^r + \alpha^s + b)}H_1$, where $H_1 = p(a + b)^2 - bc(a + b) + 2\alpha^r(bc - ap - bp) - \alpha^s(bc + 2bp + ap - 2\alpha^r p)$. It follows that $\pi_{tt}^{s*} \geq \tilde{\pi}_{tt}^{s*}$ if $H_1 \leq 0$. Therefore, let $\mathcal{S}_0 = \{(\alpha^r, \alpha^s) : a \leq \alpha^s \leq 2\alpha^r - a; \alpha^s \leq a + b - bc/p; a \leq \alpha^r \leq a + b\}$, $\mathcal{S}_1 = \{(\alpha^r, \alpha^s) : p(a + b)^2 - bc(a + b) + \alpha^r(bc - 2ap - 3bp) - \alpha^s p(a + b - 2\alpha^r) \leq 0; \alpha^s \leq \alpha^r\}$, $\mathcal{S}_2 = \{(\alpha^r, \alpha^s) : p(a + b)^2 - bc(a + b) + 2\alpha^r(bc - ap - bp) - \alpha^s(bc + 2bp + ap - 2\alpha^r p) \leq 0; \alpha^s \geq \alpha^r\}$, then $\tilde{\pi}_{tt}^{s*} \leq \pi_{tt}^{s*}$ if $(\alpha^r, \alpha^s) \in (\mathcal{S}_1 \cup \mathcal{S}_2) \cap \mathcal{S}_0$; otherwise, the supplier benefits from the retailer type misidentification.

As for the retailer, when $\alpha^s \leq \alpha^r$, we have $\pi_{tt}^{r*} - \tilde{\pi}_{tt}^{r*} = -\frac{p(\alpha^s - a)}{2b(a - \alpha^s + 2b)^2}H_2$, where $H_2 = a(a + b)^2 + \alpha^r(4\alpha^r b - 2a^2 + 4b^2 + 3a\alpha^r) - 2(\alpha^s)^2(a + b - 2\alpha^r) + \alpha^s(4ab + 3b^2 + a^2 - 3(\alpha^r)^2 - 8\alpha^r b - 2a\alpha^r)$. Note that $d^2 H_2/d(\alpha^s)^2 = 4(2\alpha^r - a - b) \leq 0$, and thus H_2 is concave in α^s . When $\alpha^s = a$, we have $H_2 = 4ab(a + b) + 4b\alpha^r(\alpha^r + b - 2a) > 0$. When $\alpha^s = \alpha^r$, $H_2 = a(a + b)^2 + \alpha^r(7b^2 + 4ab - a^2 - \alpha^r(a + 6b) + (\alpha^r)^2) \geq 0$ so $H_2 \geq 0$ when $a \leq \alpha^s \leq \alpha^r$.

When $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, we should have $\pi_{tt}^{r*} - \tilde{\pi}_{tt}^{r*} = -\frac{p(a + b - \alpha^s)(2\alpha^r - a - \alpha^s)}{2b(a - \alpha^s + 2b)^2(a - 2\alpha^r + \alpha^s + b)}H_3$, where $H_3 = a(a + b)^2 - 2\alpha^r(2a^2 + 3ab + b^2) + 4(\alpha^r)^2(a + b) + \alpha^s(9b^2 + 3a^2 + 10ab - 4(\alpha^r)^2 - 2\alpha^r b) + (\alpha^s)^2(4\alpha^r - 5a - 8b) + (\alpha^s)^3$. We can also prove that H_3 is non-negative for all $a \geq 0, b \geq 0, \alpha^r \leq \alpha^s \leq \min\{2\alpha^r - a, a + b - bc/p\}$, and $a \leq \alpha^r \leq a + b$.

For the whole chain, if $\alpha^s \leq \alpha^r$, $\Pi_{tt}^* - \tilde{\Pi}_{tt}^* = -\frac{(\alpha^s - a)(a + b - \alpha^r)}{2b(a - \alpha^s + 2b)^2}H_4$, where $H_4 = p(a + b)(3a + 4b) - 2bc(2b + a) - p\alpha^r(3a + 4b) + \alpha^s(2bc - 3ap - 3bp + 3\alpha^r p)$. Besides, if $\alpha^r \leq \alpha^s \leq 2\alpha^r - a$, $\Pi_{tt}^* - \tilde{\Pi}_{tt}^* = -\frac{(2\alpha^r - a - \alpha^s)(a + b - \alpha^s)}{2b(a - \alpha^s + 2b)^2}H_5$, where $H_5 = p(a + b)(3a + 4b) - 2bc(2b + a) - 2p\alpha^r(a + b) + \alpha^s(2bc - 4ap - 5bp + 2\alpha^r p) + (\alpha^s)^2 p$. We then have the proposition by letting $\mathcal{S}_3 = \{(\alpha^r, \alpha^s) : p(a + b)(3a + 4b) - 2bc(2b + a) - p\alpha^r(3a + 4b) + \alpha^s(2bc - 3ap - 3bp + 3\alpha^r p) \leq 0; \alpha^s \leq \alpha^r\}$, and $\mathcal{S}_4 = \{(\alpha^r, \alpha^s) : p(a + b)(3a + 4b) - 2bc(2b + a) - 2p\alpha^r(a + b) + \alpha^s(2bc - 4ap - 5bp + 2\alpha^r p) + (\alpha^s)^2 p \leq 0; \alpha^s \geq \alpha^r\}$. ■

Online Appendix C: Survey on Setting Target Profit

To examine the applicability of the linear target formation model as well as our target-oriented decision framework, we conducted a survey for 74 EMBA students in a top Asian university. The survey questionnaire we used is as follows.

A Survey on Setting Target Profit

Dear participants,

Thank you very much for taking your time to complete this anonymous survey on setting target profits by firms. It has two pages with ten questions, and may take you up to five minutes to complete it.

1. Country/Region you are from: _____
2. Years of work experience:
☐ <5 years ☐ 5-10 years ☐ 10-15 years ☐ >15 years
3. Industry you work in: _____
4. Position in the company you work for: _____
5. Does your company set target profits? (Note: Target Profit is the expected amount of profit that the managers of a business expect to achieve by the end of a designated accounting period.)
☐ Yes ☐ No ☐ I don't know

6. Have you had experience in setting the target profit?
☐ Yes ☐ No

[If Yes, please go to questions 7 to 10; otherwise, please go to questions 11 to 14.]

7. All else being equal, would you set a higher/lower target profit if the profit margin increases/decreases? (Note: Profit margin = Unit selling price – Unit cost)
☐ Yes ☐ No

8. All else being equal, would you set a higher/lower target profit if the forecasted sales increase/decrease?
☐ Yes ☐ No

9. Do you think the following formula provides a reasonable proxy for the target profit?

Target Profit = Forecasted sales × (Unit selling price – Unit cost) – Operating cost

- ☐ Yes ☐ No

10. If your answer to question 9 is No, what do you think is a better way to decide the target profit?

Thank you again for your participation. We really appreciate it.

11. If you were to set the target profit, all else being equal, would you increase/decrease the target profit if the profit margin increases/decreases? (Note: Profit margin = Unit selling price – Unit cost)
☐ Yes ☐ No

12. If you were to set the target profit, all else being equal, would you increase/decrease the target profit if the forecasted sales increase/decrease?
☐ Yes ☐ No

13. Do you think the following formula provides a reasonable proxy for the target profit?

Target Profit = Forecasted sales × (Unit selling price – Unit cost) – Operating cost

- ☐ Yes ☐ No

14. If your answer to question 13 is No, what do you think is a better way to decide the target profit?

Thank you again for your participation. We really appreciate it.

Figure C.1 The survey ¹

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Summary of Subject Demographics

Country or region The respondents come from various countries including China (46.58%), Singapore (19.18%), United States (13.7%), India (4.05%), Australia (2.7%), and etc.

Years of working experience Among the 74 participants, 50 of them have more than 15 years of working experience, 21 have worked for 10-15 years, and the rest three 5 to 10 years.

Industries and designations Respondents work in various industries including manufacturing, oil & gas, fast-moving consumer goods (FMCC), healthcare, information technology, etc., and they hold managerial positions such as CEO (8/74), general manager (10/74), director (15/74), manager (10/74), etc.

Online Appendix D: Data Analysis for Top Nine Oil & Gas Companies

We picked the crude oil & gas companies as they have a relatively simple product mix, which makes the analysis more feasible. For example, for Occidental, oil and gas segments accounts for 72.85% of the total revenue in the second quarter of 2019. On average, sales from oil accounts for 90.5% of the total revenue in that segment each day.

We extracted a dataset of top nine publicly traded crude oil & gas companies in the U.S.A. from the I/B/E/S analyst-by-analyst historical earnings estimate database in Wharton Research Data Services (WRDS, <https://wrds-web.wharton.upenn.edu/wrds/>). A screenshot of the data is shown in Figure D.1 (left). This dataset provides different analysts' quarterly estimates of each company's pre-tax profit as well

										A	C	D	E	F	G		
1	TICKER	CUSIP	CNAME	ESTIMATOR	ANALYS	MEASURE	VALUE	USFIRM	FPEDATS	ACTUAL	1	Data Date	Company Name	ISO Currency Code	Fiscal Data Year and Quarter	Cost of Goods Sold	Total Revenue
2	CHV	16676410	CHEVRON TEXACO	98	702	PRE	2367	1	20021231			7	20010630	CHEVRON CORP	USD	2001Q2	21300
3	CHV	16676410	CHEVRON TEXACO	98	702	PRE	2363	1	20030331	3864	8	20010930	CHEVRON CORP	USD	2001Q3	18713	23750
4	CHV	16676410	CHEVRON TEXACO	100	15304	PRE	1730	1	20030331	3864	9	20011231	CHEVRON CORP	USD	2001Q4	15862	19606
5	CHV	16676410	CHEVRON TEXACO	98	702	PRE	2919	1	20030331	3864	10	20020331	CHEVRON CORP	USD	2002Q1	15657	19156
6	CHV	16676410	CHEVRON TEXACO	98	702	PRE	2996	1	20030331	3864	11	20020630	CHEVRON CORP	USD	2002Q2	18779	23472
7	CHV	16676410	CHEVRON TEXACO	98	702	PRE	2998	1	20030630		12	20020930	CHEVRON CORP	USD	2002Q3	19576	23899
8	CHV	16676410	CHEVRON TEXACO	98	702	PRE	2634	1	20031231	2458.192	13	20021231	CHEVRON CORP	USD	2002Q4	20768	25158
9	CHV	16676410	CHEVRON TEXACO	98	702	PRE	2788	1	20040331	4379.056	14	20030331	CHEVRON CORP	USD	2003Q1	22820	28879
10	CHV	16676410	CHEVRON TEXACO	98	702	PRE	4914	1	20040930	4453.428	15	20030630	CHEVRON CORP	USD	2003Q2	21721	27126
11	CHV	16676410	CHEVRON TEXACO	98	702	PRE	5198	1	20040930	4453.428	16	20030930	CHEVRON CORP	USD	2003Q3	22852	28227
12	CHV	16676410	CHEVRON TEXACO	98	702	PRE	4812	1	20041231	5073.512							
13	CHV	16676410	CHEVRON TEXACO	98	702	PRE	4626	1	20050331	4907							
14	CHV	16676410	CHEVRON TEXACO	98	702	PRE	5679	1	20050630	6456							
15	CHV	16676410	CHEVRON	98	702	PRE	7326	1	20050930	6675							
16	CHV	16676410	CHEVRON	98	702	PRE	8960	1	20051231	7159							

Figure D.1 Screenshot of the Pre-tax Profit Data (Left) and the the Cost and Revenue Data (Right) of Top Nine U.S. Oil & Gas Companies

as the companies' actual profit. In the dataset, "TICKER", "CUSIP", and "CNAME" are identifiers of company, "ESTIMATOR" and "ANALYS" are identifiers of the analysts, "MEASURE" is the pre-tax profit (PRE) and the corresponding forecasted value is "VALUE", and "FPEDATS" is the date of the accounting period. We average over all analysts' estimates for each quarter as the profit forecast. We believe that this profit forecast is a good proxy for the target profit, as a public firm would strive to meet the forecast; missing the forecasted profit can result in significant loss of the firm's value. Amazon, for example, lost more than 12% of market value after reporting a less than expected Q4 revenue in 2015 (Lieberman 2016).

We also exported the quarterly cost ("Cost of Goods Sold" column) and revenue ("Total Revenue" column) data for each company from Compustat, which is also a dataset provided in WRDS. A screenshot of the dataset is shown in Figure D.1 (right). In addition, we downloaded the crude oil price (Price) from FRED (<https://fred.stlouisfed.org>), and approximated the sales quantity as $\frac{\text{Total Revenue}}{\text{Price}}$. We then divided the Cost of Goods Sold by the sales quantity to obtain the marginal cost. As such, the marginal profit for one barrel of crude oil is approximately calculated as: $\text{Price} - \frac{\text{Cost of Goods Sold} \times \text{Price}}{\text{Total Revenue}}$.

Linear regression results We conducted a linear regression on the model $\tau = \alpha * (p - w)$ and the results are shown in Table D.2. As can be seen, the linear relationship between the target and the profit margin is significant for all the nine companies except CONOCOPHILLIPS.

Table D.2 Linear regression results for top nine oil & gas companies in US

Companies	α	t value	$\text{Pr}(> t)$
EXXON MOBIL CORP	1037.56	19.90	$< 2e-16^{***}$
CHEVRON	541.21	16	$< 2e-16^{***}$
CONOCOPHILLIPS	20.25	0.67	0.51
EOG RESOURCES	8.18	6.10	$6.96e-08^{***}$
OCCIDENTAL PETE	25.66	7.21	$1.09e-09^{***}$
PHILLIPS 66	266.46	5.19	$2.01e-05^{***}$
VALERO ENERGY CP	275.57	13.50	$< 2e-16^{***}$
HALLIBURTON	39.35	12.27	$< 2e-16^{***}$
MARATHON PETROLE	132.39	5.40	$8.37e-06^{***}$

Signif. codes: '***', 0.001; '**', 0.01; '*', 0.05; '.', 0.1; ' ', 1