BETA
Bureau
d'économie
théorique
et appliquée

Documents de travail

« Incentives for sustainable efforts considering double moral hazard and multi goals in supply chains »

Auteurs

Bo WU, Ioana FILIPAS

Document de Travail n° 2025 – 25

Juin 2025

Bureau d'Économie
Théorique et Appliquée
BETA

https://www.beta-economics.fr/

Contact :
jaoulgrammare@beta-cnrs.unistra.fr

Incentives for sustainable efforts considering double moral hazard and multi goals in supply chains

Bo WU[1,2], Ioana FILIPAS[2]*

(1.Glorious Sun School of Business & Management, Donghua University, Shanghai 200051, China)

(2. Faculté des sciences économiques et de gestion BETA, Université de Strasbourg, Strasbourg 67000, France)

Abstract: This paper investigates the GHG emission reduction incentive problem when a supply chain faces dual moral hazard and multi-goal. We innovatively characterize dual moral hazard and multi-goal functions of a supply chain and obtain some findings. First, when a brand prioritizes multiple goals, it will make greater efforts to reduce GHG emissions than the manufacturer. Surprisingly, the more complex the environment of moral hazard, the less likely the manufacturer will make concessions. In general, considering multi-goal of brand reduces the problem of double marginalization in a supply chain. Second, while supply chains face complex double moral hazard, the brand's burden of GHG reduction can only be reduced by prioritizing heavily sustainability and consumer surplus goals. Third, firms face a dual moral hazard when pursuing sustainability and consumer surplus goals, which can sometimes be positive.

Key words: sustainable efforts; moral hazard; multi goals; risk aversion; uncertainty

JEL Code: Q5 Environmental Ecomnomics ; Q51, Q58s

1. Introduction

Rapid economic development has made us increasingly aware of the importance of sustainability. And sustainability of supply chain has been a hot topic for experts and scholars to investigate. Some companies have started to set supply chain sustainability goals. For example, electronics factory of Samsung achieves GHG reduction target by upgrading waste gas handling equipment in 2021.[1] Decathlon has decided to achieve net-zero emissions in its value chain by 2050.[2] In addition, many countries have introduced corresponding policies for sustainable development. GHG tax policies are one of the most highly discussed measures. Under the GHG tax policy, companies need to pay a tax on GHG when their emissions surpass their pre-

[1] https://www.samsung.com/global/sustainability/media/pdf/Samsung_Electronics_Sustainability_Report_2023_ENG.pdf#:~:text=Samsung%20Electronics%20will%20continue%20to%20join

[2] https://sustainability.decathlon.com/decathlon-annual-sustainable-development-reports

established threshold. The price can be subsidized when a surplus of GHG quota remains (Choi, 2013a; Choi, 2013b).

However, the realization of sustainability goals (i.e., We focus on the climate action of sustainability goals set by the United Nations.) in the supply chain is not easy. In particular, the issue of moral hazard in sustainable development has been often overlooked. Moral hazard in sustainable supply chains refers to the lazy behaviors of supply chain members in GHG emission reduction (e.g., not purchasing GHG emission reduction equipment or using non-environmentally transportation methods, etc.). On the one hand, brand companies are concerned that suppliers may have moral hazard issues in their sustainability efforts. Higher tier suppliers as well as sub-suppliers of a company can perform unethical and social norm violating behaviors (Govindan et al., 2021). Multi-tier suppliers have not shown much initiative in implementing Corporate Social Responsibility (CSR) and sustainability initiatives (Meinlschmidt et al., 2018). Volkswagen says its manufacturers are non-transparent about CO_2 emissions throughout the supply chain. VW sees it as a challenge to optimize the supply chain and reduce GHG emissions.[3] Most of Apple's suppliers have yet to publicly disclose details of their renewable energy usage and CO_2 emissions data to the public. In addition, some of Apple's suppliers have not implemented solutions of clean energy technologies in time, resulting in poor GHG reductions in the Apple Watch supply chain.[4] On the other hand, suppliers find that brand companies often ignore their own moral hazard. In 2020, the Italian Competition and Market Authority (ACMA) fined the Italian oil company Eni €5 million for falsely advertising that its "green" diesel product, Eni Diesel+, had a positive impact on the environment, saving fuel and reducing greenhouse gas emissions.[5] As a result, companies have been finding solutions (e.g., incentive contracts) to drive sustainable supply chain goal achievement. Even now businesses tend to focus on more goals (i.e., profit, sustainability goals, consumer surplus, and social welfare).

Motivated by the GHG tax policy and moral hazard of sustainability efforts, this study

---

[3] https://annualreport2023.volkswagen-group.com/group-management-report/sustainable-value-enhancement/sustainability.html#:~:text=Based%20on%20the%20business%20model%20of

[4] https://www.apple.com/newsroom/2023/09/apple-advances-supplier-clean-energy-commitments/#:~:text=New%20commitments%20from%20more%20than%2050

[5] https://biofuels-news.com/news/oil-major-eni-fined-e5-million-for-deceiving-customers-over-green-diesel/#:~:text=Eni%20has%20been%20fined%20the%20highest

investigates how brands use their power (e.g., incentive contracts) to push supply chain to reduce GHG emissions in order to achieve multi goals. This study is the first to consider moral hazard and multi goals in a supply chain of GHG emission abatement. The main motivation of our study is to fill this gap. As such, the research issues we discuss are as follows. The impact of single moral hazard and double moral hazard on supply chain GHG emission reduction when brand owners focus only on profit. And the impact of single moral hazard and double moral hazard on supply chain GHG reduction when the brand focus on multiple goals. Will the problem of moral hazard in the supply chain be mitigated with brand multi-goal?

The rest of the paper is structured as follows. In Section 2, we first review the relevant literature. We provide a model description in Section 3. The supply chain equilibrium results of single moral hazard and double moral hazard considering only the profit objective are covered in Section 4. The supply chain equilibrium results of single moral hazard and double moral hazard considering multi objectives are covered in Section 5. In Section 6, we derive the main results through comparative analysis. In Section 7, we conclude with the results.

2. State of the art

This paper is mainly connected to three lines of literature. The literature on a supply chain's sustainability is the firstly relevant to our investigation. Park et al. (2015) explore whether imposing carbon costs affects supply chain structure and social welfare. Xu et al. (2022) investigate the usefulness of energy performance contracts in light of the carbon tax policy. The impact of carbon policies on businesses' investments in carbon reduction technology is examined by Fan et al. (2023). Nguyen-Van et al. (2021) suggest that social influence is necessary for the emergence of pro-environmental behaviors. In order to address this sustainability challenge, Cantele et al. (2023) suggest two possible solutions: first, integrating supply chain agility with sustainability practices; and second, utilizing the resource orchestration theory framework (ROT) to assist supply chain managers in making more informed decisions regarding sustainability. Ngo et al. (2024) look into how suppliers, consumers, and the financial performance of Vietnamese clothing industry companies are affected by supply chain risks related to sustainability. In addition, the adoption of sustainability in multi-tiered food supply chains is hindered by several major obstacles, including supply chain complexity, lack of infrastructure, knowledge gaps, and the expense of sustainability (Oyedijo et al., 2024). Previous researches of supply chain's sustainability mainly focused on incentives of sustainable efforts. Our study introduces incentive contracts and principal-agent theory considering multi-goal to deal with single (double) moral hazard problem, which is different from the above literature in terms of research objectives and methods.

The second body of research is that on moral hazard based on principal-agent theory. Most moral hazard research has focused on sales force compensation. Dai & Jerath (2013) consider the newsvendor demand function and use it to portray the problem of designing incentive contracts in the context of salesperson effort when demand is limited by inventory levels. Dai & Jerath (2019) further extend research on effort incentive contracts to discuss the timing of a firm's incentive contract formulation under a double moral hazard model. Kräkel & Schöttner (2016) analyze optimal contracts for a two-period moral hazard model with binary effort choices. They also investigate a scenario in which the second-period sales opportunity is randomly determined by the outcome of the first period using exogenous probabilities. Schöttner (2017) consider dynamic moral hazard modeling in sales compensation systems. They examine a multi-period setting with varying sales probabilities, where the firm can only obtain aggregate sales data. However, some scholars have found that moral hazard also exists in other areas such as machine learning products and supply chains. For example, Gurkan & Véricourt (2022) consider the issue of moral hazard in the supply chain of machine learning products. The firm's decisions depend on the interaction between the amount of data on which the machine is trained and the provider's effort. These distortions sometimes improve social welfare. Cai et al. (2021) find that "triple marginalization" occurs in platform operations. Blockchain technology is used to address moral hazard in the platform supply chain. Choi et al. (2023) investigate the issue of moral hazard in the fashion supply chain. They demonstrate that when the fixed payment from the retailer to the manufacturer under the ETO (ethical operations) case is sufficiently small, the retailer prefers to adopt ethical operations. We find less literature focusing on the issue of moral hazard in sustainability. And this is the focal point of our study.

The third part of the literature focuses on supply chain optimization objectives. Most of the studies only consider maximizing profits of firms. These are called ***single-goal*** researches. Some scholars focus on maximizing profits in traditional supply chains. Jabarzare & Rasti-Barzoki (2020) maximize profits for optimal pricing and quality decisions. Nagurney (2021) explore the profit optimization problem with labor constraints. Mamoudan et al. (2024) study food products pricing by maximizing profits of retailer and supplier. Most of the above literature is on maximizing profit objectives. Instead, Schöttner (2017) explores the objective of minimizing cost under constraints in two and multiple periods. Other scholars consider maximizing the profits of platform supply chains. Zha et al. (2022) focus on information sharing strategy and maximizing platform profits. Zhao et al. (2022) talk about information acquisition and sharing of an online platform based on Bertrand competition model. Zhang et al. (2023) study online travel platform in a tourism supply chain where competition exists. However, scholars acknowledge that profit alone is an inadequate indicator. These are called ***multi-goal*** researches. For example, Wang & Li (2021) investigate whether a retailer can benefit from being a dual-purpose corporation and how their dual objectives impact consumer surplus. However, this study considers more objectives which distinguishes it. Filipas et al. (2024) propose a framework for integrating the three pillars of sustainability--economic, environmental, and social responsibility--into a company's management. Although Fan et al. (2023) consider consumer surplus, this indicator is indeed optimized separately from the profit indicator. We are optimizing multiple objectives at the same time. We find that although multi-objective studies have addressed both consumer surplus and social welfare. However, fewer studies consider sustainability as an indicator. And most of these indicators are optimized independently.

Table 1 summarizes the related studies and the paper's position in the literature. Our work considers more comprehensive scenarios that encompass multi-goal and double moral hazard problem based on game model. Moreover, ours is the first to articulate this theme in the context of sustainability. In particular, the above literature suggests that firms often ignore the moral hazard problem of supply chain. And this literature does not provide a detailed analysis of the effects of risk delivery on the incentive contracts of sustainability. We try to handle such problem through contracts in a supply chain. By modelling the scenarios, we explore the effects of incentives on carbon reduction and how to re-estimate the impact of multi-goal on sustainable incentives, which has certain academic value and practical significance.

Table 1. Related studies and positioning of this paper

Paper	Supply chain's sustainability	Moral hazard	Single-goal	Multi-goal	Modeling tools
Park et al. (2015)	√		√		Game theory

Xu et al. (2022)	√		√		Game theory
Fan et al. (2023)	√		√		Game theory
Dai & Jerath (2013, 2019)		√	√		Principal-agent theory
Gurkan & Véricourt (2022)		√	√		Principal-agent theory
Cai et al. (2021)		√	√		Blockchain technology
Schöttner (2017)		√	√		Principal-agent theory
Wang & Li (2021)				√	Game theory
Filipas et al. (2024)	√			√	Framework theory
This paper	√	√	√	√	Game theory

3. Model

Based on the above literature analysis, we will propose our mathematical model with the help of game theory. We innovatively consider the impact of dual moral hazard and multi-goal on sustainable investment of a brand. Much of the previous literature has focused on the topics of single-goal and single moral hazard. Therefore, we will fill this gap. This is the focus of our paper. We try to explore the mechanism of dual moral hazard and multi-goal on the equilibrium outcomes of sustainable supply chain.

Consider a supply chain system consisting of a manufacturer and a brand (e.g., Tesla). As shown in the yellow area in Fig. 1. The manufacturer distributes its products to the brand at a wholesale price of w, and the brand sells them to consumers at a price of p. The cost of production is c. With the increase of consumers' awareness of environmental protection, consumers will have a higher preference for the products with low-GHG. Green consumers, as in Fig. 1, indicate that consumers are concerned about the environment. Thus, consumer utility can be expressed as $U = v + \varepsilon + e_M + e_R - p$, where v represents the consumer valuation of the product and $v \sim U[0,1]$. ε denotes the fluctuation of the market demand and is assumed to be $\varepsilon \sim N(0, \sigma_\varepsilon^2)$. e_M and e_R denote sustainable efforts of the manufacturer and the brand to reduce the GHG emissions, respectively. Then, we can derive the market demand as $D = a + \varepsilon + e_M + e_R - p$. The cost of GHG reduction efforts by manufacturers and brand is $\frac{1}{2}e_i^2$, $i \in \{M, R\}$. The quadratic form of the cost is widely used in many literatures (Anand & Giraud-Carrier, 2020; Subramanian et al., 2007). The initial value of GHG emission per unit of product is γ, and the final GHG emission per unit of product is $\gamma - e_M - e_R$. So the total GHG emission is $C = (\gamma - e_M - e_R)D$.

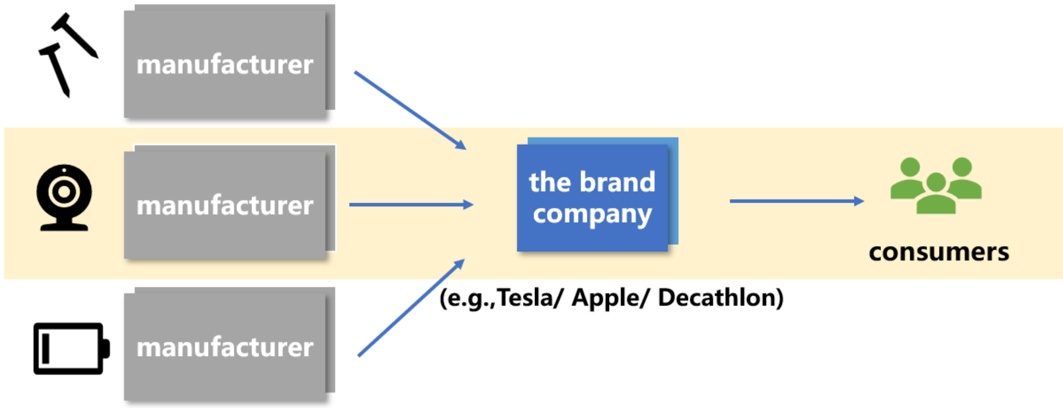

Fig. 1 Supply chain structure

Following Fan et al. (2023), the government allots to the company a certain amount of GHG emissions, represented by the symbol c_0. A permanent GHG tax $\overline{g}$, when these emissions surpass c_0, predetermines the GHG price under the GHG tax policy. When the GHG emissions exceed the pre-allocated allowance (i.e., $c_0 < C$), a tax $\left((\gamma - e_M - e_R)D - c_0\right)\overline{g}$ is charged. However, when the supply chain as a whole does not reach the pre-allocated allowance (i.e., $c_0 \geq C$), a subsidy $(c_0 - (\gamma - e_M - e_R)D)\overline{g}$ is provided.

As there is often information gap between upstream and downstream of the supply chain in real scenarios. Therefore, the study focuses on the asymmetric information operating environment that is closer to reality. That is to say, supply chain members' efforts in sustainability are often not known by other members, such as whether supply chain members are fully committed or lazy when reducing GHG. In economics, we call this kind of behavior as an agent with some moral hazard. In this paper, we consider two scenarios, one in which a brand publishes its GHG reduction efforts on its website, and the other in which a manufacturer and a brand are unaware of each other's GHG reduction efforts. In order to incentivize the upstream to pay GHG reduction efforts together, the downstream is compensated with transfer payments α as incentives.

Assuming that the manufacturer is risk averse. And his utility is $u = -e^{-r\pi_M(w,e_M)}$, where $r(r > 0)$ measures the level of risk aversion. Therefore, the manufacturer's certainty equivalence (CE) is given by

$$E\left(\pi_M(w, e_M)\right) = (w - c) * D + \alpha - \frac{1}{2}e_M^2 - \frac{1}{2}r(w - c)^2\sigma_\varepsilon^2 \qquad (1)$$

Consequently, on the right-hand side of Eq. (1), the first term is the net profit (i.e., the difference between sales revenue and production costs). The second term is the transfer payments.

The third term is the sustainability costs for manufacturer efforts. The last term is the impact of manufacturer risk aversion. We can also obtain the brand's profit (e.g., The brand owner here is equivalent to the contractor), that is

$$E\big(\pi_R(p, e_R, \alpha)\big) = (p - w) * D - \alpha - \tfrac{1}{2}e_R^2 - \big((\gamma - e_M - e_R)D - c_0\big)\overline{g} \quad (2)$$

In order to avoid trivial cases, we assume $g + g^2 > 3 + 2r\sigma_\varepsilon^2$. The single moral hazard and double moral hazard are represented by the superscript symbols "S" and "D", respectively. And the goal for only profit and the multi goals are represented by the superscript symbols "S" and "M", respectively.

4. Single goal – for profit

First, we consider the equilibrium outcomes when the supply chain solely aims at profits. We use the absence of moral hazard as a benchmark. This is a more idealized condition. But it is extremely important for the subsequent analysis. It helps us to distill the impact of moral hazard from different supply chain members. Then based on this, we study the impact of single and double moral hazard on the supply chain system.

4.1 Single moral hazard

Based on the previous analysis, we build the following model. The brand pursues profit as its only goal. The first term on the right-hand side of the objective function is the net profit of the brand. The second term is the brand's transfer payments to incentivize manufacturers to make GHG reduction efforts. The third term is the cost to the brand of reducing GHG emissions. The fourth term is the amount of GHG tax paid by the brand. For the P^{SS} model, we also need to satisfy two constraints. The individual rationality constraint $(IR - SS)$ ensures that upstream manufacturer is willing to accept the brand's incentives and fulfill the GHG reduction mission. The incentive compatibility constraint $(IC - SS)$ is the manufacturer's willingness to maximize GHG reduction efforts on profitable terms. This ensures the effectiveness of the brand incentive. It should be noted that single moral hazard implies that in this model we only consider the risk of the upstream manufacturer (i.e., $e_M > 0$ and $e_R = 0$).

$$(P^{SS}): \quad \max E\left(\pi_R^{SS}(p, e_R, \alpha)\right)$$

$$= (p - w) * (a + \varepsilon + (e_M + e_R) - p) - \alpha - \frac{1}{2}e_R^2 - \big((\gamma - e_M - e_R)D - c_0\big)\overline{g}$$

$$s.t. \quad E\left(\pi_M^{SS}(w, e_M)\right) = (w-c)*D + \alpha - \frac{1}{2}e_M^2 - \frac{1}{2}r(w-c)^2\sigma_\varepsilon^2 \geq 0 \qquad (IR-SS)$$

$$e_M^* \in argmax\, E\left(\pi_M^{SS}(w, e_M)\right) \qquad (IC-SS)$$

Solving (P^{SS}), **Proposition 1** characterizes the equilibrium prices, the emission abatement effort, and the incentive transfer payments (α^{SS*}).

Proposition 1 *Under the single-goal and single moral hazard scenario,*

(a) The band's optimal price is p^{SS*}*, and the manufacturer's optimal wholesale price is* w^{SS*}*, where*

$$p^{SS*} = \frac{(c+g\gamma)(g-2r\sigma_\varepsilon^2)+a(g+g^2-3-2r\sigma_\varepsilon^2)}{2g+g^2-3-4r\sigma_\varepsilon^2},\ w^{SS*} = \frac{2g\gamma-2a+c(2g+g^2-1-4r\sigma_\varepsilon^2)}{2g+g^2-3-4r\sigma_\varepsilon^2},$$

(b) The manufacturer's emission abatement effort is e_M^{SS*}*, and the band's incentivized transfer payments are* α^{SS*}*, where*

$$e_M^{SS*} = \frac{(1+g)(c-a+g\gamma)}{2g+g^2-3-4r\sigma_\varepsilon^2},\ \alpha^{SS*} = \frac{(c-a+g\gamma)^2}{2(2g+g^2-3-4r\sigma_\varepsilon^2)}.$$

We find that under single moral hazard, the price of product p^{SS*} increases with market size a if the brand focuses only on profits. Yet this is not the same for wholesale price. The wholesale price decreases as market demand increases. This can be interpreted as a compromise by the manufacturer to ensure that it receives sufficient transfer payments α^{SS*} in order to reduce GHG e_M^{SS*}.

4.2 Double moral hazard

Based on Section 4.1, we study the impact of double moral hazard. At this stage, in addition to considering the upstream manufacturer moral hazard problem, we need to add the possible moral hazard problem of the brand itself. Therefore, we add a constraint to construct the P^{SD} based on the P^{SS}. The incentive compatibility constraint $(IC-SD2)$ expresses the assurance that the brand will put in maximum GHG reduction efforts in a profitable way. In particular, dual moral hazard means that we need to consider both the manufacturer's and the brand's risk (i.e., $e_M > 0$ and $e_R > 0$) .

$$(P^{SD}):\ \max E\left(\pi_R^{SD}(p, e_R, \alpha)\right)$$

$$= (p-w)*(a+\varepsilon+(e_M+e_R)-p) - \alpha - \frac{1}{2}e_R^2 - \left((\gamma - e_M - e_R)D - c_0\right)\overline{g}$$

$$s.t. \quad E\left(\pi_M^{SD}(w, e_M)\right) = (w-c)*D + \alpha - \frac{1}{2}e_M^2 - \frac{1}{2}r(w-c)^2\sigma_\varepsilon^2 \geq 0 \qquad (IR-SD)$$

$$e_M^* \in argmax\ E\left(\pi_M^{SD}(w, e_M)\right) \qquad (IC - SD)$$

$$e_R^* \in argmax\ E\left(\pi_R^{SD}(p, e_R, \alpha)\right) \qquad (IC - SD2)$$

Solving (P^{SD}), **Proposition 2** characterizes the equilibrium prices, the emission abatement effort, and the incentive transfer payments (α^{SD*}).

Proposition 2 *Under the single-goal and double moral hazard scenario,*

(a) The band's optimal price is p^{SD*}*, and the manufacturer's optimal wholesale price is* w^{SD*}*, where*

$$p^{SD*} = \frac{1}{2}(a + (e_M^{SD*} + e_R^{SD*})(1 - g) + w^{SD*} + g\gamma),\ w^{SD*} = \frac{a + c + (e_M^{SD*} + e_R^{SD*})(1 + g) - g\gamma + 2cr\sigma_\varepsilon^2}{2 + 2r\sigma_\varepsilon^2},$$

(b) The manufacturer's and the band's emission abatement efforts are e_M^{SD*} *and* e_R^{SD*}*, and the band's incentivized transfer payments are* α^{SD*}*,where*

$$e_M^{SD*} = \frac{2(1+g)(c-a+g\gamma)(1+r\sigma_\varepsilon^2)}{\xi_1},\ e_R^{SD*} = \frac{(1+g)(c-a+g\gamma)(1+2r\sigma_\varepsilon^2)^2}{\xi_1},$$

$$\alpha^{SD*} = \frac{2(c-a+g\gamma)^2(2g-3+g^2-4r\sigma_\varepsilon^2)(1+r\sigma_\varepsilon^2)^2}{{\xi_1}^2},\ \xi_1 = (2g + g^2)(3 + 6r\sigma_\varepsilon^2 + 4r^2\sigma_\varepsilon^4) - 5 - 10r\sigma_\varepsilon^2 - 4r^2\sigma_\varepsilon^4.$$

We find that under dual moral hazard, the price of the product p^{SD*} increases with the wholesale price w^{SD*}. The wholesale price, in turn, depends on the GHG reduction efforts of the manufacturer and the brand (i.e., $e_M^{SD*} + e_R^{SD*}$). The presence of dual moral hazard motivates GHG reduction efforts by the brand even if the brand is only concerned with profits.

5. Multi-goal – for profit & sustainability & consumer surplus

We consider the situation where the brand is multi-goal based on Section 4. We define the goal of the environment as $S = (\gamma - e_M - e_R)D$. Brands want to achieve a higher effect of their GHG reduction efforts by paying a certain cost. S is smaller to indicate that the supply chain is investing more in GHG reduction, which implies a good effect in achieving sustainability goals. We employ this as a measure of a firm's concern for the environment. ρ denotes the extent of a firm's concern for sustainability goal. The consumer surplus follows the setup of Fan et al. (2023), which we denote as $CS = \frac{1}{2}D^2$. Consequently, our multi goals function can be characterized as

$$multi\ goals = E\left(\pi_R^M(p, e_R, \alpha)\right) + CS + \rho S$$

5.1 Single moral hazard

First, we explore the impact of single moral hazard on multi-goal of the brand. We find that a brand's multi-objective affects the objective function compared to Section 4.1. Therefore, the P^{MS} model will calculate the equilibrium results under multi-goal.

$$(P^{MS}): \quad \max E\left(\pi_R^{MS}(p, e_R, \alpha)\right) = E\big(\pi_R(p, e_R, \alpha)\big) + CS + \rho S$$

$$s.t. \quad E\left(\pi_M^{MS}(w, e_M)\right) = (w-c) * D + \alpha - \frac{1}{2}e_M^2 - \frac{1}{2}r(w-c)^2\sigma_\varepsilon^2 \geq 0 \qquad (IR-MS)$$

$$e_M^* \in argmax\ E\left(\pi_M^{MS}(w, e_M)\right) \qquad (IC-MS)$$

Solving (P^{MS}), **Proposition 3** characterizes the equilibrium prices, the emission abatement effort, and the incentive transfer payments (α^{MS*}).

Proposition 3 *Under the multi-goal and single moral hazard scenario,*

(a) The band's optimal price is p^{MS*}*, and the manufacturer's optimal wholesale price is* w^{MS*}*, where*

$$p^{MS*} = \frac{a(g+g^2-1-\rho-2g\rho+\rho^2)+\big(c+\gamma(g-\rho)\big)(g-\rho-r\sigma_\varepsilon^2)}{g^2-1-2g(\rho-1)-2\rho+\rho^2-r\sigma_\varepsilon^2},\ w^{MS*} = \frac{\gamma(g-\rho)-a+c(2g+g^2-2\rho-2g\rho+\rho^2-r\sigma_\varepsilon^2)}{g^2-1-2g(\rho-1)-2\rho+\rho^2-r\sigma_\varepsilon^2},$$

(b) The manufacturer's emission abatement effort is e_M^{MS*}*, and the band's incentivized transfer payments are* α^{MS*}*,where*

$$e_M^{MS*} = \frac{\big(c-a+\gamma(g-\rho)\big)(1+g-\rho)}{g^2-1-2g(\rho-1)-2\rho+\rho^2-r\sigma_\varepsilon^2},\ \alpha^{MS*} = \frac{\big(a-c+\gamma(\rho-g)\big)^2}{2\big(g^2-1-2g(\rho-1)-2\rho+\rho^2-r\sigma_\varepsilon^2\big)}.$$

In contrast to Section 4, the equilibrium outcomes of the supply chain are related to how much the brand cares about the environment ρ. The impact of how much a brand care about the environment is also more complex. This is because the objective of a brand is no longer just to pursue profits. This means that the brand needs to consider sustainability and consumer surplus.

5.2 Double moral hazard

We continue to explore the impact of double moral hazard on multi-goal brand. In contrast to section 5.1, we focus on the impact of multiple goals on the brand's own GHG reduction efforts in addition to changes in the objective function. The incentive constraints need to be reset. We altered the formulation for solving for e_R^* (e.g., $(IC-MD2)$).

$$(P^{MD}): \ \max E\big(\pi_R^{MD}(p, e_R, \alpha)\big) = E\big(\pi_R(p, e_R, \alpha)\big) + CS + \rho S$$

$$s.t. \quad E\big(\pi_M^{MD}(w, e_M)\big) = (w-c) * D + \alpha - \frac{1}{2}e_M^2 - \frac{1}{2}r(w-c)^2\sigma_\varepsilon^2 \geq 0 \qquad (IR-MD)$$

$$e_M^* \in argmax\ E\big(\pi_M^{MD}(w, e_M)\big) \qquad (IC-MD)$$

$$e_R^* \in argmax\ E\big(\pi_R^{MD}(p, e_R, \alpha)\big) + CS + \rho S \qquad (IC-MD2)$$

Solving (P^{MD}), **Proposition 4** characterizes the equilibrium prices, the emission abatement effort, and the incentive transfer payments (α^{MD*}).

Proposition 4 *Under the multi-goal and double moral hazard scenario,*

(a) The band's optimal price is p^{MD*}, and the manufacturer's optimal wholesale price is w^{MD*}, where

$$p^{MD*} = w^{MD*} + (\gamma - e_M^{MD*} - e_R^{MD*})(g-\rho)\,,\; w^{MD*} = \frac{a+c+(e_M^{MD*}+e_R^{MD*})(1+g-\rho)-g\gamma+\gamma\rho+cr\sigma_\varepsilon^2}{2+r\sigma_\varepsilon^2},$$

(b) The manufacturer's and the band's emission abatement efforts are $e_M^{MD*}$and e_R^{MD*}, and the band's incentivized transfer payments are α^{MD*},where

$$e_M^{MD*} = \frac{(\gamma(g-\rho)-a+c)(1+g-\rho)(2+r\sigma_\varepsilon^2)}{\xi_2},\; e_R^{MD*} = \frac{(\gamma(g-\rho)-a+c)(1+g-\rho)(1+r\sigma_\varepsilon^2)^2}{\xi_2},$$

α^{MD*} is the solution of Eq. $E\left(\pi_M^{MD*}(w^{MD*}, e_M^{MD*})\right) = 0$, *where* $\xi_2 = (g^2 - 2g(\rho-1) - 2\rho + \rho^2)(3 + 3r\sigma_\varepsilon^2 + r^2\sigma_\varepsilon^4) - 1 - r\sigma_\varepsilon^2$.

Multi-goal considerations for the brand also complicate the system equilibrium outcomes when the supply chain faces a more complex risk environment (e.g., dual moral hazard). The price of the product still rises as the wholesale price rises. A detailed analysis will be unfolded in the next section.

6. Comparative analysis

In this section, we will analyze the equilibrium results of the four models mentioned above. Moral hazard and multi-goal concerns will be our focal point.

Proposition 5 *The brand's and manufacturer's optimal efforts of GHG reduction:*

(a) Double moral hazard reduces manufacturer's GHG reduction efforts; multi-goal targeting concerns also reduce GHG reduction efforts in the supply chain.

(b) If $\rho \geq \rho_1$, $e_R^{SD*} \geq e_M^{MD*}$; otherwise, $e_R^{SD*} < e_M^{MD*}$; if $\rho \geq \rho_2$, $e_M^{SD*} \geq e_M^{MS*}$; otherwise, $e_M^{SD*} < e_M^{MS*}$.

Proposition 5 summarizes the characteristics of supply chain GHG reduction efforts influenced by moral hazard and multiple objectives. First, double moral hazard reduces upstream manufacturer incentives to reduce GHG emissions (i.e., $e_M^{SD*} < e_M^{SS*}$ and $e_M^{MD*} < e_M^{MS*}$), regardless of whether the brand is focused on profit alone or on multiple objectives. Due to double moral hazard, the brand will take on a portion of the GHG emission reduction task (i.e., $e_R^{SD*} > 0$ and $e_R^{MD*} > 0$). However, the pressure to reduce GHG emissions is all concentrated on upstream manufacture in a single moral hazard situation. To some extent this will alleviate the pressure on manufacturers to reduce GHG emissions. Second, multi-goal is negative for supply chain GHG reduction when the brand focuses on more than profits (e.g., blue and yellow areas in Fig. 2). This is because in the presence of moral hazard in the supply chain, each member of the supply chain is unwilling to compromise for sustainability goal and consumer surplus. In addition, we find that the negative effect of the brand on multi-goal pursuit is limited under double moral hazard. In other words, the magnitude of the effect of multi-goal under single moral hazard is lower than in the case of double moral hazard (i.e., the blue area is larger than the yellow area in Fig. 2). Third, when the brand pays more attention to multi-goal (i.e., $\rho \geq \rho_1$), the brand will exert more efforts to reduce GHG emissions compared to the manufacturer (i.e., $e_R^{SD*} \geq e_M^{MD*}$). Only when the brand's focus on multiple goals was high (i.e., $\rho \geq \rho_2$), the manufacturer was more enthusiastic about reducing GHG emissions (i.e., $e_M^{SD*} < e_M^{MS*}$).

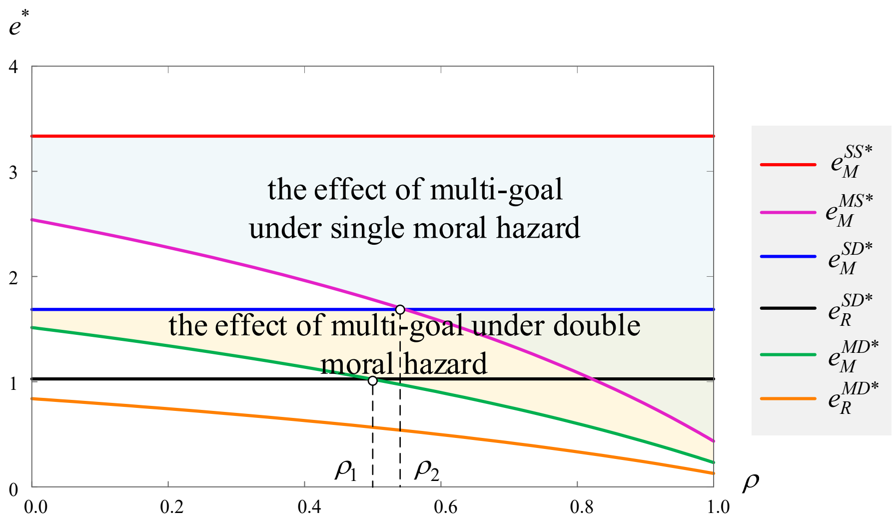

Fig. 2 GHG reduction efforts with respect to ρ.

Proposition 6 *The manufacturer's optimal wholesale price:*

(a) Double moral hazard reduces the optimal wholesale price in the single-goal scenario;

(b) If $\rho \geq \rho_3$, $w^{MD*} \geq w^{MS*}$; otherwise, $w^{MD*} < w^{MS*}$.

Proposition 6 characterizes the optimal wholesale price. Double marginalization of the supply chain is mitigated by double moral hazard when the brand focuses only on profits (e.g., the blue area in Fig. 3). The manufacturer has to distort the wholesale price downwards (i.e., $w^{SS*} > w^{SD*}$) in order to shift the GHG reduction burden and thus reduce the negative impact of brand's moral hazard. However, when the brand focuses on multiple goals, the positive effect of double moral hazard only works when the brand is less considerate of sustainability goal and consumer surplus (i.e., when ρ is smaller than ρ_3, the yellow area in Fig. 3). As the brand's focus on sustainability increases (i.e., $\rho \geq \rho_3$), the manufacturer is more willing to lower wholesale prices in a single moral hazard environment. This means that the more complex the environment of moral hazard, the lower the likelihood that the manufacturer will provide concessions. In general, the consideration of brand multi-goal alleviates the problem of double marginalization in a supply chain.

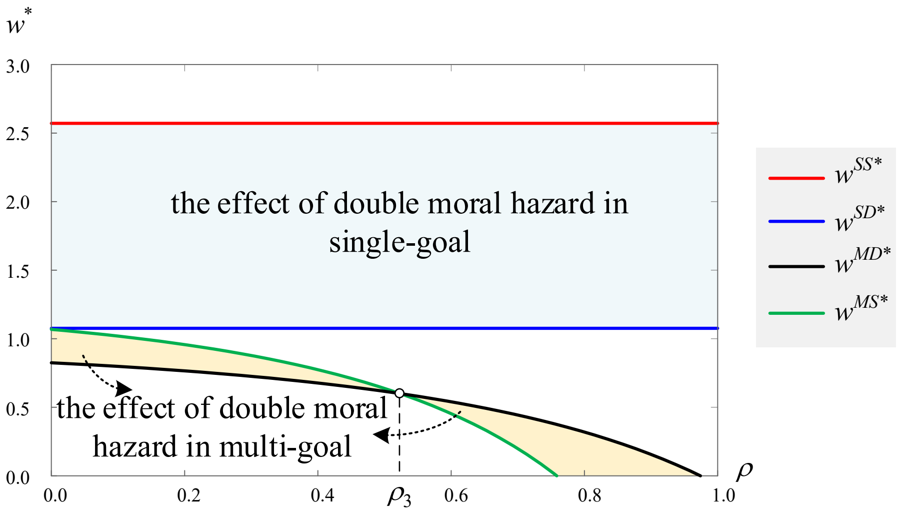

Fig. 3 Wholesale price with respect to ρ.

Proposition 7 *The brand's optimal price:*

(a) Double moral hazard increases the optimal price in the single-goal scenario;

(b) If $\rho \geq \rho_4$, $p^{SS*} \geq p^{MS*}$; otherwise, $p^{SS*} < p^{MS*}$; if $\rho \geq \rho_5$, $p^{SS*} \geq p^{MD*}$; otherwise, $p^{SS*} < p^{MD*}$.

The optimal pricing of the product is summarized in Proposition 7. Double moral hazard can cause the brand to increase the selling price of its products (i.e., $p^{SD*} \geq p^{SS*}$and $p^{MD*} \geq p^{MS*}$ in Fig. 4). The brand does not consider other objectives than profits in a complex moral hazard environment. This can harm consumers. Nevertheless, simple moral hazard environment can bring significant benefits to the brand when the brand is less concerned with multiple goals (i.e., $\rho < \rho_4$ in Fig. 4). As the multi-goal focus increases (i.e., $\rho \geq \rho_5$ in Fig. 4), the brand is willing to lower the price of the product for sustainability goal and consumer surplus regardless of the single moral hazard or double moral hazard scenarios. This suggests that the brand is prepared to make some compromises for the sake of the multi-goal.

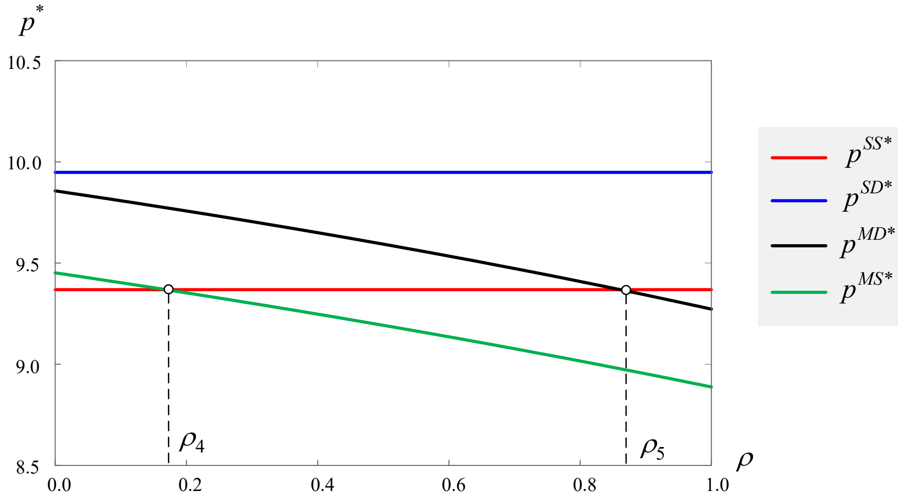

Fig. 4 Price with respect to $\boldsymbol{\rho}$.

Proposition 8 *The brand's optimal transfer payments of incentives:*

(a) Multi-goal pursuit reduces incentive costs in the single moral hazard scenario;

(b) If $\rho \geq \rho_6$, $\alpha^{SD*} \geq \alpha^{MD*}$; otherwise, $\alpha^{SD*} < \alpha^{MD*}$.

We describe the incentive intensity (burden of GHG reduction incentives) of the brand with the help of the variable transfer payments. Proposition 8 summarizes the interesting findings. We find that brand focusing on multiple goals can reduce incentive intensity for GHG reduction in a single moral hazard scenario. The green line is lower than the red line as in Fig. 5. Moreover, it is favorable for the brand to focus on sustainability and consumer surplus to alleviate the burden of GHG emission reduction incentives. That is, as the degree of brand attention to multiple goals increases, the lower the transfer payments of the brand will be. However, this conclusion does not always hold when the moral hazard environment of the supply chain becomes more complex (e.g., black and blue lines in Fig. 5). While supply chains face complex double moral hazard, the brand's burden of GHG reduction can only be reduced by focusing heavily on sustainability and consumer surplus objectives (i.e., when $\rho \geq \rho_6$, $\alpha^{SD*} \geq \alpha^{MD*}$ in Fig. 5). This implies that in a complex moral hazard environment of supply chain, a brand's focus on profit goal alone will increase incentive costs instead.

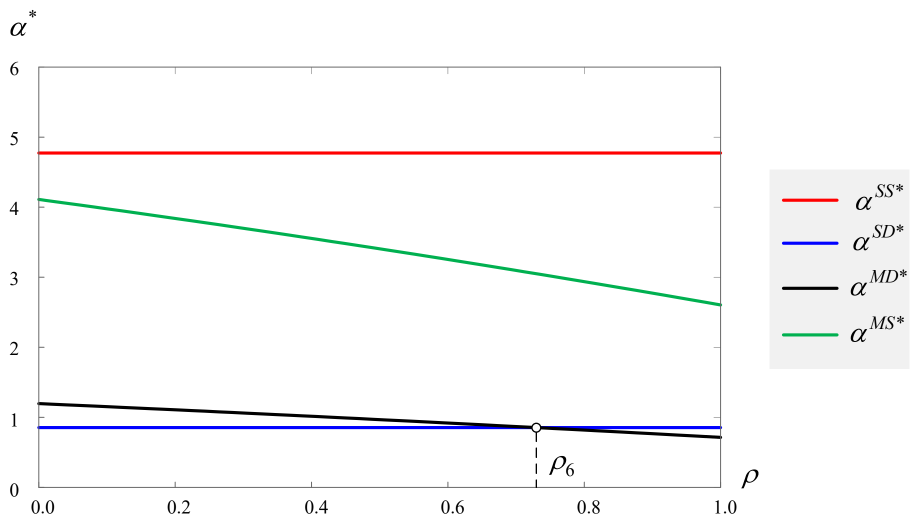

Fig. 5 Transfer payments of incentives with respect to *ρ*.

Proposition 9 *The brand's optimal profits:*

(a) *If* $\rho \geq \rho_7$, $\pi^{MD*} \geq \pi^{SD*}$ *; otherwise,* $\pi^{MD*} < \pi^{SD*}$*; if* $\rho \geq \rho_8$, $\pi^{MS*} \geq \pi^{SS*}$ *; otherwise,* $\pi^{MS*} < \pi^{SS*}$*;*

(b) *The effect of multi-goal on brand's profits improvement under double moral hazard is more significant.*

Proposition 9 concludes the profit characteristics of the brand under the influence of moral hazard and single (dual) objectives. When the supply chain faces a single moral hazard issue, this can be profitable for the brand as long as the brand focuses on maintaining high sustainability and consumer surplus goals (e.g., the yellow area in Fig. 6). In contrast, when supply chain faces a dual moral hazard issue, it can be profitable for the brand to consider sustainability and consumer surplus objectives even if they are not considered too much (e.g., the blue area in Figure 6). That is, complex moral hazard environment also brings higher gains for the brand (e.g., the green area in Fig. 6). It implies that the dual moral hazard faced by firms and the pursuit of sustainability and consumer surplus goals are not always negative. In addition, the effect of multi-goal on brand's profits improvement under double moral hazard is more significant.

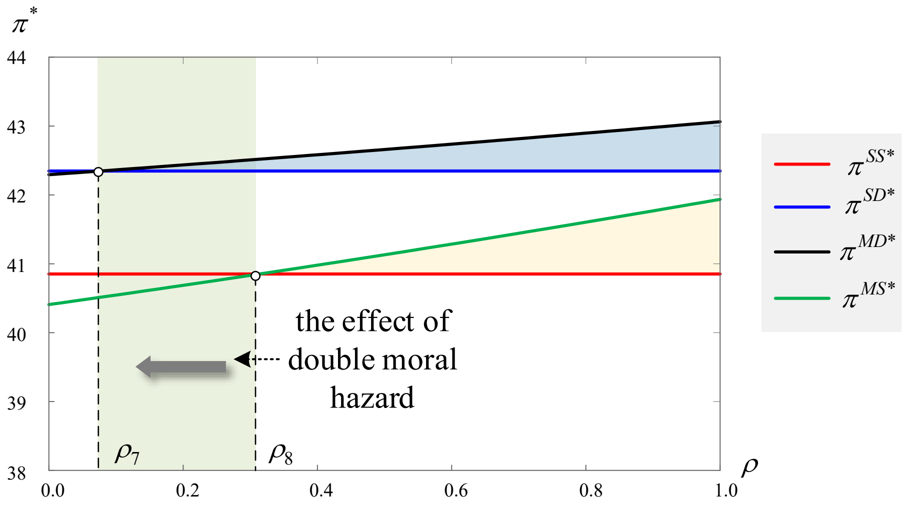

Fig. 6 Profits of the brand with respect to *ρ*.

7. Conclusions

This paper innovatively gathers on the topic of dual moral hazard in supply chain GHG reduction. At the same time, we explore the impact of a brand's multi-goal concerns on supply chain pricing and GHG abatement incentives. We emphasize on exploring the optimal supply chain GHG abatement solution under the mutual interaction of moral hazard and multi-goal.

The findings of our study are as follows. (1) Upstream manufacturer incentives for lowering GHG emissions are diminished by double moral hazard. When a brand focuses on more than just profits, it has a negative impact on supply chain GHG reduction. The brand's negative effect on multi-goal pursuit is limited due to double moral hazard. When a brand prioritizes multiple goals, it will make greater efforts to reduce GHG emissions than the manufacturer. (2) When a brand focuses on multiple goals, the positive effect of double moral hazard only occurs when the brand is less concerned with sustainability and consumer surplus. The manufacturer is less likely to make concessions in a more complex moral hazard environment. In general, the consideration of brand multi-goal alleviates the problem of double marginalization in a supply chain. (3) It is advantageous for the brand to focus on sustainability and consumer surplus in order to reduce the burden of GHG emission reduction incentives. While supply chains face complex double moral hazard, the brand’s burden of GHG reduction can only be reduced by focusing heavily on sustainability and consumer surplus objectives. In a complex moral hazard environment of supply chain, a brand’s focus on profit goal alone will increase incentive costs instead. (4) Firms face a dual moral hazard when pursuing sustainability and consumer surplus goals, which is not always negative. In addition, the effect of multi-goal on brand's profits improvement under double moral hazard is more significant.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Choi, T. M. (2013a). Optimal apparel supplier selection with forecast updates under carbon emission taxation scheme. *Computers & Operations Research*, *40*(11), 2646-2655.

Choi, T. M. (2013b). Local sourcing and fashion quick response system: The impacts of carbon footprint tax. *Transportation Research Part E: Logistics and Transportation Review*, *55*, 43-54.

Dai, T., & Jerath, K. (2013). Salesforce compensation with inventory considerations. *Management Science*, *59*(11), 2490-2501.

Dai, T., & Jerath, K. (2019). Salesforce contracting under uncertain demand and supply: Double moral hazard and optimality of smooth contracts. *Marketing Science*, *38*(5), 852-870.

Fan, X., Chen, K., & Chen, Y. J. (2023). Is price commitment a better solution to control carbon emissions and promote technology investment?. *Management Science*, *69*(1), 325-341.

Xu, S., Fang, L., & Govindan, K. (2022). Energy performance contracting in a supply chain with financially asymmetric manufacturers under carbon tax regulation for climate change mitigation. *Omega*, *106*, 102535.

Govindan, K., Shaw, M., & Majumdar, A. (2021). Social sustainability tensions in multi-tier supply chain: A systematic literature review towards conceptual framework development. *Journal of Cleaner Production*, *279*, 123075.

Meinlschmidt, J., Schleper, M. C., & Foerstl, K. (2018). Tackling the sustainability iceberg: a transaction cost economics approach to lower tier sustainability management. *International Journal of Operations & Production Management*, *38*(10), 1888-1914.

Gurkan, H., & de Véricourt, F. (2022). Contracting, pricing, and data collection under the AI flywheel effect. *Management Science*, *68*(12), 8791-8808.

Kräkel, M., & Schöttner, A. (2016). Optimal sales force compensation. *Journal of Economic Behavior & Organization*, *126*, 179-195.

Schöttner, A. (2017). Optimal sales force compensation in dynamic settings: Commissions vs. bonuses. *Management Science*, *63*(5), 1529-1544.

Cai, Y. J., Choi, T. M., & Zhang, J. (2021). Platform supported supply chain operations in the blockchain era: Supply contracting and moral hazards. *Decision Sciences*, *52*(4), 866-892.

Choi, T. M., Feng, L., & Li, Y. (2023). Ethical fashion supply chain operations: product development and moral hazards. *International Journal of Production Research*, *61*(4), 1058-1075.

Filipas, I., Marmier, F., & Picard, N. (2024). A framework for analysing sustainability trade-offs. Focus At Company Level. working paper.

Wang, N., & Li, Z. (2021). Supplier encroachment with a dual-purpose retailer. *Production and Operations Management*, *30*(8), 2672-2688.

Jabarzare, N., & Rasti-Barzoki, M. (2020). A game theoretic approach for pricing and determining quality level through coordination contracts in a dual-channel supply chain including manufacturer and packaging company. *International Journal of Production Economics*, *221*, 107480.

Mamoudan, M. M., Mohammadnazari, Z., Ostadi, A., & Esfahbodi, A. (2024). Food products pricing theory with application of machine learning and game theory approach. *International Journal of Production Research*, *62*(15), 5489-5509.

Nagurney, A. (2021). Supply chain game theory network modeling under labor constraints: Applications to the Covid-19 pandemic. *European journal of operational research*, *293*(3), 880-891.

Zha, X., Zhang, X., Liu, Y., & Dan, B. (2022). Bonded-warehouse or direct-mail? Logistics mode choice in a cross-border e-commerce supply chain with platform information sharing. *Electronic Commerce Research and Applications*, *54*, 101181.

Zhao, Y., Chen, J., Shi, P., & Hou, R. (2022). The value of information acquisition and sharing on an online intermediary platform. *Electronic Commerce Research*, 1-27.

Zhang, X., Liu, Y., Dan, B., Zha, X., & Sui, R. (2023). Selling mode choice and information sharing in an online tourism supply chain under channel competition. *Electronic Commerce Research*, 1-28.

Oyedijo, A., Kusi-Sarpong, S., Mubarik, M. S., Khan, S. A., & Utulu, K. (2024). Multi-tier sustainable supply chain management: a case study of a global food retailer. *Supply Chain*

Management: An International Journal, *29*(1), 68-97.

Ngo, V. M., Quang, H. T., Hoang, T. G., & Binh, A. D. T. (2024). Sustainability-related supply chain risks and supply chain performances: The moderating effects of dynamic supply chain management practices. *Business Strategy and the Environment*, *33*(2), 839-857.

Park, S. J., Cachon, G. P., Lai, G., & Seshadri, S. (2015). Supply chain design and carbon penalty: Monopoly vs. monopolistic competition. *Production and Operations Management*, *24*(9), 1494-1508.

Nguyen-Van, P., Stenger, A., & Tiet, T. (2021). Social incentive factors in interventions promoting sustainable behaviors: A meta-analysis. *Plos one*, *16*(12), e0260932.

Cantele, S., Russo, I., Kirchoff, J. F., & Valcozzena, S. (2023). Supply chain agility and sustainability performance: A configurational approach to sustainable supply chain management practices. *Journal of Cleaner Production*, *414*, 137493.