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RESEARCH ARTICLE

Optimal online channel configuration for a Manufacturer under price and lead time-sensitive demand

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Abstract

The purpose of this paper is to model and compare the performance of online dual-channel supply chain configurations comprising of a Manufacturer and an E-tailer and to identify the optimal configuration under the assumption that demand is both price and lead time sensitive. The study considers two distinct online dual-channel formats, viz. (i) E-tailer–direct online channel (DOC) of the Manufacturer and (ii) E-tailer and an Agency Channel (e-marketplace) of the Manufacturer. The competition between the channels has been modelled with the help of game theory and optimal decisions of the channel members were derived from equilibrium analysis. Further, a numerical analysis was carried out to quantify the optimal decisions and to derive the managerial insights. The study finds that E-tailer–DOC configuration is beneficial for the Manufacturers compared to E-tailer–Agency Channel configuration in the case of products for which customers' price sensitivity is higher than the lead time sensitivity. However, the Manufacturer is gainful by choosing E-tailer–Agency Channel configuration over E-tailer–DOC configuration in the case of products having higher lead time sensitivity.

Keywords Online retailing · Game theory · Dual-channel supply chain · Direct online channel · Agency Channel · The E-tailer

Introduction

The commendable growth and acceptance of Internet during the first decade of twenty-first century enabled suppliers and Manufacturers to reach out to customers and markets by selling their products through e-commerce. E-commerce is likely to grow at a Compounded Annual Growth Rate (CAGR) of 25% between 2020 and 2025 motivating more Manufacturers to join the bandwagon (Chawla and Kumar 2022; Barman et al. 2023; Ghosh et al. 2023). Owing to the tremendous potential of e-commerce, numerous Manufacturers and retailers have established online sales channels, in addition to their existing physical sales channels, leading to a dual-channel supply chain (DCSC) structure. Leading global Manufacturers belonging to different industries, such as Fashion and Apparel (e.g. Nike and Adidas), Consumer Electronics (e.g. Apple and Dell) and Toys (e.g. Mattel), have shifted to DCSC structure in response to the e-commerce boom. The emergence of DCSC structure has disrupted the retail industry leading to innovative business models (Li and Mizuno 2022). The DCSC structure and associated business models have posed several questions to the researchers related to pricing (Zhou et al. 2020; Du et al. 2023), service (Dan et al. 2018), lead time (Modak and Kelle 2019), advertising (Kar et al. 2023; Li et al. 2023; Pal et al. 2023), omni channel retailing (Jiang et al. 2020), coordination (Chen et al. 2023), consumer behaviour such as showrooming (Li et al. 2019) and webrooming (Sun et al. 2022a). Further, there are papers addressing the problem of channel configuration selection by considering multiple channel configurations and power structures and comparing the performance among them (He et al. 2019, 2023; Xiao et al. 2023). The recent literature on DCSC focuses on the issues such as trade credit coordination policy (Li et al. 2022), big-data-driven credit payment services (Wu et al. 2022) and free riding behaviour (Tian et al. 2022).

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The extant literature treats DCSC as a combination of traditional and online channel. However, this study challenges the current DCSC structure and proposes to model DCSC as a combination of online sales channels alone due to several reasons. For instance, it can be observed that the customer acceptance of online channels has been increasing at a commendable rate driving the global online retail sales prior to the pandemic itself (Abhishek et al. 2016). There has been a paradigm shift in the customer preference for online channels owing to the pandemic. The different measures to contain the spread of the pandemic such as lock down, social distancing and work from home boosted the online sales compelling the Manufacturers and retailers to reach out to the market through online channels disrupting the sales channel portfolios (Sawik 2022). Therefore, the revised projection is in the magnitude of 8.1 trillion dollars by 2026 (Statista 2022). In this context, the following question is highly relevant for Manufacturers and retailers: Can the Manufacturers completely rely on online sales channels for market access?

The answer to this question depends on the factors such as level of Internet penetration, logistics infrastructure, and the product category in question. But it can be seen that the smartphone adoption and Internet infrastructure development are driving Internet penetration (Dhiman et al. 2020; Baishya and Samalia 2020; Tolstoy et al. 2022). In developing countries like India, the Internet user population is forecasted to touch 666.4 million by 2023 (Billewar et al. 2021). This will have a significant impact on reinforcing the online buying behaviour of customers. Therefore, the answer to the question on whether the Manufacturers can rely on online channels is Yes and it is leading to a further issues as follows.

If the Manufacturer is relying on online channels alone, the question arises on the type of online channel to be configured by the Manufacturer. Under direct online channel (DOC) format, the Manufacturer reaches out to the customers through the firm's own website. Under Agency Channel format, the Manufacturer is engaged with an Agency Channel or e-marketplace primarily based on a commission contract (Chang et al. 2018; Ha et al. 2022). Under online retailer format, the Manufacturer sells the product first to the E-tailer who further resells the product to the customers (Ha et al. 2022). The different online channel formats have advantages and disadvantages (Ali et al. 2022). For instance, the Manufacturer's website acts as a DOC and is an exclusive platform for the Manufacturers to brand and sell their products with complete control over pricing and delivery lead time (Zhao and Niu 2022). On the other hand, a DOC has limited visibility compared to an Agency Channel like Amazon.com or Flipkart.com. If the Manufacturer lists the products in an Agency Channel, the margin will be reduced since the commission has to be provided to the Agency Channel (Tian et al. 2022). Moreover, the Manufacturer has to comply with the promotional offers launched by the Agency Channels, such as Big Billion Day by Flipkart or Great Indian Festival by Amazon. To a great extent, the participation of the Manufacturer in such promotional offers depends on the interplay of channel power between the Manufacturer and the Agency Channel. Nevertheless, such events can impact the dilution of brand equity for some Manufacturers. If the Manufacturer sells the product through an indirect channel such as an E-tailer, then there is no need to bother about the downstream supply chain activities related to the delivery of the product to the customers. However, the Manufacturer loses control over the product and pricing decisions while selling through an indirect channel (Matsui 2022). Further, the final price of the product while selling through an indirect channel (E-tailer) will be higher owing to double marginalization, i.e. both the Manufacturer and the E-tailer take a margin. This may lead to a lower market share for the Manufacturer if the competing Manufacturers are selling through direct channels.

Irrespective of whether the online platform is a DOC, Agency Channel, or E-tailer, technological solutions and the immersive experience promised by Web 3.0 solutions are bringing online shopping closer to traditional shopping. Immersive commerce of 3D e-commerce employs state-of-the art technologies such as Augmented Reality (AR) and Virtual Reality (VR) help e-commerce platforms to offer a superior experience to the customers (Yim et al. 2017; Kowalczuk et al. 2021). The AR and VR technologies will help the customers to make the product evaluation easier by mitigating the uncertainty emerging from not being able to physically examine the product. Immersive commerce is highly relevant for experiential products such as apparel, shoes and so on where customers face fit uncertainty while purchasing from online channels (Manchanda and Deb 2021; Hewei and Youngsook 2022). With further advancements in techniques such as machine learning and artificial intelligence, online sales platforms can completely substitute traditional stores, motivating more and more Manufacturers to consider an online-only supply chain structure for larger market reach (Song et al. 2019; Chatterjee et al. 2021).

Thus, different online channel formats have their unique pros and cons and all the online channel formats are improving in providing a real-world shopping experience making it important for the Manufacturer to address the following research questions.

- What should be the format of online sales channels that the Manufacturers should consider? Should it be the Manufacturers' DOC, an Agency Channel (e-marketplace) such as Amazon.com, or should it be an independent online retailer (E-tailer)?

- What is the optimal combination of online channels that the Manufacturer should employ to maximize the profit?

The extant literature does not address the questions raised and therefore this paper seeks answers to the above-mentioned questions by considering the combination of three online channel formats, viz. (i) Manufacturer's DOC, (ii) Agency Channel and (iii) E-tailer. Among these three formats, the Manufacturer's DOC and Agency Channels are direct channels since the product's price is determined by the Manufacturer. In contrast, the E-tailer is an indirect channel since the Manufacturer sells the product first to the E-tailer for further reselling in the market. The study considers the combination of a direct online channel and an indirect online channel. Thus, the following DCSC structures are covered in this study: (i) E-tailer–DOC DCSC structure and (ii) E-tailer–Agency Channel DCSC structure. Reputed smartphone brands such as Samsung, One Plus and Apple have a channel configuration of E-tailer and DOC. It can be observed that the PC Manufacturers like Dell and HP also follow the same strategy for their channel configuration. Baby brands such as Baby Hug and Fisher Price sell through First Cry, an E-tailer and Amazon, an Agency Channel. Similarly, the FMCG brand Nestle sells through Netmeds, an E-tailer and Flipkart, an Agency Channel. These are excellent examples of the E-tailer–Agency Channel DCSC structure. Under both the structures, Manufacturer acts simultaneously as a supplier and competitor to the indirect channel member, i.e. E-tailer. With this background, the objectives of this study are as follows:

I. To model the competition between Manufacturer and E-tailer under (i) E-tailer–DOC DCSC structure and (ii) E-tailer–Agency Channel DCSC structure and to derive the optimal decisions and profit of the supply chain members.
II. To quantify the optimal price and profit of the supply chain members and to obtain managerial insights.
III. To carry out the sensitivity analysis based on the parameters that influence the optimal price and profit of the supply chain members.

To address the above-mentioned research objectives and to model the competition between the online channels in the proposed DCSC configurations, we resort to game-theoretic models. Game theory is the most appropriate tool for modelling competition and to derive insights under interactive decision-making framework (Fudenberg and Tirole 1991; Osborne 2004; Tadelis 2013). In this study, a sequential (Stackelberg) game has been modelled to capture the interaction between the Manufacturer and the E-tailer (Rofin and Mahanty 2020; Barman et al. 2023; Mandal and Pal. 2023). In a sequential (Stackelberg) game, one player moves first (leader) in taking a decision and the other player (follower) follows and takes the decision after observing the decision of the leader (Li and Sethi 2017; Zhao et al. 2023; Xiao et al. 2023).

This work contributes to the body of knowledge in the following ways: (i) This study is the first of its kind to capture the competition between different modes of online channels. (ii) The study contributes to the literature by simultaneously considering the impact of lead time and price on the demand and further on the nature of competition between online channels. (iii) The study prescribes the optimal dual-channel structure for the Manufacturers selling through online channels and acts as a decision-support mechanism for Manufacturers. Therefore, this study sets a different direction for researchers and academics to explore the optimal channel configuration when the channels are online. In this way, the implications of the study are futuristic.

The remaining content of this study is sequenced as follows. "Related literature" section reviews the literature, and "Model description" section provides the model description. The equilibrium analysis and numerical analysis are presented in "Equilibrium analysis" and "Numerical analysis" sections, respectively. "Sensitivity analysis" section deals with sensitivity analysis. Conclusion, managerial implications, and future research directions are given in "Discussion" section.

Related literature

The literature related to this study is primarily concerned with channel structure under a DCSC framework. The pioneering study in DCSC with DOC has been done by Chiang et al. (2003). After their work on DOC, numerous studies have been reported covering various aspects such as pricing, lead time, service, coordination, and sustainability. The current focus of DCSC literature is on supply or demand uncertainty, dynamic pricing, low-carbon operations, and channel structure. For instance, Ghosh et al. (2020) modelled a DCSC under and found that a buyback contract is an effective solution for coordinating the decentralized DCSC under emission-sensitive stochastic demand and government intervention. Asl-Najafi et al. (2021) examined the issue of yield uncertainty faced by the original equipment Manufacturer (OEM), leading to difficulty in product allocation between traditional and online channels. They proposed the mechanism of targeted capacity allocation as a solution for effective product allocation. Zhu et al. (2020) modelled the uncertainties in demand and yield using the CVaR criterion and identified that a combination of revenue sharing and buyback contract could coordinate the DCSC. Qiu et al. (2021) examined the DCSC under batch ordering and drop shipping fulfilment of E-tailer when the demand is uncertain. They adopted a distribution-free approach for modelling demand uncertainty and identifying the desirable fulfilment policy for the channel members based on the market share. Pei et al. (2022) extended the degree of demand uncertainty by considering uncertainty in demand distribution under the assumption that the OEM has capital constraints. They suggested three financing strategies and established the interdependence between the effectiveness of financing strategies and uncertainty parameters.

Pricing strategies have been and continue to remain a focus area in the DCSC literature. Matsui (2020) focused on the wholesale pricing strategy of the OEM under a DCSC structure and identified the optimal timing for the OEM to bargain the wholesale price. The result of the study suggests that the Manufacturer should set the wholesale price for the retailer before determining the price in the DOC. Kittaka et al. (2022) investigated the impact of the price matching strategy of a retailer under a DCSC comprising a supplier selling the physical products through a retailer and electronic products through an E-tailer. They found that the price matching strategy would benefit the retailer only if the bargaining power of the E-tailer is significantly less. Zhang et al. (2021a, b) derived the optimal pricing strategy of channel members belonging to a DCSC by assuming that the Manufacturer produces high-quality and low-quality products. Wang and He (2022) compared two DCSCs. In the first DCSC, the Manufacturer sells the standard product through the retailer and customized product through the DOC, while in the second DCSC, the product is sold through the online channel of the retailer. Considering the Manufacturer's return policy, they established conditions under which the Manufacturer should consider DOC. In DCSC, the showrooming approach influences pricing and service (Li et al. 2019), and customers' changing shopping behaviour has led Manufacturers to adopt both online and offline channels in the supply chain (Ranjan and Jha 2019).

Recently, there has been an increase in interest among scholars in exploring dynamic pricing strategies. For example, Zhang and Wang (2018) examined the system stability of a DCSC under a dynamic pricing strategy and established the association between the bullwhip effect and price adjustment parameters. Jia et al. (2019) addressed the problem of frequent product introductions of the Manufacturer and associated challenges of pricing by the logistic service providers when the Manufacturer sells through a DOC. The dynamic pricing strategies for multi-generation products and the competition between generations have been examined with the help of numerical examples. Li et al. (2021) employed a differential game to model the dynamic pricing under a DCSC under which the Manufacturer offers coupons in the DOC, and the retailer offers coupons in the traditional store. Li and Mizuno (2022) derived the optimal dynamic pricing and inventory strategies under distinct channel power structures when the demand is stochastic. Apart from focus areas such as pricing, inventory, and demand uncertainty, recent DCSC literature comprises issues such as sustainability (Zhang et al. 2021a, b; Pathak et al. 2022), service effort (Liu et al. 2022), delivery time (Xu and Wang 2021) and coupon promotion (Li et al. 2020).

A significant focus area of DCSC literature is the channel structure or channel structure. Shao (2021) initially considered a DCSC where one of the competing downstream retailers sells through an online channel and the other sells through an offline channel. This basic channel structure has been extended by considering omnichannel options for both the retailers and its impact on the supply chain performance has been assessed. They found that the strategy where both retailers operate under an omnichannel structure is undesirable for the Manufacturer. Wang et al. (2022) compared three channel DCSC structures where the Agency Channel is a common factor across the DCSCs. They establish the optimal structure based on the commission rate charged by the Agency Channel. Zhang and Wu (2022) compared four DCSC channel structures comprising competing Manufacturers and an E-tailer. Channel structures are formed based on whether the Manufacturer sells directly to the customers or through the E-tailer. They related the channel structure's performance to the channel members' contractual agreements. Thus, it can be observed that the DCSC literature is evolving based on the emerging business models and technological advancements.

A summary of the recent literature is presented in Table 1, showing the research gap in the DCSC literature and the contribution of this study in bringing down the gap.

From Table 1, it was identified that there is an evident gap in channel structure decisions when the upstream Manufacturer sells only through online sales channels. Further, no study has considered different types of online channels.

Model description

In this section, we describe the models. As shown in Figs. 1 and 2, we have considered two models (i) E-tailer–DOC DCSC structure and (ii) E-tailer–Agency Channel DCSC structure.

Assumptions of the model

Assumption 1 Linear demand function (Zhang et al. 2021a, b; Wang and He 2022).

Table 1 Recent dual-channel supply chains studies

Author (year)	Channel structure		Type of online channel	Price	Service/ lead time	Methodology
	Direct channel	Indirect channel				
Li et al. (2019)	Online	Offline	DOC	✓	✓	Stackelberg game
Ranjan and Jha (2019)	Online	Offline	DOC	✓		Stackelberg game
Modak and Kelle (2019)	Online	Offline	DOC	✓		Stackelberg game
Heydari et al. (2019)	Online	Offline	DOC	✓		Stackelberg game
Pi et al. (2019)	Online	Offline	DOC	✓		Stackelberg game and Nash game
Barman et al. (2021)	Online	Offline	DOC	✓		Stackelberg game
Yang et al. (2021)	Online	Offline	DOC	✓		Stackelberg game
Yang et al. (2022a, b)	Online	Offline	DOC	✓		Stackelberg game
Xin et al. (2022)	Online	Offline	DOC	✓		Stackelberg game
Sun et al. (2022b)	Online	Offline	DOC	✓		Data-driven approach
Zhu and Lu (2022)	Online	Offline	DOC	✓		Stackelberg game
This study	Online	Online	DOC, Agency Channel, E-tailer	✓		Stackelberg game

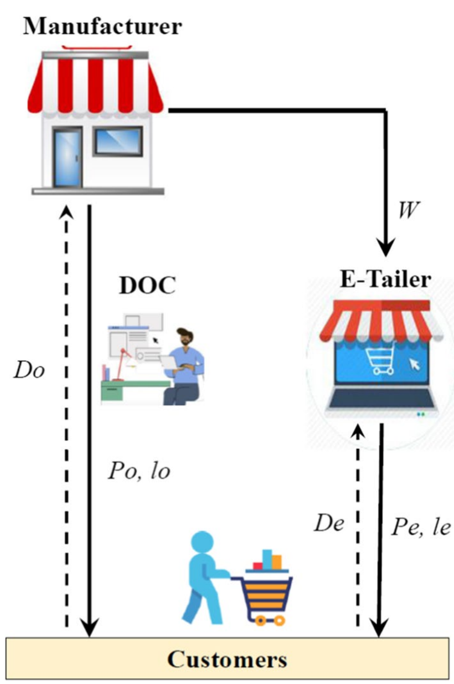

Fig. 1 E-tailer–DOC DCSC

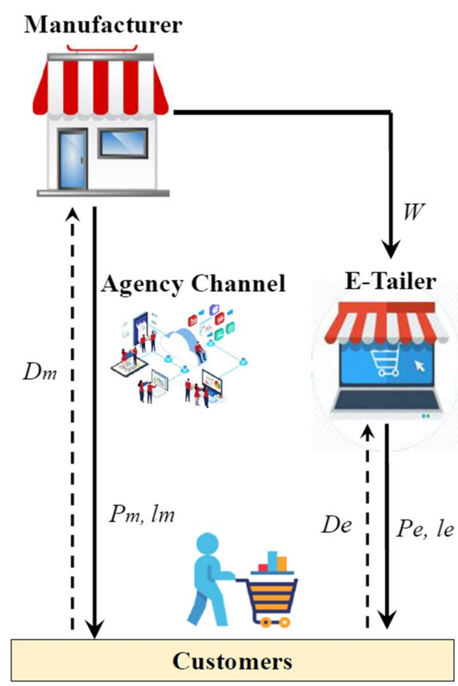

Fig. 2 E-tailer–Agency Channel DCSC

Demand for DOC under EW DCSC

$$D_{\mathrm{o}}^{\mathrm{EW}} = a(1-\gamma) - bp_{\mathrm{o}}^{\mathrm{EW}} + cp_{\mathrm{e}}^{\mathrm{EW}} - dl_{\mathrm{o}} + el_{\mathrm{e}}. \tag{1}$$

Demand for E-tailer under EW DCSC

$$D_{\mathrm{e}}^{\mathrm{EW}} = a\gamma - bp_{\mathrm{e}}^{\mathrm{EW}} + cp_{\mathrm{o}}^{\mathrm{EW}} - dl_{\mathrm{e}} + el_{\mathrm{o}}. \tag{2}$$

Demand for Agency Channel under EM DCSC

$$D_{\mathrm{m}}^{\mathrm{EM}} = a(1-\gamma) - bp_{\mathrm{m}}^{\mathrm{EM}} + cp_{\mathrm{e}}^{\mathrm{EM}} - dl_{\mathrm{m}} + el_{\mathrm{e}}. \tag{3}$$

Demand for E-tailer under EM DCSC

$$D_{e}^{EM} = a\gamma - bp_{e}^{EM} + cp_{m}^{EM} - dl_{e} + el_{m}. \tag{4}$$

In the demand functions, $D_o, D_e,$ and D_m represent the demands for DOC, E-tailer, and Agency Channel, respectively. Similarly, $p_o, p_e,$ and p_m indicate the price charged by the Manufacturer in the DOC, the E-tailer, and the Manufacturer in the Agency Channel, respectively. In the demand function, a indicates the base demand and γ represents the customer preference towards the E-tailer. Customer preference towards the E-tailer is a function of several factors such as E-tailer's reputation, the product range available with the E-tailer, the delivery reliability of the E-tailer, payment security offered by the E-tailer and other factors offered by the E-tailer. Since γ is multiplied directly with the base demand, a, we can say that the value of γ determines the effective base demand. Parameter b is the own-price sensitivity, i.e. the effect of the firm's own price on its demand and the parameter c is the cross-price sensitivity, i.e. the effect of the competitor's price on its demand. $l_o, l_e,$ and l_m represent the lead time while selling through the DOC, the E-tailer, and the Agency Channel, respectively. Similar to the price parameters, parameter d is the own-lead time sensitivity, i.e. the effect of the firm's delivery lead time on its demand and the parameter e is the cross-lead time sensitivity, i.e. the effect of the competitor's delivery lead time on its demand. It is generally assumed that own-price elasticity (b) is greater than cross-price elasticity (c) (Kittaka et al. 2022; Ghosh et al. 2020). Similarly, it is logical to assume that own-lead time elasticity (d) is higher than cross-lead time elasticity(e).

Assumption 2 The interaction between Manufacturer and downstream E-tailer follows the Stackelberg game with the Manufacturer having channel leadership and E-tailer being follower (Matsui 2020; Shao 2021; Ghasemi et al. 2022).

Assumption 3 It is assumed that sales volume is same as order quantity. In other words, whatever is ordered by the E-tailer from the Manufacturer is sold. We have not considered the lost sales and back ordering (Rofin and Mahanty 2017).

Assumption 4 There is no information asymmetry (Ghasemi et al. 2021). Manufacturer knows the demand of the downstream channel members and customers know the prices charged in the channels.

Equilibrium analysis

First, the equilibrium analysis of E-tailer–DOC DCSC is presented followed by the equilibrium analysis of E-tailer–Agency Channel DCSC.

Equilibrium analysis of E-tailer–DOC DCSC

We start with the demand functions for the channels.

Demand for DOC and E-tailer is follows

$$D_{o}^{EW} = a(1-\gamma) - bp_{o}^{EW} + cp_{e}^{EW} - dl_{o} + el_{e}, \tag{5}$$

$$D_{e}^{EW} = a\gamma - bp_{e}^{EW} + cp_{o}^{EW} - dl_{e} + el_{o}. \tag{6}$$

We apply backward induction to solve the sequential game. The decision-making sequence of the channel members is shown (Fig. 3).

Figure 3 can be explained as follows.

Step 1: The Manufacturer takes the decision on the wholesale price at which the product should be sold to the E-tailer and the price at which the product should be sold in DOC.

Step 2: The E-tailer chooses its price after observing the wholesale price at which the Manufacturer provides the product for the E-tailer.

Step 3: Sales is realized in the market, and revenue is generated for the firms.

When we apply backward induction to solve the game, we begin from the end. That is, we derive the decisions in the reverse order. By that logic, we first derive the E-tailer's price, and then we derive the wholesale price at which the

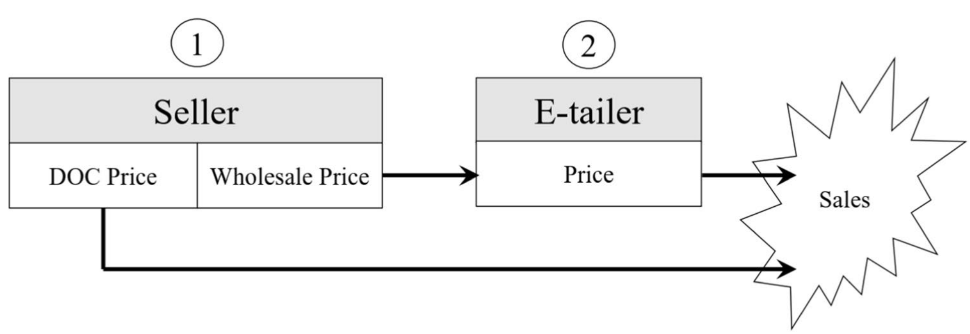

Fig. 3 Decision sequence of E-tailer–DOC DCSC

Manufacturer sells the product to the E-tailer and the price at which the Manufacturer sells the product in the DOC.

Profit of the E-tailer is as follows

$$\pi_{\mathrm{e}}^{\mathrm{EW}} = \left(p_{\mathrm{e}}^{\mathrm{EW}} - w^{\mathrm{EW}}\right)D_{\mathrm{e}}^{\mathrm{EW}} = \left(p_{\mathrm{e}}^{\mathrm{EW}} - w^{\mathrm{EW}}\right) \times \left(a\gamma - bp_{\mathrm{e}}^{\mathrm{EW}} + cp_{\mathrm{o}}^{\mathrm{EW}} - dl_{\mathrm{e}} + el_{\mathrm{o}}\right). \tag{7}$$

The rational E-tailer chooses the price in such a way as to maximize his/her profit. Mathematically,

$$p_{\mathrm{e}}^{\mathrm{EW}*} \in \underset{p_{\mathrm{e}}^{\mathrm{EW}}}{\operatorname{argmax}} \pi_{\mathrm{e}}^{\mathrm{EW}}\left(p_{\mathrm{r}}^{\mathrm{RE}} \middle| w^{\mathrm{RE}}\right).$$

The expressions for optimal price of the E-tailer is obtained by solving the first-order differential equation of $\pi_{\mathrm{e}}^{\mathrm{EW}}$ [i.e. Eq. (7)] with respect to $p_{\mathrm{e}}^{\mathrm{EW}}$. We prove the concavity of the E-tailer's profit function ($\pi_{\mathrm{e}}^{\mathrm{EW}}$) in $p_{\mathrm{e}}^{\mathrm{EW}}$ as shown in "Appendix A.1". The following proposition shows the optimal price of E-tailer.

Proposition 1 *The optimal price for the E-tailer under E-tailer–DOC DCSC structure is as follows*

$$p_{\mathrm{e}}^{\mathrm{EW}} = \frac{a\gamma + bw^{\mathrm{EW}} - dl_{\mathrm{e}} + el_{o} + cp_{\mathrm{o}}^{\mathrm{EW}}}{2b}. \tag{8}$$

From the optimal price of the E-tailer, we can determine the optimal order quantity for the E-tailer by substituting Eq. (8) into Eq. (6). This is under the assumption that the E-tailer orders the optimal order quantity with the Manufacturer. The optimal order quantity thus obtained is presented in the following corollary.

Corollary 1 *The optimal order quantity of the E-tailer under E-tailer–DOC DCSC structure is as follows*

$$Q_{\mathrm{e}}^{\mathrm{EW}^*} = \frac{1}{2}\left(a\gamma - bw^{\mathrm{EW}} - dl_{\mathrm{e}} + el_{\mathrm{o}} + cp_{\mathrm{o}}^{\mathrm{EW}}\right). \tag{9}$$

The Manufacturer, being the Stackelberg leader, can obtain the information of E-tailer and thus anticipates the optimal decisions of E-tailer. The Manufacturer maximizes its profit by considering the optimal decisions of E-tailer. The Manufacturer derives profit from two sources: (i) The margin obtained from the product sold to the E-tailer. (ii) The margin obtained from selling through the DOC. Thus, the profit of the Manufacturer can be formulated as follows.

$$\pi_{\mathrm{s}}^{\mathrm{EW}} = \left(w^{\mathrm{EW}} - s\right)Q_{\mathrm{e}}^{\mathrm{EW}} + \left(p_{\mathrm{o}}^{\mathrm{EW}} - s\right)Q_{\mathrm{o}}^{\mathrm{EW}}. \tag{10}$$

The rational Manufacturer will choose wholesale price and price to be charged in DOC so as to maximize his/her profit. Mathematically,

$$w^{\mathrm{EW}*} \in \underset{w^{\mathrm{EW}}}{\operatorname{argmax}} \pi_{\mathrm{s}}^{\mathrm{EW}}\left(w^{\mathrm{EW}}, p_{\mathrm{o}}^{\mathrm{EW}*}\right),$$

$$p_{\mathrm{o}}^{\mathrm{EW}*} \in \underset{p_{\mathrm{o}}^{\mathrm{EW}}}{\operatorname{argmax}} \pi_{\mathrm{s}}^{\mathrm{EW}}\left(p_{\mathrm{o}}^{\mathrm{EW}}, w^{\mathrm{EW}*}\right).$$

The concavity of the profit function of the Manufacturer is established as shown in "Appendix A.3". The expressions for optimal wholesale price and price in the DOC can be derived from the first-order conditions of $\pi_{\mathrm{s}}^{\mathrm{EW}}$ [i.e. Eq. (10)] with respect to w^{EW} and $p_{\mathrm{o}}^{\mathrm{EW}}$. The following proposition shows the optimal decisions of the Manufacturer.

Proposition 2 *Under E-tailer–DOC DCSC structure, the optimal wholesale price and the optimal price in the DOC are*:

$$w^{\mathrm{EW}^*} = \frac{ac + s(b^2 - c^2) + a\gamma(b - c) + l_{\mathrm{e}}(ce - bd) + l_{\mathrm{o}}(be - cd)}{2\left(b^2 - c^2\right)}, \tag{11}$$

$$p_{\mathrm{o}}^{\mathrm{EW}^*} = \frac{ab + s(b^2 - c^2) + a\gamma(c - b) + l_{\mathrm{e}}(be - cd) + l_{\mathrm{o}}(ce - bd)}{2\left(b^2 - c^2\right)}. \tag{12}$$

Substituting w^{EW^*} and $p_{\mathrm{o}}^{\mathrm{EW}^*}$ into the Eq. (5) will yield the Manufacturer's decision on optimal sales quantity to be allotted to the DOC as shown in the following corollary.

Corollary 2 *Under E-tailer–DOC DCSC structure, the optimal sales quantity to be allotted to the DOC by the Manufacturer is as follows*;

$$Q_{\mathrm{o}}^{\mathrm{EW}^*} = \frac{2ab + bs(c - 2b) + c^2 s + a\gamma(c - 2b) + l_{\mathrm{e}}(2be - cd) + l_{\mathrm{o}}(ce - 2bd)}{4b}. \tag{13}$$

Substituting the optimal decisions into Eqs. (7) and (10) will yield the optimal profit functions of the Manufacturer and the E-tailer as shown in the following corollary.

Corollary 3 *Under E-tailer–DOC DCSC structure, the optimal profit of the E-tailer and Manufacturer is as follows*:

$$\pi_{\mathrm{e}}^{\mathrm{EW}^*} = \frac{\left(s(c - b) + a\gamma - dl_{\mathrm{e}} + el_{\mathrm{o}}\right)^2}{16b}, \tag{14}$$

$$\pi_{\mathrm{s}}^{\mathrm{EW}^*} = \frac{1}{8}\left(\frac{b\left(bs - cs - a\gamma + dl_{\mathrm{e}} - el_{\mathrm{o}}\right)\Upsilon_1 + \Delta_1 + \Delta_2}{b(b^2 - c^2)}\right). \tag{15}$$

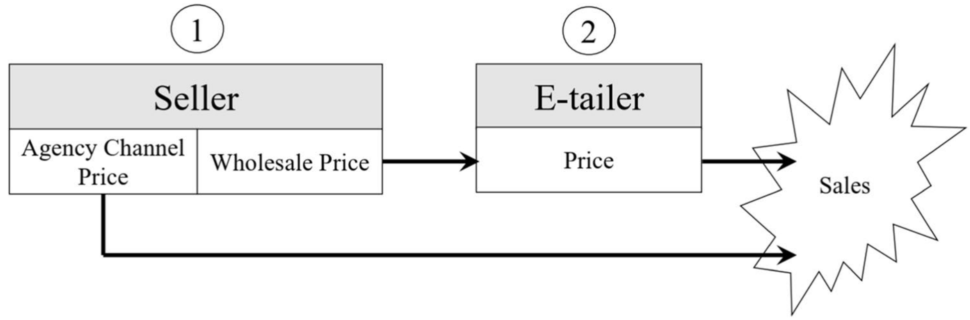

Fig. 4 Decision sequence of E-tailer–Agency Channel DCSC

Equilibrium analysis of E-tailer–Agency Channel DCSC structure

In this section, we present the equilibrium analysis of E-tailer–Agency Channel DCSC structure.

Demand for Agency Channel and E-tailer is as follows:

$$D_{\mathrm{m}}^{\mathrm{EM}} = a(1-\gamma) - bp_{\mathrm{m}}^{\mathrm{EM}} + cp_{\mathrm{e}}^{\mathrm{EM}} - dl_{\mathrm{m}} + el_{\mathrm{e}}, \tag{16}$$

$$D_{\mathrm{e}}^{\mathrm{EM}} = a\gamma - bp_{\mathrm{e}}^{\mathrm{EM}} + cp_{\mathrm{m}}^{\mathrm{EM}} - dl_{\mathrm{e}} + el_{\mathrm{m}}. \tag{17}$$

We apply backward induction to solve the sequential game. The sequence in which the decisions are taken in the practical scenario is shown in Fig. 4.

Figure 4 can be explained as follows.

Step 1: The Manufacturer takes the decision on the wholesale price for the E-tailer and the price to be charged in the Agency Channel.

Step 2: After observing the wholesale price, the E-tailer chooses the price.

Step 3: Sales is realized in the market and revenue is generated for the firms.

As in the case of E-tailer–DOC DCSC structure, we apply backward induction to solve the game. We derive the decisions in reverse order. By that logic, we first derive the E-tailer's price, and then, we derive the wholesale price for the E-tailer and the price to be charged in the Agency Channel.

The E-tailer's profit is as follows:

$$\begin{aligned}\pi_{\mathrm{e}}^{\mathrm{EM}} &= \left(p_{\mathrm{e}}^{\mathrm{EM}} - w^{\mathrm{EM}}\right)D_{\mathrm{e}}^{\mathrm{EM}} = \left(p_{\mathrm{e}}^{\mathrm{EM}} - w^{\mathrm{EM}}\right)\\ &\quad\times\left(a\gamma - bp_{\mathrm{e}}^{\mathrm{EM}} + cp_{\mathrm{o}}^{\mathrm{EM}} - dl_{\mathrm{e}} + el_{\mathrm{o}}\right).\end{aligned} \tag{18}$$

The rational E-tailer chooses the price in such a way as to maximize his/her profit. Mathematically,

$$p_{\mathrm{e}}^{\mathrm{EM}*} \in \underset{p_{\mathrm{e}}^{\mathrm{EM}}}{\mathrm{argmax}}\,\pi_{\mathrm{e}}^{\mathrm{EM}}\left(p_{\mathrm{r}}^{\mathrm{EM}} \middle| w^{\mathrm{EM}}\right).$$

The expressions for the optimal price of the E-tailer can be derived from the first-order conditions of $\pi_{\mathrm{e}}^{\mathrm{EM}}$ [i.e. Eq. (18)] with respect to $p_{\mathrm{e}}^{\mathrm{EM}}$. Since $\pi_{\mathrm{e}}^{\mathrm{EW}}$ and $\pi_{\mathrm{e}}^{\mathrm{EM}}$ are mathematically identical functions, the concavity of $\pi_{\mathrm{e}}^{\mathrm{EM}}$ is obvious from "Appendix A.1".

Proposition 1 *E-tailer's optimal price under E–tailer-Agency Channel DCSC structure is as follows*:

$$p_{\mathrm{e}}^{\mathrm{EM}} = \frac{a\gamma + bw^{\mathrm{EM}} - dl_{\mathrm{e}} + el_{\mathrm{m}} + cp_{\mathrm{m}}^{\mathrm{EM}}}{2b}. \tag{19}$$

Next, we can determine the optimal order quantity for the E-tailer by substituting Eq. (19) into Eq. (17). This is under the assumption that the E-tailer orders the optimal order quantity with the Manufacturer. The optimal order quantity thus obtained is presented in the following corollary.

Corollary 1 *E-tailer's optimal order quantity under E-tailer–Agency Channel DCSC structure is as follows*:

$$Q_{\mathrm{e}}^{\mathrm{EM}^*} = \frac{1}{2}\left(a\gamma - bw^{\mathrm{EM}} - dl_{\mathrm{e}} + el_{\mathrm{m}} + cp_{\mathrm{m}}^{\mathrm{EM}}\right). \tag{20}$$

The Manufacturer, being the Stackelberg leader, can obtain the information of E-tailer thus anticipates the optimal decisions of E-tailer. The Manufacturer maximizes his profit by considering the optimal decisions of E-tailer. The Manufacturer derives profit from two sources: (i) the margin obtained from the product sold to the E-tailer and (ii) the margin obtained from selling through the DOC. Thus, the profit of the Manufacturer can be formulated as follows.

$$\pi_{\mathrm{s}}^{\mathrm{EM}} = \left(w^{\mathrm{EM}} - s\right)Q_{\mathrm{e}}^{\mathrm{EM}} + \left(p_{\mathrm{m}}^{\mathrm{EM}}(1-\delta) - f - s\right)Q_{\mathrm{m}}^{\mathrm{EM}}, \tag{21}$$

where δ is the commission charged by the Agency Channel and f is the fixed charges to be paid to the Agency Channel.

The rational Manufacturer will choose the wholesale price for the E-tailer and price in the Agency Channel so as to maximize his/her profit. Mathematically,

$$w^{\mathrm{EM}*} \in \underset{w^{\mathrm{EM}}}{\mathrm{argmax}}\,\pi_{\mathrm{s}}^{\mathrm{EM}}\left(w^{\mathrm{EM}}, p_{\mathrm{m}}^{\mathrm{EM}*}\right),$$

$$p_{\mathrm{m}}^{\mathrm{EM}*} \in \underset{p_{\mathrm{m}}^{\mathrm{EM}}}{\operatorname{argmax}} \pi_{\mathrm{s}}^{\mathrm{EM}}\left(p_{\mathrm{m}}^{\mathrm{EM}}, w^{\mathrm{EM}*}\right).$$

The concavity of profit function of the Manufacturer is established as shown in "Appendix A.3". The expressions for optimal wholesale price and price in the Agency Channel can be derived from the first-order conditions of $\pi_{\mathrm{s}}^{\mathrm{EM}}$ [i.e. Eq. (21)] with respect to w^{EM} and $p_{\mathrm{o}}^{\mathrm{EW}}$. The following proposition shows the optimal decisions of the Manufacturer.

Proposition 2 *Under E-tailer–Agency Channel DCSC structure, the optimal wholesale price and the optimal price in the Agency Channel are as follows*:

$$w^{\mathrm{EM}^*} = \frac{(\mathrm{X}_1 + \mathrm{X}_2 - \mathrm{X}_3)}{b\left(8b^2(\delta - 1) + c^2\left(8 - 8\delta + \delta^2\right)\right)}, \tag{22}$$

$$p_{\mathrm{m}}^{\mathrm{EM}^*} = \frac{(\mathrm{X}_4 + \mathrm{X}_5 + \mathrm{X}_6)}{8b^2(\delta - 1) + c^2\left(8 - 8\delta + \delta^2\right)}. \tag{23}$$

Substituting w^{EM^*} and $p_{\mathrm{m}}^{\mathrm{EM}^*}$ into the Eq. (20) will yield the Manufacturer's decision on the optimal sales quantity to be allotted to the Agency Channel as shown in the following corollary.

Corollary 2 *Under E-tailer–Agency Channel DCSC structure, the optimal sales quantity to be allotted to the Agency Channel by the Manufacturer is as follows*:

$$Q_{\mathrm{m}}^{\mathrm{EM}^*} = \frac{(X_7 + X_8 + X_9 + X_{10} + X_{11})}{b\left(8b^2(\delta - 1) + c^2\left(8 - 8\delta + \delta^2\right)\right)}. \tag{24}$$

Substituting the optimal decisions into Eqs. (18) and (21) will yield the optimal profit functions of the Manufacturer and the E-tailer as shown in the following corollary.

Corollary 3 *Under E-tailer–Agency Channel DCSC structure, the optimal profit of the E-tailer and Manufacturer is as follows*:

$$\pi_{\mathrm{e}}^{\mathrm{EM}^*} = \frac{(X_{12} + X_{13} + X_{14} + X_{15})^2}{b\left(c^2\left(8 - 8\delta + \delta^2\right) - 8b^2(1 - \delta)\right)^2}, \tag{25}$$

$$\pi_{\mathrm{s}}^{\mathrm{EW}^*} = \frac{1/b\left(X_{16} + X_{17} + X_{18} + X_{19} + X_{20}\right)\left(X_{21}\right)\left(X_{22} + X_{23} + X_{24}\right)\Gamma_1}{c^2(8 - 8\delta + \delta^2) - 8b^2(1 - \delta)}. \tag{26}$$

Numerical analysis

In this section, we compare the EW DCSC and EM DCSC using a numerical example. The motivation for employing a numerical analysis is the complexity of mathematical expressions of the optimal decisions of the supply chain members. It can be observed that the mathematical expressions corresponding to that of the optimal profit of the Manufacturer and the optimal profit of the E-tailer are too complex to be compared analytically. We have considered two cases under numerical example: (i) price sensitivity is higher than the lead time sensitivity, and (ii) lead time sensitivity is higher than price sensitivity.

Case 1: Price sensitivity is higher than the lead time sensitivity

For Case 1, we choose the following values for a numerical example.

$$a = 300, \gamma = 0.5, b = 2.0, c = 1.7, d = 1.5,$$
$$e = 1.3, \delta = 0.10 \text{ and } s = 50.$$

The following assumptions are used while selecting the numerical values.

(i) The value of the base demand is much higher than other parameters of the model.
(ii) Own-price elasticity is higher than cross-price elasticity.
(iii) Own-lead time elasticity is higher than cross-lead time elasticity.
(iv) DOC and Agency Channel are equally preferred by the customers.

Using the numerical values, we have quantified the analytical expressions and the results obtained are presented in Table 2.

From Table 2, we can observe that E-tailer is better off under EM DCSC and the Manufacturer is better off under EW DCSC. In other words, it is better for E-tailer to compete with Agency Channel than to compete with the Manufacturer's DOC. However, since the Manufacturer is better off under EW DCSC, DOC will be chosen as a preferred channel. The assumed channel leadership is also in favour of the Manufacturer. Therefore, when the DOC and Agency Channel is equally preferred by the customers, it is better for the Manufacturer to sell through the DOC for products about which the customers' price sensitivity dominates the lead time sensitivity.

Table 2 Profit of Manufacturer and E-tailer—EW DCSC and EM DCSC—Case 1

	E-tailer's profit	Manufacturer's profit
EW DCSC	657.03	28,540.29
EM DCSC	1144.48	26,188.63

Case 2: Lead time sensitivity is higher than the price sensitivity

The same numerical assumptions are used as in Case 1. However, the values of price sensitivity and lead time sensitivity are different as follows.

$a = 300, \gamma = 0.5, b = 1.7, c = 1.3, d = 2.0,$

$e = 1.5, \delta = 0.10$ and s = 50.

The profit of the supply chain members in Case 2 is as shown in Table 3.

From Table 3, it can be deduced that E-tailer is better off under EM DCSC and the Manufacturer is better off under EW DCSC. As in Case 1, it is better for E-tailer to compete with Agency Channel than to compete with the Manufacturer's DOC. Though the results are similar in Cases 1 and 2, there is a significant difference in the magnitude of the profit of the supply chain members, especially in the case of the Manufacturer. Therefore, when the DOC and Agency Channel are equally preferred by the customers and when the lead time sensitivity dominates the price sensitivity, EM DCSC clearly dominates the EW DCSC.

Sensitivity analysis

In this section, we examine the sensitivity of profit of the supply chain members with respect to the customer preference towards an E-tailer in the case of products with price sensitivity dominance and lead time sensitivity dominance. The motivation behind considering the customer preference towards E-tailer is its dynamic nature. There are several areas where the E-tailer can improve its operations such as website interface (Lin 2007), modes of payment (Tandon and Kiran 2019), product presentation (Park et al. 2005), customer care (Cheng and Jiang 2020), and delivery experience (Vakulenko et al. 2019). E-tailers are continuously striving to improve their operations in these areas to deliver greater values to the customers and thereby improving the customers' perception and preference. Therefore, sensitivity analysis is the right mechanism to capture the dynamic aspect of customer preference towards E-tailer and its subsequent impact of the performance of the channel members. Further, customer preference for E-tailer determines the base demand for the E-tailer and the base demand for the DOC in the case of EW DCSC and base demand for Agency Channel in the case of EM DCSC. The range of the parameter γ is 0 to 1. We vary the parameter γ from 0.05 to 0.95 to understand its impact on the profit of supply chain members. The sensitivity analysis was carried out in the software Wolfram Mathematica version 12.

Impact of variation in customer preference towards E-tailer on profit: Case 1

We can observe that the profit of the Manufacturer decreases with increase in customer preference towards E-tailer under both EW DCSC and EM DCSC. The dynamics of profit variation of the Manufacturer under EM DCSC can be explained with the help of Table 4, which shows the wholesale price for E-tailer, price, and sales volume in the case of EM DCSC.

From Table 4, we can observe that with increase in the customer preference for E-tailer, the wholesale price for the E-tailer increases. This increase in wholesale price is also reflected in the price of the E-tailer and sales volume of the E-tailer. The increase in price and sales volume is

Table 3 Profit of Manufacturer and E-tailer—EW DCSC and EM DCSC—Case 2

	E-tailer's profit	Manufacturer's profit
EW DCSC	730.92	18,732.08
EM DCSC	1654.39	42,812.18

Table 4 Customer Preference towards E-tailer vs. Price and Sales Volume—EM DCSC Case 1

Customer Preference towards E-tailer	Wholesale Price for E-tailer	Price in the Agency Channel	E-tailer's Price	E-tailer's Sales Volume	Sales Volume through the Agency Channel
0.1	249.39	297.67	258.61	18.43	113.88
0.2	254.12	294.24	267.02	25.78	105.04
0.3	258.85	290.82	275.43	33.13	96.19
0.4	263.59	287.38	283.84	40.48	87.34
0.5	268.32	283.96	292.24	47.84	78.49
0.6	273.05	280.53	300.65	55.19	69.64
0.7	277.78	277.10	309.06	62.55	60.79
0.8	282.52	273.67	317.47	69.91	51.95
0.9	287.25	270.25	325.88	77.26	43.10

directly related to the increase in base demand with respect to the increase in customer preference towards E-tailer. It can be inferred from Table 4 that it is optimal for E-tailer to charge higher prices when the base demand is high. We can also observe that with increase in the base demand for the E-tailer, there is a consequent reduction in the base demand for the Agency Channel. From Table 4, we can see that the price in the Agency Channel and sales volume through the Agency Channel decrease with an increase in customer preference towards E-tailer. In other words, it is optimal for the Manufacturer to charge lower prices when the customer preference towards E-tailer is high. Table 5 shows the wholesale price for E-tailer, price, and sales volume in the case of EW DCSC.

The variation of wholesale price, price and sales volume with respect to the customer preference towards E-tailer under EW DCSC is analogous to that under EM DCSC, i.e. increase in the customer preference towards E-tailer results in increase in wholesale price, increase in price of the E-tailer, increase in sales volume of the E-tailer, decrease in price on the DOC and decrease in sales volume through the DOC. The base demand shift with respect to the customer preference towards E-tailer explains the dynamics under EW DCSC also.

Further, it can be noticed from Fig. 5 that the decrease in profit is prominent in the case of EW DCSC. Specifically, there is a reduction of 5.3% in profit of the Manufacturer under EM DCSC whereas the reduction in profit for the Manufacturer in the case of EW DCSC is 11.5%. It can be deduced that it is better for a Manufacturer to sell through the DOC than to sell through the Agency Channel irrespective of the customer preference towards the E-tailer. To understand the reason behind higher profitability of Manufacturer under EW DCSC, we investigated the price and sales volume variation in the DOC and Agency Channel with respect to the customer preference towards the E-tailer. We found that the Manufacturer is able to charge a lower price on the DOC compared to that in the

Table 5 Customer Preference towards E-tailer vs. Price and Sales volume—EW DCSC Case 1

Customer Preference towards E-tailer	Wholesale price for E-tailer	Price in the DOC	Price of the E-tailer	Sales Volume of the E-tailer	Sales Volume through the DOC
0.1	258.29	287.71	261.42	6.25	126.61
0.2	262.35	283.64	269.23	13.75	117.98
0.3	266.41	279.59	277.03	21.25	109.36
0.4	270.46	275.54	284.84	28.75	100.74
0.5	274.51	271.48	292.64	36.25	92.11
0.6	278.56	267.43	300.44	43.75	83.49
0.7	282.62	263.37	308.25	51.25	74.86
0.8	286.67	259.32	316.05	58.75	66.24
0.9	290.73	255.27	323.85	66.25	57.61

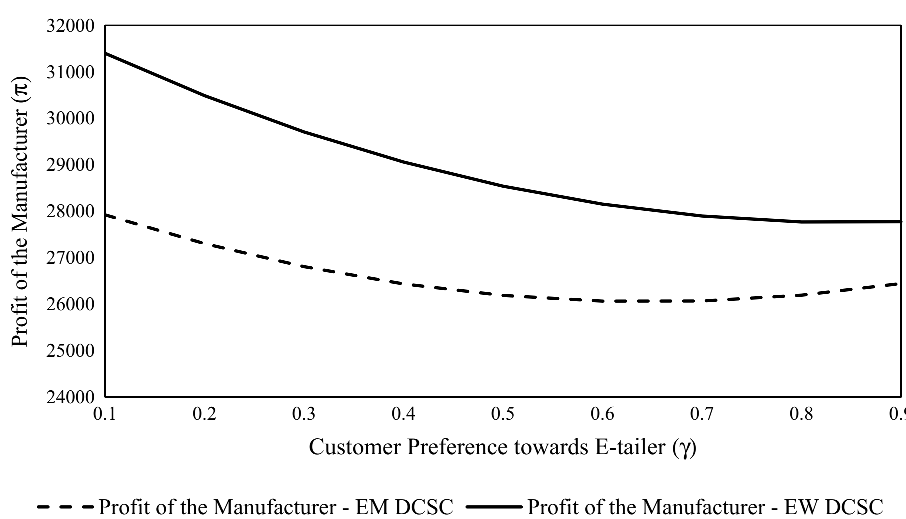

Fig. 5 Profit of the Manufacturer vs. Customer Preference towards E-tailer—Case 1

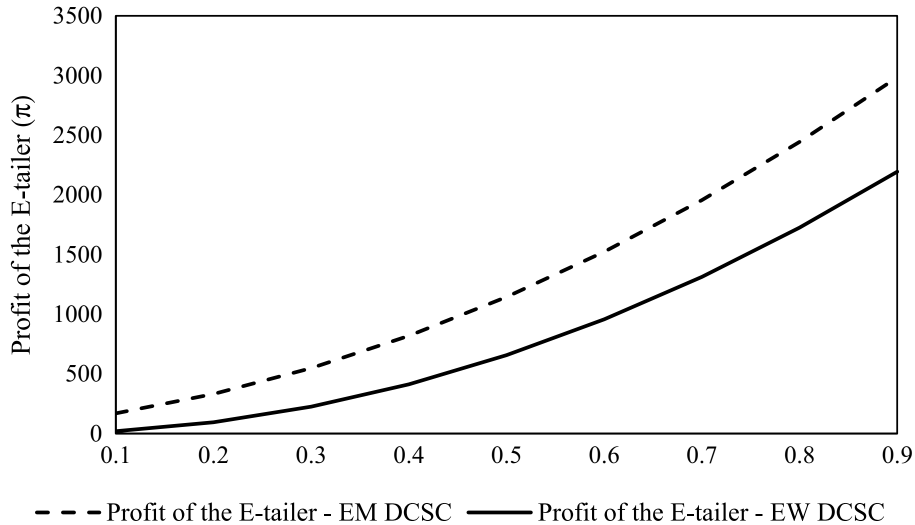

Fig. 6 Profit of the E-tailer vs. Customer Preference towards E-tailer—Case 1

Agency Channel as shown in Table 4. Due to the lower price in the DOC, the Manufacturer is enjoying a higher sales volume in the DOC compared to the sales volume through Agency Channel. This explains the higher profit of the Manufacturer under EW DCSC.

Figure 6 shows the impact of change in customer preference towards E-tailer on the profit of the E-tailer.

From Fig. 6, we can observe that the profit of the E-tailer is increasing with an increase in customer preference towards the E-tailer. The increase in profit can be directly attributed to the improvement in base demand resulting from the increase in customer preference towards E-tailer. We can deduce that it is better for an E-tailer to compete with Agency Channel rather than to compete with DOC, irrespective of the customer preference towards the E-tailer.

Impact of change in customer preference towards E-tailer on profit: Case 2

In this section, we present the impact of change in γ on the profit of the supply chain members in the case of products with lead time sensitivity dominance, as shown in Fig. 7.

We can observe that Manufacturer derives higher profit under EM DCSC than under EW DCSC in the case of products having lead time sensitivity dominance. Under both EM DCSC and EW DCSC, the profit of the Manufacturer is decreasing when the customer preference for E-tailer increases and stabilizes at moderate and higher values of customer preference towards E-tailer. The dynamics of profit variation with respect to the price variation is analogous to Case 1.

The profit variation in the case of E-tailer with respect to the customer preference towards E-tailer is shown in Fig. 8.

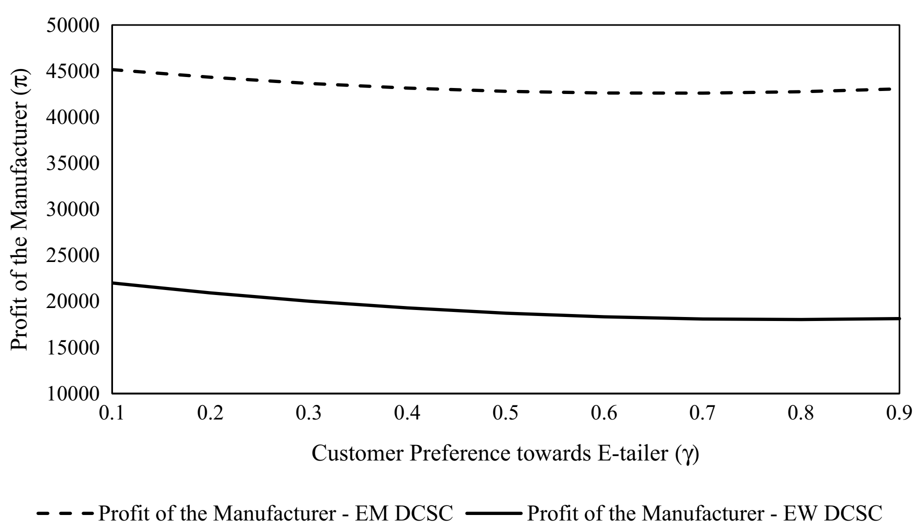

Fig. 7 Profit of the Manufacturer vs. Customer Preference towards E-tailer—Case 2

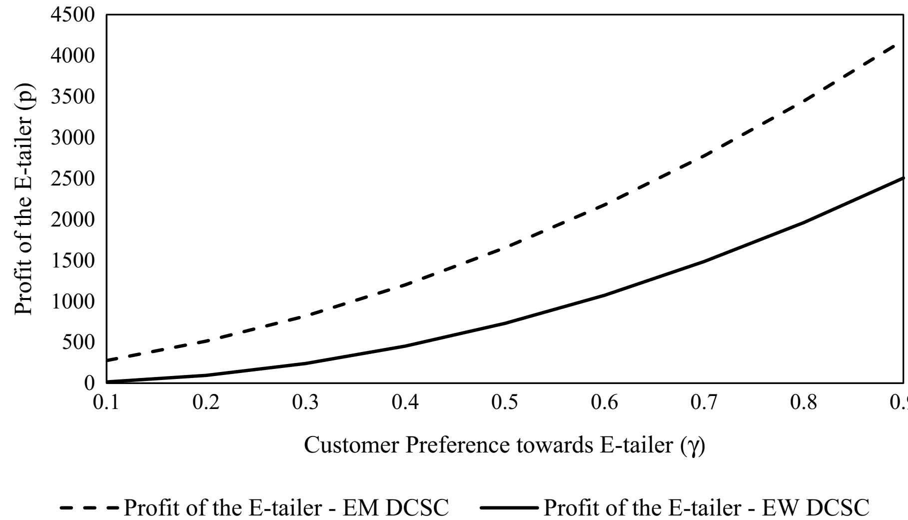

Fig. 8 Profit of the E-tailer vs. Customer Preference towards E-tailer—Case 2

We can observe that the profit of the E-tailer steadily increases with increase in customer preference towards E-tailer.

Comparison of Cases 1 and 2: impact of variation in customer preference towards E-tailer on profit

The following deductions can be made by comparing Cases 1 and 2 with regard to the profit of the supply chain members.

Profit of the Manufacturer

- Under Case 1, EW DCSC dominates EM DCSC whereas under Case 2, EM DCSC dominates EW DCSC in terms of the profit of the Manufacturer. Thus, it can be deduced that in the case of price sensitivity-dominant products, it is gainful for a Manufacturer to sell through the DOC whereas in the case of lead time sensitivity-dominant products, the Manufacturer will be better off by selling through the Agency Channel.
- The profit difference, in the case of Manufacturer, between EM DCSC and EW DCSC is higher under Case 2 compared to Case 1. However, the profit difference, in the case of E-tailer, between EM DCSC and EW DCSC is comparable under Cases 1 and 2. Thus, it can be inferred that the choice of Manufacturer regarding DOC or Agency Channel is critical in the case of lead time sensitivity-dominant products.

Discussion

There is growing interest in the research comparing different online channel formats. Our findings extends the current literature. For instance, Abhsihek et al. (2016) and Chen et al. (2022) report that the Agency Channel is the profitable option for the Manufacturer than the indirect reselling channel, E-tailer. However, this study shows that choosing the combination of DOC and E-tailer is gainful for the Manufacturers compared to the combination of Agency Channel and E-tailer. In both the configurations considered in this study, the indirect channel is same, i.e. the E-tailer whereas the direct channel takes two different forms, i.e. DOC and Agency Channel. In that sense, we establish that DOC is profitable than Agency Channel for the Manufacturer, under a DCSC configuration. In this way, this study contributes to the literature in establishing the superior performance of DOC over Agency Channel. Further, the study finds the link between online channel performance and nature of the product in terms of sensitivity towards price and lead time. For instance, the result that E-tailer–DOC combination outperforms E-tailer–Agency Channel combination is applicable in the case of products for which customers' price sensitivity is higher than the lead time sensitivity. This is a clear extension of the theory on online channel formats and their performance.

Furthermore, it is interesting to note that the result is reversed when we consider the products for which customers' lead time sensitivity is higher than the price sensitivity. In other words, the Manufacturer is gainful by choosing E-tailer–Agency Channel structure compared to E-tailer–DOC structure in the case of products having higher lead time sensitivity than price sensitivity. This result is based on the assumption that the lead time for DOCs is higher compared to that of E-tailers and Agency Channels. This assumption is consistent with reality due to the continuous capital investments by Agency Channels firms and E-tailers for building their infrastructure such as fulfilment centres across the country they are operating. The warehousing and logistics infrastructure helps Agency Channel firms and E-tailers to place the products closer to the customer depending on the demand pattern of a geographical area. Further, practices such as anticipatory shipping, where products are shipped closer to the customers before they actually place the order (Weingarten and Spinler 2021). Products such as medicines, gifts, household supplies and perishable goods are those for which customers have higher lead time sensitivity than the price sensitivity. Also, certain seasons such as festival seasons make customers more sensitive about the lead time. Thus, the finding of the study that E-tailer–Agency Structure is gainful for the Manufacturers selling products which are more lead time sensitive is establishing the link between the nature of the product and channel structure.

Conclusion

In this study, we explored the optimal channel structure for a Manufacturer while operating through online distribution channels. The rationale for exploring the optimal online channel configuration is the significant shift of retailing towards online platforms and prevalence of different types of online channels. The literature lacks studies that address the problem of optimal online channel configurations. The current literature reports dual-channel supply chain configuration as a combination of online and traditional brick and mortar channels. Further, current literature does not consider different formats of online retailing (Du et al. 2023; Kar et al 2023; Xiao et al. 2023). To bridge this gap in the literature and to provide managerial insights on online channel configuration, this study considered two commonly seen channel structures in the market (i) E-tailer–DOC DCSC Structure and (ii) E-tailer–Agency Channel DCSC Structure. By considering DOC, E-tailer and Agency Channel, we covered the major online retailing formats. Game-theoretic models was employed to examine the interactions between Manufacturers and E-tailers by assuming that the Manufacturer holds higher channel power and acts as the supply chain leader. Further, this study classified the results obtained for two broad product categories, i.e. (i) products for which customers' price sensitivity dominates the lead time sensitivity and (ii) products for which customers' lead time sensitivity dominates the price sensitivity.

The findings of this study can be implemented by the Manufacturers or channel managers depending on the kind of product they are dealing with. It is found from the study that it is beneficial for the E-tailers to compete with the Agency Channels irrespective of the category of the product. Therefore, it can be deduced that the interests of Manufacturers and E-tailers are aligned in the case of products having higher lead time sensitivity and they are in conflict in the case of products having higher price sensitivity. Since we have assumed that a Manufacturer has higher channel power, the conflicting interests will make the E-tailer worse off in the case of products having higher price sensitivity.

Several managerial insights can be derived from the sensitivity analysis with respect to the customer preference towards E-tailers. This parameter is a function of product category and it depends on the efforts of the E-tailers to reduce the difference between traditional buying experience and online buying experience. The E-tailers are implementing technological solutions to reduce the fit uncertainty which is a significant barrier for customers to buy experience products from an online platform. Application of techniques such as ML and AI also helps E-tailers to achieve operational excellence in terms of reducing leading time and improve customer satisfaction. The dynamic nature of the parameter is the rationale behind choosing it for sensitivity analysis. The obtained results are in alignment with the intuition. In other words, increase in customer preference towards E-tailer is beneficial for the E-tailers in terms of profit. However, this is undesirable for the Manufacturers since they derive higher margins through direct online channels and Agency Channels. Technically, a Manufacturer would prefer to obtain higher share of his sales through direct channel rather than through an intermediary. In other words, an intermediary should only be preferred by a Manufacturer when the intermediary can add values in terms of reaching out to a wider market or when the nature of the product is such that the customer would like to engage in pre-purchase examination of the product at the premise of the intermediary.

There are important insights for managers from the sensitivity analysis with respect to the parameter customer preference towards the E-tailer. The rationale for selecting this parameter is the E-tailer's efforts to be customer friendly in terms of mitigating the gap between traditional shopping and online shopping. It is intuitive that the E-tailer's effort to improve the operations in different aspects such as lead time, shopping experience, customer service and return policy will positively impact the profit. However, in this study, the impact of improvement in customer preference for E-tailer on the reduction of profit for the Manufacturer has been noticed. This happens since the Manufacturer derives higher margin while selling though direct channels like DOC and Agency Channel. The increase of indirect channel demand leads to the demand reduction in the direct channel due to the zero-sum nature of the game and vice versa. Nevertheless, the demand increment in the indirect channel is gainful for the Manufacturer compared to that in the indirect channel. This finding translates into an important insight for the managers to either improve the operations of DOC or partner with an Agency Channel preferred by the customers. The improvement of DOC operations comes with huge capital commitment in building logistics infrastructure to match with the service level of an Agency Channel. Thus DOC operations improvement is feasible for a Manufacturer who is not capital constrained.

The study has a lot of scope in the future and can be extended in several directions. In this study, it is assumed that the Manufacturer is the channel leader on account of higher channel power. Nevertheless, E-tailer may enjoy higher channel power and therefore can hold the channel leadership (Song et al. 2023; Zhao et al. 2023). It will be interesting to study the impact of E-tailer channel leadership on the profit of the channel members. Further, in this study, we have not differentiated the popularity among the online platforms, i.e. DOC, Agency Channel, and E-tailer. In a few cases, it is seen that Agency Channel could be more popular than the DOC of the Manufacturer or the E-tailer. This can cause a difference in base demand. The study can be extended by considering a demand function which captures the popularity difference among the online platforms. Furthermore, there are Manufacturers who sell through multiple online and traditional channels simultaneously. This can lead to a triple or quadruple supply chain structure. The study can be extended from a dual-channel structure to a triple or quadruple-channel structure.

Appendix

Concavity of E-tailer's profit function under EW DCSC $\left(\pi_{\mathrm{e}}^{\mathrm{EW}}\right)$

$$\pi_{\mathrm{e}}^{\mathrm{EW}} = \left(p_{\mathrm{e}}^{\mathrm{EW}} - w^{\mathrm{EW}}\right)\left(a\gamma - bp_{\mathrm{e}}^{\mathrm{EW}} + cp_{\mathrm{o}}^{\mathrm{EW}} - dl_{\mathrm{e}} + el_{\mathrm{o}}\right). \tag{27}$$

We check the concavity of $\pi_{\mathrm{e}}^{\mathrm{EW}}$ and obtain $\frac{\partial^2 \pi_{\mathrm{e}}^{\mathrm{EW}}}{\partial p_{\mathrm{e}}^{\mathrm{EW}2}} = -2b < 0$.

Concavity of Manufacturer's profit function under EW DCSC $\left(\pi_{\mathrm{s}}^{\mathrm{EW}}\right)$

$$\begin{aligned}\pi_{\mathrm{s}}^{\mathrm{EW}} = {} & \left(p_{\mathrm{o}}^{\mathrm{EW}} - s\right)\left(a(1-\gamma) + el_{\mathrm{e}} - dl_{\mathrm{o}} + cp_{\mathrm{e}}^{\mathrm{EW}} - bp_{\mathrm{o}}^{\mathrm{EW}}\right) \\ & + \left(w^{\mathrm{EW}} - s\right)\left(a\gamma - dl_{\mathrm{e}} + el_{\mathrm{o}} - bp_{\mathrm{e}}^{\mathrm{EW}} + cp_{\mathrm{o}}^{\mathrm{EW}}\right).\end{aligned} \tag{28}$$

To check the concavity of $\pi_{\mathrm{s}}^{\mathrm{EW}}$ with respect to $p_{\mathrm{o}}^{\mathrm{EW}}$ and w^{EW}, we present the Hessian matrix of $\pi_{\mathrm{s}}^{\mathrm{EW}}$ with respect to $p_{\mathrm{o}}^{\mathrm{EW}}$ and w^{EW} as follows.

$$H\left(\pi_{\mathrm{s}}^{\mathrm{EW}}\right) = \begin{bmatrix} \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EW}}}{\partial p_{\mathrm{o}}^{\mathrm{EW}2}} & \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EW}}}{\partial p_{\mathrm{o}}^{\mathrm{EW}} \partial w^{\mathrm{EW}}} \\ \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EW}}}{\partial w^{\mathrm{EW}} \partial p_{\mathrm{o}}^{\mathrm{EW}}} & \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EW}}}{\partial w^{\mathrm{EW}2}} \end{bmatrix} = \begin{bmatrix} -2b & c \\ c & 0 \end{bmatrix}. \tag{29}$$

Concavity of $\pi_{\mathrm{s}}^{\mathrm{EW}}$ with respect to $p_{\mathrm{o}}^{\mathrm{EW}}$ and w^{EW} is established since the Hessian matrix is negative definite.

Concavity of Manufacturer's profit function under EM DCSC $\left(\pi_{\mathrm{s}}^{\mathrm{EM}}\right)$

$$\begin{aligned}\pi_{\mathrm{s}}^{\mathrm{EM}} = {} & \left(p_{\mathrm{m}}^{\mathrm{EM}}(1-\delta) - f - s\right)\left(a(1-\gamma) + el_{\mathrm{e}} - dl_{\mathrm{o}} + cp_{\mathrm{e}}^{\mathrm{EM}} - bp_{\mathrm{m}}^{\mathrm{EM}}\right) \\ & + \left(w^{\mathrm{EM}} - s\right)\left(a\gamma - dl_{\mathrm{e}} + el_{\mathrm{o}} - bp_{\mathrm{e}}^{\mathrm{EM}} + cp_{\mathrm{m}}^{\mathrm{EM}}\right)\end{aligned} \tag{30}$$

For checking the concavity of $\pi_{\mathrm{s}}^{\mathrm{EM}}$ with respect to $p_{\mathrm{m}}^{\mathrm{EM}}$ and w^{EM}, we present the Hessian matrix of $\pi_{\mathrm{s}}^{\mathrm{EM}}$ with respect to $p_{\mathrm{m}}^{\mathrm{EM}}$ and w^{EM} as follows.

$$H\left(\pi_{\mathrm{s}}^{\mathrm{EM}}\right) = \begin{bmatrix} \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EM}}}{\partial p_{\mathrm{m}}^{\mathrm{EM}2}} & \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EM}}}{\partial p_{\mathrm{m}}^{\mathrm{EM}} \partial w^{\mathrm{EM}}} \\ \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EM}}}{\partial w^{\mathrm{EM}} \partial p_{\mathrm{m}}^{\mathrm{EM}}} & \frac{\partial^2 \pi_{\mathrm{s}}^{\mathrm{EM}}}{\partial w^{\mathrm{EM}2}} \end{bmatrix} = \begin{bmatrix} -2b(1-\delta) & c \\ c & 0 \end{bmatrix}. \tag{31}$$

Concavity of $\pi_{\mathrm{s}}^{\mathrm{EM}}$ with respect to $p_{\mathrm{m}}^{\mathrm{EM}}$ and w^{EM} is established since the Hessian matrix is negative definite.

Expansion of terms in w^{EM^*} (A.6–A.8)

$$\begin{aligned}\mathrm{X}_1 = {} & 4bc^2 s - 4ab^2\gamma + 4abc\gamma + 6abc\delta \\ & - 2b^2 cf\delta + c^3 f\delta - 4abc - 4b^3 s,\end{aligned}$$

$$\begin{aligned}\mathrm{X}_2 = {} & 4b^3 s\delta - 2b^2 cs\delta - 3bc^2 s\delta + c^3 s\delta + 4ab^2\gamma\delta \\ & - 6abc\gamma\delta + ac^2\gamma\delta(1-\delta) + 2abc\delta^2(\gamma-1),\end{aligned}$$

$$\begin{aligned}\mathrm{X}_3 = {} & (\delta-1)\left(4b^2 d + 2bce(\delta-2) - c^2 d\delta\right)l_e \\ & + (\delta-1)\left(4b^2 e + 2bcd(\delta-2) - c^2 e\delta\right)l_m.\end{aligned}$$

Expansion of terms in $p_{\mathrm{m}}^{\mathrm{EM}^*}$ (A.9–A.11)

$$\mathrm{X}_4 = 4c^2 f - 4ab - 4b^2 f - 4b^2 s + 4c^2 s + 4ab\gamma - 4ac\gamma,$$

$$\mathrm{X}_5 = 4ab\delta - c^2 f\delta + bcs\delta - c^2 s\delta - 4ab\gamma\delta + 3ac\gamma\delta,$$

$$\mathrm{X}_6 = (cd(4-3\delta) - 4be(1-\delta))l_e + (4bd(1-\delta) - ce(4-3\delta))l_{\mathrm{m}}.$$

Expansion of terms in $Q_{\mathrm{m}}^{\mathrm{EM}^*}$ (A.12–A.16)

$$\begin{aligned}X_7 = {} & 4abc^2 - 4ab^3 + 4b^4 f - 6b^2 c^2 f + 2c^4 f \\ & + 4b^4 s - 2b^3 cs - 6b^2 c^2 s + 2bc^3 s + 2c^4 s,\end{aligned}$$

$$X_8 = 4ab^3\gamma - 2ab^2 c\gamma - 4abc^2\gamma + 2ac^3\gamma + 4ab^3\delta - 3abc^2\delta,$$

$$X_9 = b^3 cs\delta - bc^3 s\delta - 4ab^3\gamma\delta + 3ab^2 c\gamma\delta + 3abc^2\gamma\delta - 2ac^3\gamma\delta,$$

$$X_{10} = \left(b^2 cd(2-3\delta) + bc^2 e(4-3\delta) - 2c^3 d(1-\delta) - 4b^3 e(1-\delta)\right)l_e,$$

$$X_{11} = \left(4b^3 d(1-\delta) + 2c^3 e(1-\delta) - bc^2 d(4-3\delta) - b^2 ce(2-3\delta)\right)l_{\mathrm{m}}.$$

Expansion of terms in $Q_{\mathrm{m}}^{\mathrm{EM}^*}$ (A.17–A.20)

$$X_{12} = 2b^2cf - 2c^3f - 2b^3s + 2b^2cs + 2bc^2s - 2c^3s + 2ab^2\gamma - 2ac^2\gamma,$$

$$X_{13} = abc\delta - b^2cf\delta + c^3f\delta + 2b^3s\delta - b^2cs\delta - 2bc^2s\delta + c^3s\delta,$$

$$X_{14} = 3ac^2\gamma\delta - 2ab^2\gamma\delta - abc\gamma\delta - abc\delta^2 + abc\gamma\delta^2 - ac^2\gamma\delta^2,$$

$$X_{15} = (1-\delta)\left(c^2d(2-\delta) + bce\delta - 2b^2d\right) \times l_{\mathrm{e}} - (1-\delta)\left(c^2e(2-\delta) + bcd\delta - 2b^2e\right)l_{\mathrm{m}}.$$

Expansion of terms in $\pi_{\mathrm{s}}^{\mathrm{EW}^*}$ (A.21–A.23)

$$\Delta_1 = \big(2b(a-bs) + bcs + c^2s - 2ab\gamma + ac\gamma + (2be-cd)l_e + (ce-2bd)l_{\mathrm{o}}\big),$$

$$\Delta_2 = \left(ab + s\left(c^2-b^2\right) - ab\gamma + ac\gamma + (be-cd)l_{\mathrm{e}} + (ce-bd)l_{\mathrm{o}}\right),$$

$$\Upsilon_1 = \left(s(b^2-c^2) + a\gamma(c-b) - ac + l_{\mathrm{e}}(bd-ce) + l_{\mathrm{o}}(cd-be)\right)$$

Expansion of terms in $\pi_{\mathrm{s}}^{\mathrm{EM}^*}$ (A.24–A.39)

$$\Gamma_1 = (-s + 1/(b\left(8b^2(\delta-1) + c^2\left(8-8\delta+\delta^2\right)\right)))(X_{25}+X_{26}-X_{27}),$$

$$X_{16} = -4ab^3 + 4abc^2 + 4b^4f - 6b^2c^2f + 2c^4f + 4b^4s - 2b^3cs - 6b^2c^2s,$$

$$X_{17} = 2sbc^3s + 2c^4s + 4ab^3\gamma - 2ab^2c\gamma - 4abc^3\gamma + 2ac^3\gamma + 4ab^3\delta - 3abc^2\delta,$$

$$X_{18} = b^3cs\delta - bc^3s\delta - 4ab^3\gamma\delta + 3ab^2c\gamma\delta + 3abc^2\gamma\delta - 2ac^3\gamma\delta,$$

$$X_{19} = \left(b^2cd(2-3\delta) + bc^2e(4-3\delta) + 2c^3d(\delta-1) + 4b^3e(\delta-1)\right)l_{\mathrm{e}},$$

$$X_{20} = \big(4b^3d(1-\delta) + 2c^3e(1-\delta) + bc^2d(3\delta-4) + b^2ce(3\delta-2)\big)l_{\mathrm{m}}),$$

$$X_{21} = -f - s + 1/(8b^2(\delta-1) + c^2\left(8-8\delta+\delta^2\right)) \times (\delta-1)(4ab + 4b^2f - 4c^2f + \Phi_1 + \Phi_2),$$

$$\Phi_1 = (4be(1-\delta) - cd(4-3\delta))l_{\mathrm{e}} + (ce(4-3\delta) - 4bd(1-\delta))l_{\mathrm{m}}),$$

$$\Phi_2 = 4b^2s - 4c^2s - 4ab\gamma + 4ac\gamma - 4ab\delta + c^2f\delta - bcs\delta + c^2s\delta + 4ab\gamma\delta - 3ac\gamma\delta,$$

$$X_{22} = -2b^2cf + 2c^3f + 2b^3s - 2b^2cs - 2bc^2s + 2c^3s - 2ab^2\gamma + 2ac^2\gamma - abc\delta,$$

$$X_{23} = b^2cf\delta - c^3f\delta - 2b^3s\delta + b^2cs\delta + 2bc^2s\delta - c^3s\delta + 2ab^2\gamma\delta,$$

$$X_{24} = abc\gamma\delta - 3ac^2\gamma\delta + abc\delta^2 - abc\gamma\delta^2 + ac^2\gamma\delta^2 + (1-\delta)\Phi_3),$$

$$\Phi_3 = \left(2b^2d + c^2d(-2+\delta) - bce\delta\right)l_{\mathrm{e}} - (1-\delta)\left(2b^2e - c^2e(2-\delta) - bcd\delta\right)l_{\mathrm{m}},$$

$$X_{25} = -4abc - 4b^3s + 4bc^2s - 4ab^2\gamma + 4abc\gamma + 6abc\delta - 2b^2cf\delta + c^3f\delta + 4b^3s\delta - 2b^2cs\delta - 3bc^2s\delta + c^3s\delta,$$

$$X_{26} = 4ab^2\gamma\delta - 6abc\gamma\delta + ac^2\gamma\delta - 2abc\delta^2 + 2abc\gamma\delta^2 - ac^2\gamma\delta^2,$$

$$X_{27} = (\delta-1)\left(4b^2d - 2bce(2-\delta) - c^2d\delta\right)l_{\mathrm{e}} - (1-\delta)\left(4b^2e - 2bcd(2-\delta) - c^2e\delta\right)l_{\mathrm{m}}))).$$

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