Demand Model Development Considering Supply Chain Disruption

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Abstract. The concept of distributes and selling products through retailers (offline channels) and also online channels is called a dual-channel supply chain (DCSC). In DCSC, one manufacturer manages the online channel and distributes the product to one independent retailer. Disruptions are all activities that disrupt the supply chain activities so that the supply chain cannot operate normally. Another major aspect to be considered in DCSC is the customer shift in preferences because with adding an online channel, the online channel has several advantages. This paper's objective is to investigate the effect of supply chain disruption on demand in the online and offline channels. The customer knows beforehand that there is a disruption in the supply chain before even try to purchase the product in DCSC, therefore it will affect the customer preferences that will also affect the channel demand. From a numerical example, it is shown that the retail channel is suffering more than the online channel. The greater the probability of disruption and the proportion of disruption, the demand on the offline channel will decrease.

1. Introduction
The development of the internet and growth in internet users provides manufacturers the opportunity to be able to expand their business. Manufacturers that initially only sell their products in stores (offline channels) can sell their products directly to their customers via the internet. Therefore, manufacturers use two channels simultaneously to sell their products. Data from Bank Indonesia (BI), online shop transactions in Indonesia throughout 2018 reached Rp77,766 trillion. This figure has increased by 151% compared to 2017 which Rp30,942 trillion. Meanwhile, the Central Bureau of Statistics (BPS) states that the e-commerce business in Indonesia increased by 17 percent in the last 10 years reaching 26.2 million units business. The concept of distributes and selling products through retailers (offline channels) and also online channels is called a dual-channel supply chain (DCSC in short hereinafter). In DCSC, one manufacturer manages the online channel and distributes the product to one independent retailer [1].

DCSC offers some benefits to supply chain players. The internet store can respond to changes in demand and competition so that it can adjust its price and promotions. Moreover, by customizing the product based on customer preference in channels, the manufacturer can obtain their market coverage [2]. Furthermore, DCSC customers can choose which channel will be used to buy goods. The dual-channel also means more shopping choices and cost savings to customers [3]. In DCSC, customers may be attracted by product descriptions online and photographs in an online channel so the customers prefer to purchase the product via online channel [4]. Although manufacturers can enjoy addition in
revenues with the addition of an online channel, it can also threaten the relationship with retailers [5]. One way to suppress the channel conflict is pricing strategy [6].

Recently, many studies discuss disruption in supply chains. Disruptions are all activities that disrupt the supply chain activities so that the supply chain cannot operate normally. So, disruptions are all undesirable events happens in the supply chain and it can affect the material flow and the performances of supply chain partners [7]. According to [8], the potential impact of disruption and the probability of disruption can be associated with supply chain risks. There are many types of research about disruption in DCSC. A study by [9] investigates demand disruption in producing and selling green products in the dual-channel supply chain. Another study by [10] studies the optimal pricing, inventory, and preservation decisions that maximize individual profit.

Another major aspect to be considered in DCSC is the customer shift in preferences because with adding an online channel, the online channel has several advantages like its convenience, product variety availability and online channel operate 24 hours [11], [12]. However, even if the disruption can occur in the supply chain channel, the effect of disruption to customer preferences has not been discussed in the literature. Customer can suddenly change their channel preferences even before they try to purchase the product in the retail or online channels, given the information customers get about the disruption. Therefore, this paper's objective is to see the effect of supply chain disruption on customer preferences, where customer preferences will affect the demand of retail channels and online channels.

2. Model Description
DCSC system observed can be seen in figure 1. In figure 1, it can be seen that the DCSC system consists of one manufacturer, one retailer, and one online channel.

Figure 1 shows that the manufacturer sells the product to one independent retailer and directly to customers. Customers can buy the products from an online channel or retail channel, according to their preferences. Customers can purchase the product from a retail channel with price \( p_r \), or purchase the product from online with price \( p_o \). The customers will buy the product when the customer surplus is larger than 0.

One issue address in this paper is supply chain disruption can change customers' preference in buying the product from a retail channel or online channel. Customers know that there is a disruption in the supply chain before the customer has had time to try to buy products in the retail channel or online channel. So that customer preferences will be affected. Thus, customer preferences will affect the demand on each channel.
3. Model Development

In this paper, disruption results in changes in customer preferences so that demand on each channel also changes. Therefore, we develop the demand portions in the retail channel where demand portions channel is depending on customer preferences in the channel. The portion of customers who buy products in the retail channel, according to [14] and [15] is:

\[
\theta = \frac{E(x_1 + x_2 + \ldots + x_m)}{a_m} = \frac{\sum_{j=1}^{m} P(p_r - p_d \leq \xi_j)}{a_m} = \frac{a_m P(p_r - p_d \leq \xi_j)}{a_m} = P(p_r - p_d \leq \xi_j) \tag{1}
\]

Parameter \(\xi_j\) describe the product brand loyalty. If the value of \(p_r - p_d < \xi_j\) customer will consider buying the product in the retail channel, but if the value of \(p_r - p_d \geq \xi_j\) Customers will consider buying the product in an online channel.

Because \(\xi_j\) is uniformly distributed on \([a,b]\) in which -1 ≤ a ≤ 0 and 0 ≤ b ≤ 1, therefore

\[
\theta = \begin{cases} 
1, & p_r - p_d \leq a \\
\frac{b - (p_r - p_d)}{b - a}, & a < p_r - p_d < b \\
0, & p_r - p_d \geq b 
\end{cases} \tag{2}
\]

The customer only can buy the product in either retail channel or online channel in the system, therefore the consumer portion in retail channel become:

\[
\theta = \frac{b - (p_r - p_d)}{b - a} \tag{3}
\]

The customer portion then develops by considering disruptions that affect customer preferences. The disruptions parameter using parameter by [16]. The disruption probability denoted by \(\emptyset\) and the disruption proportions denoted by \(\lambda\). According to [13], disruption can be caused by various reasons such as a breakdown in channels, customers rushing to e-channel (and therefore sales website going out of reach due to overload), legal impositions, terrorist attacks, and so forth, channels may go disrupted. Therefore, the number of demands in the retail and online channels will also change. The difference between initial customer portions and customer portions affected with disruption will be the new value of customer portions. Therefore, the customer portions with disruptions model in the retail channel:

\[
\theta_a = \theta_o - \left(\frac{b - (p_r - p_d)}{b - a}\right) \lambda \emptyset) \tag{4}
\]

The next step is to formulate the demand function in the DCSC system. The demand model consists of two demand model. First is the traditional retail channel demand model and online channel demand model. The demand model reference using a demand model by [17]. Each demand function will be explained below:

3.1. Demand Model in Retail Channel

\[
D_r = \theta_a D_{\text{max}} - \alpha_1 p_r + \beta_1 p_o \tag{5}
\]

\[
D_r = \left(\theta_o - \left(\frac{b - (p_r - p_d)}{b - a}\right) \lambda \emptyset\right) D_{\text{max}} - \alpha_1 p_r + \beta_1 p_o \tag{6}
\]
3.2. Demand Model in Online Channel

\[ D_o = (1 - \theta_o)D_{max} - \alpha_2 p_o + \beta_2 p_r \]  

(7)

\[ D_o = \left(1 - \left(\theta_o - \left(\frac{b - (p_r - p_o)}{b - a}\right)\lambda \phi\right)\right)D_{max} - \alpha_2 p_o + \beta_2 p_r \]  

(8)

In the function (5), (6), (7), and (8) the retail channel and online channel denoted by subscript r and o, respectively. The demand function (5) is the retail channel demand function, and (7) is the online channel demand function in DCSC structure. This model is already considering the customer portions and the interplay between retailers and online channels. The demand or demand portions in the retail channel is denoted by \( \theta \). Customer portions with disruption (4) were then substituted in (6) and (8). Therefore, demand function (6) and (8) is a demand function that already considers channel disruption in which the disruptions affect the customer preferences and customer portions. \( D_{max} \) is a potential customer if the product is free of charge. The share demand or demand portions for a retail channel is denoted by \( \theta_a \), and the rest \( 1 - \theta_a \) goes to the online channel, when \( p_r \) and \( p_o \) are zeros. \( \alpha_1 \) and \( \alpha_2 \) are the coefficients of the self-price elasticity of \( D_r \) and \( D_o \), respectively. The cross-price sensitivities \( \beta_1 \) and \( \beta_2 \) reflect the degree to which the products sold via the two channels are substitutes.

4. Numerical Example

We present some numerical examples to illustrate the effect of disruption on customers' preferences. When the customers’ preferences changes, the demand portions each channel will changes too so that demand in each channel will be affected too. The initial parameter is used in-demand model using parameter by [14], [15], and [16]. The initial parameters are \( D_{max} = 600 \), \( a = -0.2 \), \( b = 0.2 \), \( \beta_1 = 0.35 \), \( \beta_2 = 0.75 \), \( \alpha_1 = 2 \), \( \alpha_2 = 2.5 \), \( \lambda = 0.3 \), \( \phi = 0.5 \), \( p_r = 0.772 \), \( p_o = 0.701 \). Numerical example to find the optimum demand by maximizing the demand for both channels with considering the dual channel system. In this numerical example, optimization is carried out separately between offline channel and online channel. The initial solution is \( p_r = 0.972 \) with demand total in retail channel \( D_r = 359 \) and for online channel \( p_r = 0.901 \) with demand total in online channel \( D_o = 329 \).

The relationship of customers’ demands in DCSC and customers demand portions according to customers preferences after channel disruptions shown in Figure 2 and Figure 3,
From figure 2 we can see that there is a trade-off between demand in online channel and demand in the offline channel when $\emptyset = \pm 0.5$. When the probability of disruption below $\pm 0.5$, the retail channel generates higher demand than the online channel. But when the probability of disruption is high, more than $\pm 0.5$, online channel generates higher demand than the retail channel.

![Figure 3. Comparison between demand in online channel and demand](image)

From figure 3, we can see that there is a trade-off between demand in online channel and demand in the offline channel when $\lambda = \pm 0.3$. When disruption proportion below $\pm 0.3$, the retail channel generates higher demand than the online channel. But when disruption proportion is high, more than $\pm 0.3$, online channel generates higher demand than the retail channel.

5. Conclusion

This paper is considered a dual-channel supply chain system with a single product, one manufacturer, and one independent retailer. The manufacturer owns and manages an online channel. Customers can purchase the product either from the retail channel or online channel, according to their preferences. We study the condition when channel disruption happens, customers will change their preferences depends on disruptions probability and proportions. Therefore, the demand in the retail channel and online channel will change. From a numerical example, it is shown that the retail channel will be lost demand more than an online channel if the probability and proportions of disruption high.

For further studies, this model needs to develop further so that we can see the effect of channel disruption in customer preferences in the retail channel and online channel profit. Secondly, this paper can consider a different scenario in maximizing profit each channel and DCSC profit as a whole system. The retail and online channels can choose the most appropriate strategy in their channel.

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