The Impacts of Logistics Services on Short Life Cycle Products in a Global Supply Chain

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 **Abstract**

In this study, we construct a three-echelon supply chain consisting of one global supplier, one local seller and one logistics service provider for products with short life cycles. We study the trade-off between transportation time and cost in a global supply chain. We find that the global supplier should decide the transportation mode when selling relatively short life cycle products, and the local seller should always decide the transportation mode when selling relatively long life cycle products. Our results provide important insights into how to manage logistics service leadership, enhance consumer surplus and social welfare in a global supply chain.

**Keywords:** Short life cycle products, global supply chain, logistics services provider.

# Introduction

Short life cycle (SLC) products such as fashion, food, seasonal products and consumer electronics and corresponding accessories have extensive business opportunities in global supply chains (Jiang 2017) and currently account for a considerable level of trade (Chen 2018). The life cycles of SLC products are typically between three and six months, so timely logistics services are essential (Patil et al. 2010). The logistics time for SLC products can directly influence the economic performance of supply chain members. The trade-off between the cost and logistics speed is of primary concern in supply chain management (Kurawarwala and Matsuo 1996; Chan et al. 2009; Wang et al. 2015; Hu et al. 2018). For example, delivering SLC products by air cargo may not be possible as the transportation costs may be too high, but ocean shipping may also not be suitable as the logistics time will be too long considering the short product life (Wen et al. 2019). In this paper, our major aim is to evaluate the impact of logistics services on SLC products in a global supply chain.

Logistics services are essential in international trading (Choi et al. 2016). This is particularly important for SLC products. Recently, the logistics in a global supply chain are becoming more efficient when transportation modes are more diversified than before (Wen et al. 2019). For example, China recently launched the Railway Express between Asia and Europe. The aim of the Railway Express is to fully connect cities along the network. Traditional ocean transportation from China to Europe can take about 60 days, whilst the China Railway Express will make the journey in 12-14 days, given that the high-speed trains can shorten the waiting time by more than two thirds (Yan 2018). In terms of cost, taking the example of shipping pork from Europe to China, the logistics cost per kilogram is US$0.71 for ocean shipping, US$1.7 for the China Railway and US$2.8 for air cargo (Cai 2016).

Developing a fast and efficient global supply chain system is extremely challenging. First, the logistics mode is based on international trading rules and is decided either by the supplier or the seller, and differences in logistics outputs can arise from different service leadership approaches (Lun et al. 2015). Thus, clearly establishing who should determine transportation modes in supply chains is essential. Second, consumer welfare and social welfare have been important objectives for responsible firms. Many large firms release corporate social responsibility (CSR) reports in the annual financial statement in which consumers and society are the key performance indicators. Thus, businesses in the responsible firms aim not only to make profits, but also to enhance consumer and social welfare. Methods of enhancing consumer and social welfare are important indicators for firms and policymakers when examining responsible supply chain performance. Third, to achieve better performance, the collaboration mechanisms among various members in the global supply chain should be identified.

In this paper, based on the above three challenges, we examine the impacts of the leadership of supply chain, consumer and social welfare, and coordination. We examine the logistics services for SLC products, and to the best of our knowledge, this is the first study to do so. Our research questions (RQs) are as follows.

**RQ1:** Will it be more efficient to let the seller decide the logistics service of SLC products, rather than the supplier?

**RQ2:** *What are the optimal contracts for the logistics service provider to deliver SLC products?*

**RQ3:** *What mechanism can improve the global supply chain performance?*

In this study, we examine the effects of logistics services on SLC products in a global supply chain. Based on actual global business practices, we consider a three-echelon supply chain consisting of one global supplier, one local seller and one logistics service provider (LSP). The seller orders products from the supplier and sells the products to local consumers. The LSP is responsible for transporting products from the supplier to the seller. We consider two modes: Mode 1, in which the local seller decides the transportation mode (i.e., the logistics speed), and Mode 2, in which the supplier decides the transportation mode. The main contributions of this study are as follows. First, we find that Mode 1 is always superior to Mode 2 for all supply chain members in terms of profit, consumer surplus and social welfare when there is no arrival time requirement. However, with the constraint of arrival time, we find that if the products must arrive earlier, Mode 2 is more effective in increasing the seller’s profit and enhancing social welfare, but not the supplier’s profit. Thus, the product life cycle is a key for supply chain members to decide which transportation mode should be used. Second, using Mode 1 could induce the LSP to provide a less expensive contract, and improve the profits of the LSP, supplier, and seller, namely, achieve an all-win outcome. Third, both revenue sharing and logistics cost sharing contracts are found to be helpful in achieving supply chain coordination.

This paper is organised as follows. In Section 2, we review the relevant literature. Section 3 introduces the base model. Section 4 presents an analysis of logistics service leadership. In Section 5 we evaluate consumer surplus and social welfare, and we explore three extensions in Section 6. Section 7 concludes the paper with suggestions for managerial insights and future research directions. All of the technical proofs are provided in the Appendix.

# Literature Review

Our study relates to the extensive supply chain management literature that focuses on third-party LSPs. Several review papers have been published, such as those of Selviaridis and Spring (2007), Marasco (2008) and Aguezzoul (2014). The majority of these studies take an empirical approach to evaluate the role of third-party LSPs in supply chains, while there are also some analytical studies conducted. Considering we take an analytical approach, the focus of our review below is on these analytical studies.

Liu and Wang (2015) study quality control in the logistics service supply chain with various risk attitudes. They model a service supply chain consisting of one logistics service integrator (LSI) and one functional LSP (FLSP). They find that the LSI is more willing to work with a risk-seeking FLSP to achieve the possibility of low supervision and higher compliance. Govindan and Chaudhuri (2016) examine the logistics risk of using a third-party logistics provider in supply chains, and find that manufacturing companies in a country with a low logistics capacity can achieve higher performance benefits. Liu et al. (2018b) evaluate the role of demand information updating and fairness preference in a two-echelon service supply chain consisting of one LSI and multiple FLSPs. They identify the optimal solution for service levels and further use real data to verify the analytical results. Liu et al. (2018c) evaluate the impact of peer-induced fairness concerns on order allocation in logistic service supply chains. Based on the literature, such as the study by Liu and Wang (2015), we also consider that the LSP plays a critical role in quality design. However, unlike the above literature, we examine logistics service leadership and explore the effect of transportation time on global supply chain performance.

Logistics services for products with SLC are examined in our study. These products exhibit a steep decline in market demand (Goldman 1983), leading to a time-dependence market demand in supply chain and logistics management (Kurawarwala and Matsuo 1996). Time dependence can refer to the effort made to either extend the time period of the product in the market or to get it to the selling point earlier than expected. Chen et al. (2008) use a consumer choice model to capture the effect of delivery lead time on consumers’ decisions. Our study is similar to Cai et al. (2010) and Cai et al. (2013). Cai et al. (2010) study a two-echelon supply chain consisting of one producer and one distributor. The producer first decides the wholesale price, and then the distributor decides the shipping quantity and effort required to keep the product fresh. They consider the transportation cost to be incurred by the distributor. The market demand depends on the product freshness level and the retail price. They identify the value of coordination in efforts to keep the products fresh. Cai et al. (2013) examine the impact of a third-party logistics provider on fresh products transportation in a three-echelon supply chain. They assume that the producer pays the transportation cost and bears the risk of product deterioration during transportation. They assume the market demand depends on the product freshness level and the retail price. After the product arrives at the market, the producer determines the wholesale price for the distributor. A wholesale-market clearance contract between the producer and the distributor is proposed, along with wholesale-price-discount sharing between the producer and the third-party logistics provider. They find that these two contracts can achieve coordination. Logistics speed affects product freshness and further influences market demand. Both Cai et al. (2010) and Cai et al. (2013) consider that the market demand depends on product freshness level when it reaches the market, namely, if the product has a higher degree of freshness, the market demand is higher. As the higher degree of product freshness depends on the speed of logistics, this setting is similar to ours in which the market demand for the short life cycle products depends on the speed of logistics.

Lu et al. (2017) examine the carrier portfolio for shipping seasonal products. They consider that for the seasonal products, earlier arrival leads to a higher price in the market, but faster logistics services are more costly. We follow this assumption in our model and consider the cost of logistics service is increasing in the speed of logistics. Moreover, Lu et al. (2017) consider that the selling price declines over time but differently we consider the market demand drops over time in terms of product arrival time. Xiao and Jin (2012) investigate the lead-time dependent market demand for supply chain coordination. Pekgün et al. (2016) study the lead-time sensitive demand in centralised and decentralised competition environments. They find that the duration of lead time negatively influences market demand. If lead-time competition is intensive, the first-mover advantage may not only increase profits, but can also influence the equilibrium strategy. Our study also follows the assumptions of Xiao and Jin (2012) and Pekgün et al. (2016). We assume that the lead time of transportation is sensitive to market demand. Specifically, we consider that the market demand is dependent on logistics speed. If the supply chain member decides to use the quicker transportation mode, the market demand is higher. This assumption is well consistent with the practices of SLC products. For instance, to ensure the fresh fruits can sell well in the target market, the supply chain member transports them via aircrafts and they could be arrived as early as possible (Cui and Song 2018).

This paper is relevant to channel leadership[[1]](#footnote-1). Channel leadership affects supply chain performance (Choi et al. 2013; Fang et al. 2017). Li et al. (2016a) consider models in which a third-party services provider is managed by either the seller or the manufacturer. They find that the service cost advantage encourages supply chain members to manage third-party services providers, and a higher level of market sensitivity leads to a greater service cost advantage. They verify the robustness of their analytical results with service providers’ behaviour based on a survey-based empirical study. Li et al. (2016b) examine the impact of channel leadership (i.e. supplier-leader and manufacturer-leader games) on logistics systems reliability enhancement in the supply chain. They find that supply chain members prefer to make the decision earlier than the other. They identify the coordination mechanisms for both channel leadership and find that the supplier-leader game may benefit the supply chain more in terms of coordination when the enhancement cost is sufficiently low, and the manufacturer-leader game is more desirable for supply chain coordination when the enhancement cost is sufficiently high. Shen et al. (2017) study the optimal supply chain structure and channel leadership about deciding the design innovation service. They find that for two kinds of design innovation service leadership (the retailer or the manufacturer decides), the profit sharing contract can coordinate the supply chain but the revenue sharing contract cannot.

This paper examines one of the topics in global supply chain management. The important topics on global supply chain management include tariffs/duties, currency exchange rate, corporate income tax, logistics, inventory cost, worker skills and more (Meixell and Gargeya 2005). In this paper, we focus on examining the impacts of logistics on global supply chains in which the third-party logistics service provider may provide the different transportation choices such as ocean shipping, railway transportation, and air logistics. Nagurney et al. (2015) propose global supply chain network models with multiple manufacturers and competing freight service providers. Their models deal with different types of transportation modes and maximize the individual profits by considering quality and price levels. Choi et al. (2019) examine the value of air logistics in a global supply chain. Air logistics could realize the supply chain members to order and replenish products quickly. They identify the condition of achieving channel coordination with air logistics when the supply chain members are risk averse.

Table 1 shows the positioning of this paper.

**Table 1.** Positioning of this paper

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Paper | Third-party logistics service | Time-sensitive market demand | Service leadership | Channel coordination |
| Chen et al. (2008) |  | ✓ |  |  |
| Cai et al. (2010) |  | ✓ |  | ✓ |
| Xiao and Jin (2012) |  | ✓ |  | ✓ |
| Cai et al. (2013) |  | ✓ |  | ✓ |
| Liu and Yang (2015) | ✓ |  |  |  |
| Liu et al. (2015) | ✓ |  |  |  |
| Nagurney et al. (2015) | ✓ |  |  |  |
| Govindan and Chaudhuri (2016) | ✓ |  |  |  |
| Li et al. (2016a) | ✓ |  | ✓ |  |
| Li et al. (2016) |  |  | ✓ | ✓ |
| Pekg et al. (2016) |  | ✓ | ✓ |  |
| Lu et al. (2017) | ✓ | ✓ |  |  |
| Shen et al. (2017) |  |  | ✓ | ✓ |
| Liu et al. (2018b) | ✓ |  |  |  |
| Liu et al. (2018c) | ✓ |  |  |  |
| Choi et al. (2019) | ✓ |  |  | ✓ |
| **Our paper** | ✓ | ✓ | ✓ | ✓ |

# The Model

We consider a make-to-order supply chain consisting of one global supplier, one local seller and one LSP. The seller orders products from the global supplier and sells them to local consumers. The LSP is responsible for delivering products from the global supplier to the seller. The SLC product has steep-decline market demand (Goldman 1983). Thus, we assume that the market demand for SLC products is time-sensitive, i.e., the arrival time influences market demand (the earlier the product arrives, the higher the market demand). Such delivery time dependent market demand can also be supported by the extant literature like Chen et al. (2008), which proves the delivery lead time is always counted in consumer’s valuation of the product. We use the speed of logistics to represent the arrival time and delivery lead time. We denote the speed of logistics as *t* (), and a high *t* implies a high speed of logistics[[2]](#footnote-2). Taking the transportation time between Asia and Europe as an example, air cargo has a high *t*, the railway express has a moderate *t* and ocean shipping has a low *t* (Goh and Goettig 2018). If the arrival time is earlier, namely, it is in the earlier stage of the product life cycle and the product has a higher degree of stylishness, then the market demand is higher (Cai et al. 2010; Cai et al. 2013). The market demand is *q*, and the unit retail price is *p*. The market demand of products with SLC is , where refers to the market size and  is the coefficient of time-to-market (TTM) on market demand[[3]](#footnote-3).

The unit production cost is *c*, and the unit wholesale price is *w*. The unit logistics service fee charged by the LSP is *s*. The speed of logistics influences not only the arrival time but also the logistics cost (Kurawarwala and Matsuo 1996; Cai et al. 2013, Sun et al. 2015). For example, air cargo has a high *t* so its corresponding logistics cost is also high, the railway express has a moderate *t* and a moderate logistics cost and shipping has a small *t* and thus its logistic cost is also small. We consider that the logistics cost is convex and increasing in the speed of logistics *t*. For example, the logistics cost of per kilogram pork is US$0.71 for ocean shipping (58 days), US$1.7 for the China Railway (13 days), and US$2.8 for air shipping (2 days) (Cai 2016). It can be seen that the logistics cost is increasing in the speed of logistics and well fit the quadratic cost function. Consistent with real logistics services, the transportation price has quantity discounts, i.e., the discount increases if the shipping quantity is larger (Ke et al. 2014). We consider that the unit transportation price is , where  () is the coefficient of transportation speed and quantity discount, i.e., a high  implies that the LSP offers an expensive contract[[4]](#footnote-4). The LSP pays the unit operating cost of transportation, which is , where  implies the coefficient of the logistics service cost. We denote members’ profit as , where , i.e., seller, supplier and LSP, respectively. We summarise our notation in Table 2.

**Table 2.** Notation used in this paper

|  |  |
| --- | --- |
| Variable | Meaning |
| *t* | Speed of logistics |
| *q* | Market demand |
|  | Unit retail price |
| *c* | Unit production cost |
| *w* | Unit wholesale price |
|  | Market size |
|  | Coefficient of time-to-market on market demand |
|  | Unit transportation price |
|  | Coefficient of transportation speed and quantity discount, where  |
|  | Unit operating cost of transportation |
|  | Coefficient of logistics service cost, where  |
| *R, S, L* | Seller, supplier and logistics service provider |
|  | Profit for *i*, where *i = R,S,L*.  |
|  | Revenue sharing portion for *i*, where *i = R,S,L*. |
|  | Logistics cost sharing portion the seller pays |
| CS | Consumer surplus |
| SW | Social welfare |

# Logistics Service Leadership

In this section, we investigate the effect of logistics service leadership on supply chain performance. The logistics service leader decides the mode of transport, and the decision of who is appointed leader is important and strategic in the supply chain (Harps 2003). This decision is critical to the success of the SLC product as its TTM significantly influences consumer purchases. We have two modes: in Mode 1 the seller decides the transportation mode, and in Mode 2 the global supplier decides the mode. In later sections, we refer to these simply as 1 and 2. Figure 1 shows the game sequence of Mode 1 and Mode 2.



**Figure 1.** Game sequence of Mode 1 and Mode 2.

As a remark, in this section, we assume that the LSP does not need to make a decision on the transportation contract, i.e., the coefficient of transportation speed and quantity discount is exogenous. In the extended model (Section 6), we assume that the LSP needs to make a decision on the transportation contract, namely, the coefficient of transportation speed and quantity discount  is endogenous.

* 1. **Mode 1: The seller decides the transportation mode**

When the seller decides the transportation mode, the game sequence is as follows. First, the LSP determines the transportation contracts. Second, the global supplier offers the supply contract to the local seller. Third, the seller decides on the transportation mode and the retail price. Under Mode 1, the profit functions of the seller, supplier and LSP are:

, (4.1)

 and (4.2)

. (4.3)

To ensure the LSP has the incentive to do business, we consider . As our problem is a Stackelberg game, we use a backward induction approach to solve the optimal solutions. By jointly solving and satisfying the two-first-order conditions of this programme, we obtain the optimal wholesale price, the optimal logistics speed, the optimal retail price, and the corresponding optimal sales quantity, as follows.

, , , and .

By substituting the above optimal solutions into profit functions, we obtain the following optimal profits of the seller, the supplier and the LSP.

,

, and

 .

The logistics speed significantly influences the LSP’s contract. We differentiate  with respect to , and we find that . Thus, the optimal logistics speed  is decreasing in .

* 1. **Mode 2: the supplier decides the transportation mode**

In this subsection, we assume that the global supplier decides the transportation mode. The game sequence is as follows. The LSP first determines the transportation contracts, then the supplier decides on the transportation mode and offers the supply contract to the local seller. The seller then determines the retail price. Under Mode 2, the profit functions of the seller, supplier and LSP are as follows:

, (4.4)

 and (4.5)

. (4.6)

Similar to Section 4.1, we use a backward induction approach to solve the optimal solutions in Stackelberg game. By jointly solving and satisfying the two-first-order conditions of this programme, the optimal solutions can be obtained. The optimal wholesale price, logistics speed and retail price, and the corresponding optimal sales quantity are as follows:

, , and , and .

By substituting the above optimal solutions into profit functions, we obtain the following optimal profits of the seller, the supplier and the LSP:

,

, and

.

Similar to Mode 1, the logistics speed can significantly influence the LSP’s contract. We differentiate  with respect to , and obtain . Thus, the optimal logistics speed is decreasing in . Comparing  with , we find that , i.e., the optimal logistics speed in Mode 1 drops more quickly than in Mode 2 in terms of contract coefficient .

* 1. **Analytical Comparison**

In this subsection, we compare supply chain performance between Modes 1 and 2, and obtain Propositions 1 and 2.

***Proposition 1.*** *Without the constraint of logistics speed*[[5]](#footnote-5)*, we have**(i) , (ii), (iii) If ,; If , (iv) .*

Proposition 1(i) implies that if the local seller (global supplier) decides the transportation mode, the quicker (slower) mode is likely to be selected. This result implies that the local seller as the transportation mode decision maker will use the quicker transportation mode and push the products to the market earlier so that a larger market demand can be realised (as shown in Proposition 1(iv)), whereas the supplier as the transportation mode decision maker will use the slower transportation mode. This is an important finding for supply chain management. To speed up the logistics, the local seller should take the leadership position to decide the transportation mode, instead of the supplier. Therefore, logistics service leadership, which influences the transportation mode selection, is critical to the development of logistics services for the SLC products market.

From Proposition 1(ii), it is intuitive that the wholesale price is higher in Mode 2, because the global supplier pays for transportation. From Proposition 1(iii), if the coefficient of transportation speed and quantity discount is moderate, the retail price is more expensive in Mode 1, whereas if these are relatively large, the retail price is more expensive in Mode 2. In other words, if the coefficient of transportation speed and quantity discount is high, the seller in Mode 2 (when the global supplier decides the mode of transport) has to offer a higher retail price than in Mode 1 to compensate for the high wholesale price; if the coefficient of transportation speed and quantity discount is low, the seller in Mode 1 must offer a higher retail price than in Mode 2 to compensate for the high transport costs. This interesting finding implies that when the transport cost is high, letting the seller decide on the transportation mode is more beneficial for the entire transaction. Proposition 1(iv) indicates that with Mode 1 more is sold in the market than with Mode 2. This is consistent with previous findings. The seller would be more willing to use the quicker transportation mode to satisfy the larger market demand.

***Proposition 2.*** *Without a constraint on logistics speed, we have (i) , (ii) , (iii) .*

From Proposition 2, we can see that Mode 1 is always superior to Mode 2 for all supply chain members. The potential explanation is that the seller’s profit is more sensitive to demand, and TTM of goods is heavily influenced by the decision of transport speed. From the profit perspective, it is always optimal to let the seller decide on the transportation mode. This is a result of the unique characteristics for countries in Africa where the suppliers are economically vulnerable. Based on the analytical results above, obviously letting the local seller determine the transportation mode is more efficient than the supplier. The local sellers (even though they are impoverished) should take a leadership position in deciding on the transportation mode.

# Consumer surplus and social welfare

CSR is now the important key performance indicator (KPI) for responsible firms. In terms of CSR, firms aim not only to make profits, but also to enhance consumer surplus and social welfare. In this subsection, we quantify consumer surplus (CS) and social welfare (SC). We examine which transportation mode is more efficient to generate higher consumer surplus and social welfare.

We define  and  as the consumer surpluses in Mode 1 and Mode 2, respectively. Consumer surplus is a part of social welfare. Here, we aim to evaluate consumer surplus when adopting Mode 1 and Mode 2, respectively. Followed by Xiong et al. (2016), the consumer surplus function can be expressed as follows:

, where *l=1,2*.

We substitute the results in Section 4 and have

, and

.

We then investigate social welfare as the sum of consumer surplus and firm profit (Su 2009). We denote social welfare as , where *l = 1,2*. We substitute the optimal retail prices and service quality level with the social welfare functions. We have

 , and

.

To compare the consumer surplus and social welfare in Modes 1 and 2, we have Proposition 3.

***Proposition 3.*** *(i) (ii) .*

Proposition 3 indicates that adopting Mode 1, i.e., when the seller decides the transportation mode, can lead to the higher consumer surplus and social welfare. When considering time-sensitive market demand, the seller should always be the leader that decides the transportation mode. The lower wholesale price and transportation cost mean that the consumers under Mode 1 can enjoy both a lower retail price and a shortened lead time. This, intuitively, brings more consumer surplus. Additionally, social welfare is also better in the case under which when the seller decides the transportation mode. Consumer surplus and social welfare improvements are the keys for government and companies. Using Mode 1 definitely performs better than Mode 2 from consumer surplus and social welfare perspectives. This result implies that no matter the local sellers are the start-up companies with capital constraint or the large companies who have healthy cash flow, the transportation mode decided by the local seller is always a dominating strategy.

We conduct numerical studies using real data on delivering pork from Europe to China (Cai 2016). Recall that the logistics cost of per kilogram is US$0.71 for ocean shipping (58 days), US$1.7 for the China Railway (13 days) and US$2.8 for air shipping (2 days). In our numerical analysis in Figures 2-6, we input the real data of transportation cost *s* and let $t=\frac{90 ×0.1}{real data of lead time } $. This setting would ensure the optimal solutions’ conditions are satisfied but would not influence the comparison results.

**Figure 2.** The sales quantities with various transportation modes

|  |  |
| --- | --- |
| $$π\_{R}$$**Figure 3.** Seller’s profit with various transportation modes | $$π\_{S}$$**Figure 4.** Supplier’s profit with various transportation modes |
| $$π\_{L}$$**Figure 5.** LSP’s profit with various transportation modes | $$CS$$**Figure 6.** Consumer surplus with various transportation modes |

|  |
| --- |
| **Remarks:** We set $a=20$, $c=5$, $β=0.3$, real data and  90/real data\*0.1. |

As shown in Figures 2-6, if the coefficient of TTM on market demand is large, air shipping encourages the seller to order more, and is more desirable than other transportation modes in terms of profits and consumer surplus. Railway shipping is not a good choice for the supplier and the seller, but it is beneficial to the LSP. Thus, if the pork is of extremely good quality and freshness will significantly influence its quality (i.e., the coefficient of TTM on market demand is large), air shipping is the best transportation mode. Compared with the optimal solutions, from the perspectives of profits and consumer surplus, Mode 1 is always better. This is consistent with the analytical results from Propositions 2 and 3. Thus, the supply chain members should negotiate with the LSP for the efficiency of logistics service so that they can receive better performance.

# Extensions

In this section, we extend our model with three perspectives: 1) logistics service contract design, 2) the logistics speed constraint and 3) supply chain coordination.

* 1. **Logistics service contract design**

In this subsection, we examine the optimal logistics service contract design by the LSP. We consider  as endogenous. This setting allows us to explore how the LSP should design the logistics contract. We can find the optimal solutions for Modes 1 and 2 using backward induction.

For Mode 1, by jointly solving and satisfying the two-first-order conditions of this programme, we obtain the optimal wholesale price, the optimal retail price, the optimal logistics speed and the optimal contract as follows:

, , , and .

Substituting the above optimal solutions into the profit functions, we obtain

,

, and

.

For Mode 2, by jointly solving and satisfying the two-first-order conditions of this programme, we obtain the optimal wholesale price, the optimal retail price, the optimal logistics speed and the optimal contract as follows:

, , , and .

Substituting the above optimal solutions into the profit functions, we obtain

,

, and

.

To compare Mode 1 with Mode 2, when , the findings are as follows.

***Proposition 4.*** *(i) If , ; If , . (ii) . (iii) , (iv)*

***Proposition 5.*** *(i) . (ii) . (iii) .*

Propositions 4 and 5 indicate the analytical comparison when  is endogenous. The results are the same as when  is exogenous. Mode 1 is more desirable for both the seller and supplier. Recall that a high (low)  implies that the logistics service is expensive (cheap). Proposition 4(iv) indicates that in Mode 1, the LSP would offer a less expensive contract (i.e. a smaller **) than in Mode 2. This provides an important managerial insight into logistics service contract design in international trading. In Mode 1, the LSP can use a less expensive logistics contract to induce the seller to deliver more products, thus enhancing its own profit. This increased market demand also benefits the global supplier, as it can enjoy both an increase in profit and reduced potential risks. This argument is consistent with Proposition 5. Using Mode 1 could induce the LSP to provide a less expensive contract, and improve the profits of the LSP, supplier, and seller, namely, achieve an all-win outcome. These results are consistent with Proposition 2 when  is exogenous. Thus, no matter the coefficient of transportation speed and quantity discount  is exogenous or endogenous, the outcomes of comparing the seller’s and supplier’s profit performance will not be affected because the LSP is the first mover to make decisions in the supply chain. As a remark, in the following sections, for tractable results, we still assume the coefficient of transportation speed and quantity discount  is exogenous.

* 1. **With the constraint of arrival time**

In this extension, we consider a limitation in the arrival time, i.e., the products must arrive at the seller’s store before a particular date. This constraint is critical for SLC products. For example, cultural textile and apparel products for special events in a local market have an arrival time constraint, as they must arrive in the local market before the event or festival, and fresh fruit and vegetables have short expiry times and must be sold before they spoil. Thus, we have the arrival time constraint . As  and  are concave in *t*, if , the optimal solutions of *t* equal to , whereas if , the optimal solutions is still .

In Mode 1, when , we can have , , and . The corresponding optimal profits are , , and ; whereas when , the optimal solution is the same as in Section 4.1.

In Mode 2, when , we can have , , and . The corresponding optimal profits are ,, and . whereas when, the optimal solution is the same as in Section 4.2.

***Proposition 6.*** *(i) When, , ,, ,, .**(ii) When , if ,; otherwise, .,, ,,if ,, otherwise, . (iii) When , the results are same as Propositions 1 and 2.*

Proposition 6 indicates the results when considering an arrival time constraint. When there is such a constraint, Mode 1 is not always better than Mode 2 from the supply chain members’ profit perspective. It depends on the value of . Specifically, if the product has an extreme SLC (i.e. **), the optimal retail price, the optimal wholesale price and the optimal logistics speed are the same in Mode 1 and Mode 2. The profits of the seller and the supplier are not different between Modes 1 and 2 because of the logistics expense responsibility. When the product life cycle is relatively large, Mode 1 is still more desirable than Mode 2 from the seller’s profit perspective. Thus, the supplier may be forced to decide on the mode of transport when the product life cycle is relatively short (Tong et al. 2018).

With the constraint of arrival time, we can obtain findings for the optimal consumer surplus and social welfare, as follows.

***Proposition 7.*** *(i)When, , . (ii)When , , . (iii) When, the same with Proposition 3.*

With the constraint of arrival time, we find that the consumer surplus will not be worse in Mode 1 than it is in Mode 2. However, social welfare is better in Mode 2 if the constraint of arrival time is large. These results are different from the case without arrival time constraints.

$$\overbar{t}$$

$$q$$

$$t^{1\*}$$

$$t^{2\*}$$

**Figure 7.** Impact of arrival time constraint on sales quantities

|  |  |
| --- | --- |
| $$\overbar{t}$$$$π\_{R}$$$$t^{1\*}$$$$t^{2\*}$$**Figure 8.** Impact of arrival time constraint on seller’s profit | $$\overbar{t}$$$$π\_{S}$$$$t^{2\*}$$$$t^{1\*}$$**Figure 9.** Impact of arrival time constraint on supplier’s profit |
| $$\overbar{t}$$$$CS$$$$t^{1\*}$$$$t^{2\*}$$**Figure 10.** Impact of arrival time constraint on consumer surplus | $$\overbar{t}$$$$SW$$$$t^{1\*}$$$$t^{2\*}$$**Figure 11.** Impact of arrival time constraint on social welfare |

|  |
| --- |
| **Remarks:** We set *a=10*, *c=5*, $μ=0.5$, $β=0.2$ and  and $\overbar{t}$ range from 1.1 to 1.65 for Figures 1 to 4. All parameters are set with respect to the model assumptions and fit real world situations. |

Figures 7-11 show the supply chain performance with the arrival time constraint. When the arrival time constraint is very restrictive (i.e., the product has a relatively SLC), the sales quantity, the consumer surplus is indifferent between Modes 1 and 2, but the seller’s profit and social welfare in Mode 2 are larger than in Mode 1. This provides an important insight into extremely SLC products if there is a logistics speed constraint. Recall the finding in Proposition 6(i) that if the product has an extremely SLC, although the supplier’s profit in Mode 1 is always better than Mode 2, using Mode 2 has the greater profit performance for the seller and better social welfare for the local market, which means Mode 2 may be a better strategy supply chain management with an arrival time constraint.

* 1. **Supply chain coordination**

In this subsection, we examine a centralised supply chain and the achievability of channel coordination. We denote SC as the supply chain system. The supply chain profit function is:

. (6.1)

Taking the first and second differentiations of *p* and *t*, respectively, we can jointly solve and satisfy the two-first-order conditions of this programme, and obtain the optimal retail price and logistics service in the centralised system:

 and .

Substituting the optimal retail price and logistics service into the channel profit function, we obtain the optimal channel profit as follows.

 .

***Proposition 8.***

*(i) If , ; If , ; If , ; If , . (ii) . (iii) .*

From Proposition 8(i), we can see that when is sufficiently small (), the centralised price is higher than the decentralised prices, whereas whenis sufficiently large (), the centralised price is lower than the decentralised prices. We find that when is sufficiently moderate, (), . These findings imply that there is a trade-off between the coefficient of enhancing arrival time on market demand and the coefficient of the cost of enhancing logistics speed, which is extremely important in global supply chain management when considering the participation of economically vulnerable suppliers who are capital constrained. Proposition 8(ii) shows that the optimal logistics service quality in the centralised channel is greater than in the decentralised channel, due to the superior performance (i.e. supply chain profit) in the centralised system in terms of logistics. In other words, it is wise to choose a faster logistics speed mode in a centralized system. Proposition 8(iii) indicates that the centralised supply chain performance is always better than the decentralised performance. This result motivates us to explore how the supply chain system can achieve channel coordination and thus enhance the performance of the centralised system.

In this study, we propose to use revenue sharing and logistics cost sharing contracts for coordination in a three-echelon supply chain. The revenue sharing contract is widely used in supply chain systems (Cachon and Lariviere 2005). We assume that the revenue sharing portions are decided by the centralised planner. We represent revenue sharing by RS. In Mode 1, the seller decides the transportation mode. We assume the global supplier can collect  portion of the seller’s revenue and the LSP collects  portion of the seller’s revenue.

Under Mode 1, the profit functions of the seller, supplier and LSP via the revenue sharing contract are:

, (6.2)

, and (6.3)

. (6.4)

When , we can obtain the optimal retail price and logistics service of the revenue sharing contract:

 and ,

To coordinate the supply chain, we letand , where *i* = 1,2. Supply chain coordination can be achieved if the following solution is satisfied:

.

To ensure the coordination solution of  and could be obtained, the conditions are showed in Appendix.

In Mode 2, the global supplier decides the transportation mode. We assume the global supplier can collect  portion of the seller’s revenue and the LSP collects  portion of the supplier’s revenue. Under Mode 2 with the revenue sharing contract, the profit functions of the seller, supplier and LSP are as follows.

, (6.5)

, and (6.6)

. (6.7)

We find that when  , the optimal retail price and logistics service quality from the revenue sharing contract in Mode 2 is:

 and .

We find that supply chain coordination can be achieved if the following solution is satisfied:

.

We also examine the logistics cost sharing contract for channel coordination. We represent logistics cost sharing by LCS. The cost sharing portion is . The seller pays  portion of the logistics cost and the supplier pays the remaining () portion.

Under Mode 1, the profit functions of the seller and supplier via the logistics cost sharing contract are:

, and (6.8)

 . (6.9)

 We find that when , the optimal retail price and logistics service from the logistics cost sharing contract in Mode 1 is:

 and 

The supply chain coordination can be achieved when is satisfied.

Under Mode 2, the profit functions of the seller and supplier are:

, (6.10)

, and (6.11)

We find that the optimal retail price and logistics service by the logistics cost sharing contract in Mode 2 is:

 and .

When is satisfied, supply chain coordination can be achieved.

***Proposition 9.*** *Both revenue sharing and logistics cost sharing contracts can help achieve supply chain coordination in Mode 1 and Mode 2.*

Although the coordination conditions are complex, the supply chain with the appropriate revenue sharing portions or logistics cost sharing portion is able to achieve coordination. Both revenue sharing and logistics cost sharing contracts are kind of sharing contract and have been used in practice. Supply chain members enable to achieve better performance through cooperation and using sharing contracts. By using the revenue sharing contract, the LSP is possible to receive the share of revenue which may increase the profit of LSP. The LSP plays an important role in a global supply chain. The better incentive for the LSP could definitely improve logistics services quality. This finding provides an important insight into how supply chain members can collaborate to achieve the best performance.

# Conclusion

In this study, we examine the effects of logistics services in a global supply chain. Based on the real world of global business, we consider a three-echelon supply chain consisting of one global supplier, one local seller and one LSP. The seller orders products from the global supplier and sells them to the local consumers. We consider the product has a short life cycle and its arrival time to the local market influences the market demand. The research results provide important insights into developing logistics services in the new global supply chain framework. We address our research questions in Table 3.

**Table 3.** Summary of the results of research questions

|  |  |
| --- | --- |
| Research questions | Results |
| Will it be more efficient to let the seller decide the logistics service of SLC products, rather than the supplier? | Not always. If the product life cycle is relatively long, the seller should always decide the transportation mode when selling long life cycle products, and the global supplier is better to decide the transportation mode when selling short life cycle products. |
| What are the optimal contracts for the logistics service provider to deliver SLC products? | The LSP offers a less expensive contract in Mode 1 than Mode 2. |
| What mechanism can improve the global supply chain performance? | Both revenue sharing and logistics cost sharing contracts can help achieve economic development coordination in the global supply chain. |

* 1. **Managerial insights**

The results of this study provide the following managerial insights into global supply chain management.

* **Selling appropriate products with the consideration of product life cycle:** If the product life cycle is long, having the seller as the leader is always beneficial for all supply chain members’ profits, consumer welfare and social welfare. If the product life cycle is short, it is not always beneficial to let the buyer be the leader because if the supplier is the leader the profit performance of the seller will be better, social welfare in the local market will be better, but consumer surplus will be indifferent.

*Insights for logistics managers:* Fruit and other food usually have an extremely short life cycle, whereas apparel and textile products have a relatively longer life cycle. When delivering foodstuffs, it may be beneficial for the global supplier to determine the transportation mode instead of the seller. However, if the products are apparel and textiles, which may have relatively longer life cycles, it may be better if the seller decides the transportation mode.

* **Designing the optimal logistics service contract design:** A proper contract design for individual logistics services is critical for the LSP. Different contracts can be provided for different types of products and supply chain members to maximise the benefits.

*Insights for logistics managers:* the LSP can use a less expensive logistics contract to induce the seller to deliver more products. This increased market demand also benefits the global supplier, as it can enjoy both an increase in profit and reduced potential risks. A cash flow shortage of foreign currencies may for example be a potential risk, as a major operational challenge for members such as suppliers from Ethiopia, which can be substantially reduced if the seller pays the transportation cost.

* **Developing regional coordination mechanisms in the global supply chain:** Both revenue sharing and logistics cost sharing contracts can help achieve supply chain coordination. Revenue sharing among the seller, supplier and the LSP is one method of achieving economic development coordination in the global supply chain. Logistics cost sharing between the seller and the supplier can enable them to share the benefit and the risk in terms of logistics in a global supply chain.

*Insights for logistics managers:* Sharing contracts can help coordinate supply chain members and thus achieve centralised optimal performance. The current slow economic, investment and trade growth worldwide makes this particularly important. Sharing (no matter whether revenue or cost sharing) may not only be an effective mechanism to encourage buyers, suppliers and LSPs to work closely together, but also be the key to achieving all-win results.

**7.2 Limitations and future research directions**

Our study has four main limitations, which suggest fruitful directions for future research. First, we study a local market with no competition. In further research, it would be interesting to examine the competition effect in the local market (Chen et al. 2017; Zhao et al. 2018). Second, we consider the quantity discount in our paper is linearly decreasing. In the future research, we will consider different setting of quantity discounts (Ke et al. 2013). Third, in a real supply chain setting, the LSP may be integrated into either the supplier or the seller. Thus, investigating the value of supply chain integration in terms of supply chain performance would be of benefit (Lam and Dai 2015), and information sharing and updating could help performance improvement in supply chain integration (Shen and Chan 2017; Chan et al. 2018; Dong et al. 2018; Shen et al. 2019). Four, considering the economic vulnerability of capital constrained supply chain members, further investigations of capacity constrained supply chain members are required (Choi et al. 2016; Shen et al. 2017).

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**Appendix: All Proofs**

**Proof of Proposition 1:**

To ensure that all the optimal solutions exist, we have Hessian matrix  in Mode 1 and  in Mode 2. We take  and obtain the following results:

(i)It is easy to find that , so **.

(ii) Recall that and .  can be rewritten as .Thus,.

(iii) Recall that ,. Thus  when, vice versa.

*(iv)* Substituting the optimal solutions into the demand function, we can haveand. Because , . (Q.E.D.)

**Proof of Proposition 2:** We can find that

,  and, thus **, ** and **. (Q.E.D.)

**Proof of Proposition 3:** We first rewrite the demand function as , then the consumer surplus function can be expressed as , where *l=1,2*. As , we can have ** . Moreover, as ,  can be obtained. (Q.E.D.)

**Proof of Proposition 4 & 5:** By substituting the optimal *p*, *w*, and *t* into  , , respectively, we solve the first-order derivative condition  and , and get  and . Then, we derive the optimal solutions when  is endogenous. Finally, Propositions 4 and 5 can be obtained by using the same approach as that in Propositions 1 and 2.

 (Q.E.D.)

**Proof of Proposition 6 & 7 & 8:** All the comparison results can be derived by using the same method in Proposition 1 and 2. (Q.E.D.)

**Proof of Proposition 9:** To coordinate supply chain, we let and . When using the revenue sharing contract, from Hessian matrix we can obtain the conditions  in Mode 1 and  in Mode 2. Under Mode 1, we can have  and . They can be rewritten as  and . Thus the condition to achieve the supply chain coordination can be derived by rearrange the equation.

We use the same method to get the condition under which the supply chain coordination can be achieved in Mode 2. To ensure that the conditions of coordination can be satisfied, we did the further works as follows:

In Model 1, we let , then . As , we obtained when , , , and, the coordination can be achieved if the above conditions are satisfied.

In Mode 2, we re-arrange the condition as, which can always satisfy . Thus the coordination in Mode 2 can be satisfied if the above condition is satisfied.

When using the logistics cost sharing contracts to achieve coordination for Modes 1 and 2, the results can be obtained by repeating the above process. (Q.E.D.)

1. For the details of channel leadership, readers can refer to the review paper of Guo et al. (2017). [↑](#footnote-ref-1)
2. The speed of logistics cannot be zero or infinite because the product life cycle and the speed of air cargo (the fastest transportation) are limited. [↑](#footnote-ref-2)
3. Notice that as highlighted by Chen et al. (2008), the time sensitive consumers always have their own willingness to wait for a product and they follow their expected utilities to make their purchasing decision. This means their expected utilities are with some boundaries. As a result, it is reasonable to adopt a linear market demand function here, which effectively captures the characteristics of time sensitive consumers in the market. [↑](#footnote-ref-3)
4. In this paper, we consider that the quantity is finite. This assumption is important to ensure that the transportation price will not tend to be zero. We thank one of the reviewers to point it out. [↑](#footnote-ref-4)
5. In Section 6.2, we will extend the model and consider the case with the constraint of logistics speed. [↑](#footnote-ref-5)