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Subsidies, Competition, and Capacity Allocation: Coordinating Logistics Networks for the Belt and Road Initiative

Xiaotong Liu*

Shandong Energy Group Co., Ltd., Jining, Shandong, 272102, China
**Corresponding Author*

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Abstract: In September 2013, President Xi proposed the Silk Road Economic Belt to foster regional collaboration, introducing a novel paradigm for international cooperation formally known as the Belt and Road Initiative (BRI). A core objective of the BRI is to reconfigure the logistics and transportation networks across participating regions to spur economic development, making the establishment of cross-regional logistics service supply chain (LSSC) cooperation highly imperative. Motivated by this, our paper investigates the impact of government interventions-specifically, subsidies and tax incentives-and horizontal supply chain competition on enterprises' willingness to participate in the BRI. By developing game-theoretic models and conducting numerical simulations, we derive several key insights. First, under a provider monopoly, an increase in government subsidies leads to a higher price for logistics service capacity, with the price growing at an accelerating rate. Second, in scenarios involving competing integrators, a higher intensity of market competition necessitates a correspondingly larger government subsidy to effectively incentivize BRI participation.

1. Introduction

In September 2013, President Xi proposed the establishment of a new regional cooperation model, the "Silk Road Economic Belt", to promote regional collaboration. These proposals are officially known as the One Belt One Road (OBOR) or the Belt and Road Initiative (BRI) [1]. The BRI aims to connect China with Asia and its neighboring regions, involving over 60 countries and regions, in an effort to usher in a new era of economic and regional diplomacy. Among the core objectives of the BRI, a key focus is to alleviate bottlenecks in cross-border trade, particularly by investigating how to develop accessible transportation infrastructure through effective logistics services [2]. At the 2017 Belt and Road Forum for International Cooperation, President Xi emphasized the need to continually advance an integrated land, sea, and air transportation network and to optimize the cross-regional logistics network.

As a national strategy, the Belt and Road Initiative (BRI) entails significant government involvement, which profoundly impacts supply chains. Through the construction of railway and aviation infrastructure alongside other coordination mechanisms, China and European countries are

collaborating to establish a highly accessible and efficient international logistics network and service system [2]. The BRI has received substantial financial support from the government. For instance, the $40 billion Silk Road Fund established by the Chinese government directly serves the BRI strategy [3].

Under the BRI, logistics and transportation networks require comprehensive replanning and reconstruction [4], prompting a growing body of research on logistics. Sheu and Kundu [5] proposed using Markov chains to forecast time-varying logistics distribution flows within a three-tier supply chain framework. Zeng et al. [6] modified a gravity prediction model to estimate variations in transshipment flows. Yang et al. [7] explored a bi-level programming model to reconstruct the shipping service network between Asia and Europe. However, previous studies have predominantly focused on macro-level logistics transportation networks, failing to consider the individual demands within the logistics service supply chain and the strategic behaviors of logistics enterprises.

From a governmental perspective, this paper introduces government decision-making into the coordination problem of the logistics service supply chain. While prior literature has primarily focused on the application of government interventions in reverse supply chains and green supply chains, this study contributes to filling the research gap regarding the coordination mechanisms of logistics service supply chains under the BRI.

Consequently, we proceed to investigate the impact of deeper government interventions-specifically, providing subsidies or tax deductions to logistics service integrator-on the logistics service supply chain (LSSC). Since the infrastructure construction of the BRI possesses certain characteristics of public goods, the government can consider implementing preferential policies to incentivize enterprises to expand their logistics service networks in countries along the BRI routes. Based on the above analysis, we seek to explore the following critical research questions:

(1) Under what level of government subsidy do the integrator and the provider possess the willingness to participate in the BRI cooperation?

(2) How do the logistics service price and capacity fluctuate in response to changes in the government subsidy level?

The remainder of this chapter is organized as follows: Section 2 presents the problem description and assumptions, establishing a baseline model with government intervention. Section 3 first discusses the impact of government subsidies on the integrator's behavior, and subsequently investigates scenarios involving a provider monopoly, horizontal competition between two logistics service integrators, and government participation through tax mechanisms. Section 4 conducts a numerical analysis to validate the theoretical results. Finally, Section 5 concludes this chapter with the main findings and managerial implications.

2. Model Formulation

We consider a logistics service integrator who allocates logistics services between domestic and overseas markets. Let d denote the logistics service capacity allocated to the overseas market. The wholesale price of the logistics service capacity is w, where $w<a$. The focus of this study is on how the government's incentive measures for the BRI affect market outcomes. We assume that the government provides subsidies to the integrator for participating in the BRI. The government subsidy can be expressed as $s[p(q)-w]d$, where $s\geq 0$ reflects the level of the government subsidy. The parameters used in this chapter are summarized in Table 1:

Table 1: Summary of Parameters

Symbol	Description
a	Maximum market potential for domestic logistics services
p	Logistics service price
q	Procurement quantity of logistics services
s	Government subsidy level
d	Overseas logistics service capacity
w	Wholesale price of logistics service capacity
c	Unit operational cost of logistics service capacity
l	Competition coefficient of the integrators

Based on the above analysis, the profit function of the logistics service integrator under government subsidies can be expressed by Equation 1. In Section 3, we will conduct further analysis and discussion based on this profit function.

$$\Pi=p(q)q-w(q+d)-c(q+d)^2+sd[p(q)-w] \tag{1}$$

3. Results and Discussion

This chapter first discusses the impact of government subsidies on the integrator's participation in the BRI based on the baseline model, and subsequently investigates scenarios involving a provider monopoly and market competition among integrators.

3.1 Subsidy Effects

When investigating the economic benefits of subsidies, we first consider the incentive effect of government subsidies on the integrator's participation in the BRI. With sufficient subsidies, the integrator will be more motivated to expand the logistics service network along the BRI routes, meaning the allocated capacity $d>0$. The integrator determines the domestic logistics service quantity q and the BRI logistics service capacity d to maximize the profit Π.

$$\frac{\partial\Pi}{\partial q}=a-w-2q(1+c)-d[2c+s]=0 \tag{2}$$

$$\frac{\partial\Pi}{\partial d}=s(a-q-w)-w-2dc-2qc=0 \tag{3}$$

$$q_1^*=\frac{a(2c-2cs-s^2)+sw(1+2c+s)}{4c-4cs-s^2} \tag{4}$$

$$d_1^*=\frac{a(s-2c+2cs)-w(s+2cs+2)}{4c-4cs-s^2} \tag{5}$$

By setting q_1^* and d_1^* to zero, we can obtain two thresholds for the government subsidy level s, denoted as $\overline{s_1}$ and $\widehat{s_1}$. Thus, we present Lemma 1.

LEMMA 1. *The equilibrium conditions for the integrator's logistics service capacity allocation* between *the domestic and overseas markets are as follows: When* $s\le\widehat{s_1}$, $d=0$ *and* $q=\frac{a-w}{2(1+c)}$. *When* $s\ge\widehat{s_1}$, $d=d_1^*$ *and* $q=q_1^*$, *where*

$$\widehat{s_1}=\frac{2(ac+w)}{(2c+1)(a-w)} \tag{6}$$

This lemma indicates that government subsidies enhance the integrator's willingness to

participate in the BRI.

Lemma 1 demonstrates that government subsidies promote the integrator's enthusiasm for participating in the BRI. Moreover, as the government subsidy increases, the integrator becomes more willing to invest in the construction of the logistics service network along the BRI routes.

PROPOSITION 1. *(1) The condition for the integrator to participate in the BRI is that the government subsidy satisfies* $s>\overline{s_1}$*;*

(2) The integrator's willingness to participate in the BRI increases with the subsidy, i.e., $\frac{\partial d}{\partial s}>0$.

The relationship between the government subsidy and the integrator's BRI capacity allocation presented in Proposition 1 aligns with practical experience, confirming that the integrator's participation degree is stimulated by government subsidies.

PROPOSITION 2. *When the government subsidy satisfies* $s>\overline{s_1}$*, i.e., the integrator participates in the overseas BRI logistics construction:*

(1) The price of domestic logistics service products will increase, i.e., $p(q_1^*)-p(q(w,\hat{s_1}))>0$*;*

(2) The price of domestic logistics service products increases as the subsidy increases, i.e., $\frac{\partial[p(q_1^*)-p(q(w,\hat{s_1}))]}{\partial s}>0$.

Proposition 2 reveals that while government subsidies encourage the integrator to participate in the overseas BRI logistics services, they also artificially inflate the price of domestic logistics service products, thereby harming the domestic market. Synthesizing Propositions 1 and 2, the government must balance the positive and negative impacts of subsidies when participating in the construction of the BRI logistics service network.

3.2 Impact of Provider Monopoly

In this subsection, we extend the basic model to consider a provider monopoly scenario, meaning the wholesale price w shifts from an exogenous parameter to a decision variable of the provider. In this case, the provider determines the logistics service wholesale price w with the objective of maximizing its own profit:

$$\max_{w} \Pi_p = w(q+d) \tag{7}$$

By taking the derivative of the provider's profit function with respect to w, we can summarize the conclusions in the following proposition.

PROPOSITION 3. *When the provider determines the wholesale price:*

(1) The integrator participates in the BRI if and only if $s>\tilde{s}=\sqrt{\frac{2c}{2c+1}}$*;*

(2) Government subsidies will decrease the wholesale price of logistics services, i.e., $w(s)<w(\tilde{s})$ *and* $\frac{\partial w(s)<w(\tilde{s})}{\partial s}<0$ *for* $s>\tilde{s}$*;*

(3) The domestic logistics service price will increase, i.e., $p(q(w,s))>p(q(w,\tilde{s})$ *, and* $\frac{\partial p(q(w,s))>p(q(w,\tilde{s})}{\partial s}>0$ *for* $s>\tilde{s}$.

3.3 Multiple Integrators

This section considers the scenario where two integrators compete in the market, denoted by 1 and 2, respectively. Due to this competition, their demand functions are interdependent and can be expressed as $p_1=a-q_1-lq_2$ and $p_2=a-q_2-lq_1$, where l represents the intensity of competition.

PROPOSITION 4. *When the two integrators engage in logistics capacity competition (Cournot*

competition), we can derive the following conclusions:

(1) The integrators are willing to expand into the markets covered by the BRI if and only if the subsidy level reaches $s>\hat{s}^C(l)=\frac{2ac+w(2+l)}{(2c+1)(a-w)}$;

(2) Participating in the BRI leads to an increase in the price of domestic logistics services, which grows as the government subsidy increases, i.e., $p_i^C(w,s)>p_i^C(w,\hat{s}^C)$ *and* $\frac{\partial[p_i^C(w,s)>p_i^C(w,\hat{s}^C)]}{\partial s}>0$ *for* $s>\hat{s}^C$;

(3) Competition between the integrators dilutes the incentive effect of government subsidies, i.e., $\hat{s}^C(l)>\hat{s}$ *and* $\frac{\partial\hat{s}^C}{\partial l}>0$.

The first point to note from Proposition 4 is that, given a sufficiently large subsidy, the integrators become more willing to participate in the BRI logistics services. Furthermore, it demonstrates that regardless of the competition intensity, the subsidy will inflate the price of domestic logistics service products. From the third point of Proposition 4, we can observe that intense market competition requires the government to provide higher subsidies to incentivize integrators to expand into the overseas BRI market; however, concurrently, the magnitude of the increase in domestic logistics service prices is relatively mitigated.

Next, we consider the price competition between the two integrators under a Bertrand game.

PROPOSITION 5. *When the two integrators engage in price competition for logistics service products, we can derive the following conclusions:*

(1) The integrators are willing to expand into the markets covered by the BRI if and only if the subsidy level reaches $s>\hat{s}^B(l)=\frac{2ac+w(2+l-l^2)}{(2c+1-l^2)(a-w)}$;

(2) Government subsidies for the integrators' participation in the BRI lead to an increase in logistics service product prices, which grows as the subsidy increases, i.e., $p_i^B(w,s)>p_i^B(w,\hat{s}^B)$ *and* $\frac{\partial[p_i^B(w,s)>p_i^B(w,\hat{s}^B)]}{\partial s}>0$ *for* $s>\hat{s}^B$;

(3) Price competition between the integrators further diminishes the incentive effect of government subsidies compared to capacity competition, i.e., $\hat{s}^B(l)>\hat{s}^C(l)$ *and* $d_i^B(w,s)\leq d_i^C(w,s)$.

The first two parts of Proposition 5 indicate that the key results regarding government subsidies for BRI logistics services persist under Bertrand competition, demonstrating the robustness of our conclusions. The third part further reveals that price competition dilutes the incentive effect of government subsidies. This occurs because price competition is fiercer than capacity competition, leading to lower logistics service product prices than those under capacity competition, which subsequently squeezes the profit margins of the enterprises.

3.4 Tax Deductions

Here, instead of considering direct government subsidies for integrators participating in the BRI, we examine how tax deductions can indirectly promote their participation. We assume that tax deductions are applied to the integrator's overseas logistics operations, with the deduction rate denoted by β. Since the logistics service industry currently operates under a value-added tax (VAT) system, let τ denote the VAT rate. The integrator's after-tax profit is thus formulated as:

$$\begin{aligned}\Pi^T&=p(q)q-w(q+d)-c(q+d)^2-\tau[(p(q)-w)q-c(q+d)^2-(\beta p(q)+(1-\beta)w)d]\\&=(1-\tau)[p(q)q-w(q+d)-c(q+d)^2+\frac{\tau\beta}{1-\tau}d(p(q)-w)=(1-\tau)\Pi^S\end{aligned}\tag{8}$$

As can be seen from the above equation, under the tax deduction mechanism, the integrator's

after-tax profit shares a linear relationship with its profit under the direct subsidy mechanism. Thus, we can derive the following proposition:

PROPOSITION 6. *The market effects generated by tax deductions are equivalent to those generated by direct subsidies, mapping the direct subsidy level s to* $\frac{\tau\beta}{1-\tau}$.

Proposition 6 is thus proven. In other words, although our basic model is formulated based on direct government subsidies, it is equally applicable to scenarios where such incentives are provided indirectly through tax reductions. A final caveat to this interpretation is that while tax deductions encourage integrators to engage in overseas logistics services, relying solely on tax incentives may not be sufficient to generate the necessary motivation. The government could adopt a more comprehensive portfolio of public-private support mechanisms, such as loan assistance, to further propel enterprises to advance the construction of the logistics service network along the BRI routes.

4. Numerical Analysis

We first summarize the equilibrium results for the various scenarios in Table 2:

Table 2: Summary of Equilibrium Solutions

Condition	Domestic logistics service q	Overseas logistics service d
1	$\frac{a(2c-2cs-s^2)+sw(1+2c+s)}{4c-4cs-s^2}$	$\frac{a(s-2c+2cs)-w(s+2cs+2)}{4c-4cs-s^2}$
2	$\frac{a(2c-2cs-s^2)+sw(1+2c+s)}{2c(2+l)(1-s)-(1+l)s^2}$	$\frac{a(s-2c+2cs)-w(2+l+2cs+s)}{2c(2+l)(1-s)-(1+l)s^2}$
3	$\frac{2ac(1-l)(1-s)-sw[2c+(1-l^2)(1+s)]}{2c(2-l)(1-s)-(1-l^2)s^2}$	$\frac{a[s(1-l^2)-2c+2cs]-w[2+l+2cs+s-l^2(1+s)]}{(1+l)[2c(2-l)(1-s)-(1-l^2)s^2]}$

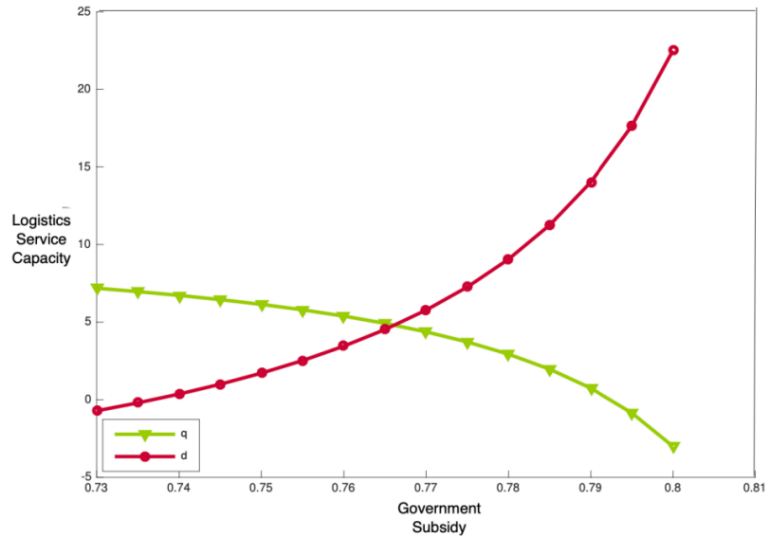

Figure 1: Impact of government subsidy (s) on logistics service capacity allocation

As depicted in Figure 1, as the government subsidizes the integrator for participating in the BRI, the logistics service capacity allocated to the overseas BRI market gradually increases, and this growth accelerates. Conversely, the logistics service capacity allocated to the domestic market experiences a decline.

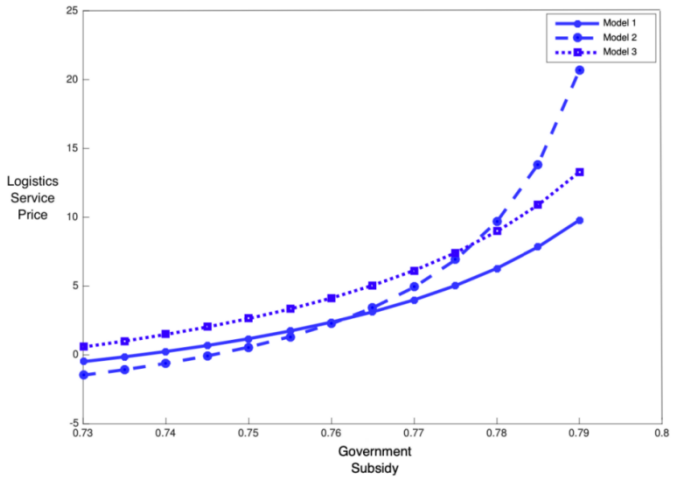

Figure 2: Impact of government subsidy (s) on the domestic logistics service price

Figure 2 illustrates the impact of government subsidies on the domestic logistics service price under different competitive environments. We observe that when the government subsidy is relatively low, the price under price competition (Bertrand) is higher than the prices under both the no-competition and capacity competition (Cournot) scenarios. However, as the government subsidy increases, capacity competition drives up the logistics service price more significantly. This is because the integrators' overall logistics service capacity is relatively limited; when they allocate more capacity to the overseas market, the capacity available for the domestic market decreases, prompting the integrators to raise the domestic logistics service price.

From Figure 3, we can observe that under a provider monopoly scenario, a higher government subsidy leads to a higher domestic logistics service price, and its growth rate accelerates. In contrast, its impact on the wholesale price of the BRI logistics service capacity is not highly significant.

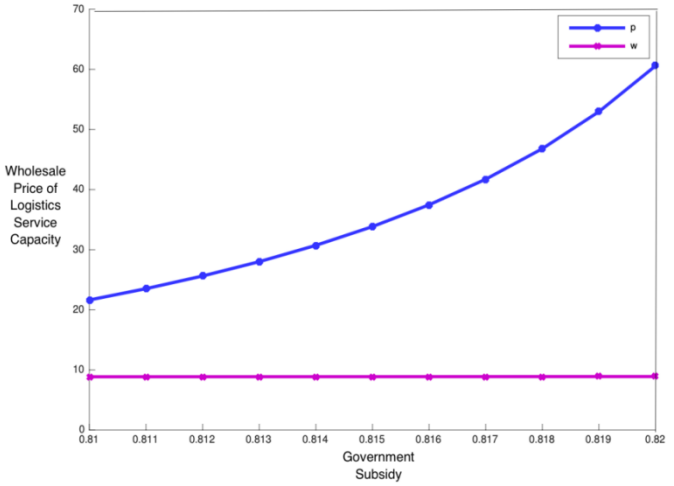

Figure 3: Impact of government subsidy (s) on logistics service price and capacity wholesale price under provider monopoly

Figure 4 demonstrates that when two integrators compete, a higher intensity of competition necessitates a larger government subsidy. Comparing the scenarios of capacity competition and price competition between the integrators, we observe that under price competition, the required government subsidy rises rapidly as the competition intensity increases. In comparison, under capacity competition, the increase in the required subsidy is much less pronounced. Consequently, given a fixed government subsidy rate, the more intense the price competition between the

enterprises, the lower their willingness to engage in the BRI market expansion.

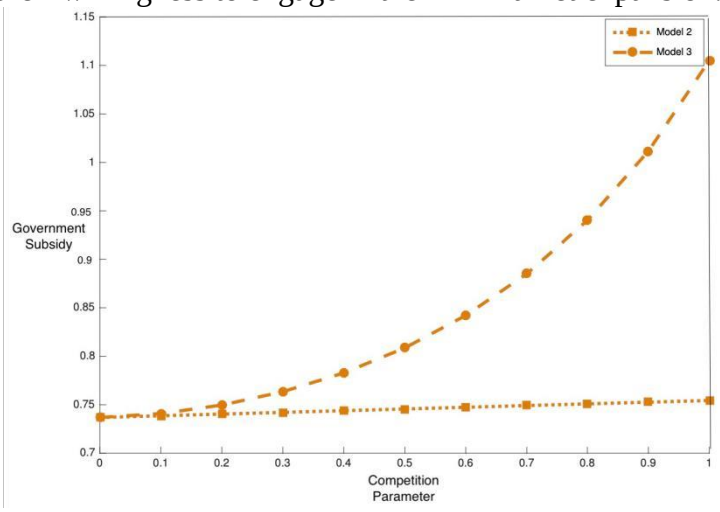

Figure 4: Impact of market competition intensity on the required government subsidy (s)

5. Conclusion

This chapter investigates the impact of government subsidies and tax deductions on the coordination of a logistics service supply chain, while also considering the market competition between two integrators. Several key findings and managerial implications are derived.

5.1 Main Findings

Our main findings can be summarized in three aspects. First, higher government subsidies lead to a stronger willingness among enterprises to participate in the construction of the BRI logistics service network. Second, an increase in government subsidies leads to higher prices for domestic logistics service products. In particular, the aforementioned findings hold even under intense competition between the two integrators, demonstrating the robustness of our model. Finally, capacity and price competition between enterprises undermines the effectiveness of government subsidies. Furthermore, since tax deductions can be regarded as an implicit form of subsidy, our conclusions regarding the effects of government subsidies are equally applicable to scenarios involving tax deductions.

5.2 Managerial Implications

When the government intervenes to incentivize logistics service enterprises to expand into the "Belt and Road" market, policymakers must comprehensively weigh both the positive and negative effects to determine an optimal subsidy rate. Moreover, intense competition in the logistics market dilutes the impact of government subsidies, thereby reducing the willingness of enterprises to engage in the construction of the "Belt and Road" logistics network.

5.3 Future Research Directions

This chapter provides a preliminary investigation into government incentives for "Belt and Road" logistics services. Future research could explore broader forms of government intervention, such as supporting the construction of logistics networks through loans, state funds, or other investment mechanisms. Additionally, extending current models to incorporate more complex

supply chain structures and uncertain demand for logistics services represents a promising direction for future work.

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