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Research Article

Customized Transportation, Equity Participation, and Cooperation Performance within Logistics Supply Chains

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Customized transportation has received growing concerns by researchers and practitioners in recent years. Despite the fact that one consignor often holds partial ownership of its carrier within a supply chain, the existing interpretations behind them remain relatively unexplored. Based on the game models, we find that a simple take-or-pay contract is not likely to solve the low-efficient customized production problem, and equity participation mechanism plus simple contract may improve the cooperation performance of customized transportation. In the case of the owner-managed carrier, only when purchasing at par can it be ensured to obtain the socially optimal customization investment, but when purchasing at premium or discount, the optimal partial ownership selected by consignor cannot motivate the carrier to make the most efficient customization investment. With the optimal solutions, we also provide a theoretic foundation for calculating the optimal partial ownership and for interpreting why the interfirm share-holding ratios of the member-firms within the familial-type logistic supply chains are much larger than the ratios within the public-type logistic supply chains. Finally, our results show that the familial-type logistic supply chains may choose more efficient customized production level than public-type logistic supply chains.

1. Introduction

Customized production is a production strategy focused on the broad provision of personalized products and services, mostly through modularized product/service design, flexible processes, and integration between supply chain members. Recent years have witnessed growing concerns about customized transportation services within logistic supply chains. The customization relationships among two or more member-firms form a complex network, in which there exists quite thorough and formal cooperation pointed out by Choi [1]. Strategic cooperation usually occurs in the shape of subcontracts, or manufacturing and marketing interfaces, so that cooperative arrangement for technical sharing, technical transfer, and customization service has become one of the most important cooperation ways in the last two decades [2].

According to Richardson [3], since two parties must not only take promised responsibilities for their future cooperation behaviors, but also should be provided with equivalent guarantee, then long-term contracts or equity participation schemes become the quite formal cooperation ways. Many of the interfirm research and development (R&D) cooperation in the United States among small biotechnology firms and established pharmaceutical companies are cemented by equity participation [4].

In China, it is well documented that many manufacturers (consignor) hold minority equity ownership in their transportation service suppliers (carrier), and, thereafter, these transportation service providers make substantial investments, such as refrigerating equipment for retaining freshness, or integrated ERP systems used as tracking parcel that Choi et al. suggested in [5], and provide customized transportation service for their downstream consignor [5, 6], just as the similar cases of Japanese auto industry described by Aoki et al. [7, 8]. In fact, these features have been suggested as some keys to the success of Chinese logistic industry. For

the above mentioned cooperation transactions, why is equity participation adopted rather than long-term contract? That is exactly the paradox in transaction efficiency from different cooperative arrangements that we want to investigate.

In reality, due to the complexity, and uncertainty of future affairs and traders' bound rationality, it is impossible or implausible to list all the related details of contract when taking transaction cost into consideration. Since incomplete contracts cannot resolve the "*hold-up*" problem of opportunists and discounts its value [9], under the backgrounds of opportunism [10], assets specificity [11], incomplete contracts, and future's uncertainty [12], various organizational interventions, such as vertical integration, exchange hostages, shifting property rights, and designing an authority relationship, are proposed to solve the "*hold-up*" problem, which can prevent two parties from breaking a contract.

Cooperative transaction among member-firms within logistic supply chain may lose efficiency because of *ex post* opportunistic behavior caused by specific investment resulting likely from customized production or outside options. Williamson [13], Klein et al. [14] believe that specific investment does not likely acquire the optimal efficiency with the anticipation of *ex post* opportunistic behaviors and vertical integration instead of spot market can avoid or reduce opportunistic behaviors caused by assets specificity. The final choice is made based on the comparison of transaction costs of two types of cooperative mechanisms.

However, integration (internal transaction) is not always more outperformed than market transaction, which means that it would lead to inefficiency when all productive activities are arranged in one integrated organization. Why cannot market relationship among independent entities be replaced fully by integration? Williamson's replacement model provides the following reasons for avoiding integration. That is, if firms manufacture inputting products by themselves, economies of scale and economies of scope may not be achieved. Otherwise, when the degree of assets specificity is low, governance cost of internal organizations will be larger than that of market organizations [13]. When analyzing the disadvantage of governance cost of internal organizations, related interpretations of loss of control rights and malfunction of selective optimal intervention are convincing.

Based on the criticism and inheritance of existent theories, Milgrom and Roberts [15] propose that the cost of political activities within one organization is also an important obstacle for concentration of control rights, which interprets that internal transaction within integration organizations is not always better than market transaction among entities in view of nonmarket transaction costs. The limitations of integration organizations indicate that a single mode of integration among parent firm and its member-firms is not optimal, and the concurrence of various bonding relationships within supply chains is a feasible choice of decision-makers when constructing an up-down stream relationship.

With growing cooperation transactions within supply chains, share-holding arrangement (partial ownership) becomes one of the most important cooperative schemes. However, there are few theoretical explanations aiming at equity participation phenomena, especially within logistic supply chain [2, 16]. Conventional wisdom is that partial ownership, by reducing opportunism, helps to promote the bond between upstream firms and downstream firms through inspiring greater specific investment and customized production level [9–12]. So, without contractual remedies, equity participation may perhaps play a role instead. However, under symmetric information, equity participation by the downstream firm in an upstream supplier has no effect on the payoffs when two parties bargain to allocate the benefits of specific investment [11]. In view of this, it remains unclear how partial ownership promotes the bond.

In the related models, Bolton and Whinston [17] and Rajan and Zingales [18] discuss how to make optimal ownership allocation in details. However, they only make some analyses about efficiency loss within integration organization, but do not measure enhanced efficiency resulting from cooperation mechanism of partial ownership. Different from their works, this paper focuses on demonstrating what roles partial ownership plays in customized production used to motivate investors, and simultaneously, probing into why the complete ownership is not possible to be optimal.

Dasgupta and Tao [19] provide some theoretical interpretations for partial ownership phenomena, based on the models about selective investment decision made by the upstream firms. They consider two types of investment, in which specific investment levels differ. Given potential income of investment to be random, when the downstream firm holds partial ownership of the upstream firm, the upstream firm would choose more efficient types of investment than the simple contract.

Compared with innovative mechanism design theory of ownership suggested by Aghion and Tirole [20], Dasgupta's theoretical interpretation on partial ownership is more profound, as they not only agree on the viewpoint that the relative bargaining power of the trade parties will affect the efficiency of ownership allocation but also install the bargaining power parameter into the models and obtain the relevance between the related parameters and the magnitude of partial ownership. When the downstream firm takes equity participation ratio into account, the optimal partial ownership is not only of the credible commitment that can boost the upstream firm to choose a high specific investment level, but also of the mechanism arrangement in order to maximize the benefits of the downstream firm. The equity participation ratio decision must tradeoff these two mechanisms, which means that the downstream firm maximizing its own benefits does not have to choose equity participation ratio that can motivate the upstream firm to make the complete specific investment.

Hence, viewing customization level as a variable chosen by the upstream firm may meet the realistic condition within logistic supply chains better. In this paper, the potential income of customization investment is assumed to increase with customized production level, which accords with rational principle and is our logic starting point of research.

In addition, the existence of partial ownership may affect customization decision and the success probability of obtaining outside opportunity income slightly. On the one hand, partial ownership could lower the diligence expenditure of the upstream firm's entrepreneurs. On the other

hand, it has the supervisory effects on them imposed by the downstream firm which was neglected by Dasgupta and Tao [19], but is taken into account in our paper. Then, in fact, partial ownership won't change the diligence expenditure of decision-makers evidently. Once investment and customized production are made, both the investment income and the outside option income are supposed to be realizable. This is why we incorporate customization level, partial ownership, and outside opportunity into the same analytical framework, which become a key point that distinguishes our research from other customization literatures.

In addition to analyzing the case of the owner-managed upstream firms, our model also involves the case of public-firms managed by professional managers. Obviously, the decision-makers of these two kinds of firms have so many differences between their customization decision behaviors that we should probe into them separately. From this angle of view, we can demonstrate why the familial-type logistic supply chains may choose more efficient customized production level than public-type logistic supply chains.

The remaining portion of this paper is organized as follows. Section 2 outlines the basic model and analyzes the limitations of the simple contract. Section 3 probes into the problem of equity participation of the owner-managed carrier. Section 4 discusses the first-best partial ownership of the publicly traded carrier. Section 5 analyses the effects of the optimal ownership strategy on the efficiency of customized transportation. Finally, conclusion is made in Section 6.

2. The Customized Transportation Models

2.1. Model Settings. Assuming that the member-firms within the logistic supply chain are respectively one carrier and one consignor in a transportation trade, the two parties can make the specific investment for customized transportation bilaterally or unilaterally. Without loss of generality, we assume that the carrier can make the unilateral specific investment and customized transportation for consignor, which can increase the goods' value of the consignor. For example, if the carrier invests in refrigerating equipment or ant-vibration appliance for consignor's goods in the great risk of decoy or brittleness, then this customized transportation would increase the goods' value and consignor would make a larger profit.

The carrier can either be owner-managed firms or public-firms run by professional managers. Here, we call the owners of owner-managed firms as entrepreneur and call the decision-maker of the publicly traded firm as the manager. We assume that the consignor is run by professional managers in the interest of the stockholders. To be mentioned, the owner-managed consignor will not affect our analyses. Unless specially pointed out, carrier is seen as an owner-managed one in our analyses. In addition, all players are assumed to be risk-neutral.

For simplicity of the analyses and the generalization of models, three stages of game are considered; that is, $t = 0, 1, 2$. At $t = 0$, the consignor offers to buy a fraction $r \in [0, 1]$ of the transportation carrier at price $P(r)$, and the entrepreneur can accept or reject the offer.

At $t = 1$, the entrepreneur chooses the customization level parameter a based on the potential value $V(a)$ and the cost function $C(a)$ of customized transportation, where $a \in [0, 1]$. Larger a means the higher customized transportation level for carrier. In order to grasp the nature of customization investment behavior, we assume, the value of transportation service $V(a)$ and its investment in customized transportation, for example, $C(a)$, are convexly increasing in a. For simplifying analyses and without loss of generality, we adopt the following function shape: $V(a) = e^a g$ and $C(a) = \beta a^2$, where g represents the general transportation service value without customized investment (in the case of $a = 0$) and β is a constant expressing the needed investment in the case of complete customization service. In addition, we also suppose that the net revenue function of customized production $[V(A) - C(A)]$ is concave, which ensures that there exists the optimal a in our analyses. That is, $\forall a \in [0, 1]$ and $r \in [0, 1]$, and inequalities $e^a g > 2\beta a$ and $e^a g < 2\beta$ hold.

At $t = 2$, $V(a)$ and $C(a)$ are realized. $V(a)$ and $C(a)$ are common knowledge, but they cannot be verified, so the contract cannot be consigned on it.

Then, we consider that at $t = 0$, the carrier and the consignor sign a simple take-or-pay contract, and (P_T, P_N) is the payoff portfolio the consignor will pay to the carrier in two cases when trade in the contract occurs or not. At $t = 2$, the carrier makes renegotiation with the consignor bilaterally. If the renegotiation between them fails, carrier will trade with other consignor, and the potential value of the customization will be reduced to $g(1 - a)$.

If the relative bargaining power of the consignor is assumed to be λ, then that of the upstream carrier is $(1 - \lambda)$, where $\lambda \in [0, 1]$. We incorporate the analyses of surplus allocation in the cases of trade or nontrade into the framework of the Nash bargaining solutions. By backward deductive method, since (P_T, P_N) can be renegotiated at $t = 2$, it means (P_T, P_N) should obey the constraints of the Nash bargaining solutions.

Under what condition could simple contract (P_T, P_N) acquire the optimal incentive outcome? And why can equity participation arrangement enhance more efficient customization level? These paradoxes are what we are interested in.

2.2. Simple Contract and Customization Level Choice. Given simple contract (P_T, P_N) and the equity participation ratio $\mathbf{r}$ of consignor, the payoff matrix of two trading parties is expressed as in two cases when the negotiation either triumphs (denoted by T) or fails (denoted by N) as following:

$$\begin{array}{ccc} & \text{Carrier} & \text{Consignor} \\ T & (1-r)\left[P_T - C(a)\right] & V(a) - P_T + r\left[P_T - C(a)\right] \\ N & (1-r)\left[P_N + g(1-a) - C(a)\right] & r\left[P_N + g(1-a) - C(a)\right] - P_N \end{array} \tag{1}$$

In the game model of the repeated bargains, the Nash bargaining solutions require that contract (P_T, P_N) satisfies

$$\max\left\{(1-r)\left[P_T - C(a)\right] - (1-r)\left[P_N + g(1-a) - C(a)\right]\right\}^{1-\lambda}$$

$$* \{V(a) - P_T + r[P_T - C(a)] - r[P_N + g(1-a) - C(a)] + P_N\}^{\lambda}. \quad (2)$$

The first order condition of P_T demands

$$\frac{(1-\lambda)(1-r)}{(1-r)[P_T - P_N - g(1-a)]} + \frac{\lambda(r-1)}{V(a) - P_T + r[P_T - P_N - g(1-a)] + P_N} = 0. \quad (3)$$

Then

$$P_T = \frac{[e^a - r(1-a) + (1-a-e^a)\lambda]g}{1-r} + P_N. \quad (4)$$

Using payoff matrix, we know that when transaction occurs, the revenues of carrier and consignor are $(1-r)[P_T - C(a)]$ and $(V(a) - P_T + r[P_T - C(a)])$ respectively, expressed by $S_T(r, P_N)$ and $B_T(r, P_N)$. So we have

$$\begin{aligned} S_T(r, P_N) &= [e^a - r(1-a) + (1-a-e^a)\lambda]g \\ &\quad + (1-r)[P_N - \beta a^2], \\ B_T(r, P_N) &= [e^a\lambda + (1-a)(r-\lambda)]g \\ &\quad - (1-r)P_N - r\beta a^2. \end{aligned} \quad (5)$$

The socially optimal customization level choice must satisfy

$$\max_a [V(a) - C(a)]. \quad (6)$$

The first order condition demands

$$\frac{e^a}{a} = \frac{2\beta}{g}. \quad (7)$$

That is, the first-best customization level parameter $a_{\text{fb}} = \arg[e^a/a = 2\beta/g]$. But, if $r = 0$, can (P_T, P_N) make sure that the entrepreneur chooses a_{fb}?

For simplicity of the analyses, let $P_N = 0$, and then it demands that the manager chooses a^* to maximize carrier's revenue as follows:

$$a^* = \arg\max_a S_T(r, P_N). \quad (8)$$

Then, we have

$$a^* = \arg\max\left[\frac{e^a}{a} = \frac{\lambda - r}{(1-\lambda)a} + \frac{2(1-r)\beta}{(1-\lambda)g}\right]. \quad (9)$$

When $r = 0$, above equation can be changed into

$$a^* = \arg\max\left[\frac{e^a}{a} = \frac{\lambda}{(1-\lambda)a} + \frac{2\beta}{(1-\lambda)g}\right]. \quad (10)$$

Apparently, from $\lambda \in [0, 1]$, we can deduce

$$\frac{\lambda}{(1-\lambda)a} + \frac{2\beta}{(1-\lambda)g} \geq \frac{2\beta}{g}. \quad (11)$$

The function $[V(a) - C(a)]$ is concave, so

$$a^* \leq a_{\text{fb}}. \quad (12)$$

It means, when the entrepreneur of the upstream carrier has the whole bargaining power ($\lambda = 0$), simple contract (P_T, P_N) can induce the entrepreneur to choose the optimal customization level. It is not difficult to understand that, when the entrepreneur with an overwhelming bargaining power can obtain all of investment surplus, he or she will make the choice of the fist-best customization level. It is consistent with the interpretation of Choi et al. [19–22] that the incomplete contract can also lead to efficient outcomes under some special conditions.

But when $\lambda > 0$, (P_T, P_N) contract cannot ensure that the entrepreneur would make the efficient customization investment. Then, how many ration of equity participation can result in efficient outcomes?

If $a^* = a_{\text{fb}}$, then $V'(a^*) = C'(a^*)$. This means

$$\frac{\beta l}{g} = \frac{\lambda - r}{(1-\lambda)a} + \frac{2(1-r)\beta}{(1-\lambda)g}. \quad (13)$$

Obviously, only when $r = \lambda$, may (14) hold. Since $P_T = V(a_{\text{fb}})$, then $(P_T, P_N) = (V(a_{\text{fb}}), 0)$.

Integrating the above analyses, we can conclude the following.

Proposition 1. *(i) Only when the entrepreneur of carrier occupies all of bargaining power (e.g., $\lambda = 1$) can simple contract $(V(a_{fb}), 0)$ result in the socially optimal customization level chosen by carrier; (ii) but if $0 < \lambda < 1$, the efficient customization investment outcome can be obtained only through equity participation $r = \lambda$ plus simple contract $(V(a_{fb}), 0)$.*

Proposition 1 does not mean the consignor d must make the decision of equity participation $r = \lambda$ at $t = 0$, because as a rational entity, maximizing its benefit, the consignor would not only consider the customization efficiency of the upstream carrier but also make benefit-cost analyses of equity participation. Hence, the optimal equity participation ratio need not satisfy the condition under which the manager would choose the socially optimal customization level. In next section, we will discuss the problem about optimal equity participation ratio.

3. Equity Participation by Consignor in Owner-Managed Carrier

This section aims at obtaining the comparative static outcome affecting the equity participation ratio factors, so we will install the cost items related to the equity participation in order to obtain the internal angle solution about the optimal partial ownership.

3.1. Optimal Equity Participation Ratio. Given r, the entrepreneur will choose a^* to maximize the customization investment revenue; that is

$$a^* = \arg\max_a S_T(r). \quad (14)$$

Given a chosen by carrier at $t = 1$, the manager of consignor would, at $t = 0$, decide on optimal equity participation ratio r to maximize its total net income. As we all know, under the mechanism of partial ownership the consignor can get a lot of benefits from customized transportation, but must pay for obtaining partial ownership of carrier. The reason why complete vertical integration is not always the optimal choice lies in the fact that the integration cost is likely to exceed the added-value benefits of customized transportation.

Assuming that other outside income of the upstream carrier is π_0, we express $P(r)$ that the consignor pays for obtaining an equity ratio r of the carrier in the following equation:

$$P(r) = (1+\theta)\left[\left(S_T(o)+\pi_0\right) - \left(S_T(r) + (1-r)\pi_0\right)\right]. \quad (15)$$

In this equation, $(S_T(o)+\pi_0)$ term represents total income of entrepreneur when $r = 0$, and $(S_T(r) + (1-r)\pi_0)$ is the correspondent revenue that entrepreneur earns when equity participation ratio is r. The surplus between these two terms can be regarded as the real value of the equity fraction r of the upstream carrier. Let θ denote the average premium (discount) price coefficient at which the consignor acquires a fraction r of the carrier, where $\theta > 0$ represents purchasing at premium, $\theta = 0$ represents purchasing at par, and $\theta < 0$ represents purchasing at discount. In order to accord with the actual scenarios of equity fight, we install θ-coefficient into the formula to calculate $P(r)$.

Let π_d denote net income of the downstream consignor; then

$$\pi_d = B_T(r) + r\pi_0 - P(r). \quad (16)$$

Substituting $B_T(r)$ and $P(r)$ into above equation, we get

$$\pi_d = e^a g - \beta a^2 + \theta S_T(r) - \theta\pi_0 r - (1+\theta) S_T(0). \quad (17)$$

Anticipating that the entrepreneur chooses a^* based on equity participation ratio r, that is, $a^* = a^*(r)$, the manager of the downstream consignor will try to acquire optimal equity ratio r^* for maximizing π_d; that is

$$r^* = \arg\max_r \pi_d. \quad (18)$$

The first order condition demands

$$\frac{\partial a^*}{\partial r}\left[V'(a^*) - C'(a^*)\right] + \theta\left[C(a^*) - g(1-a^*)\right] - \theta\pi_0 = 0. \quad (19)$$

Without loss of generality, suppose $\beta a_{\text{fb}}^2 - g(1-a_{\text{fb}}) \le 0$; we will discuss the results in the cases of different θ-values.

3.2. The Effects of θ on a^* and r^*

(1) $\theta > 0$, which means purchasing at premium.

By (9), we know

$$\frac{\partial^2 S_T(r)}{\partial (a^*)^2} < 0. \quad (20)$$

Moreover, $\partial^2 S_T(r)/\partial a^* \partial r = 2\beta > 0$.

Thus, $\partial a^*/\partial r = (-\partial^2 S_T(r)/\partial a^* \partial r)/(\partial^2 S_T(r)/\partial (a^*)^2) > 0$.

Since $V'(a^*) - C'(a^*) < 0$, when θ is sufficiently smaller, we have

$$\frac{\partial \pi_d}{\partial r|_{r=0}} > 0,$$
$$\frac{\partial \pi_d}{\partial r|_{r=\lambda}} = \theta\left[C(a_{\text{fb}}) - (1-a_{\text{fb}})g - \pi_0\right] < 0. \quad (21)$$

Thus, the optimal partial ownership $r^* \in (0,\lambda)$, and we can get $a^* > a_{\text{fb}}$.

If θ is sufficiently larger, $\forall r \in [0,1]$, $\partial\pi_d/\partial r < 0$, then $r^* = 0$.

(2) $\theta = 0$, which means purchasing at par.

Obviously, for (19) to hold, it requires

$$V'(a^*) - C'(a^*) = 0. \quad (22)$$

Then, $r^* = \lambda$ and $a^* = a_{\text{fb}}$.

(3) $\theta < 0$, which means purchasing at discount.

Evidently, when the value of the upstream fabric supplier is underestimated, the consignor will buy as much equity as possible to maximize its total net income. Although over-incentive effects of equity may lead to customized production level exceeding the social optimality, and the increase of the equity investment revenue renders the manager of the consignor to purchase the share of r^* greatly exceeding social optimal level; that is, $r^* > \lambda$. Besides, when the share-holding ratio of the downstream consignor exceeds the entrepreneur's, the customization level of carrier should equal the social optimal one. So, we have

$$a^* \begin{cases} = a_{\text{fb}} & \text{if } r^* \ge \dfrac{1}{2}, \\ < a_{\text{fb}} & \text{if } r^* < \dfrac{1}{2}. \end{cases} \quad (23)$$

If θ is sufficiently negative, then $r^* = 1$ and $a^* = a_{\text{fb}}$. Notably, we regard θ as a constant in this paper, which does not affect our analyses about the optimal equity participation ratio.

But what we must pay attention to is that, with r vibrating, average discount (or premium) price parameter θ may also be changeable. The exact magnitude of the optimal customization level a and partial ownership r will depend on θ-value.

The three-dimension chart (see Figure 1) shows that, when θ drops from 0.4 to -0.4, $\pi_d(a,r)$, the equilibrium path demonstrates an increasing trend, and the optimal customization level a is increasing in r. With equity purchase shifting from discount price to premium price, the drop of optimal equity participation ratio will result in the customization transportation level and the net income of consignor decreasing simultaneously.

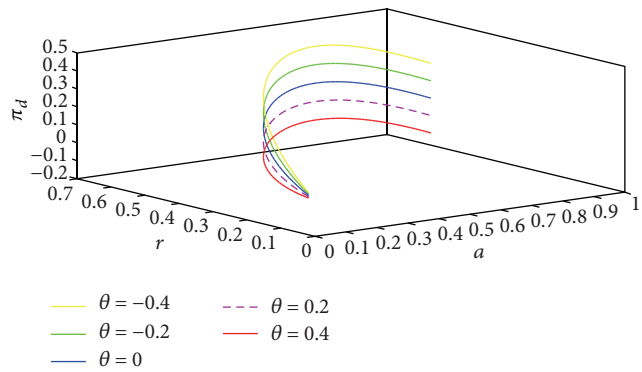

Figure 1: The relationship chart among π_d, a, and r, given $\lambda = 0.5$, $\beta = 2$, and $g = 2$.

Concluding the above analyses, we get the following.

Proposition 2. *(i) If θ is a sufficiently small positive value, $C(a_{fb}) - g(1 - a_{fb}) \leq 0$, the consignor holds the optimal partial equity of the carrier $r^* \in (0, \lambda)$, and the customization level which the entrepreneur chooses is below social optimal level; that is, $a^* < a_{fb}$. If θ is sufficiently larger, choosing $r^* = 0$ will be beneficial for the consignor.*

(ii) In the case when purchasing at par ($\theta = 0$), $r^* = \lambda$ and $a^* = a_{fb}$ hold, and the efficient customization level can be obtained.

(iii) In the case when purchasing at discount, $r^* > \lambda$ and $a^* > a_{fb}$ hold, and optimal partial ownership can motivate the entrepreneur to choose the socially optimal customization type.

Proposition 2 demonstrates that only when purchasing at par can optimal equity participation mechanism make sure that the most efficient outcome is obtained. When purchasing at premium or discount price, the distortion effects of wealth transfer will make the customization outcome brought up by optimal partial ownership deviate from social optimal investment type.

According to Proposition 2, we can interpret why the average equity ratios Chinese consignors hold of carriers' equity ownership exceed the corresponding value of American firms, under the condition of the same technology parameters. In China, majority equity ownership of the firms is under the control of individual investors or institution investors, the exchange ratio of the stock is very low, and the exchange of stock is often solved by private negotiation [22]. Generally, in this case, $P(r)$ will not deviate seriously from its real value, and θ is likely to be bigger than zero slightly. But in the United States, whose capital markets are very mature, equity ownership of firms is widely dispersed, the public shareholders hold the majority equities, the ownership r is obtained by exchange in the stock market, and the bids of many trade entities lead to θ-value exceeding zero greatly [23–25]. Therefore, when other technical parameters are not changed, the mechanism that the greater θ-value would lead to the smaller r^* will result in the interfirm equity participation ratio in China to be obviously higher than that of the same industry in the United States.

4. Equity Participation by the Consignor in the Public-Type Carrier

In this section, we will expand our analyses of the optimal partial ownership to the public carrier operated by professional managers. When the carrier is not owner-managed but is a public-firm, the analyses of last section do not apply, completely, in that professional managers in the interest of the stockholders will not be affected directly by the dispersive equities, when considering investment income. Even so, our analyses below demonstrates that partial ownership still affects the customization choice of managers, and a conclusion similar to the last section will be obtained.

For simplicity of analyses, besides the assumption that the manager of carrier is risk neutral, we also assume that there exists no manager's moral hazard about reward compensating mechanism and endeavor choice problem. Assume that rewards of manager are a minority part of the whole profit of carrier, which ensures that manager makes decisions in the interest of the stockholders. Based on these assumptions, we can attain the bargaining outcome below.

Lemma 3. *Given* **r** *and λ, let $P_N = 0$, then the consignor pays*

$$\widehat{P}_T = \frac{(1-\lambda)\, e^a g + (\lambda - r)\, g\,(1-a)}{1-r} \tag{24}$$

to the public-type carrier.

And the incomes obtained by the two trade parties are, respectively,

$$\begin{aligned} \widehat{S}_T(r) &= \frac{(1-\lambda)\, e^a g + (\lambda - r)\, g\,(1-a)}{1-r} - \beta a^2, \\ \widehat{B}_T(r) &= \lambda g e^a - (\lambda - r)\, g\,(1-a) - r\beta a^2. \end{aligned} \tag{25}$$

From the payoff matrix of two trade parties, we can obtain $\widehat{P}_T = P_T$; that is, no matter what type the carrier belongs to, the payoffs of the consignor are the same. There exist differences between two types of carrier' trade income function. But for the consignor, the function form of the trade income remains unchanged.

Observing that the manager of the carrier will choose the customization level $\widehat{a}^*$ to maximize its utility, given the manager's risk neutrality, we know

$$\widehat{a}^* = \arg\left[\frac{\partial \widehat{S}_T(r)}{\partial a} = 0\right]. \tag{26}$$

Given r, the manager would choose $\widehat{a}^*(r)$ to maximize the earnings of the carrier; then decision-makers of consignor can decide on equity participation ratio to maximize its net income $\widehat{\pi}_d$. Here, we adopt the form below to describe $\widehat{\pi}_d$:

$$\widehat{\pi}_d = \widehat{B}_T(r) + r\pi_0 - \widehat{P}(r), \tag{27}$$

where $\widehat{P}(r)$ denotes the price at which the consignor buys a fraction r of equity of the carrier. Assuming that the faction r of equity is purchased through tender offers, the real value

$\delta(r)$ of the carrier based on the partial ownership r can be expressed as

$$\delta(r) = \widehat{S}_T(r) + \pi_0. \tag{28}$$

$\widehat{P}(r)$ can be denoted as follows:

$$\widehat{P}(r) = (1+\theta) r\delta(r). \tag{29}$$

Therefore, the total net income of the consignor can be described as

$$\widehat{\pi}_d = \widehat{B}_T(r) + r\pi_0 - r(1+\theta)\left[\widehat{S}_T(r) + \pi_0\right]. \tag{30}$$

The optimal partial ownership $\widehat{r}^*$ must satisfy the first-order condition

$$\frac{\partial \widehat{\pi}_d}{\partial r \mid r = \widehat{r}^*} = 0. \tag{31}$$

We further have

$$\left(\frac{\partial \widehat{a}^*}{\partial r}\right)\left[V'(\widehat{a}^*) - C'(\widehat{a}^*)\right] - \theta\widehat{S}_T(r) - \theta\pi_0 - \frac{(1+\theta r)(1-a)g}{(1-r)^2} = 0. \tag{32}$$

Obviously, when $\theta > 0$ and is sufficiently small, $\widehat{r}^* \in (0, \lambda)$. Similar to the conclusions of the last section, the values of $\widehat{a}^*$ and $\widehat{r}^*$ will be adjusted to correspond to positive or negative θ-value. In this paper we will only analyze the case of $\theta > 0$.

By (32), we get

$$\begin{aligned}\frac{\partial^2 \widehat{\pi}_d}{\partial r \partial \lambda} &= \left[\frac{\partial \widehat{a}^*}{\partial r}\right]\left[V''(\widehat{a}^*) - C''(\widehat{a}^*)\right]\left[\frac{\partial \widehat{a}^*}{\partial \lambda}\right] - \frac{1+\beta r}{(1-r)^2} \\ &\quad * \left[-(1-\widehat{a}^*)V(\widehat{a}^*) - (1-\lambda)V(\widehat{a}^*)\left(\frac{\partial \widehat{a}^*}{\partial \lambda}\right)\right. \\ &\quad \left. + (1-a)(1-\lambda)V(\widehat{a}^*)\left(\frac{\partial \widehat{a}^*}{\partial \lambda}\right)\right] \\ &\quad + \left[\frac{\partial^2 \widehat{a}^*}{\partial r \partial \lambda}\right]\left[V'(\widehat{a}^*) - C'(\widehat{a}^*)\right] + \frac{\beta(1-\widehat{a}^*)V(\widehat{a}^*)}{1-r}.\end{aligned} \tag{33}$$

By $\partial \widehat{S}_T(r)/(\partial a \mid a = \widehat{a}^*) = 0$, we know

$$\frac{\partial \widehat{a}^*}{\partial r} > 0, \qquad \frac{\partial \widehat{a}^*}{\partial \lambda} < 0, \qquad \frac{\partial^2 \widehat{a}^*}{\partial r \partial \lambda} < 0. \tag{34}$$

Then, in (33), all the right-hand terms exceed zero; thus,

$$\frac{\partial^2 \pi_d}{\partial r \partial \lambda} > 0. \tag{35}$$

Since $\mathrm{Sign}(\partial r^*/\partial \lambda) = \mathrm{Sign}(\partial^2 \widehat{\pi}_d/\partial r \partial \lambda)$, we can get

$$\frac{\partial \widehat{r}^*}{\partial \lambda} > 0, \qquad \frac{\partial \widehat{r}^*}{\partial \pi_0} < 0. \tag{36}$$

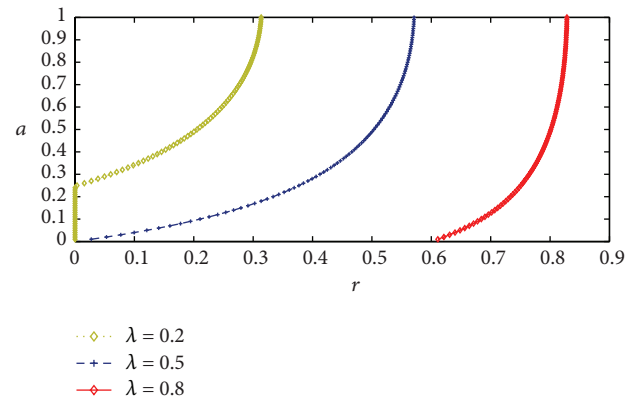

Figure 2: The relationship chart between a and r, given $\beta = 2$, $g = 1.2$.

Given the values of λ, β, and g, we can find out the relationship between a and r through numerical simulation, in Figure 2.

Our numerical result shows that parameters a and r are increasing function of λ, and a increases nonlinearly in r.

From the above analyses, we can conclude the following.

Proposition 4. *Assuming that the carrier is a public-firm managed by the manager in the interest of the share-holders, when purchasing at premium price, the optimal equity participation ratio $\widehat{r}^*$ by the consignor increases in λ, but decreases in π_0.*

5. Discussions about Customized Production Efficiency and Policy Implications

The theory of optimal ownership structure extracts the distillate of two stream academic ideas, the financial structure theory and the managerial motivation theory, which have been agreed on in economic literature [19]. For example, Jensen and Meckling [26] pointed out, that agent costs caused by dilution of ownership are derived from the fact that the incentive of inside controllers cannot keep track with that of the owner's. On the other hand, many academic papers demonstrate that an outside artificial person who holds a major part of ownership has a positive effect on the firm's value [10, 17, 26–28]. These papers emphasized the supervising function of the outside artificial persons' share-holders to the firm's managers. Compared with these existing articles, we provide a theoretical interpretation why outside artificial persons hold partial ownership under the circumstance of vertical transaction relationship. Our result is if the downstream firm holds partial ownership of the upstream firm, it may function as a bonding mechanism, which improves the performance of two parties. It means that, compared with $r = 0$, the mechanism of partial ownership improves the efficiency of customization service.

However, can the optimal partial ownership result in social optimal customized transportation level?

As we know, no matter what type the carrier is, either owner-managed one or a public-firm managed by managers, $r^* = \lambda$ or $r^* = 0.5$ is the necessary condition bringing in

social optimal customization level. If the carrier is an owner-managed one, only when the purchasing of partial ownership at par price occurs may choosing $r^* = \lambda$ be a rational decision for the consignor aiming at maximizing its total net income. But purchasing at premium price is dominant in reality; if calculated under general case of $\lambda = 0.5$, the optimal partial ownership r^* is less than λ, not large enough to motivate the decision-maker of the carrier to choose the most efficient customized production level. The marginal return obtained by the consignor through enlarging equity participation ratio will be offset by marginal costs of purchasing the equity ownership, and premium price distorting effects lead to the efficiency loss of the carrier's customization investment ($r^* < 0.5$).

On the opposite, when purchasing at discount, overmotivation leads to $r^* > \lambda$, and the customization efficiency loss may still occur. Therefore, we hold that, the effect of wealth transfer in the purchase of equity ownership is the main reason that leads to efficiency loss of customized production, which shows our theory about partial ownership different from the entrepreneur endeavor choice interpretation by Dasgupta and Tao, but similar to the conclusion of Aghion and Tirole's that partial ownership arrangement can motivate special investment, but cannot solve the investors' underinvestment problem totally.

However, when the carrier is public-managed, even if there exist $\theta = 0$ and the optimal partial ownership $\hat{r}^* < \lambda$, social optimal customization level cannot be obtained because the benefit of the consignor does not keep consistent with the trade parties' common benefit. When $\theta > 0$, $\hat{r}^*$ will become smaller and the higher loss degree of the customization investment efficiency will occur. Obviously, under the second-order condition constraint that we can get the optimal solution satisfying (32), the larger the average premium price parameter is, the smaller $\hat{r}^*$ is, the lower customized production efficiency becomes, and the greater social welfare loss will be, which holds true in the case of owner-managed carrier. As for the case of $\theta < 0$, it accords with the aforementioned analyses, that is, the overmotivation of equity ownership may lead to customized production efficiency loss.

In China, the state-owned equity reform in logistic industry just began, with unclear ownership partition, and many social functions assumed by firms are not peeled off. The high premium-price acquisitions may make carriers to choose $r^* = 0$, which leads to the undermotivation of the customization investment of consignors and the social optimal customized transportation cannot be realized. Therefore, in the developing process of logistic supply chains in China, it is necessary that the logistic firms should become the entities that can be self-managed, self-constricted, and self-motivated, and the burden of the social functions will lead to the loss of the transportation efficiency, which are all what we must pay attention to.

In addition, when all technical parameters keep constant, comparing optimal partial ownership in the cases of two different types of carrier, we can discover that, in theory, the ratio of optimal equity participation by the consignor in the owner-managed carrier should exceed the ratio in the public-managed firm; that is, $r^* > \hat{r}^*$. It provides a theoretic foundation for us to interpret that the interfirm mutual shareholding ratios of the member-firms within the familial-type logistic supply chains are much larger than those ratios within the public-type logistic supply chains. At the same time, it also means that the customized production efficiency of the former is higher than that of the latter. Although there is room for improvement, we still firmly believe that the success of Chinese logistic industry should be mainly attributed to the advantage of owner-managed efficiency.

To be mentioned, the mechanism of partial ownership undoubtedly improves the cooperative efficiency of two trade parties. Although social welfare level this arrangement provides is not optimal, the cooperative mechanism helps to enhance Pareto improvement of the return of two trade parties, compared with simple contract system.

6. Conclusions

The phenomena that one consignor holds equity ownership of one carrier within logistic supply chain are often observed. Despite its importance, the existing interpretations for interfirm partial ownership scheme remain relatively unexplored. In this paper, a theoretical explanation for equity participation arrangement existing between member-firms within logistic supply chain is provided under the background of customized production.

Based on the models in which we view the parameter for customization level as the selective variable of the carrier, we figure out that the simple contract cannot solve the low-efficient customized production problem. Equity participation mechanism together with simple contract can improve the efficiency of customized transportation. The partial ownership mechanism supported by customized production plays a role as a bond in keeping the relational transactions among member-firms, but not a role as the efficiency-enhancing mechanism resulting from outside artificial persons' supervision in some literature about equity ownership structure.

What is more, on the basis of keeping the logic deductive consistency, we obtain the outcome of the optimal partial ownership affected by the relative bargaining power λ of the consignor and the other outside income π_0 of the carrier, under two cases of owner-managed firm type and public-firm type, respectively, and show why the familial-type logistic supply chains may choose more efficient customized production level than public-type logistic supply chains.

To be mentioned, our theory provides few cases in which we can verify the interfirm equity participation ratio. Although many important conclusions we obtain seem to be consistent with some evidences, there is a need for further study, such as analyzing bilateral cross-shareholding case and considering the relationship between bargaining power and equity participation ratio through extending our models.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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