Inducing Supplier Backup via Blockchain Era

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Abstract. With the sparking of increasingly latent supply disruption risk, the global supply chains have exacerbated the risk and impact of supply disruptions. In order to cope with supply disruption, the downstream suppliers volunteer to strengthen investment in the appropriate strategy of backup production. This paper studies a single supply chain with potential supply disruption risk where the supplier implements backup production and the retailer has the advantage of using information sharing of blockchain system. This paper examines how the retailer's using information sharing of blockchain system to strengthen the adoption of backup production. Our findings reveal that, first, when the retailer voluntarily implements blockchain system to share his demand information, such demand sharing leads the supplier to produce the accurate backup production capacity. Second, the retailer strategically implements the blockchain system to utilize the supplier's backup production for more value.

Keywords. Backup production, supply disruption, blockchain system

1 Introduction

With a growing body of "black swan" and "gray rhino" events occurring, the supply disruption risk is increasingly and imperatively attaching more attention [1] [2]. Along with the supply disruption is the shutdown or even bankruptcy, usually an enormous loss, that the firm involved has to bear. For instance, Foxconn, the world's largest OEM, was forced to stop production for a while in early 2020 due to the outbreak of Covid-19, and even if it resumed production in the middle of February, the factory cannot operate at full capacity. Taking Toyota as another example, the supply disruption caused by the Tohoku earthquake in 2011 lasted more than six months [3]. These examples also illustrate that a perfect recovery from supply disruption is often not an easy and instantaneous work. Hence, many companies have been emphasizing and investing in enhancing the supply chain resilience to attenuate the impact subsequent to supply disruption. In practice, backup channel is an effective and proven instrument that often adopted by firms. The literature on backup channel-establishing, going back to [4] [5] [6], mainly focus this case of backup channel-establishing on the downstream buyers' side.

The noteworthy de facto status is that additional to the supply side uncertainty, in practice, the supplier always faces the unpredictable end-market demand, especially for the demand potential. However, taking the Benteler and BMW case as the instance again, they implement the blockchain system to build a transparent information-sharing mechanism, which enables Benteler to determine a more accurate backup production capacity in light of the demand information provided by BMW [7]. Motivated by the above examples, we wonder whether the information sharing of blockchain system strengthens the using of backup production.

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By far, the interaction between retailer's information-sharing mechanism of blockchain system and supplier-establishing backup production has been overlooked. The contradictory between theoretical literature and practical evidence incentivizes us to ask: according to the demand information sharing of blockchain system, how does the supplier set backup capacity? How the retailer's adoption of blockchain system strengthens the supplier's using of backup production? To solve the questions, we consider an unreliable supply chain with the supplier's backup production and the retailer's endogenetic adoption of blockchain system. In sum, the contributions of our paper are twofold. First, we creatively investigate the strategic impact of blockchain system on the supplier's backup production strategy. Second, we characterize the supplier's optimal blockchain adoption strategy when the retailer uses backup production strategy to attenuate the disruption risk.

2 Model Setting

We consider a supply chain with supply disruption risk where the supplier distributes goods at a wholesale price w to the retailer. To modelling the supply disruption risk, we use $\rho = \begin{cases} 1 & \text{with probability } z \\ 0 & \text{with probability } 1-z \end{cases}$ to denote the supply disruption risk, where z refers as the supply reliability [8]. To mitigate the supply risk, the supplier implements the backup production strategy. In specific, as soon as the supply disruption happens, the supplier has the ability to urgently order from other backup supply channel(s) at an additional cost $c(q_b)^2$ to recover the loss, where q_b denotes the minimum between the backup channel production capacity (hereafter backup capacity) and order quantity and $c > 0$ denotes the cost diseconomy of backup production. Due to the urgency of backup strategy, the production diseconomy can be regarded as having increasingly more expensive production capacity. The setting follows the literature [9].

The demand function is $p = \theta - q$,where θ is the demand potential and q is the retailer's order quantity. We model $\theta = \begin{cases} \theta_h & \text{with probability } 1/2 \\ \theta_l & \text{with probability } 1/2 \end{cases}$, where we use θ_h (θ_l) to denote the realized high-type (low-type) demand potential with probability 1/2.

In reality, the retailer is nearer to the final market and easier to get the first-hand data of market changes. Therefore, following [10], the manufacturer can obtain the accurate demand potential $\theta_i, i \in \{h, l\}$, while the supplier only knows the prior distribution for $\theta = \begin{cases} \theta_h & \text{with probability } 1/2 \\ \theta_l & \text{with probability } 1/2 \end{cases}$. However, when the retailer adopts the blockchain system, the accurate demand potential obtained by the retailer will share with the supplier. The sequences of the game are shown in Figure 1.

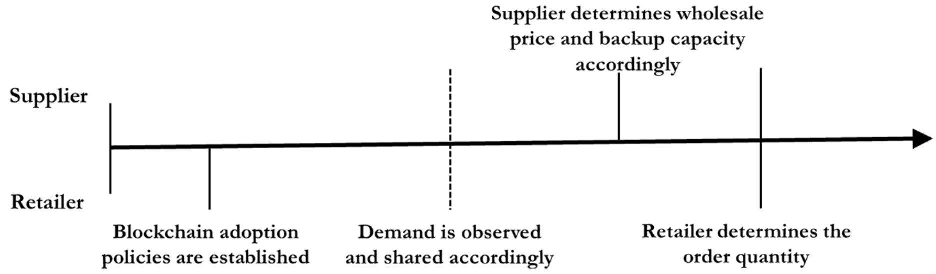

Fig. 1. Sequences of the game

3 Equilibrium Analysis

3.1 Without blockchain system

Under this scenario without blockchain system, the supplier can obtain the realized demand potential while the retailer only knows its distribution function and realized probability of demand potential. When a supply disruption happens, the supplier starts producing his backup goods to fulfill the order, and she predetermines backup capacity q_b. Considering the rational decision-making of the firms, the supplier's backup capacity is unreasonable to exceed the retailer's high-type order quantity (i.e., $q_b \le q_h$). Given the range of $q_b \in (0, q_h]$, we discuss it in two cases according to backup capacity:

(1) When the backup capacity is lower than the low-type order quantity (i.e., $0 < q_b \le q_l$) The following equations (1) and (2) are the profit functions of the retailer and supplier:

$$\pi_{R-i}(q_i) = z\,(\theta_i - q_i - w)q_i + (1-z)\,(\theta_i - q_b - w)q_b,\ \ i = \{h, l\}, \tag{1}$$

$$\Pi_S(w, q_b) = z\,(\tfrac{1}{2}wq_h + \tfrac{1}{2}wq_l) + (1-z)(wq_b - c(q_b)^2). \tag{2}$$

(2) When the backup capacity is higher than the low-type order quantity (i.e., $q_l < q_b \le q_h$), the profit functions of both firms are related to the order quantity and are formulated as follows (see equations (3) and (4)):

$$\begin{cases} \pi_{R-l}(q_l) = z\,(\theta_l - q_l - w)q_l + (1-z)\,(\theta_l - q_l - w)q_l \\ \pi_{R-h}(q_h) = z\,(\theta_h - q_h - w)q_h + (1-z)\,(\theta_h - q_b - w)q_b \end{cases}, \tag{3}$$

$$\Pi_S(w, q_b) = \tfrac{1}{2}z\,(wq_l + wq_h) + (1-z)\left(\tfrac{1}{2}wq_l + \tfrac{1}{2}wq_b - c(q_b)^2\right). \tag{4}$$

Using backward induction, the first-order optimality condition reveals the retailer's equilibrium order quality $q_i(w, q_b) = max\left\{\frac{\theta_i - w}{2}, 0\right\}$. Then, substituting $q_i(w, q_b)$ into Π_S, the equilibrium results are given by the following Lemma 1:

Lemma 1. *When the retailer opts not to adopt blockchain system, we have*:

(i) *If* $c \le \frac{\theta_h + \theta_l}{4\theta_h + 2z\theta_h - 2\theta_l}$ *, then* $q_b = \frac{3\theta_h - \theta_l}{8 + 4c(1-z)}$ *and* $w = \frac{(1 + 2c - 2cz)\theta_h + \theta_l}{4 + 2c - 2cz}$ *;*

(ii) *If* $\frac{\theta_h+\theta_l}{4\theta_h+2z\theta_h-2\theta_l} < c \leq \frac{z\theta_h+2\theta_l-z\theta_l}{2\theta_l+4z\theta_h-2z\theta_h}$, *then* $q_b = \frac{z\theta_h+\theta_l}{2(z-1+4c(1+z))}$ *and* $w = \frac{2c(z\theta_h+\theta_l)}{z-1+4c(1+z)}$;

(iii) *If* $\frac{z\theta_h+2\theta_l-z\theta_l}{2\theta_l+4z\theta_h-2z\theta_h} < c \leq \frac{z\theta_l-z\theta_h-2\theta_l}{z\theta_h-3z\theta_l}$, *then* $q_b = \frac{(2+z)\theta_l-z\theta_h}{8+4c(1-z)}$ *and* $w = \frac{z\theta_h-\theta_l(z+2cz-2-2c)}{4+2c-2cz}$;

(iv) *If* $\frac{z\theta_l-z\theta_h-2\theta_l}{z\theta_h-3z\theta_l} < c$, *then* $q_b = \frac{z(\theta_h+\theta_l)}{4(z-1+2cz)}$ *and* $w = \frac{cz(\theta_h+\theta_l)}{4cz-2+2z}$.

Intuitively, the cost diseconomy of backup production c results in a monotonic decrease in the equilibrium backup capacity q_b. It makes sense that the supplier would have less incentive to use backup production as the cost diseconomy c increases. We depict this result in Figure 2.

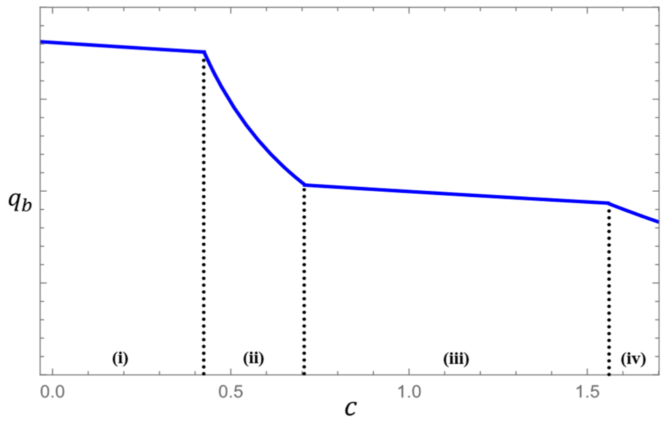

Fig. 2. Impact of c on the supplier's backup capacity ($\theta_l = 1, \theta_h = \frac{6}{5}, z = \frac{4}{5}$)

3.2 With blockchain system

We solve the scenario with blockchain system, where the realized demand potential is shared by the retailer with the supplier. The equations (5) and (6) are the firm's profit functions:

$$\pi_{R-i}(q_i) = z\,(\theta_i - q_i - w_i)q_i + (1-z)\,(\theta_i - q_{b-i} - w_i)q_{b-i}, \tag{5}$$

$$\pi_S(w_i, q_{b-i}) = z\,w_i q_i + (1-z)(w_i q_{b-i} - c(q_{b-i})^2), \text{ where } i \in \{h, l\}. \tag{6}$$

Similarly, we figure out the equilibrium decisions, as shown in Lemma 2.

Lemma 2. *When the retailer adopts the blockchain system, we have:*

(i) *If* $c \leq \frac{1}{z}$, *then* $q_i = \frac{\theta_i}{4-2c(z-1)}$, $q_{b-i} = \frac{\theta_i}{4-2c(z-1)}$ *and* $w_i = \frac{\theta_i(1+c-cz)}{2+c-cz}$;

(ii) *If* $c > \frac{1}{z}$, *then* $q_i = \frac{(z+cz-1)\theta_i}{2(z+2cz-1)}$, $q_{b-i} = \frac{z\theta_i}{2(z+2cz-1)}$ *and* $w_i = \frac{cz\theta_i}{z+2cz-1}$, *where* $i \in \{h, l\}$.

Lemma 2 uncovers that according to the retailer's adoption on blockchain system, the supplier figures out a more accurate backup capacity corresponding to the realized demand potential. In addition, the increased cost diseconomy leads to a lower backup capacity.

3.3 Comparison

On the basis of the retailer's profits, we investigate the retailer's blockchain system decision.

Proposition 1. *When* $0 < z \leq \tilde{z}$ *and* $\frac{3\theta_l-\theta_h-\sqrt{6\theta_h\theta_l+3\theta_l^2-5\theta_h^2}}{2(1-z)(\theta_h-\theta_l)} < c \leq \tilde{c}$*, the retailer opts to adopt blockchain system; otherwise, the retailer does not adopt blockchain system.*

Proposition 1 presents that depending on the supply reliability and the cost diseconomy, the retailer adopts different blockchain system strategy. In specific, the retailer strategically adopts blockchain systems to share the realized demand potential when the supply reliability is low (i.e., $0 < z \leq \tilde{z}$), and the cost diseconomy is moderate (i.e., $\frac{3\theta_l-\theta_h-\sqrt{6\theta_h\theta_l+3\theta_l^2-5\theta_h^2}}{2(1-z)(\theta_h-\theta_l)} < c \leq \tilde{c}$). This is because, on the one hand, in the presence of the supplier's backup production, the retailer suffers a strong price-raising effect from the supplier as the backup production option leads the supplier to determine an aggressive wholesale price. However, the supplier does not make an extremely aggressive wholesale price when the retailer implements blockchain system. That is, when considering the backup production strategy, the retailer's loss from an aggressive wholesale price is offset. On the other hand, the cost diseconomy impacts the backup-incentive effect of blockchain system. When the cost diseconomy is sufficiently low, the supplier has sufficient incentive to produce a high backup capacity. When the cost diseconomy is sufficiently high, the total cost of the supplier to use backup production is high. Thus, the backup-incentive effect of blockchain system on improving backup capacity is low, which corresponds to Area I in Figure 3. When the cost diseconomy is moderate, the backup capacity becomes low (i.e., $q_l < q_b < q_h$) if the retailer does not adopt blockchain system, and the backup-incentive effect of blockchain system effectively affects the backup capacity (i.e., $q_l = q_{b-l}$ and $q_h = q_{b-h}$) if the retailer adopts blockchain system. Hence, the retailer implements blockchain system if the supply reliability is low and the cost diseconomy is moderate (see Area II in Figure 3).

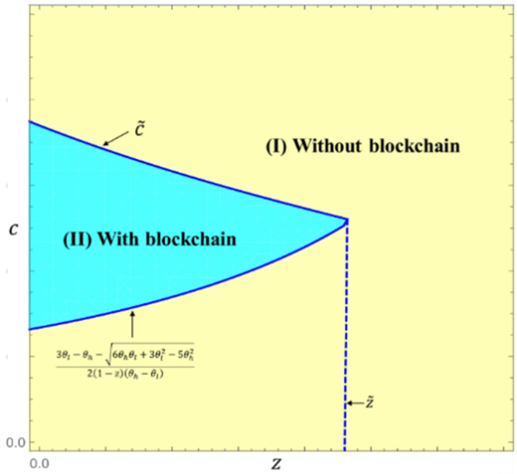

Fig. 3. Retailer's optimal blockchain adoption decision ($\theta_l = 1, \theta_h = 6/5$)

4 Concluding Remarks

Many suppliers could use backup production to respond to the risk of supply disruptions. When the supplier uses the backup production to mitigate the supply risk, the retailer determines whether to use information sharing of the blockchain system. We consider an unreliable supply chain in which a supplier has used backup production strategy and a retailer with superior demand information determines whether to adopt blockchain system. This paper explores the strategic impact of blockchain adoption on the supplier's backup production.

We highlight several results. First, according to the retailer's using of demand information sharing of blockchain system, the supplier sets a more accurate backup capacity to mitigate the supply risk. Second, the retailer voluntarily adopts the blockchain system to share his private demand information.

References

[1] Bimpikis, K., Candogan, O., Ehsani, S. (2019) Supply disruptions and optimal network structures. Management Science, 65(12): 5504-5517. https://doi.org/10.1287/mnsc.2018.3217.

[2] Jain, N., Girotra, K., Netessine, S. (2022) Recovering global supply chains from sourcing interruptions: the role of sourcing strategy. Manufacturing & Service Operations Management, 24(2): 846-863. https://doi.org/10.1287/msom.2021.0967.

[3] Goldschmidt, K., Kremer, M., Thomas, D. J., Craighead, C. W. (2021) Strategic sourcing under severe disruption risk: Learning failures and under-diversification bias. Manufacturing & Service Operations Management, 23(4): 761-780. https://doi.org/10.1287/msom.2020.0907.

[4] Saghafian, S., Van Oyen, M. P. (2012) The value of flexible backup suppliers and disruption risk information: newsvendor analysis with recourse. IIE Transactions, 44(10): 834-867. https://doi.org/10.1080/0740817X.2012.654846.

[5] Huang, H., Xu, H. (2015) Dual sourcing and backup production: Coexistence versus exclusivity. Omega, 57, 22-33. https://doi.org/10.1016/j.omega.2015.04.008.

[6] Demirel, S., Kapuscinski, R., Yu, M. (2018) Strategic behavior of suppliers in the face of production disruptions. Management Science, 64(2): 533-551. https://doi.org/10.1287/mnsc.2016.2626.

[7] Wang, G.X, Gao, F.C. (2020) The Economic Observer. http://www.eeo.com.cn/2020/1029/427645.shtml.

[8] Li, G., Liu, M., Zheng, H. (2022). Subsidization or diversification? Mitigating supply disruption with manufacturer information sharing. Omega, 112: 102670. https://doi.org/10.1016/j.omega.2022.102670.

[9] Ha, A. Y., Tong, S., Zhang, H. (2011). Sharing demand information in competing supply chains with production diseconomies. Management Science, 57(3): 566-581. https://doi.org/10.1287/mnsc.1100.1295.

[10] Huang, S., Guan, X., Chen, Y.J. (2018). Retailer information sharing with supplier encroachment. Production and Operations Management, 27(6): 1133-1147. https://doi.org/10.1111/poms.12860.