The Coordination of Service Supply Chain Based on Option and Spot Market in Emergency

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Abstract
A coordination model of service supply chain is built to analyze the optimal decision based on the combination of option contracts and spot market. Also, it is applied into the emergency circumstance, when demand, price as well as cost may be influenced. The new coordination strategy is also discussed.

Keywords: Service supply chain, Option contract, Spot market

Introduction
Kinds of emergencies happen frequently all over the world in recent years, which include natural disaster, public health events and other unexpected events. No matter what kind of these emergency events that arise, the enterprises on the supply chain will suffer enormous losses because of great change in market demand, supply interruption of raw materials, failure of production equipment and shortage of workers. To reduce the damage, it has been researched by many scholars that how to coordinate the supply chain to deal with emergencies. However, it is traditional physical product supply chain that has been discussed mostly nowadays; actually the losses that service supply chain suffered will be much larger. For instance, the 9•11 terror attack resulted in a depression of airline industry in the USA which resulted in a loss of 40 billion dollars. During the downturn at least 10 airlines filed for bankruptcy, 150,000 jobs were cut. it is until 5 years later that the whole industry was back in profit. Against this background, more attention should also turn to developing appropriate strategy against emergency events for service supply chain.

The main objective of supply chain management is to realize the maximization of the whole supply chain instead of one certain company, which requires good cooperation between enterprises. At present, most companies sign different contracts to cooperate with each other, thus the coordination of whole supply chain can be realized by managing the contracts that companies sign scientifically. Among various of contracts, option contract draws more and more attention cause of its flexibility. Option contract can be introduced into supply chain management to increase flexibility of supply chain and to deal with market uncertainty (Ritchken and Tapiero 1986). Also, it has been found out that option contracts can restrain the bullwhip effect in supply chain (Ma et al. 2004). The ordering models in the transaction on the basis of option contracts, which aim to realize the maximization of expected profit of the whole supply chain or each decision-maker in supply chain, become the focus of study on the use of option contracts, including both of single-period decision models (Guo et al. 2005) and two-period ordering models (Milner and Rosenblatt 2002).

With the development of technology, the electronic market that develops rapidly provides a more flexible and more convenient platform for spot transaction. The combined effect of contract and spot market under certain necessary condition is different from the use of contract only (Fu et al. 2010). The combination of contract and spot market increases the flexibility of procurement, which is of important significance for supply chain management in capital concentrated industry (Wu et al. 2002). What's more, the combination of option contracts and spot market results in different optimal strategies, including optimal price and capacity of the supplier and optimal order quantity of the retailer (Guo and Yang 2006, Kleindorfer and Wu 2003).

Under the circumstance that the market combined option contract and spot market, service integrator can decides whether to execute option in contract market or to procure directly from spot market to meet demand, which can increase the flexibility of supply chain and keep enterprises from losses cause of high option price or insufficient order quantity. At the same time, service supplier can sell the surplus capacity to other buyers in spot market, which can decrease the cost caused by surplus order quantity (Spinler and Huchzermeier 2003). Thus, the combination can coordination the service supply chain whose product has no salvage value, which is in favor of recovery after emergency events happen. Spinler and his team set a variable called state of the world, define the spot price, the willingness-to-pay (WTP) of the buyer as its function on behalf of market uncertainty (Spinler et al. 2006). However, in Spinler's article the procurement strategy was analyzed from the perspective of the WTP of the buyer, which is hard to describe. This paper builds and analyzes the procurement model from the perspective of market demand, and comes up with the optimal consumption strategy of service integrator and the optimal option price of the service supplier. The conclusion is that the service supplier can encourage the integrator to determine an appropriate order quantity by designing the option price. Especially, the procurement strategy is introduced into the circumstance that emergency happens, which decreases the losses of service supply chain caused by emergency events, at last, this paper brings out the optimal decision for both supplier and integrator to deal with the change caused by emergency events.

Explanation of market

The supply chain analyzed in this paper consist of one service supplier and one service integrator, the market combines the contract market represented by option contract and spot market transacted on electronic market, the information in market is completely symmetrical. The product is non-storable good or service with long lead-time and short selling season, which has no salvage after the selling season, it is difficult for this kind of product to deal with market uncertainty with use of inventory. In this case, the service supplier is the leader of the game in transaction who should determine and release option price information, the service integrator determine the order quantity as follower according to the information. After observing the market situation, the integrator should determine the execution quantity and the procurement quantity from spot market, on the other hand, the supplier can sell its surplus capacity to others in spot market.

Figure 1 illustrates the process of transaction. In period 0, the service supplier gives out information including product information and option price, the service integrator forecasts the market demand and determine order quantity, the supplier arranges the investment according to order. In period 1, the trading partners observe the market situation; the integrator can choose to execute option from contract market or purchase from other suppliers from spot market to satisfy market need, so the integrator should determine execution quantity and procurement quantity. At the same time, the supplier should execute the option and also can sell its surplus capacity, if any, to other buyers in spot market, so the supplier should determine how to allocate the capacity between contract market and spot market. After the decisions of both parties have been made, they finish the transaction to meet the market need.

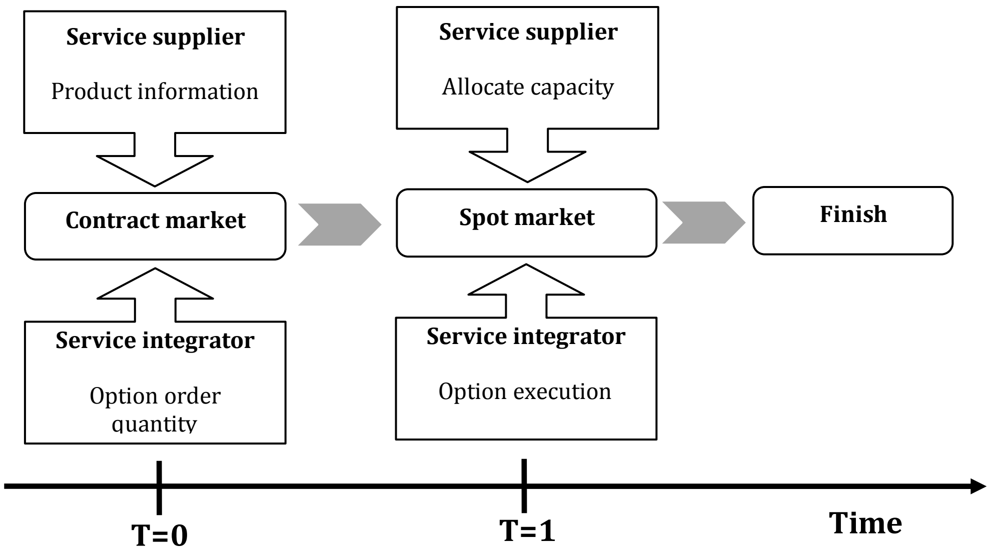

Figure 1 – Process of the transaction in the market combined contract and spot market

Basic model in normal condition

This paper introduces market economic state as a variable, market demand; service product price; spot price and various cost of product are regarded as functions of market economic state, which is decided by market and has no relationship with two parties of transaction. This paper assumes that all the capacity can satisfy market demand in normal condition, as a result the basic model doesn't consider stock-out cost. All the assumptions of variables can be shown as followings.

Market economic state is ω, its distribution function is $F(\omega)$, density function is $f(\omega)$. The demand can be shown as $D = dZ(\omega)$, $\partial D / \partial\omega > 0$. The price of service is P, $P = p\Phi(\omega)$, $\partial P / \partial\omega > 0$. The spot price of service can be shown as $C_s = c\Psi(\omega)$, $\partial C_s / \partial\omega > 0$. Investment of supplier is K. As for the cost of the service supplier, the setup cost of one unit investment is B_o, the operation cost of one unit capacity can be shown as $B = b\Theta(\omega)$, $\partial B/\partial\omega > 0$. In period 0, service supplier determines the price of option, which includes the price of option C_o and the execution fee of option C_e. The order quantity of option is Q. In period 1, service integrator determines execution quantity of option q_e and procurement quantity in spot market q_s. The probability that supplier find buyers to sell out surplus capacity: m, $0 \le m \le 1$. The variables meet the following inequalities: $B < C_s$, $B < C_e$.

The decision of service integrator

In period 0, service integrator needs to decide the order quantity of option. Actually, the service integrator takes its own profit as objective function and comes up with its order quantity Q. The profit function of the service integrator could be set up as followings.

$$\Pi_i = D * P - C_o * Q - C_e * q_e - C_s * q_s \qquad (1)$$

In period 1, service integrator needs to decide the quantity of capacity executed and procured, which will influence the order quantity of option. Thus, it should be found out that how the service integrator chooses between contract and spot market firstly. The quantity executed in contract market and procured in spot market will be different under different conditions.

The procurement decision of integrator and the corresponding market economic state can be shown as Table 1.

Table 1 – Procurement decision of integrator and corresponding state.

Particular case		q_e	q_s	Range of ω
$C_e \geq C_s$		0	D	$[0,\Psi^{-1}(C_e/c)]$
$C_e < C_s$	$D \leq Q$	D	0	$(\Psi^{-1}(C_e/c), Z^{-1}(Q/d)]$
	$D > Q$	Q	D-Q	$(Z^{-1}(Q/d), +\infty)$

The integrator can solve the following program to compute its optimal order quantity of option:

$$\text{Max } E\Pi_i(Q)$$

$$\text{s.t.} Q \geq 0.$$

Theorem 1. The optimal order quantity of integrator Q under the condition that option price of supplier is (C_o, C_e) can be shown by the implicit equation:

$$C_o = c\int_{Z^{-1}(Q/d)}^{\infty} \Psi(\omega)f(\omega)d\omega - C_e\int_{Z^{-1}(Q/d)}^{\infty} f(\omega)d\omega \qquad (2)$$

Proof. According to program (1), the expected profit of the integrator is:

$$E\Pi_i = \int_0^{\Psi^{-1}(Ce/c)}(DP - C_oQ - C_sD)dF + \int_{\Psi^{-1}(Ce/c)}^{Z^{-1}(Q/d)}(DP - C_oQ - C_eD)dF + \int_{Z^{-1}(Q/d)}^{\infty}\big(DP - C_oQ -$$
CeQ−CsD−QdF

$$= \int_0^{\Psi^{-1}(Ce/c)}(dZ(\omega)p\Phi(\omega) - C_oQ - c\Psi(\omega)dZ(\omega))dF + \int_{\Psi^{-1}(Ce/c)}^{Z^{-1}(Q/d)}(dZ(\omega)p\Phi(\omega) - C_oQ -$$
CedZ(ω)dF+Z−1(Q/d)∞(dZ(ω)pΦ (ω)−CoQ−CeQ−cΨ(ω)(dZ(ω)−Q))dF

The first and second derivative of the expected profit can be shown respectively:

$$\partial E\Pi i/\partial Q = c\int_{Z^{-1}(Q/d)}^{\infty}\Psi(\omega)f(\omega)d\omega - C_e\int_{Z^{-1}(Q/d)}^{\infty}f(\omega)d\omega - C_o$$

$$\partial^2 E\Pi i/\partial Q^2 = f(Z^{-1}(Q/d))(Z^{-1})'[Ce - c\Psi(Z^{-1}(Q/d))]/d$$

Cause $\partial^2 E\Pi i/\partial Q^2 < 0$, set $\partial E\Pi i/\partial Q = 0$, equation (2) can be acquired.

The decision of service supplier

The service supplier should establish appropriate price mechanism of option as the leader of game to make the order quantity of the integrator realize not only the maximization of its own profit but also the maximization of the profit of the whole supply chain.

Firstly, we should analyze the profit of the whole supply chain, which can be shown as:

$$\Pi = \Pi_i + C_o * Q + q_e * (C_e - B) + m * q_s * (k - q_e)^+ - B_o * K \quad (3)$$

The situation of the service supply chain and corresponding state of market can be shown as Table 2.

Table 2 – Situation of the service supply chain and corresponding market economic state.

Particular case		q_e	q_s	Surplus capacity	Range of ω
$C_e \geq C_s$		0	D	K	$[0, \Psi^{-1}(C_e/c)]$
$C_e < C_s$	$D \leq Q$	D	0	K -D	$(\Psi^{-1}(C_e/c), Z^{-1}(Q/d)]$
	$D > Q$	Q	D-Q	K -Q	$(Z^{-1}(Q/d), +\infty)$

Solving the following program to compute optimal order quantity of option Q^* for supply chain:

$$\text{Max } E\Pi(Q^*)$$
$$\text{s.t. } Q^* \geq 0.$$

Theorem 2. The optimal order quantity for the whole supply chain Q can be shown by the implicit equation:

$$c\int_{Z^{-1}(Q^*/d)}^{\Psi^{-1}(Ce/c)} \Psi(\omega)f(\omega)d\omega - b\int_{Z^{-1}(Q^*/d)}^{\Psi^{-1}(Ce/c)} \Theta(\omega)f(\omega)d\omega = 0 \quad (4)$$

Proof. The expected profit of supply chain is:

$$E\Pi = \int_0^{\Psi^{-1}(Ce/c)} \big(DP - C_sD + mK(C_s - B) - B_oK\big)dF + \int_{\Psi^{-1}(Ce/c)}^{Z^{-1}(Q^*/d)} (DP - C_eD + D(C_e - B) + m(K - D)(Cs-B)-BoKdF+Z-1(Q*/d)\infty(DP-CeQ*-Cs(D-Q*)+Q*(Ce-B)+m(K-Q)(Cs-B)-BoK)dF$$

$$= \int_0^{\Psi^{-1}(Ce/c)} (dZ(\omega)p\Phi(\omega) - c\Psi(\omega)dZ(\omega) + mK(c\Psi(\omega) - b\Theta(\omega)) - B_oK)dF + \Psi-1(Ce/c)Z-1(Q*/d)dZ(\omega)p\Phi(\omega)-CedZ(\omega)+dZ(\omega)(Ce-b\Theta(\omega))+m(K-dZ(\omega))(c\Psi(\omega)-b\Theta(\omega))-BoKdF+ Z-1(Q*/d)\infty(dZ(\omega)p\Phi(\omega)-CeQ*-c\Psi(\omega)(dZ(\omega)-Q*)+Q*(Ce-b\Theta(\omega))+m(K-Q)(c\Psi(\omega)-b\Theta(\omega))-BoK)dF$$

The first and second derivative of the expected profit can be shown respectively:

$$\partial E\Pi / \partial Q^* = (1 - m)\left(c\int_{Z^{-1}(Q^*/d)}^{\infty} \Psi(\omega)f(\omega)d\omega - b\int_{Z^{-1}(Q^*/d)}^{\infty} \Theta(\omega)f(\omega)d\omega\right)$$

$$\partial^2 E\Pi i / \partial Q^{*2} = (1 - m)f(Z^{-1}(Q^*/d))(Z^{-1})'(b\Theta(Z^{-1}(Q^*/d)) - c\Psi(Z^{-1}(Q^*/d))) < 0$$

Set $\partial E\Pi / \partial Q = 0$, equation (4) can be acquired.

The maximization of the whole supply chain is realized by the leader of the game, the service supplier, who establishes appropriate price mechanism of option to make the order quantity of the integrator equals the optimal order quantity of the whole supply chain. Set Q = Q*, the condition which option price (C_o, C_e) should satisfy can be computed.

Theorem 3. The price of option (C_o, C_e) determined by the supplier to realize the coordination of service supply chain can be shown as the following equation:

$$Ce \int_{Z^{-1}(Q/d)}^{\infty} f(\omega)d\omega + Co = mc \int_{Z^{-1}(Q/d)}^{\infty} \Psi(\omega)f(\omega)d\omega - (m-1)b \int_{Z^{-1}(Q/d)}^{\infty} \Theta(\omega)f(\omega)d\omega \quad (5)$$

Model of emergency

It is assumed in this paper that emergency events happen between period 0 and period 1, when the order quantity of option Q has been determined, but execution quantity of option qe and procurement quantity in spot market qs are unknown. Emergency events result in change of market economic state, which will influence market demand, price of service and Operation cost of service. Under this circumstance, demand may be larger than order, which makes stock-out happen.

In this model, the market economic state after emergency events happen becomes ε, its distribution function is $F(\varepsilon)$, density function is $f(\varepsilon)$. Total capacity in market: M

The variables meet the following inequalities: $B < C_s$, $B < C_e < S$, $M > K$

Once emergency events happen, market economic state will change from ω to , which means all the functions of market economic state will change, including market demand. If market demand becomes larger than total capacity in market, stock-out will happen, so emergency model should take shortage cost into consideration. As a result, the original order quantity for integrator of basic model cannot maximize its own expected profit; on the other hand, the original price strategy of option cannot coordination the supply chain any more. The decisions for both parties of emergency model should be discussed again.

Decisions for particular case are as followings:

1). When $C_e \geq C_s$, the integrator will choose to purchase service from spot market instead of executing option, $q_e = 0, q_s = D$.

The profit of integrator: $\Pi_{i1} = DP - C_oQ - C_sD$.

The profit of whole supply chain: $\Pi_1 = DP - C_sD + mK(C_s - B) - B_oK$.

2). When $C_e < C_s$, the integrator should determine the quantity of option to be executed according to market demand.

2.1). If $D \leq Q$, the integrator will execute option partly and give up purchasing from spot market, $q_e = D$, $q_s = 0$. The profit of the service integrator and the whole supply chain can be shown as:

$\Pi_{i21} = DP - C_oQ - C_eD$.

$\Pi_{21} = DP - C_eD + D(C_e - B) + m(K - D)(C_s - B) - B_oK$

2.2). If $Q < D \leq M$, procurement decision of the integrator is $q_e = Q$, $q_s = D - Q$.

$\Pi_{i22} = DP - C_oQ - C_eQ - C_s(D - Q)$.

$$\Pi_{22} = DP - C_eQ - C_s(D - Q) + Q(C_e - B) + m(K - Q)(C_s - B) - B_oK$$

2.3). If $D > M$, procurement decision of the integrator is $q_e = Q$, $q_s = M - Q$. At this time, the demand exceeds the total capacity, so the quantity of shortage is D-M.

$\Pi_{i23} = DP - C_oQ - C_eQ - C_s(M - Q) - S(D - M).$
$\Pi_{23} = DP - C_eQ - C_s(M - Q) - S(D - M) + Q(C_e - B) + m(K - Q)(C_s - B) - B_oK$

Table 3 illustrates the situation of the service supply chain, including shortage and corresponding state of market after emergency events happen.

Table 3 – Situation of supply chain and corresponding market economic state in emergency.

Particular case		q_e	q_s	Surplus capacity	Shortage	Range of ε
$C_e \geq C_s$		0	D	K	0	$[0,\Psi^{-1}(C_e/c)]$
$C_e < C_s$	$D \leq Q$	D	0	K -D	0	$(\Psi^{-1}(C_e/c),Z^{-1}(Q/d)]$
	$Q < D \leq M$	Q	D-Q	K -Q	0	$(Z^{-1}(Q/d), Z^{-1}(M/d)]$
	$D > M$	Q	M-Q	0	D-M	$(Z^{-1}(M/d),+\infty)$

The expected profit of the service integrator can be shown as:

$$E\Pi_i = \int_0^{\Psi^{-1}(C_e/c)} \Pi_{i1} dF + \int_{\Psi^{-1}(C_e/c)}^{Z^{-1}(Q/d)} \Pi_{i21} F + \int_{Z^{-1}(Q/d)}^{Z^{-1}(M/d)} \Pi_{i22} dF + \int_{Z^{-1}(M/d)}^{\infty} \Pi_{i23} dF \qquad (5)$$

The following function states the expected profit of the service integrator:

$$E\Pi = \int_0^{\Psi^{-1}(C_e/c)} \Pi_1 dF + \int_{\Psi^{-1}(C_e/c)}^{Z^{-1}(Q/d)} \Pi_{21} F + \int_{Z^{-1}(Q/d)}^{Z^{-1}(M/d)} \Pi_{22} dF + \int_{Z^{-1}(M/d)}^{\infty} \Pi_{23} dF \qquad (6)$$

By reference to the calculation method of basic model in normal situation, the new strategy of emergency model can be computed according to the derivative of $E\Pi_i$ and$E\Pi$.

Theorem 4. Once emergency events happen, the portfolio strategy of the service integrator and the price strategy of the service supplier should change with the market economic state, the new decisions for both parties of emergency model can be shown as followings respectively:

The optimal order quantity for the service integrator Q can be shown by the implicit equation:

$$C_o = c \int_{Z^{-1}(Q/d)}^{\infty} \Psi(\varepsilon) f(\varepsilon) d\varepsilon - C_e \int_{Z^{-1}(Q/d)}^{\infty} f(\varepsilon) d\varepsilon \qquad (7)$$

The service supplier need to carry out the new price strategy of option (C_o, C_e) to deal with emergency events, the new price strategy of emergency model should meet the following condition:

$$C_e \int_{Z^{-1}(Q/d)}^{\infty} f(\varepsilon) d\varepsilon + C_o = mc \int_{Z^{-1}(Q*/d)}^{\infty} \Psi(\varepsilon) f(\varepsilon) d\varepsilon - (m-1) b \int_{Z^{-1}(Q*/d)}^{\infty} \Theta(\varepsilon) f(\varepsilon) d\varepsilon \qquad (8)$$

Summing up and comparing all the theorems mentioned above, once the emergency events happen, the economic state of the market will change, it will result in the change of market demand, the price of service product, spot price and operation cost of service, which can be presented by the function of economic state of market. What's more, stock-out will become possible if demand influenced by emergency is larger than total capacity in market. As a result, the original optimal order quantity and price of option of basic model cannot realize the coordination of supply chain, the conclusion of emergency model can coordinate service supply chain again, but the change of decision for both parties has no relationship with shortage cost, which is decided be the change of economic state of market.

Conclusion

The coordination strategy of service supply chain is discussed, which few scholars have studied. Firstly, a basic model is built after computing the optimal order quantity of the service integrator aimed at maximizing its own expected profit, which determines an appropriate price strategy for the service supplier to realize the maximization of the profit of the whole service supply chain. Then, the basic model is applied into emergency situation, when market demand, price of service and operation cost change as functions of market economic state which becomes different once emergency events happen to become an emergency model. Similar to the basic model, the emergency model determines not only the new order quantity of the integrator but also the emergency option price of the supplier. The emergency model enables service supply chain to realize coordination again by use of a new set of option price determined by the supplier.

However, both of the basic and emergency models are built on the basis of a series of assumptions, which should be tested and verified by use of data gathered in practice. In addition, the supply chain studied in this paper consists of on service supplier and one service integrator, which is different from the reality. Service supply chain including more than on professional service suppliers is more common in reality, which could be the main research object for further research.

Acknowledgments

This research was supported by grants from the NSFC major program (Grant No.70971100, 71090404/71090400) and the NSFC general program (Grant No. 71272045).

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