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# Research on the Governance Mechanism of Aviation Complex Product Manufacturing Supply Chain Based on Dynamic Game Theory

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**Abstract.** In the manufacturing process of aeronautical complex products, for the following problems: develop long production cycle, a large number of ancillary products, a plurality of participating units, etc, and the status of the frequency of quality problems, using single-phase static game model in the case of asymmetric information, study on Supplier Quality insufficient investment, which resulting in opportunistic behaviour reasons. And using KMRW dynamic game model, we quantitative analysis the mechanism and crucial role of reputation mechanisms to ensure aeronautical complex product manufacturing supply chain and effective operation.

## 1 Preface

With the rapid development of aviation equipment, aviation complex products is with a high degree of complexity, a large number of ancillary products, the participating units and more capital investment. This significantly increases the difficulty of aeronautical products quality management. Aviation complex products manufacturing, is not only within one enterprise, often also involve collaboration between several companies, and even extended to the global supply chain. As long as there is one company occurs problem in the supply chain, it is possible to cause the project schedule delays, cost increases, product performance degradation and even lead to the failure of the entire project. Thus, in the aviation complex manufacturing process, we should strengthen supply chain quality management to improve the overall performance of the supply chain. Existing empirical studies show that the effective use of quality management has a significant impact on the performance of overall supply chain and a single enterprise (Robinson and Malhotra, 2005; Flynn, 2005)[1-2].

Compared with traditional single enterprise quality management methods, supply chain quality management is focusing on the supply chain operations and structure management (Hsieh and Liu, 2010)[3]. The quality of the supply chain's product depends not only on the production capacity, level of quality of manufacturers and suppliers of, but also relies on its subjective factors. Therefore, some scholars research on the quality incentive mechanism of the supply chain from the perspective of sampling strategies, reward and punishment mechanism, profit distribution mechanism, payment and so on. Such as Starbird (2001)[4] in the process of the research of supply chain contract design quality, puts forward how to design the supply chain to punish and reward and check the strategy, and proposed the corresponding quality incentive mechanism; Chao et al. (2009)[5]in the study of supplier quality control problem, puts forward how to carry out quality improvement and the contract design of product buy-back; Zhu et al. (2011)[6] studied how to make the product quality control strategy in the two-stage supply chain, and established a quality control policy model, designed a quality control contract; Zhang et al. (2012)[7] analyzed how to control the real-time quality of the product bulk ordering in the supply chain. The above studies for the quality management of complex aerospace manufacturing supply chain provide an important reference, but they didn't discuss the important role of reputation in the supply chain quality management. Therefore, we use single-phase static game model to study the motivation of quality opportunistic behavior in the aviation complex product manufacturing supply chain. And we quantitative analysis the critical effects of reputation to ensure aviation complex product manufacturing supply chain effective operate by using dynamic game model.

## 2 Analysis of supply chain quality opportunism based on single stage static game

Opportunistic behavior means that damage the interests of others for oneself in the situation of information asymmetry. In the process of aviation complex products supply chain manufacturing, various actors are opportunistic behavior, opportunistic behavior largely affected the quality of the supply chain. By using the single phase static game model, we quantitative analysis

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the behavior of the constituent entities of the supply chain strategy. We suppose that in the supply chain, the action strategies of manufacturer A and Vendor B are “cooperative" or "opportunism". Manufacturer A action strategy "cooperative" is to provide reasonable purchase price for B, and ensure its profit level; "opportunistic" is in order to reduce its cost, and then give unreasonable price. Supplier B action strategy “cooperative” is to provide A quality qualified products; "opportunistic" refers to the shoddy. Benefits matrix of the single phase static game is shown in figure 1.

**Table 1.** Benefits matrix of the single phase static game.

| | | **Supplier** | |
|---|---|---|---|
| | | Cooperative | Opportunistic |
| **Manufacturer** | Cooperative | U1，V1 | U3，U2 |
| | Opportunistic | U2，V3 | U4，V4 |

U and V represent the revenue functions of actors A and B that under different strategy combination, and assuming U2 > U1 > U4 > U3 ,V2 > V1 > V4 > V3. The game can be seen as a typical prisoner's dilemma game. To meet the goal of maximizing their own interests, actors choose opportunistic behavior in driving short-term interests. Although the benefit that (cooperative, cooperative) brings to actors A and B to is more than (opportunistic, opportunistic), but in the end their strategic combination of rational choice is (opportunistic, opportunistic). This is a non-cooperative Nash equilibrium. Thus, in single-phase static game, the final result of two actors in the supply chain is: Manufacturers formulate unreasonable purchase price, suppliers provide inferior products, supply chain product quality problems worsened. As can be seen, in the supply chain collaboration, causes of opportunistic behavior are mainly the following two aspects:

(1) “Information asymmetry”. In the supply chain, quality information asymmetry will lead to two consequences: First, prior to the signing of the contract, Since the downstream buyers cannot determine the level of quality provided by suppliers upstream products, which tend to pay the same price to all types of providers. This will result in the interests of high-quality products suppliers have been violated and to change the type. Second, after the signing of the contract, Because of asymmetric information buyers cannot effectively monitor and supervise the quality of products offered by suppliers, thus the suppliers have an incentive to reduce the quality level of the product. It will further deteriorate the product quality of supply chain.

(2) “Unstable partnership”. Unstable partnership is another major cause of product quality defects in the supply chain. Due to the cooperation of upstream and downstream enterprises of the supply chain is a temporary alliance based on interest, it is lack of trust and the partnership is in a high degree of substitutability. These features result in the potential instability of cooperation in the supply chain, and partnership of members may collapse in the short term. In non-long-term expectations, members of the supply chain will choose to maximize short-term profit and ignore the overall interests that win-win situation brings.

# 3 Analysis of Reputation Governance Mechanism of Supply Chain Based on Dynamic Game

KMRW model is raised by Kreps, Wilson, Milgrom, Roberts four scholars in 1982. They noted that the role of reputation is to provide an implicit incentive to the participants who concerned the long-term interests. Thus, reputation can be a substitute for explicit contracts. This theory has been widely used in the field of management. Mailath and Samuelson(2001) put forward that the reputation as an asset also requires investment and maintenance. Schiff et al. (2002) emphasized the role of the flow of reputation in reducing information asymmetry. They noted that the widespread of reputation can improve the efficiency of operation of the market. In China, the reputation of the model is widely used in research of innovation collaboration. Related studies have shown that the establishment of the reputation mechanism will help alleviate the problems caused by asymmetric information.

As can be seen from the analysis of the second chapter, if the members of the supply chain pay too much attention to their own interests, do not establish mutual trust, and without enough expectations for the stable relations of cooperation, it will lead to the prisoner's dilemma and the loss of long-term interests. Reputation mechanism is to reduce the behavior uncertainty of members by providing information of the trust and willingness. It can enhance the effectiveness of the interaction between supply chain members. Members can use the "reputation" to accumulate the trust between members and reduce the transaction costs. The higher level of uncertainty in the external environment, the partners will increasingly concern about its reputation. The role of reputation will become more significant(Kreps and Wilson, 1982)[8]. In the trading between members, members who take opportunistic behavior can help obtain short-term benefits, but it can be not always succeed in the long run. The cost of short-term speculation may be greater. Obviously, the protective effect of cooperation by reputation is to prevent the impact of fraudulent acts of cooperation, and thus improving the interests of the members. To test this hypothesis, this paper introduces KMRW model in supply chain quality management and to explore the mechanism of reputation in the supply chain to ensure product quality.

## 3.1 Model assumptions

Hypothesis 1. To simplify the analysis, we assume that manufacturer A and supplier B to be the participants of the supply chain game. Manufacturer A has a good sense of cooperation and does not to take opportunistic behaviour. In the first phase, the manufacturer A will use cooperative strategy. The later stage strategy will be adjusted according to the supplier B’s last stage strategy.

Once B Select uncooperative, and then the manufacturer A will never cooperate with B.

Hypothesis 2. Supplier B has two types: cooperative and opportunistic. Uncooperative type B is also possible to disguise as cooperative in the pre-transaction process for the final stage. Supplier B's type is private information, under conditions of incomplete information, the manufacturer A does not know.

Hypothesis 3. For supplier B, the higher of occupation rate, the greater of the effectiveness. In the long process of repeated game, manufacturer A can observe the behaviour of B and consequent adjustment measures. So B's effectiveness obtained due to encroachment will decrement by the defensive measures of A.

Hypothesis 4. In the transaction process between manufacturer A and supplier B, the single stage utility function is:

$$U=-\frac{1}{2}V^2+\partial(V-V^s) \quad (1)$$

$V$ is the actual occupation rate of supplier B, $0 \leqslant V \leqslant 1$; $V^s$ is the expected occupation rate of the manufacturer A, it represents manufacturers A expected judgment for the supplier B's action, $0 \le V^s \le 1$ ; α indicates the type of supplier B, When α =0, it represents supplier B is cooperative. When α =1,it represents supplier B is opportunistic.

Hypothesis 5. At the beginning of the game, $P_0$ indicates the priori probability that manufacturer A consider Supplier B is cooperative. 1- $P_0$ indicates the priori probability that manufacturer A consider Supplier B is opportunistic.

## 3.2 Model analysis

In the process of multi-stage supply chain dynamic game, $q_t$ is assumed for the probability of the supplier B choose to cooperate in *t* stage. $q'_t$ is the probability that manufacturer A consider supplier B will cooperate in *t* stage. If the manufacturer A don't observe the misappropriating behavior from supplier B in *t* stage, according to Bayes' rule, in *t + 1* stage the posterior probability of B is considered of cooperative is:

$$P_{t+1}(\alpha=0|V_t=0)=\frac{P_t\times 1}{P_t\times 1+(1-P_t)*q'_t}\ge P_t \quad (2)$$

By equation (2) can be obtained theorem 1.

Theorem 1: If the supplier B chooses to cooperate in *t* stage, then in the next stage the probability that manufacturer A consider supplier B is Cooperative will rise.

Suppose supplier B select uncooperative in *t* stage, it can get the formula (3):

$$P_{t+1}(\alpha=0|V_t=0)=\frac{P_t\times 0}{P_t\times 0+(1-P_t)*q_t}=0 \quad (3)$$

By equation (3) can be obtained theorem 2.

Theorem 2: Once the supplier B select uncooperative, the manufacturer A will consider it is uncooperative model and won't cooperate with it. This is called the grim strategy, also known as the trigger strategy.

Suppose *t* stage is the final phase, then it is as a single game in *t* stage game. Suppliers B will not choose to cooperate, it's the optimal choice is $V_t=\partial=1$ . And manufacturer A knows B' optimal choice. Therefore, the expectation for A to B is:

$$V_t^e=V_t\times(1-P_t)=1\times(1-P_t)=1-P_t \quad (4)$$

In this case, the utility level of non-cooperative supplier B is:

$$U_t(1)=-\frac{1}{2}V_t^2+\alpha(V_t-V_t^e)=-\frac{1}{2}+(1-1+P_t)=P_t-\frac{1}{2} \quad (5)$$

By equation (5) can be obtained: $\partial U_t/\partial P_t=1$,

And it can get Theorem 3,4.

Theorem 3: The utility of non-cooperative supplier B in final stage is an increasing function of the reputation that it develops in the transaction process with members. The non-cooperative B will disguise cooperation actively to improve the reputation in the supply chain.

Theorem 4: Manufacturer A more thinks B is cooperative, the bigger the $P_t$, and supplier B will encroach more utility in the final stages.

Now, we will study the non-cooperative supplier B's selection strategy in *t-1* stage. Because t stage is the final phase, and the non-cooperative B is cooperative before the *t-1* stage. Before *t-1*stage B cooperative behaviour ensures $P_{t-1}>0$. Therefore, the expectation for A to B is:

$$V_{t-1}^e=V_{t-1}^{\theta}\times(1-P_{t-1})(1-q_{t-1})=1\times(1-P_{t-1})(1-q'_{t-1}) \quad (6)$$

$V_{t-1}^{\theta}=1$is the maximum cupation rate in *t-1* stage. $\delta$ is the discount factor, reflecting the long-term patience of supply chain members. Here we only consider $q_{t-1}$=0,1,and to compare the utility of B in *t-1*stage by two strategic choice.

If the non-cooperative type B does not cooperate in *t-1* stage, namely $q_{t-1}=0$, $V_{t-1}=1$, and $P_t=0$. In this case the total utility of B is:

$$U_{t-1}(1)+\delta U_t(1)=[-\frac{1}{2}+(1-V_{t-1}^e)]-\frac{1}{2}\delta=\frac{1}{2}-V_{t-1}^e-\frac{1}{2}\delta \quad (7)$$

If the non-cooperative type B cooperate in *t-1* stage, namely $q_{t-1}=1$, $V_{t-1}=0$. In this case the total utility of B is:

$$U_{t-1}(0)+\delta U_t(1)=-V_{t-1}^e+\delta(P_t-\frac{1}{2}) \quad (8)$$

Therefore, if the following conditions are true, then the formula (8) is greater than the formula (7), namely

$$P_t\ge\frac{1}{2}\delta \quad (9)$$

By the formula (9), we can know that the total efficiency if non-cooperative supplier B chooses cooperate in *t-1* stage is greater than it doesn't. Therefore, if $q_{t-1}$ constituting a non-cooperative equilibrium strategy , $q'_{t-1}$ = 1, this means $P_t=P_{t-1}\ge\frac{1}{2}\delta$ . Theorem 5 can be obtained.

Theorem 5: When the probability of A thought B is cooperative in *t - 1* stage $P_t\ge\frac{1}{2}\delta$ , non-cooperative B will continue to pretend cooperate.

In other words, if the supplier has more reputation, it will have more enthusiasm to maintain reputation.

Conversely, if the supplier due to take opportunistic behaviour and undermines the reputation, the opportunistic behaviour will occur earlier and more frequently. By using the KMRW model, it can be seen that reputation mechanism will constraint behaviour of opportunists in the conditions of incomplete information.

## 4 Conclusion

In the aviation complex product manufacturing supply chain, due to the formation of product quality has several structural features, such as information asymmetry, double marginal and unstable partnership, these problems make the supply chain quality management is more complex and difficult respect to internal quality control. Compared with traditional single enterprise quality management methods, supply chain quality management is focusing on the supply chain operations and structure management. Existing studies pay more attention to the interests of the settlement mechanism, and didn't consider the important role of the reputation. Therefore, we use the single-phase static game model in the case of asymmetric information, study on Supplier Quality insufficient investment, which resulting in opportunistic behaviour reasons. And using KMRW dynamic game model, we quantitative analysis the mechanism and crucial role of reputation mechanisms to ensure aeronautical complex product manufacturing supply chain and effective operation.

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