

# The Supply Chain Design in Japan's Auto Industry

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**Abstract:** In this paper, analytical models are developed to study the benefits from cooperation and leadership in a supply chain. In addition to providing analytical expressions for cooperation and leadership, we investigate conditions under which cooperation and leadership policies should be taken by the leader of the supply chain. A total of eight cooperation/leadership policies of the leader company are analyzed by using four models. We give optimal decisions for the leader company under different cost combinations.

*Keywords:* Supply Chain; Cooperation; Coordination; Leadership; *Keiretsu*.

## 1. INTRODUCTION

A company in the supply chain usually holds a win-win or lose-lose relationship with its upstream players (suppliers) and downstream players (customers). They are partners and need to cooperate together to achieve win-win and avoid lose-lose. Brandenburger and Nalebuff (1996) described the total value created by players of a supply chain as a pie. The pie will grow bigger (i.e. win-win relationship) if the company, suppliers of the company and customers of the company cooperate together (p.36).

Among players in the supply chain, one often emerges as the leader that can control the performance of the whole supply chain. Majumder and Srinivasan (2006) summarized companies such as Wal-Mart, Ikea and Nike that hold contract leadership (i.e. the ability to offer wholesale price and two-part tariff contracts). These companies have a strong influence on the supply chain.

Another example of strong cooperation/leadership relations is the structure of assembler-supplier relations of Japanese auto makers. This structure is called "*keiretsu*", which enables Japanese auto assemblers to remain lean and flexible while enjoying a level of control over supply chain akin to that of vertical integration. Toyota and its partners (suppliers such as *Denso* and customers such as dealers) are conspicuous example of *keiretsu*. In a *keiretsu*, assembler (e.g. Toyota) is often the leader of the supply chain. Many publications described *keiretsu* as high trust cooperation, strong leadership, long-term purchasing relations, intense collaboration, cross-shareholding, and the frequent exchange of personnel and technology.

The current literature on *keiretsu* or *keiretsu*-like supply chains contains many popular articles that are descriptive

or provide qualitative studies. The above examples point to a need for developing quantitative models to analyze the performance of a supply chain which involves cooperation and leadership. The goal of this paper is to contribute to this objective.

We consider a supply chain which contains cooperation and leadership relations. There are three players in the supply chain: the leader company (e.g. Toyota), the supplier of the leader (e.g. *Denso*) and the customer of the leader (e.g. Dealers), see Fig. 1 for detail.

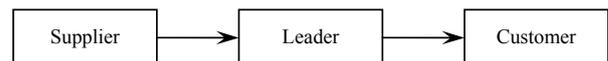


Fig. 1. A supply chain with leader

Two types of benefits are considered in this paper: the benefit from the cooperation and the benefit from the leadership. We explain these two types of benefits as follows.

**The benefit from cooperation** (Fig. 2): We assume in this paper that the cooperation only occurs between neighboring players. That is, benefit occurs if the supplier cooperate with the leader. Similarly, there is benefit between the leader and customer if they cooperate with each other. However, because there is no direct cooperation relation between the supplier and the customer, no cooperative benefit will occur between them.

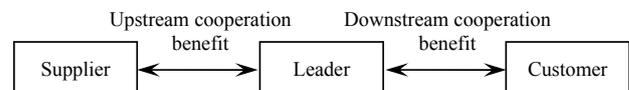


Fig. 2. The benefit from cooperations

**The benefit from the leaderships** (Fig. 3): Cooperations are prerequisites for the leadership. If the supplier or customer do not cooperate with the leader (e.g. those short-term purchasing contracts or one-time players), how can they accept the leadership of the leader company? Therefore, the benefit from the leadership only occurs when both the supplier and the customer cooperate with the leader. In this paper, we assume that if both supplier and customer cooperative relations exist, then the supply chain can obtain a benefit from the leadership of the leader company.

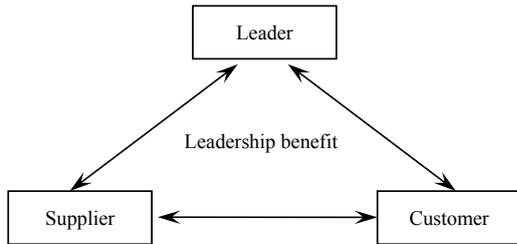


Fig. 3. The benefit from leadership

The cooperative benefits occur between two neighboring players (i.e. supplier-leader pair and leader-customer pair). Good examples of cooperations include the cooperation between supplier and purchasing division of the leader, and the cooperation between customer and marketing division of the leader. As we mentioned before, there is no benefit between supplier and customer because they do not hold direct cooperative relation (see Fig. 2).

On the other hand, the leadership benefit occurs among all three players. In other words, the leadership benefit is a chain-wide benefit. It is possible that there is benefit occurred between supplier and customer under the leadership of the leader company (see Fig. 3). A good example of leadership is the process of developing a new product model in Toyota. A special team which includes members from Toyota (leader company), parts manufacturer (supplier) and dealer (customer) is constructed. The team leader is often a senior product manager from Toyota. Clark and Fujimoto (1991) compiled skills and behaviors of a senior product manager. For example, coordination responsibility in wide areas, including production and sales as well as engineering; responsibility for specification, cost target and major part choices; possess market imagination and the ability to forecast future customer expectations based on ambiguous and equivocal clues in the present market; and other. The members of the special team collaborate with each other under the coordination of the senior product manager. From this example, to obtain leadership benefit, three sides (i.e. supplier, leader company and customer) need to collaborate closely with each other under the leadership of the leader company.

In this paper, we develop analytical models to study the two types of benefits. We investigate cooperation/leadership policies of the leader company. The paper is organized as follows. We provide a literature review in Section 2. Analytical models are constructed in Section 3. We present the result from comparative statics in Section 4. Finally, we conclude the study in Section 5.

We use Fig. 4 and Fig. 5 to interpret our models. As introduced in Section 1, there are two types of activities (i.e. cooperation and leadership) and three benefits: the benefit from the cooperation between supplier and the leader company (we use ① to represent it); the benefit from the cooperation between customer and the leader company (we use ② to represent it); and the leadership benefit from the collaboration of three companies (i.e. supplier, leader and customer) under the coordination of the leader company.

The supply chain considered in this paper includes three companies but four or five players. We explain these two cases as follows.

Fig. 4 shows the supply chain with four players (leader company includes two players: purchasing division and marketing division). In this case, benefits only occur from cooperations because no player holds the leadership to coordinate the whole supply chain.

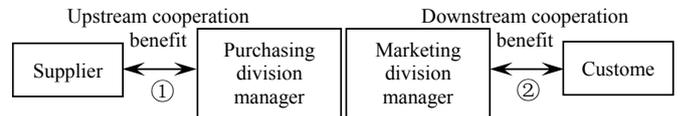


Fig. 4. The structure of cooperations

On the other hand, Fig. 5 shows the supply chain with five players (leader company includes three players: purchasing division, marketing division and senior manager). As mentioned in Section 1, the senior manager (e.g. senior product manager from Toyota) not only holds the leadership to coordinate the whole supply chain to obtain leadership benefit, she or he also holds ability to cooperate with supplier or customer to obtain cooperative benefits. Therefore, in this case, the first cooperative benefit can be obtained by cooperation between supplier and purchasing division (or senior manager) of the leader company. Similarly, the second cooperative benefit can be obtained by cooperation between customer and marketing division (or senior manager) of the leader company. However, the leadership benefit only occurs under the coordination of the senior manager.

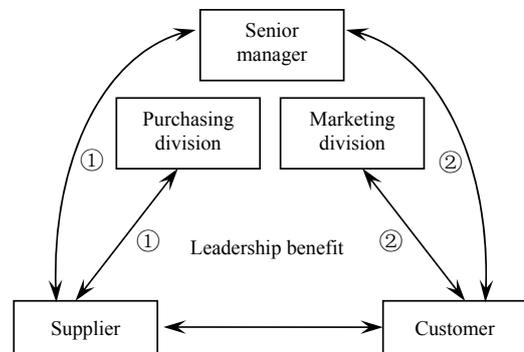


Fig. 5. The structure of cooperation and leadership

For a given supply chain, we assume that for any cooperation, ① or ②, the cost and benefit are the same,  $C_o$  (e.g. cost of purchasing/marketing division) and  $E$ , respectively. The occurrence probabilities of cooperations

① and ② are  $p_1$  and  $p_2$ , respectively. We also assume that if both cooperations occur, we obtain the leadership benefit from the coordination of the senior manager. The leadership benefit is  $T$ , and the cost of the senior manager is  $C_s$ . We assume  $T > C_s > C_o$  (senior manager is more expensive than staff from purchasing or marketing division).

We have eight cooperation/leadership policies for the leader company. For concisely, we incorporate two policies into one model. The eight policies and four models are as follows.

*Policy 1.* Doing nothing: no cooperations and no leadership.

*Policy 2.* Using senior manager to obtain all benefits from cooperations and leadership.

$$R_1 = \max\{p_1E + p_2E + p_1p_2T - C_s, 0\}. \quad (1)$$

The benefit from Policy 1 is 0. The expected benefits of Policy 2 are the expected benefits from two cooperations,  $p_1E + p_2E$ , plus the benefit from the leadership,  $p_1p_2T$  (if both cooperations are present), minus the cost of the senior manager,  $C_s$ .

*Policy 3.* Using purchasing division only to obtain the benefit from cooperation with supplier.

*Policy 4.* Using purchasing division firstly to obtain the benefit from cooperation with supplier. Then, using senior manager to obtain other benefits.

$$R_2 = p_1E - C_o + p_1 \max\{p_2E + p_2T - C_s, 0\} + (1 - p_1) \max\{p_2E - C_s, 0\}. \quad (2)$$

Policy 3 means that the supplier is the company that the leader company want to cooperate with (e.g. construct a long-term relation). The net benefit from Policy 3 is  $p_1E - C_o$ .

Policy 4 means the cooperation with the supplier is first implemented by purchasing division (same as Policy 3). Then a senior manager is used to obtain other benefits. The first cooperation occurs with probability  $p_1$ , then the benefit from another cooperation is  $p_2E$ . The leadership benefit from the coordination of the senior manager is  $p_2T$ , and the cost of the senior manager is  $C_s$ . If the first cooperation is not present, this happens with probability  $(1-p_1)$ , the benefit from another cooperation remains  $p_2E$ , but there is no leadership benefit and the cost remains  $C_s$ . Therefore, the benefits of Policy 4 are  $p_1E - C_o + p_1 \max\{p_2E + p_2T - C_s, 0\} + (1 - p_1) \max\{p_2E - C_s, 0\}$ .

It is easy to see that the benefit from Policy 4 contains the benefit from Policy 3. Thus, comparing with Policy 4, Policy 3 is often a sub-optimal policy.

*Policy 5.* Using marketing division only to obtain the benefit from cooperation with customer.

*Policy 6.* Using marketing division firstly to obtain the benefit from cooperation with customer. Then, using senior manager to obtain other benefits.

$$R_3 = p_2E - C_o + p_2 \max\{p_1E + p_1T - C_s, 0\} + (1 - p_2) \max\{p_1E - C_s, 0\}. \quad (3)$$

Policies 5 and 6 are similar and symmetric to Policies 3 and 4. Thus, we obtain the expected benefits as  $R_3$ .

*Policy 7.* Using both purchasing and marketing divisions to obtain benefits from cooperations with both supplier and customer.

*Policy 8.* Using both purchasing and marketing divisions to obtain benefits from cooperations with both supplier and customer. Then, using senior manager to obtain leadership benefit.

$$R_4 = p_1E + p_2E + p_1p_2(T - C_s) - 2C_o. \quad (4)$$

Policy 7 means that both purchasing and marketing divisions are available for cooperations (see Fig. 4). Whereas, Policy 8 means that all senior manager, purchasing and marketing divisions are available (see Fig. 5).

The net benefits from Policy 7 are  $p_1E + p_2E - 2C_o$ . the net benefits from Policy 8 are  $p_1E + p_2E - 2C_o + p_1p_2(T - C_s)$ . Since we assume  $T > C_s$ , comparing with Policy 8, Policy 7 is only a suboptimal policy.

### 3. COMPARATIVE STATICS

Using a senior manager will result in a cost  $C_s$  but will allow the leader company to obtain a leadership benefit  $T$ . The cost and revenue trade-off makes policy selection sensitive to the cost of the purchasing or marketing division, i.e.  $C_o$ . In this section, we seek insights into these trade-offs by analytically checking the optimal policy under different costs,  $C_o$ .

Without loss generality, we assume  $p_1 > p_2$ . We also assume that the benefit from leadership  $T$  is large enough,  $T \gg E$ , to make  $p_2(1 - p_1)T > p_1E$  possible. Thus, we get  $p_2E + p_2T > p_1E + p_2E + p_1p_2T$ .

According to the above assumptions, the cost of senior manager  $C_s$  should be a value in one of the following six intervals. We check the optimal decision of the leader company with different senior manager costs  $C_s$ .

$$0 \leq C_s < p_2E;$$

$$p_2E \leq C_s < p_1E;$$

$$p_1E \leq C_s < p_1E + p_2E + p_1p_2T;$$

$$p_1E + p_2E + p_1p_2T \leq C_s < p_2E + p_2T;$$

$$p_2E + p_2T \leq C_s < p_1E + p_1T;$$

$$p_1E + p_1T \leq C_s < \infty.$$

**Proposition 1.** Assume  $0 \leq C_s < p_2E$ .

If  $2C_o < \zeta_1$ , select Policy 8; where  $\zeta_1 = C_s(1 - p_1p_2)$ .

Otherwise, select Policy 2.

If the cost of the senior manager  $C_s$  is very low, e.g.  $C_s < p_2E$ , then using a senior manager to get leadership benefit is always optimal. Among all eight policies, only policies 2 and 8 are using a senior manager. Thus, the optimal policies are 2 and 8.

Comparing with Policy 2, the benefit of Policy 8 is that the senior manager is used only when both cooperations are present. If any or both cooperations are absent (with probability  $1 - p_1p_2$ ), the senior manager will not be used. Thus, Policy 8 saves  $C_s(1 - p_1p_2)$  and needs costs of purchasing and marketing divisions  $2C_o$ . Conclusively, if  $2C_o < C_s(1 - p_1p_2)$ , select Policy 8; otherwise, Policy 2.

**Proposition 2.** Assume  $p_2E \leq C_s < p_1E$ .

If  $2C_o < \min\{\zeta_1, \zeta_2\}$ , select Policy 8, where  $\zeta_2 = 2p_2E - 2p_1p_2C_s - 2p_1p_2E + 2p_1C_s$ ;

If  $2C_o > \max\{\zeta_1, \zeta_3\}$ , select Policy 2, where  $\zeta_3 = 2p_1p_2E - 2p_2E + 2C_s(1 - p_1)$ ;

Otherwise, select Policy 4.

Comparing values of  $R_1, R_2, R_3$  and  $R_4$  in Proposition 2 with those in Proposition 1, the only change is the value of  $R_2$ . Therefore, the optimal policies are Policy 8, Policy 2 from Proposition 1, and Policy 4 from  $R_2$ . Note that Policy 3 is only a sub-optimal policy as discussed in Section 3.

For Policy 8, firstly we compare it with Policy 4. The benefit of Policy 8 is that it saves the cost of the senior manager when the first cooperation is present (with probability  $p_1$ ) but the other one is not, i.e.  $p_1(1 - p_2)C_s$ . Policy 8 also gets benefits when the first cooperation (with probability  $p_1$ ) is not present but the other one is, i.e.,  $(1 - p_1)p_2E$ . However, Policy 8 costs one  $C_o$  more than Policy 4. Therefore, if  $C_o < p_1(1 - p_2)C_s + (1 - p_1)p_2E$ , or  $2C_o < 2p_2E - 2p_1p_2C_s - 2p_1p_2E + 2p_1C_s$ , Policy 8 is superior to Policy 4. As mentioned in Proposition 1, if  $2C_o < C_s(1 - p_1p_2)$ , Policy 8 is superior to Policy 2. Thus, if  $2C_o < \min\{C_s(1 - p_1p_2), 2p_2E - 2p_1p_2C_s - 2p_1p_2E + 2p_1C_s\}$ , Policy 8 is the optimal policy.

For Policy 2, firstly we compare it with Policy 4. The benefit of Policy 2 is that it saves the purchasing division cost  $C_o$ . By using Policy 4, we use senior manager only if the first cooperation is present (with probability  $p_1$ ). Thus, Policy 4 saves  $(1 - p_1)C_s$ , but loses  $(1 - p_1)p_2E$ . That is, if  $C_o > (1 - p_1)(C_s - p_2E)$ , or  $2C_o > 2p_1p_2E - 2p_2E + 2C_s(1 - p_1)$ , Policy 2 is superior to Policy 4. As mentioned in Proposition 1, if  $2C_o > C_s(1 - p_1p_2)$ , Policy 2 is superior to Policy 8. Thus, if  $2C_o > \max\{C_s(1 - p_1p_2), 2p_1p_2E - 2p_2E + 2C_s(1 - p_1)\}$ , Policy 2 is the optimal policy.

**Proposition 3.** Assume  $p_1E \leq C_s < p_1E + p_2E + p_1p_2T$ .

If  $2C_o < \min\{\zeta_1, \zeta_4, \zeta_2\}$ , select Policy 8, where  $\zeta_4 = 2p_1E - 2p_1p_2C_s - 2p_1p_2E + 2p_2C_s$ ;

If  $2C_o > \max\{\zeta_1, \zeta_5, \zeta_3\}$ , select Policy 2, where  $\zeta_5 = 2p_1p_2E - 2p_1E + 2C_s(1 - p_2)$ ;

If  $\zeta_2 < 2C_o < \zeta_3$  and  $C_s < E$ , select Policy 4;

Otherwise, select Policy 6.

Similarly, comparing with Proposition 2, the only change is the value of  $R_3$ . Thus, the optimal policy is either Policy 8, Policy 2, Policy 4, or Policy 6. Note that Policy 5 is only a sub-optimal policy.

For Policies 8 and 2, the discussions are similar with Proposition 2. The only difference is that we also need to compare with the net value from Policy 6,  $R_3$ . Since Policy 6 is similar and symmetric to Policy 4. Thus, we omit the detail here.

For Policy 4, it is easy to show from Proposition 2 that if  $2C_o > \zeta_2$ , then Policy 4 is superior to Policy 8; and if  $2C_o < \zeta_3$ , then Policy 4 is superior to Policy 2. Thus, the only thing left is the comparison between Policy 4 and Policy 6. Policies 4 and 6 are same in structure, the only difference is the probability. Comparing with Policy 6, Policy 4 has a high probability,  $p_1$ , to get benefits,  $E$ ; but it also has a high probability,  $p_1$ , to waste the cost of the senior manager,  $C_s$ . Therefore, if  $C_s < E$ , Policy 4 is superior to Policy 6. Conclusively, If  $\zeta_2 < 2C_o < \zeta_3$  and  $C_s < E$ , Policy 4 is the optimal decision.

**Proposition 4.** Assume  $p_1E + p_2E + p_1p_2T \leq C_s < p_2E + p_2T$ .

If  $2C_o < \min\{\zeta_2, \zeta_4\}$ , select Policy 8;

If  $2C_o > \zeta_2$  and  $C_s < E$ , select Policy 4;

Otherwise, select Policy 6.

Comparing with Proposition 3, the only change is the value of  $R_1$ , it's value is zero. Policy 2 is no longer a optimal policy. Thus, the optimal policy is either Policy 8, Policy 4, or Policy 6.

For Policy 8, it is easy to show from Proposition 2 that if  $2C_o < \zeta_2$ , then Policy 8 is superior to Policy 4; and from Proposition 3, if  $2C_o < \zeta_4$ , then Policy 8 is superior to Policy 6. Therefore, If  $2C_o < \min\{\zeta_2, \zeta_4\}$ , Policy 8 is the optimal decision.

The analysis of Policy 4 is the same as in Proposition 3.

**Proposition 5.** Assume  $p_2E + p_2T \leq C_s < p_1E + p_1T$ .

If  $2C_o < \min\{\zeta_4, \zeta_6\}$ , select Policy 8, where  $\zeta_6 = 2p_2E + 2p_1p_2(T - C_s)$ ;

If  $2C_o > \zeta_4$  and  $C_s < \zeta_7$ , select Policy 6, where  $\zeta_7 = (p_2E - p_1E + p_2(p_1E + p_1T))/p_2$ ;

Otherwise, select Policy 3.

Comparing with Proposition 4, the only change is the value of  $R_2$ . Now the cost of the senior manager is high enough that makes Policy 4 no longer an optimal policy. Thus, the optimal policy is either Policy 8, Policy 3, or Policy 6.

For Policy 8, the comparison with Policy 6 is the same as before. Comparing with Policy 3, the benefits of Policy 8 is that it gets the benefits from another cooperation,  $p_2E$ . If both cooperations are present, this happens with probability  $p_1p_2$ , then the senior manager is used to get the leadership benefit  $T$ . The cost is the marketing division with probability  $p_2$ . Therefore, if  $C_o < p_2E + p_1p_2(T - C_s)$ , Policy 8 is superior to Policy 3. Summarily, if  $2C_o < \min\{\zeta_4, \zeta_6\}$ , Policy 8 is the optimal decision.

For Policy 6, the comparison with Policy 8 is the same as before. Comparing with Policy 6, the benefits of Policy 3 are the benefits from the first cooperation,  $p_1E$ . On the other hand, the benefits of Policy 6 relative to Policy 3 are the benefits of the second cooperation,  $p_2E$ , and if the second cooperation is present, this happens with probability  $p_2$ , then a senior manager is used to get the benefit from the first cooperation and also the benefit from the leadership  $T$ . Minus the cost of the senior manager. Therefore, if  $(p_2E + p_2(p_1E + p_1T - C_s)) - p_1E > 0$ , that is, if  $C_s < \zeta_7$ , Policy 6 is superior to Policy 3. Summarily, if  $2C_o > \zeta_4$  and  $C_s < \zeta_7$ , Policy 6 is the optimal decision.

**Proposition 6.** Assume  $p_1E + p_1T \leq C_s < \infty$ .

If  $2C_o < \zeta_6$ , select Policy 8;

Otherwise, select Policy 3.

Comparing with Proposition 5, the only change is the value of  $R_3$ . Now the cost of the senior manager is high enough that makes Policy 6 no longer an optimal policy. Since Policy 5 has a low probability, it is an absolute suboptimal policy to Policy 3. Thus, the optimal policy is either Policy 8 or Policy 3. The comparison between Policies 8 and 3 is same as before.

**Corollary 1.** Policies 1, 5 and 7 are absolutely suboptimal.

Corollary 1 asserts that, except obtaining the cooperative benefit which holds a high probability, strategies without using a senior manager will never be optimal.

**Corollary 2.** Policy 8 is the only anytime candidate for Propositions 1-6.

Corollary 2 tells us an important truth: Policy 8 is a policy independent of the cost  $C_s$ . No matter how high the cost of the senior manager may be, Policy 8, i.e. *using both purchasing and marketing divisions to obtain benefits from cooperations with both supplier and customer. Then, using senior manager to obtain leadership benefit.*, is always a choice for optimal strategic decision. The reason is the benefit brought by the leadership.

**Proposition 7.** If  $T$  is sufficiently large, then using a senior manager is always an optimal selection.

Since  $T$  is very large, we can get  $p_1E + p_2E + p_2p_2T > C_s$ . From Propositions 1-3, optimal Policies are 2, 4, 6 and 8. All these policies involve using a senior manager. This proposition shows the power of the leadership in a supply chain.

#### 4. CONCLUSION

We consider cooperation and leadership relations of a supply chain in this paper. A good example is the *keiretsu* of Japanese automobile industries. Supply chains with three companies (i.e. supplier, customer and leader company) but four or five players are considered in this paper. Four

analytical models are developed to study the benefits from cooperation and leadership in a supply chain. We investigate conditions under which cooperation and leadership policies should be taken by the leader of the supply chain.

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