A Causal Scheme for Supply Chain Collaboration: The Fuzzy DEMATEL Approach

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ABSTRACT

Supply chain collaboration is usually taken as a strategic movement for manufacturers to increase the overall supply chain performance. However, collaboration arguably has the most disappointing failure record in various supply chain management practices to date, which has proved to be difficult to implement. Part of the problem has been the uncertain of environment, overreliance on technology, and lack of trust. The fuzziness of interdependency among the dimensions of environment, asset specificity, trust, and their influences on the supply chain collaborative processes still remain unknown. This study, focus on the Taiwanese manufacturing firms as an example case, empirically probes the impact between these dimensions and its criteria. To overcome the vagueness and imprecise of human judgments by response of natural language, the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) technique is applied to examine the causal relationship. The result in a comprehensive impact relation map illustrated a clear cause-and-effect relationship between dimensions and among its criteria. This study provides useful insights for supply chain practitioner.

Keywords: Supply chain collaboration; Decision Making Trial and Evaluation Laboratory (DEMATEL); fuzzy logic.

1. INTRODUCTION

Intensive market competition and increasing customer awareness has obliged companies to possess a greater level of efficiency and responsiveness when addressing customer needs (Simatupang & Sridharan, 2008). This in turn has driven companies to collaborate with other members in the supply chain. Supply chain collaboration, emerged in the mid-1990s, has recently drawn the attention of both academics and practitioners (Barratt, 2004). It involves the cooperation of participating members in order to reach a common objective. Collaborating firms shift their strategic focus from short-term company gains to increase the satisfaction of their end consumers. Given the importance of supply chain collaboration to the success of emerging competitive strategies, managers and analysts need to understand more completely the impact-relations of current supply chain practice in order to effectively formulate and implement their supply chain collaboration strategies.

The value-created of collaboration in supply chains can be seen in its aid in effectively matching demand and supply to increase the overall supply chain performance (Simatupang & Sridharan, 2008). However, along with the benefits that it brings, collaboration makes firms vulnerable to opportunistic behavior of partner firms. It is possible for firms to make decisions that are guided by self-interest, such as lying, cheating, and subtle violations of agreements (Grover & Malhotra, 2003). Due to this risk, a rational course of action for managers is to monitor and make sure of a partner firm's fidelity to the collaboration agreement. These monitoring activities increase the cost of transacting with a partner firm, thus reducing the benefits and profits, which are contrary to why the firms decided to collaborate in the first place. To address this issue, studies have been conducted to examine other methods to enforce agreements. For example, Anderson and Weitz (1992) presented that idiosyncratic investments have a substantial impact on the commitment between firms.

The aim of this paper is to apply the fuzzy DEMATEL technique to explore the causal relationship among key dimensions and criteria in supply chain collaboration for better strategic development of manufacturing firms. The Taiwanese manufacturer and supplier are presented as an empirical study.

2. CONCEPTS ON THEORETICAL FOUNDATION AND LITERATURE REVIEW

This research aims to investigate the interrelationships among trust, asset specificity, environmental uncertainty and collaborative processes between manufacturing firms and their suppliers. This section first reviews the theoretical foundation this research based on, and later builds the decision-making dimension/criteria structure through literature review.

Transaction cost economics (TCE) has been applied to fields including sociology, organizational theory, marketing, and more recently, operations management (Grover and Malhotra, 2003). It is the dominant theoretical framework that is used to decide whether firms should perform activities in-house or outsource them (Williamson, 1985). Scholars have also applied TCE to the willingness of firms to create alliances or to cooperate with each other (Heide and John, 1990; Joshi and Stump, 1999; Lee et al., 2008). TCE proposes that asset specificity and uncertainty positively affect the level of collaboration between firms.

One basic assumption of TCE is that firms make decisions in order to minimize transaction costs which include direct costs of transacting with another firm and opportunity costs from making sub-optimal decisions (Rindfleisch and Heide, 1997). According to TCE, environmental uncertainty will force transacting firms to incur higher transaction costs due to frequent requirement changes and renegotiations regarding these changes (Grover and Malhotra, 2003). David and Han (2004) stated that cooperative strategies such as supplier alliances can reduce these problems. Asset specificity is another fundamental construct in TCE. According to TCE, when a firm invests in partner-specific assets, it puts itself at risk to the opportunistic behavior of its partner. Collaborative practices such as information sharing and joint decision-making reduces the chance for partner firms to practice opportunistic behavior due to easier monitoring of decisions and joint control over the assets. Heide and John (1990) supported this perspective by considering joint action as a means of safeguarding firms from opportunism.

Relational exchange theory (RET) posits that all exchanges have some relational elements (Zaheer & Venkatraman, 1995). It depicts a socialized view of transactions between firms by looking into the social determinants for collaboration. Macneil (1985) suggested that there are norms that are necessary for relations to continue, including role integrity which he defines as the likelihood that parties involved will behave properly in all situations. In addition, Zaheer and Venkatraman (1995) considered trust as a key sociological determinant for joint action between firms. According to Lui et al. (2008), RET predicts that trust is positively related to cooperative behavior.

Table 1 shows the dimension/criteria as the foundation of fuzzy DEMATEL causal analysis.

Table 1 Dimension and criteria of this study

Dimensions	Criteria
Environmental Uncertainty (D_1)	Market Uncertainty (C_{11})
	Technological Uncertainty (C_{12})
Asset Specificity (D_2)	Manufacturer's Asset Specificity (C_{21})
	Supplier's Asset Specificity (C_{22})
Trust (D_3)	Trust (C_{31})
Collaborative Processes (D_4)	Decision Synchronization (C_{41})
	Information Sharing (C_{42})
	Performance Measurement (C_{43})
	Incentive Alignment (C_{44})

3. FUZZY DEMATEL TECHNIQUE FOR BUILDING STRUCTURAL MODEL

Causal relationship analysis significantly affects the efficiency of decision-making. Previous studies in examine the causal model mainly adopt the Structural Equation Modeling (SEM). The collected statistical data, however, allow researchers to modify the model frequently to arrive at good model fitness, and SEM is often misapplied when the data are merely fitted to an SEM and the theory is then extended from the analytical result based on presumed hypotheses (Wei et al., 2010).

To solve this issue, it is suitable to use the DEMATEL technique (Gabus & Fontela, 1973), which is a potent method that helps in gathering group knowledge for forming a structural model, as well as in visualizing the causal relationship of sub-systems through a causal diagram. However, in many cases, the judgments of decision-making are often given as crisp values, but crisp values are an inadequate reflection of the vagueness of the real world (Bellman & Zadeh, 1970; Zadeh, 1975). The fact that human judgment about preferences are often unclear and hard to estimate by exact numerical values, so that fuzzy logic is necessary for handling problems characterized by vagueness and imprecision (Zadeh, 1975). Hence, there has a need to extend the DEMATEL technique with fuzzy logic for making better decisions in fuzzy environments.

DEMATEL (Fontela and Gabus, 1976; Gabus and Fontela, 1973) is a comprehensive method for building and analyzing a structural model involved of causal relationships between complex

factors. It was developed in the belief that the proper use of scientific research methods could facilitate comprehension of the specific problematique, the cluster of intertwined problems, and contribute to recognition of practical solutions by a hierarchical structure. The methodology, according to the characteristics of objective affairs, can verify the interdependence among the variables/attributes/criteria and confine the relation that reflects the characteristics with an essential system and evolution trend (Chiu et al., 2006; Huang and Tzeng, 2007). The method is a practical and useful tool, especially for visualizing the structure of complex causal relationships with matrices or digraphs. The matrices or digraphs show a contextual relation between the elements of the system, in which a numeral represents the strength of influence of each element. Thus, the DEMATEL technique is able to convert the relationship between the causes and effects of criteria into an intelligible structural model of systems (Wei et al., 2010).

The detail process of DEMATEL technique for group decision-making in a fuzzy environment, please refer to Jeng (2012).

4. EMPIRICAL STUDY: CASE OF TAIWANESE MANUFACTURING FIRMS

This research conducted a paper-based survey over a four-month period in between March and June of 2010. The candidate manufacturers were selected from the list of 2009 Taiwan Top 1000 Firms from CommonWealth Magazine (CommonWealth Magazine, 2009). The respondents who considered as experts must be in the managing position of supply chain management and their companies must practice in supply chain collaboration. The pair-wise comparison questionnaire was developed based on the criteria shown in Table 1. A total of 52 valid surveys were returned for data analysis. The fuzzy and defuzzied influence of concern factors in criteria level are presented in Table 2 and Table 3, respectively. Based on the above analysis, a comprehensive impact relation map can be generated as illustrated in Fig. 1.

Table 2 The fuzzy influence of concern factors in criteria level

Dimensions/Criteria	$\tilde{d}_i$	$\tilde{r}_i$	$\tilde{d}_i - \tilde{r}_i$	$\tilde{d}_i + \tilde{r}_i$
D_1 Environmental Uncertainty				
C_{11} Market Uncertainty	(0.6552,1.2803,2.7317)	(0.1159,0.4544,1.4716)	(0.7711,1.7347,4.2033)	(-0.8164,0.8259,2.6158)
C_{12} Technological Uncertainty	(0.6936,1.3334,2.8111)	(0.0835,0.4124,1.4081)	(0.7771,1.7458,4.2192)	(-0.7145,0.9210,2.7276)
D_2 Asset Specificity				
C_{21} Manufacturer's Asset Specificity	(0.5798,1.1346,2.4974)	(0.1482,0.5081,1.5687)	(0.7279,1.6427,4.0661)	(-0.9889,0.6265,2.3492)
C_{22} Supplier's Asset Specificity	(0.4949,1.0064,2.3118)	(0.2188,0.6084,1.7205)	(0.7137,1.6147,4.0323)	(-1.2256,0.3980,2.0930)
D_3 Trust				
C_{31} Trust	(0.4640,0.9670,2.2305)	(0.3743,0.8588,2.1294)	(0.8383,1.8257,4.3599)	(-1.6654,0.1082,1.8562)
D_4 Collaborative Processes				
C_{41} Decision Synchronization	(0.0737,0.3886,1.3727)	(0.7974,1.4748,2.9982)	(0.8711,1.8635,4.3709)	(-2.9245,-1.0862,0.5753)
C_{42} Information Sharing	(0.1522,0.5085,1.5532)	(0.7266,1.3527,2.8208)	(0.8788,1.8612,4.3740)	(-2.6685,-0.8442,0.8266)
C_{43} Performance Measurement	(0.2463,0.6455,1.7694)	(0.5919,1.1588,2.5357)	(0.8382,1.8043,4.3052)	(-2.2894,-0.5133,1.1776)
C_{44} Incentive Alignment	(0.2564,0.6670,1.8022)	(0.5596,1.1029,2.4270)	(0.8160,1.7700,4.2291)	(-2.1706,-0.4359,1.2426)

Table 3 The defuzzied influence of concern factors in criteria level

Dimensions/Criteria	d_i	r_i	d_i+r_i	d_i-r_i
D_1 Environmental Uncertainty				
C_{11} Market Uncertainty	1.4545	0.6042	2.0587	0.8503
C_{12} Technological Uncertainty	1.5070	0.5584	2.0653	0.9486
D_2 Asset Specificity				
C_{21} Manufacturer's Asset Specificity	1.3082	0.6637	1.9719	0.6444
C_{22} Supplier's Asset Specificity	1.1797	0.7706	1.9503	0.4092
D_3 Trust				
C_{31} Trust	1.1352	1.0390	2.1743	0.0962
D_4 Collaborative Processes				
C_{41} Decision Synchronization	0.5330	1.6445	2.1775	-1.1115
C_{42} Information Sharing	0.6612	1.5268	2.1879	-0.8656
C_{43} Performance Measurement	0.8079	1.3357	2.1436	-0.5278
C_{44} Incentive Alignment	0.8306	1.2744	2.1050	-0.4437

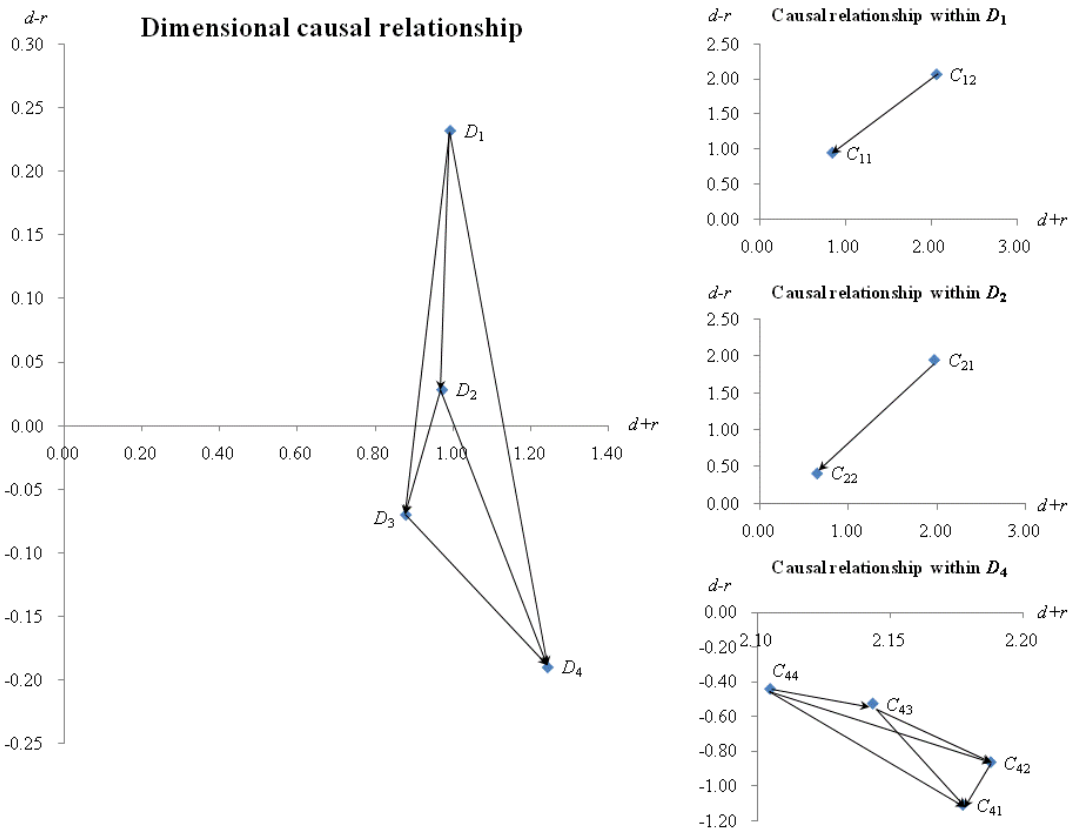

Figure 1 The comprehensive impact relation map

5. DISCUSSION AND IMPLICATION

This study has shown that the existence of trust is a key factor that resulted in a success collaboration practice. For firms to promote supply chain cooperative behavior, managers should foster trust among their partners. Stated by D.N. Bert, professor and director of the University of San Diego's Institute of Supply Chain Management, "Trust is the basis of agility, of flexibility. Yet, it is an incredible challenge to establish trust and maybe even harder to maintain it…trust enables [a firm] to make fast decisions, which lets [firm] be more innovative and get rid of unproductive work. Trust is a competitive advantage" (Beth et al., 2003, p.69). The senior director of global sourcing for Agilent Technologies' electronic products and solutions group, S. Beth, as well mentioned that firms would lose out on efficiencies when trust is not presented (Beth et al., 2003).

One way to foster trust is by investing in assets that are dedicated to the specific partner firm. Investments in specialized assets represent a firm's dedication towards the success of the collaboration. In a way, they are an assurance that the investing firm will make decisions not only with the future of its company in mind, but rather, the future and growth of the collaboration and it increases the credibility of the investing firm. These investments also play an important role in achieving objectives and potential competitive advantages brought by collaboration. Thus, managers who plan to use collaboration as a business strategy should be prepared to invest in relational specific investments if these will foster trust and promote cooperative behavior.

Finally, the study has shown that environmental uncertainty would affect a firm's cooperative behavior. With the effect of globalization, the boundaries of a firm's environment have been extended to an international level, and managers must keep in mind that they are competing in a transnational arena. Enterprises should shift their strategies from one that is based on individual transactions with other firms, to the creation and growth of partnerships. Working in collaboration with other firms will allow the company to become competitive in a global market. A good example would be the A-team of Taiwanese bicycle alliance, which Giant and Merida, two major bicycle manufacturers and direct competitors forms the strategic alliance with their suppliers to compete in global high-end bicycle market.

6. CONCLUDING REMARKS

This research is among the limited studies that attempt to explore the interrelationships among trust, asset specificity, environmental uncertainty, and supply chain collaborative processes through the theoretical perspective with empirical validation. Going beyond previous research, based on TCE and RET, this study highlights the significance of impact between key influential factors. This study makes contributions both to the supplier and buyer in supply chain practice. The finding offer organization suggestions for supply chain collaboration processes.

Causal analysis largely influences the effectiveness of decision-making and business operations. Only correct causal analysis helps manager make right decision. The results of the study demonstrated that the fuzzy DEMATEL method may be an efficient, complementary, and effective approach to deal with vague and imprecise of human judgments. In addition, it can also

divide a set of complex factors into cause and effect groups, further produce a visible causal diagram. Through this comprehensive impact relationship map, the complexity of a problem is easier to capture, whereby support the decision-making.

References available upon request from the author: jeng@mail.ncku.edu.tw.