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RESEARCH NOTE

The strategic motives behind firm's engagement in cooperative research and development

A new explanation from four theoretical perspectives

Yiping Bai and G.C. O'Brien
La Trobe University, Melbourne, Australia

Abstract

Purpose – The aim is to investigate and group the strategic motives that firms engage in cooperative R&D by exploring a new method.

Design/methodology/approach – Four theories are adopted to explain the motives and they are cited as the base to categorize the motives into four factors. A survey questionnaire of participants in the aluminum industry is used to examine the empirical prevalence and clustering of these different categories of strategic motives. Factor analysis is used to test this measurement modeling.

Findings – The results of the confirmatory factor analysis support this grouping of strategic motives as reliable and valid method.

Research limitations/implications – The techniques used in this study when applied to group other motives or other similar issues could produce useful information in business and management research. Moreover, the theories employed in this research can help in hypothesis development and the relationship test between the factors and the formation of R&D alliances.

Practical implications – The incentives such as strategic motives and the formation of R&D alliances studied in this paper can be used to investigate how they might be related to the aluminum or any other industry characteristics.

Originality/value – This paper contributes to the modeling of measurement model in management by exploring a new method.

Keywords Research and development, Strategic evaluation, Economic cooperation, Strategic alliances, Factor analysis

Paper type Research paper

Introduction

Since the early 1980s, there has been a striking change in the nature of the competitive environment, in which firms operate. Growing evidence of increased collaborative activities demonstrates that firms must learn how to collaborate with their competitors to succeed in the new market landscape. The last two decades have witnessed a growing emphasis on the use of strategic alliances as the dominant form of business organization pursued by firms. Entering the twenty-first century, strategic alliances are becoming increasingly popular. Researchers explain this popularity by noting that an unprecedented number of strategic alliances between firms are being formed each year. These strategic alliances are a logical and timely response to intense and rapid changes in economic activity, technology, and globalization (Rigby and Zook, 2003).

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As a result of this increased cooperation between firms, strategic alliances have been attracting attention from both business practitioners and academic researchers. Here, a strategic alliance is defined as a cooperative strategy in which firms combine some of their resources and capabilities to create or gain a competitive advantage (Hitt *et al.*, 2005, p. 271). Thus, as linkages between firms, strategic alliances involve firms with some degree of exchange and sharing of resources and capabilities to create value and develop additional resources and capabilities as the foundation for new competitive advantages. As the definition indicates, the primary reason for firms to form strategic alliances is that most firms lack the full set of resources and capabilities needed to reach their objectives and partnering with others increases the probability of achieving them.

Extant literature shows that, there are diverse benefits for firms to combine some of their resources and capabilities in business activities. Porter and Fuller (1986) identify strategic alliances as a mechanism through which companies could hedge risk. By partnering with a firm in a different geographical market and different product market, losses in one market may be offset by gains in others, reducing the risk of the partner firm's overall portfolio of investment. Boateng and Glaister (2003) posit that strategic alliances can reduce average unit cost by pooling together each partner's capabilities and resources in order to achieve the benefits of large-scale of production. Furthermore, where components are made by both partners in different locations and with unequal costs, production could be transferred to the lower cost location thereby further lowering sourcing costs.

Alliances also provide strategic benefits from the exploration of synergies, technology or other skills transfer (Harrigan, 1985). Thus, strategic alliances can be formed in order to pool the complementary technologies of the partners so that partnering firms can acquire expertise without having to develop the capabilities in-house. Several alliances in the pharmaceutical and biotechnology industries, for instance, are built on this rationale (Odagiri, 2003; Bagchi-Sen, 2004). Each partner contributes a missing piece. Pooling and utilizing partner's resources through strategic alliances not only lead to superior product but also create financial and operating synergies by sharing complementary knowledge, skills and information. As discussed above, strategic alliances involve firms with some degree of exchange and sharing of resources, such as knowledge and expertise, to create value and develop additional resources and capabilities as the foundation for new competitive advantages.

Beside the benefits mentioned above, there are some other benefits from strategic alliances such as: gaining access to a restricted market, speeding up the development of new goods or services, maintaining market leadership, overcoming uncertainty, gaining market power (MP), overcoming trade barriers, and setting up barriers for new entrants (Hitt *et al.*, 2005, p. 274). For these reasons, strategic alliances have been used widely in many different ways. R&D alliance as one of the major mechanisms of cooperative R&D is an arrangement among a group of firms to share the costs and results of an R&D project (Sakakibara, 1997). R&D alliances have been extensively used in high-technology industries such as pharmaceuticals, biotechnology, and telecommunications (Odagiri, 2003; Bagchi-Sen, 2004; Sampson, 2004). More recently, as a result of their success, R&D alliances have been adopted by firms in many other industries such as forests, non-ferrous metals, and petroleum (Sakakibara, 2001; Nakamura *et al.*, 2003). This new phenomenon raises the question: why do firms conduct cooperative R&D?

From the perspective of strategic management, these benefits from R&D alliances are "strategic" in nature. In this paper, thus, all the potential benefits from strategic alliances are referred to as strategic motives. While there is a rich prior literature on the motivations that lead firms to a collaborative organizational model such as strategic alliance, few studies have been conducted on the motivation for firms to conduct cooperative R&D. Cooperative R&D between firms has been examined empirically in only a few studies and comprehensive empirical research is almost nonexistent. There are some case studies (Levin, 1988; Katz and Ordover, 1990; Hart, 1993; Odagiri, 2003; Nakamura *et al.*, 2003). These case studies have been based on anecdotal evidence, or on a few highly publicized cooperative projects. The focus of past empirical research has been on motivations, formation issues such as governance, performance and the outcomes of R&D alliances. In general, the existing research on R&D alliances does not provide empirical evidence regarding the factors that lead to cooperative R&D activities. No one single study has been done systematically on the inducement factors (motivations) that influence firm's participation in R&D alliances.

In examining this "hole" in the literature, our study seeks to identify all the relevant strategic motives that lead firms to pursue cooperative R&D from four perspectives: cost sharing (CS), risk sharing (RS), skill sharing, and MP. All previously identified strategic motives on both strategic alliances and cooperative R&D are grouped into these four categories (inducement factors). Moreover, rational explanations are provided for these four inducement factors. Transaction cost theory is used to explain CS, risk theory is used to explain RS, organization learning theory is used to explain skill sharing, and strategic management theory is used to explain gaining MP. Together, these theories provide clear reasons why firms conduct cooperative R&D. As mentioned earlier, there are some other benefits from strategic alliances such as: social networking (Bagchi-Sen, 2004), abstracting external investment (Caloghirou *et al.*, 2003), and exploiting research synergy (Fusfeld and Haklisch, 1985). These motives are unrelated to these four theories and thus are not the interest of this paper.

In fulfilling the objective, the structure of this paper is organized as follows: in section two, theoretical explanations for strategic motives for firms to engage in cooperative R&D are provided. These theories are also the guiding principle for grouping the strategic motives into these four categories. In the third section, four constructs (referring to the four inducement factors we use to categorize the strategic motives in this paper) and their measuring variables (strategic motives) are discussed. Data collection procedure is also discussed in this section. Data analysis is conducted including validating the measurement and testing the reliability and validity of the measurement in section four. This paper ends with conclusions in section five.

Theoretical explanations for motives

From a theoretical perspective, there are several advantages from R&D alliances. Four theoretical approaches are particularly relevant in explaining the benefits and choice of strategic alliances. One approach is derived from transaction cost theory (Williamson, 1975, 1985). The second approach focuses on strategic motivations (benefits) and consists of a catalogue of formal and qualitative models describing competitive behavior. A third approach is derived from organizational learning theory, which has been developing quickly recently in terms of explaining the choice of strategic alliances as a vehicle to improve the capability of firms. Last, risk theory (Tyler and Steensma, 1995;

Reuer and Leiblein, 2000; Das and Teng, 1999) can be used to explain the strategic motives arising from RS inducing firms to participate in strategic alliances.

Cost sharing motives: transaction cost theory

As is well known, transaction cost theory has been advocated most strongly by Williamson (1975, 1985). A transaction occurs when a good or service is transferred across a technologically separable interface, such as when a firm buys an input from an independent supplier. Williamson (1985) proposes that firms choose how to transact according to the criterion of minimizing the sum of production and transaction costs. For analytical purposes, this can be broken down into two parts: minimizing production costs and minimizing transaction costs. Production costs may differ between firms due to the scale of operations, learning, or proprietary knowledge. Transaction costs refer to the expenses incurred in writing and enforcing contracts, in haggling over terms and contingent claims, in deviating from optimal kinds of investments in order to increase dependence on a party or to stabilize a relationship, and in administering a transaction (Kogut, 1988).

Proponents of the transaction cost perspective also claim that the firm has distinct advantages over markets, but argues that these advantages primarily relate to the control or reduction of opportunism threats posed by transaction characteristics (Williamson, 1985). In the absence of opportunism, all transactions could be organized by a series of contracts, such that the firm would be an unnecessary organizational form. By the imposition of bureaucracy, partner incentives to behave opportunistically are diminished because there is greater monitoring and control over partner actions and greater incentives to work out disputes privately. As a result, incentives to cooperate and share resources or/and knowledge are preserved (Sampson, 2004).

It has been argued that, the smaller the number of capable partners for a desired relationship, the lower the bargaining power of the firm relative to any given potential partner. Likewise, the need to invest in assets specific to the cooperative project and of limited value outside the relationship can lead to higher switching or exit costs for the firm (Kogut, 1988; Williamson, 1985). These two factors are particularly pertinent for technology-based relationships. There are generally a limited number of firms capable of providing expertise in advanced technology development or customization. Leading-edge technology can also require extensive sophisticated training and equipment, which may be of limited value outside its relatively narrow domain. Such conditions constrain the opportunities for the firm and may increase its dependence upon the partner. This dependence can allow the partner to charge excessive prices and perhaps behave opportunistically unless such actions are offset through stringent contracting and monitoring (Tyler and Steensma, 1995).

It is well recognized that it is economical to produce a certain product or service in a large volume or jointly with other products/services. It is often argued that increases in the minimum efficient scale of a number of economic activities have led firms to enter into strategic alliances. For example, the desire to reduce costs through economies of scale in the aluminum industry is usually given as a cause for the spate of strategic alliances in this industry. Recently, the minimum efficient scale of a bauxite mine or of an alumina refinery is larger than that of an aluminum smelter. Only the largest aluminum firms have enough downstream capacity to absorb the output of an efficiently sized upstream facility. As a result, most bauxite mines and alumina

refineries after 1980 have been built by consortia of aluminum producers, and strategic alliances account for more than half of the world's bauxite and alumina capacity (Hennart, 1988).

Risk sharing motives: risk theory

Risk theory provides an additional lens through which technological cooperative partnerships can be evaluated. According to risk theory, executives consider the risks and rewards associated with investment choices in order to maximize their expected returns. A collaborative relationship can contribute. Companies may through technological collaboration gain valuable experience and skills, which lower the risks associated with R&D and thus improve the probability of success. Such is often the case when two or more firms with related skills combine those skills to develop technology. In these situations the expertise of the various firms causes the combined effort to have a higher probability of success than would be the case if a single firm tried to develop the technology alone. Collaborative technological arrangements that are likely to increase the probability of success are attractive to executives (Tyler and Steensma, 1995).

Empirical studies have identified one objective of research partnerships, that is, to share risks and decrease market and technological uncertainty. Such risks are thought to increase the further away the subject of the cooperative research is from extant activities of the firm (Caloghirou *et al.*, 2003). Porter and Fuller (1986) identify strategic alliance as a mechanism through which companies can hedge risk. The high levels of uncertainty and failure in R&D allow for risk-balancing organizational arrangements, such as alliances (collaborations) with other organizations and firms to promote innovation and to mitigate the risk (Bagchi-Sen, 2004).

Option theory – a subcategory of risk theory extends the concept of risk taking under uncertainty to a consideration of strategic flexibility afforded firms that purchase a portfolio of options. An option contract allows an investor to make an investment to buy an option, hold it until the opportunity arrives, and then decide between buying the option to capture the opportunity or abandoning it (Tyler and Steensma, 1995). For a given cost, a technological cooperative relationship that allows these costs to be committed incrementally contingent on positive outcomes will be more attractive than one in which costs must be committed up front. A project of this sort can be thought of as a series of options where the firm can stop buying subsequent options contingent on the outcomes of the collaboration.

Market power gaining motives: strategic management theory

In the theory of strategic behavior, strategic competitiveness is achieved when a firm successfully formulates and implements a value-creating strategy. When a firm implements such strategy and other companies are unable to duplicate it or find it too costly to imitate, this firm has a sustained (or sustainable) competitive advantage, which is also called competitive advantage (Hitt *et al.*, 2005). So, according to the strategic management theory, the main objective of strategic management theory is to help firms to gain competitive advantage in the market competition.

A cooperative strategy is one in which firms work together to achieve a shared objective. Strategic alliances, as cooperative strategies in which firms combine some of their resources and capabilities to create a competitive advantage, are the primary form of cooperative strategies (Hitt *et al.*, 2005). In an era of intense global competition,

firms realize that the effective use of proper strategy contributes significantly to their market performance. Increasingly, successful firms use a higher level of strategic alliance to gain competitive advantage. Strategic alliances may enhance a firm's superior performance through the combination of resources and capabilities in unique ways (Murray, 2001). Many firms enter into strategic alliances with a wish to strengthen their competitive advantages in the market.

But "competitive advantage" is an ambiguous term and there is much confusion about the term. Day and Wensley (1988) in their article, "Assessing competitive advantage: a framework for diagnosing competitive superiority," have developed a process that can be used to ensure a thorough assessment of the reasons for competitive success or failure. Day and Wensley propose that a firm, which has superior sources of advantage (superior skills and superior resources), will win a superior position in the markets.

A positional advantage will lead in turn to superior performance outcomes such as greater customer satisfaction and loyalty, and obvious result of greater customer satisfaction and loyalty is more market share. From the previous discussion, it can be inferred that firms participating in strategic alliances want to gain competitive advantage, and the competitive advantage will result in more market share for the firms, which means, in other words, more MP.

Skill sharing motives: organizational learning theory

Resource-based view (RBV) and organizational learning theory can be used to explain the skill sharing motives on R&D alliances. RBV takes a firm as a collection of physical and human resources, and these tangible and intangible resources have to be used by the firm to achieve growth. According to the RBV, sources of sustained competitive advantage are the firm's resources that are valuable, rare, costly to imitate and non-substitutable. A firm's broad-based skills and capabilities are often referred to as core competencies. These resources are generally much harder to acquire, imitate, or substitute than physical resources and are more likely to provide the company with a longer-term competitive advantage (Tyler and Steensma, 1995). But the skills and capabilities can only be gained or enhanced through innovation and learning for firms to grow (Odagiri, 2003).

Organizational learning theory is regarded as the key factor in achieving sustainable competitive advantage. Organizational learning refers to the process by which the organizational knowledge base is developed and shaped. The ability of firms to acquire knowledge and to transfer it into a competitive weapon has long been a part of the research agenda. Stata (1989) even predicts that the rate at which individual and organizational learning may grow to become the only sustainable competitive advantage. As Hamel (1991) says, learning through internalization, which refers to acquiring skills to close the gap between partners, and sustainable learning helps reapportion the value-creating core competencies in an alliance context, giving partners the ability to match or overtake competition. Therefore, learning, be it related to technology transfer, acquiring skills, or improving learning capability ("absorptive capacity," Cohen and Levinthal, 1990), is a critical consideration for firms (Iyer, 2002).

Winners in the global marketplace have been firms that can demonstrate timely responsiveness and rapid and flexible product innovation, coupled with the management capability to effectively coordinate and redeploy internal and external competences. Teece *et al.* (1997) have proposed the "dynamic capability" approach to

firm-level advantage suggesting that a firm's ability to continually learn, adapt, and upgrade its capabilities is key to competitive success. The term "dynamic" refers to the capacity to renew competences so as to achieve congruence with the changing business environment; certain innovative responses are required when time-to market and timing are critical, the rate of technological change is rapid, and the nature of future competition and markets difficult to determine. The term "capability" emphasizes the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences to match the requirements of a changing environment. Dynamic capabilities thus reflect an organization's synthetic ability to gain competitive advantage and dynamic capability can be created and enhanced through experience, learning, investment and innovation. As Teece *et al.* (1997) posit, the concept of dynamic capabilities as a coordinative management process opens the door to the potential for inter-organizational learning.

Alliances are viewed by partner firms as vehicles that provide opportunities to learn to enhance their strategies and operations. Kogut (1988) argues, based on organizational learning theory, that alliances by their inherent long-term partnering nature provide opportunities for partners to transfer embedded knowledge between them. This embedded or tacit knowledge is generally difficult to transfer between firms. Alliances are like a short-circuit method for acquiring critical tacit knowledge (Hamel, 1991). Characteristically, however, alliances are long-term exchange relationships. Learning occurs all along the evolutionary path, and the dynamics of learning and relationship interactions continuously change as the alliance grows. Learning priorities evolve and change with the alliance process. The different phases of alliance evolution represent an ongoing managerial task of balancing cooperation and compatibility between partners on the one hand and learning/building of new sources of competitive advantage on the other (Iyer, 2002). So in a sense, the alliance creates a laboratory for learning (Inkpen, 1998).

Construct measurement and data

The four perspectives of transaction cost theory, risk theory, strategic behavior theory, and organizational learning theory provide distinct, though at times, overlapping explanations for strategic alliances behavior. Transaction cost theory has theorized inter-firm partnering as an economic phenomenon between market transaction and hierarchies. Transaction cost theory analyzes strategic alliances as an efficient solution to the hazards of economic transactions. Risk theory takes strategic alliance as a mechanism through which companies could hedge risk. Organizational learning theory regards strategic alliances as a vehicle by which organizational knowledge is exchanged and imitated. Finally, strategic management theory places strategic alliances in the context of competitive rivalry and collusive agreements to enhance MP (Kogut, 1988).

According to the four theories, in this study, four relevant constructs (factors) are used to study the strategic motives that firms engage in cooperative R&D activities. We name these four inducement factors as follows: CS, RS, skill sharing, and MP. For each of the four factors, we use several strategic motives (variables), which are identified from previous research, to measure the factor.

Cost sharing

Costs sharing related motives are also called scale-based motives (Sakakibara, 1997). Five independent variables are adopted to measure the factor of CS. In previous economic

theoretical research, fixed cost-sharing among R&D participants, the realization of economies of scale in R&D, and the avoidance of "wasteful" duplication, are frequently referred to as scale-based motives (Katz, 1986; D'Aspremont and Jacquemin, 1988; Katz and Ordover, 1990; Motta, 1992; Sakakibara, 1997). Additionally, Glaister (1996) points out that a strategic alliance may also lower costs by pooling the comparative advantages of each partner. There are potential cost savings from centralized functions when firms work together (Ugboro *et al.*, 2001). Accordingly, "pursuing R&D cost reduction" is added to the factor of CS as the fourth variable. And the fifth variable, sharing complementary R&D resources among R&D consortium participants is also accepted from the papers of Sakakibara (1997) and Nakamura *et al.* (1997).

Risk sharing

The strategic risks that companies face stem from uncertainty in their technological, market and competitive environments. This means that, they cannot be confident of the pay-off of a given strategic move, such as investment in a new plant or the development of a new product. A strategic alliance is one approach which can help to reduce strategic risks (Gomes-Casseres, 2000). Strategic alliances not only help a company to hedge risks, but also help mitigate the costs of responding to unpredictable circumstances. In this current study, four variables are adopted from the literature to measure the factor of RS motives:

(1) *Spreading risks among participants.* Alliances are seen as an attractive mechanism for hedging risk because partners share both the risk and the cost of the alliance activity (Porter and Fuller, 1986).

(2) *Buffering threats from external competitors.* The ability to effectively buffer members against various threats such as unfavorable legislation and external competition including foreign competitors (Souder and Nassar, 1990).

(3) *Reducing competition among participating firms in the marketplace.* Alliances can influence whom a firm competes with and the basis of that competition. Potential (or existing) competition can be mitigated by forming a strategic alliance with competitors, therefore, a strategic alliance can be used as a defensive strategy to reduce competition among participating firms in the marketplace (Contractor and Lorange, 1988; Boateng and Glaister, 2003).

(4) *Reducing uncertainty.* High levels of uncertainty in R&D activities allow for risk-balancing organizational cooperation, such as alliances (henceforth, referred to as collaborations) with other firms and organizations, to promote innovation (Bagchi-Sen, 2004). Reducing, minimizing and sharing the uncertainty of R&D are believed to be an important motive for firms performing cooperative R&D (Hagedoorn, 1993).

Skill sharing

Skill sharing motives are also called learning-based motives (LE) (Sakakibara, 1997). They are the most frequently mentioned motives in the literature. More and more scholars and business leaders have recognized that inter-organizational learning is critical to competitive success, noting that organizations learn by collaborating with other firms as well as by observing and importing their practices (Powell *et al.*, 1996;

Levinson and Asahi, 1996; Dyer and Nobeoka, 2000). For the factor of LE, five variables are adopted from previous research:

(1) *Access to complementary knowledge*. From the perspective of organizational learning theory, cooperative R&D is viewed as a vehicle by which firms overcome their resource constraints through the learning of complementary knowledge from other participants (Sakakibara, 1997; Brockhoff *et al.*, 1991; Hagedoorn, 1993).

(2) *Technology transfer*. The opportunity to improve technology transfer among the members is an important advantage that has motivated the formation of R&D consortia (Souder and Nassar, 1990; Smilor and Gibson, 1991). Aldrich *et al.* (1998) found, the transfer of technology to member firms is the main objective of R&D consortia.

(3) *Information exchange*. From a practical standpoint, the decision to coordinate research via inter-firm R&D consortia forces firms to develop explicit mechanisms for exchanging information between members (Gibson *et al.*, 1994; Aldrich *et al.*, 1998).

(4) *Management training*. Firms might seek partners with either expertise or knowledge in a particular area that they lack such as specialized manufacturing process or technology management (Souder and Nassar, 1990). Bagchi-Sen (2004) points out that a good partnership with firms in alliances will help firms to get educated in corporate intelligence and business development.

(5) *Researcher training*. R&D consortium can be viewed as a training centre for firms sending their R&D researchers to learn the R&D skills from other researchers in the R&D consortium (Souder and Nassar, 1990; Bagchi-Sen, 2004). Participants get educated on how to do R&D.

Market power

In this study, six variables identified in previous papers are used to measure the factor of MP. These six strategic motives are:

(1) developing new and advanced products (Bradmore, 1996);

(2) developing new markets or access to new markets (Hagedoorn, 1993);

(3) speeding up products from development to market (Oliver and Liebeskind, 1998; Contractor and Lorange, 1988);

(4) expansion of product range/product diversification (Katz, 1993; Seldon, 1992);

(5) setting up barriers against new market entrants (Hart, 1993; Nelson, 1996); and

(6) facilitating international expansion (Nelson, 1996; Glaister, 1996; Boateng and Glaister, 2003).

Data collection

The aluminum industry provides an opportunity to examine the issues of cooperative R&D. Firstly, the aluminum industry has four distinct stages of production – bauxite mining, alumina refining, aluminum smelting and the manufacture of semi-finished aluminum products. The distinct production chain gives aluminum companies the opportunity to form strategic alliances because firms are suppliers and buyers along

the production chain. Secondly, technology is a crucial factor in the aluminum industry because it not only improves productivity, but also reduces costs, saves resources, lowers air pollution, and secures workforce. Enhancements and technology advances in production, processing, and fabrication will increase the industry's energy efficiency, reduce greenhouse gas emissions, and improve productivity. This feature of technology-intensiveness leads firms in the aluminum industry to place R&D at the top level of their long-term strategic planning. Lastly, the commercially successful process for alumina reduction to produce aluminum, commonly referred to as the Hall-Héroult process, was invented in 1886 and is still in use. Though the engineering has improved vastly, the process fundamentals are basically unchanged today. This feature may give firms in primary aluminum production more common interests to conduct cooperative R&D. Particularly, data used for analysis in this project was collected from the Chinese aluminum industry.

Questionnaires about strategic motives that lead firms to participate in cooperative R&D are used to obtain the data for this project. The questionnaire is aimed at high-level managers in companies because high-level managers are believed to have knowledge to answer the questions. At the beginning of the questionnaire, a definition of R&D alliance is given to make sure all respondents have at least the basic understanding of cooperative R&D. Most answers are reported on a five-point Likert scale with "5" meaning strongly agree with the motives and "1" meaning strongly disagree with the motives. This questionnaire was personally administrated during April-May, 2005. Questionnaires were distributed to the senior and middle managers who work for companies in Chinese aluminum industry. About 22 companies were randomly sampled and 550 questionnaires were sent out with the help from Chinese Aluminum Industry Association. About 224 questionnaires were returned. Among 224 returned questionnaires, 199 were completely answered and another 25 were not with one or more questions missed. So the useful return rate is 36.2 percent.

Analysis

From the perspective of statistics, a research model is also called a statistical model. In general, the statistical model has two parts, a measurement model and a structure model. The measurement model is concerned with the links between the latent variables (factors or constructs) and their observed measures (variables). The structure model is concerned with the links between the latent variables themselves. The aim of this study is not to test casual relationships based on a structure model, but to test the validity of the measurement model. The reason for this is that we group the strategic motives identified from previous studies into four factors, respectively, according to four relevant theories. In other words, we use several strategic motives (variables) to measure one particular factor, which is linked to the theory. Both the grouping and relevance of these factors need to be justified.

Confirmatory factor analysis (CFA) of a measuring instrument is most appropriately applied to measures that have been fully developed and their factor structures validated. The legitimacy of CFA is tied to its conceptual rationale as a hypothesis-testing approach to data analysis. That is to say, based on theory, empirical research, or a combination of both, the researcher postulates a measurement model and then tests for its validity given the sample data. In testing for the validity of factorial structure for an assessment measure, the researcher seeks to determine the extent to

which variables designed to measure a particular factor (latent variable) actually do so. Analysis of moment structures (AMOS) is a computer software package which is designed and based on CFA. AMOS tests the validity of the indicator variables (Byrne, 2001, p. 147). In this study, we firstly use AMOS to validate our proposed measurements for each of the four inducement factors and then, the CFA module of statistical package for the social sciences (SPSS) is used to test the reliability of the validated measurements for each of the four inducement factors.

Descriptive statistics

The mean, standard deviations of all variables of the four inducement factors are displayed in Table I. The highest mean value among all the observed variables is 4.56 for the variable $q12$, which is "information exchange" in the factor of skill sharing. The lowest mean value among these observed variables is 3.35 for variable $q24$, which is "setting up barriers against new market entrants" in the factor of MP.

Validating the measures of each factors

All of the measures (observed variables) for each of the factors were tested. For example, the factor, CS, with its five variables was analyzed by AMOS GRAPHICS (Figure 1). Once the factorial measurement model is drawn, a Goodness of fit test was applied. For the goodness of fit, four indices were adopted: incremental index of fit (IFI) introduced by Bollen (1989); Tucker-Lewis index (TLI) introduced by Tucker and Lewis (1973); comparative fit index (CFI) developed by Bentler (1990); and root mean square error of approximation (RMSEA). For IFI, TLI, and CFI, a value greater than 0.90 is considered indicative of a well-fitting model (Bentler, 1990). There is no generally accepted criterion for RMSEA, but recently Byrne (2001) suggests less than 0.08 as an acceptable value for RMSEA.

Factor	Variable	Description of variable	Mean	SD
Cost sharing (CS)	$q1$	Sharing fixed cost	4.22	0.784
	$q6$	Avoidance of wasteful duplication	4.47	0.744
	$q11$	Earning economy of scale in R&D	4.13	0.818
	$q16$	Sharing R&D resources	4.31	0.720
	$q21$	Pursuing R&D cost reduction	4.25	0.802
Learning based motives (LB)	$q2$	Access to complementary knowledge	4.46	0.716
	$q7$	Technology transfer	4.33	0.840
	$q12$	Information exchange	4.56	0.632
	$q17$	Management training	4.11	0.907
	$q22$	Researcher training	4.34	0.713
Risk sharing (RS)	$q3$	Risk spreading among participants	4.25	0.809
	$q8$	Buffering threats from external competitors	3.98	0.904
	$q13$	Reducing competition	3.86	0.903
	$q18$	Reducing uncertainty in cooperative R&D	3.93	0.929
Market power (MP)	$q4$	Developing new and advanced products	4.27	0.897
	$q9$	Developing or accessing to new markets	4.04	0.878
	$q14$	Speeding up products from R&D to market	3.99	0.945
	$q19$	Expansion of product range	3.76	0.953
	$q24$	Setting up barriers against new entrants	3.35	1.023
	$q27$	Facilitating international expansion	3.93	0.922

Table I.
Descriptive statistics for all variables

For the four factors, three yielded a well-fitting measuring instrument with values greater than 0.90 for all of IFI, TLI, and CFI, and RMSEA values are all under 0.08. These three factors are: skill sharing, RS, and MP. The hypothesized model for measuring the fourth factor, CS, fits the data set poorly with a TLI of 0.802 and an RMSEA of 0.119. On examining the report of "modification index," it was seen variable $q11$ (earning economy of scale in R&D activities) correlates highly with variable $q21$ (pursuing R&D cost reduction). Highly correlation between the two variables means that either of two variables can represent the other.

As mentioned above, economies of scale are concerned with the average cost of production in relation to the productive capacity of a plant. A joint venture can reduce average unit cost by pooling together each partner's capabilities and resources in order to achieve the benefits of large-scale production (Boateng and Glaister, 2003). This suggests that "pursuing R&D cost reduction" can be represented by "earning economies of scale in R&D activities" in the factor of CS. Thus, one variable $q21$, "pursuing R&D cost reduction" was dropped from the factor of CS (Figure 2 the adjusted instrument model).

Turning to Table II, we see that the new RMSEA value for the adjusted model is 0.000, which indicates a good fit of the new measurement model with the data. The IFI is now 1.008, TLI is now 1.024 and CFI now is 1.000, all greater than the 0.90 threshold. Thus, the adjusted model is a good fit with the observed data. So after the validity testing for every single factor, only one variable was dropped, that is variable $q21$, pursuing R&D cost reduction from the factor of CS.

The four relevant theories used to explain the motives that induce firms to participate in cooperative R&D differ principally and fundamentally in the objectives attributed to firms, but they also share several commonalities. Kogut (1988) points out that these

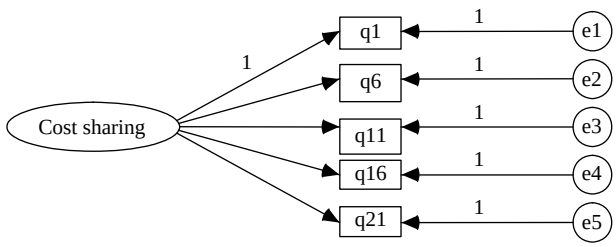

Figure 1.
Measuring instrument for CS

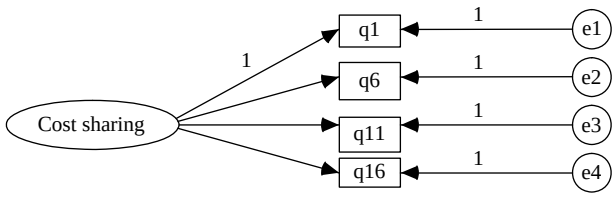

Figure 2.
Adjusted measuring instrument for CS

Model	RMSEA	IFI	TLI	CFI
Your model	0.000	1.008	1.024	1.000

Table II.
Model fit report for factor of CS

theoretical approaches are not carefully distinguished from one another when Kogut explains the phenomenon of joint ventures from theoretical and empirical perspectives. Kogut's viewpoint is echoed by Odagiri (2003) in determining the motives and determinants of the R&D boundaries of a firm, in which Odagiri posits that, the theories for explaining why firms conduct cooperative R&D need not be mutually exclusive. From previous studies, we can conclude that, the four theories used for grouping motives into four factors are supportive of each other, in some way. They are somewhat overlapping and complementary rather than either exclusive or separate. In order to improve the validity of the measuring instruments, we provide a new hypothesized instrument model, in which four motivation factors are put together (Figure 3). AMOS has the capability to test the factorial validity of scores from a measuring instrument with correlated factors.

In this model, CS, LB, RS, and MP denote the four factors: CS, LB, RS, and MP, respectively. The variable *q*21 has already been dropped from this model. For consistency, we use the same criteria for testing this model: IFI, CFI, TLI, and RMSEA. In the output report for this model, IFI is 0.898, TLI is 0.879, CFI is 0.896, and RMSEA is 0.068. These values are indicative of a poor fit of the model to the data. Thus, it is apparent that some modification is needed in order to determine a model that better

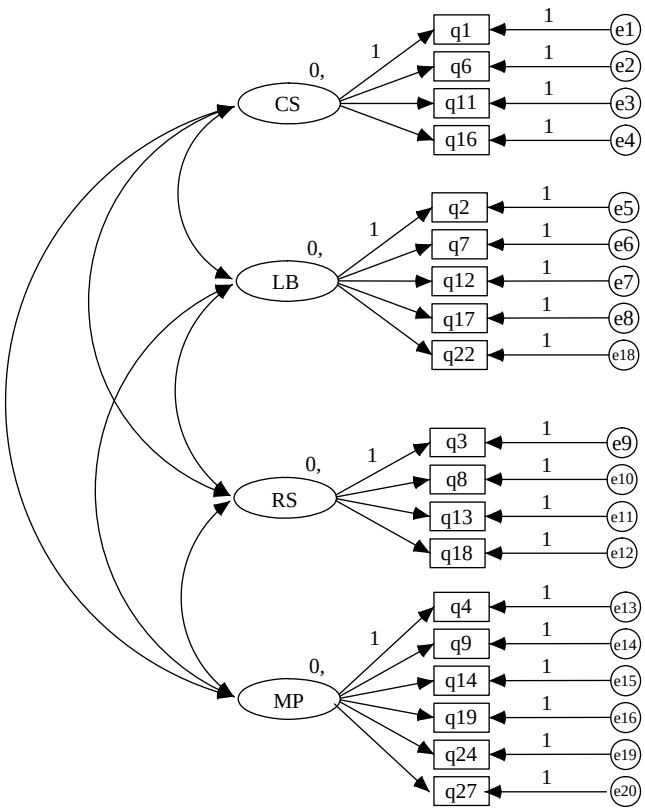

Figure 3.
Hypothesized 19-variable model of factorial structure for motives

represents the sample data. The modification indices were used to identify possible areas of misfit, we examined the modification indexes. These are presented in Table III.

Based on the CFA model, error terms close to a value of 0.0 are of substantial interest; and large M.I.s would indicate the presence of error covariance. In AMOS, M.I.s are computed for all parameters implicitly assumed to be zero, as well as those that are explicitly fixed to zero or to some nonzero value. In Table III, we draw attention to the highest value (M.I. = 20.396) between errors, e13 and e16. This is clear evidence of misspecification associated with the pairing of variables $q4$ and $q19$. Although, admittedly, there are a few additional large M.I. values shown, this highest value is substantially larger indicating mis-specified error covariance. This measurement error covariance represents systematic, rather than random, measurement error in the variables, and this may derive from characteristics specific either to the variable or to the respondents (Aish and Joreskog, 1990). Another effect that can trigger correlated errors is a high degree of overlap in variable content. Such redundancy occurs when a variable, although worded differently, essentially asks the same question.

These two variables are both included in the factor of MP motives. Variable $q4$ is "developing new and advanced products" and variable $q19$ is "expansion of product range or product diversification." Cooperative R&D can help to develop new and advanced products, so that product range is expanded and diversified. We believe that, the second reason is true for this instrument. Thus, variable $q19$ was excluded. The output report for the new instrument yielded values of IFI = 0.914, CFI = 0.912, and RMSEA = 0.062, but TLI is still under 0.90, standing at 0.896. According to the modification index, we found that variable $q17$ and variable $q18$ have the highest error covariance even though the value of error covariance is not substantial larger than others, but variable $q17$ is also highly correlated to variable $q11$ and variable $q16$. So, we decide to remove variable $q17$ from the instrument model. The finalized model has a good fit to the sample data with IFI = 0.937, CFI = 0.936, TLI = 0.923, and RMSEA = 0.055.

Error			M.I.	Par change
e19	↔	RS	6.460	0.046
e18	↔	MP	6.596	0.053
e18	↔	E20	9.660	0.093
e16	↔	LB	6.528	0.042
e14	↔	E16	7.199	−0.077
e14	↔	E15	6.651	0.077
e13	↔	E16	20.396	0.167
e12	↔	E16	6.647	0.092
e11	↔	E18	7.498	−0.082
e10	↔	E19	7.981	0.123
e10	↔	E16	10.427	−0.116
e9	↔	E13	10.017	0.110
e8	↔	E12	10.194	0.130
e7	↔	E13	6.647	0.064
e4	↔	E8	8.548	−0.101
e3	↔	E10	6.551	−0.094
e3	↔	E8	7.242	0.101
e1	↔	E13	8.232	0.102
e1	↔	E4	6.261	0.082

Table III. Covariance of hypothesized model

Reliability testing of factors

After testing and validating the measuring instrument, this section describes the results of the tests undertaken to examine the finalized constructs in this study. Specifically, construct reliability is conducted to show that all the variables adopted are reliable and valid. Construct reliability tests the degree to which individual variables used in a construct are consistent in their measurements (Nunnally, 1978). Reliability examines whether the measurement of a given construct can be repeated; that is, reliability assesses whether the measurement of a construct can be duplicated over time (Hair *et al.*, 1995). In other words, the measuring procedure should yield consistent results on repeated tests. The more consistent the results given by repeated measurements, the higher the reliability of the measurement procedure (Carmines and Zeller, 1979).

For testing the reliability of a given construct, one popular method is to provide a reliable estimation of the coefficients. This method is referred to as a measure of internal consistency and is calculated by averaging the correlation between variables (Nunnally, 1978). The assumption of internal consistency is that a good construct is comprised of variables which are homogenous within this construct. Hence, methods concerning internal consistency measure inter-variable correlation. A construct is considered to have high-internal consistency when its variables are highly inter-correlated, for this suggests that the variables are all measuring the same thing.

As suggested by Nunnally (1978), the most recommended measure of reliability is provided by coefficient α or Cronbach's α as it provides a good reliability estimate in most situations. The value of α ranges from 0 to 1. The nearer of α to 1, the better the reliability of the constructs. A widely cited minimum threshold for Cronbach α is 0.70. However, some scholars suggest that an α as low as 0.60, is acceptable (Churchill, 1991).

The coefficient α for the different constructs were computed using SPSS and are presented in Table IV. Most of the constructs used in this study exceed the 0.60 threshold. We also used two-step process to test the reliability. The first step is to calculate the α for each of the four factors individually without considering their overlap. In this step, the values of α range from 0.614 for CS to 0.861 for MP. The second step is to compute α for each of the four factors when consider their overlaps. The values of α range from 0.614 for CS to 0.830 for MP in step two.

Validity testing

Construct validity refers to the degree to which instruments (variables) measure the constructs that they are intended to measure. In other words, validity is defined as the accuracy of measurement. In this paper, we tested the validity of the measurements validated by AMOS for each factor by conducting CFA. The results of CFA in this study support the measurements validated by AMOS. There are two categories of

		Step 1		Step 2	
Construct	Initial variables	Used variables	Cronbach's α	Used variables	Cronbach's α
Cost sharing	5	4	0.614	4	0.614
Skill sharing	5	5	0.733	4	0.696
Risk sharing	4	4	0.704	4	0.704
Market power	6	6	0.861	5	0.830

Table IV.
Construct reliability statistics

construct validity, both of which were examined in this study: convergent validity and discriminant validity:

(1) Convergent validity is demonstrated when different variables are used to measure the same construct and when scores from these different variables are correlated. Carmines and Zeller (1979) suggest that factor analysis provides a suitable means to examine convergent validity. In factor analysis, factor loadings are used to detect whether or not a variable appropriately loads on its predicted construct. Factor loadings reflect the strength of the relationship between a variable and a particular construct or factor. The higher the loading, the better the representation that particular variable has on the factor. Typically, loadings of 0.50 or greater are considered to be significant. To assess convergent validity in this study, factor analysis through SPSS with VARIMAX rotation was conducted. As with the reliability testing of constructs, we took two steps to test the convergent validity. In both steps, all factor loadings used for each of the factors in this study are higher than 0.50, which supports the convergent validity of those variables.

(2) Discriminant validity assesses whether the variables that measure a construct do not correlated too highly with measures from other constructs from which they are supposed to differ. In other words, all variables load higher on their predicted constructs than on their cross-loadings, thus suggesting a good fit. To test the discriminant validity, factor analysis through SPSS with VARIMAX rotation was conducted. To evaluate the measures, a comparison is made between the loadings of a variable with its associated construct to its cross-loading. All variables are found to have higher loadings with their corresponding constructs in comparison to their cross-loadings. In this case, the evidence suggests discriminant validity of those variables.

Conclusion

Firms engage in cooperative R&D activities for various reasons. This paper takes a new approach to examining the strategic motives for firms to engage in cooperative R&D. We grouped the relevant strategic motives into four, based, respectively, on: transaction cost economics, risk theory, learning organization theory, and strategic management theory. These four theories provide a rational explanation of each strategic motive. We then group strategic motives identified in previous studies into theses categories, named CS, RS, skill sharing, and MP. In this research project, we used a survey questionnaire to measure the perceived motives and their factors. AMOS computer software, based on CFA was used to validate the measurements we proposed for each factor (group). The results of the CFA show that our measurements are reliable and valid.

Past research into the underlying driving forces which induce R&D cooperation between firms has focused only on the motives, and has not generally provided rational explanations for these motives. Some of the previous studies used exploratory factor analysis to group the motives, but the results are very diverse. The main contribution of this research is to overcome this problem. Firstly, we used four theories to explain the driving forces that induce firms to pursue cooperative R&D. Secondly, based on these four theories, we identified the relevant motives from extant research papers and group them into these four categories. Lastly, statistical techniques were used to

justify this grouping. The factors with fixed motives in this study overcame the problem caused by the diverse results in previous research.

This research paper has implications for future research. The variables identified in this paper for each inducement factors can be used in future research to test the relationship between the inducement factors and the formation of R&D alliances. The results of the AMOS analysis indicate that researchers need to be careful when they use more than one inducement factor to study R&D alliances because the factors and their variables are correlated to some extent. Some of the variables may need to be dropped from the inducement factors because they may cause a misfit between the measurement model and data set. In this study, we used four theories to explain the motives that firms engage in cooperative R&D. But this does not include all the motives which lead firms to pursue cooperative R&D. There are other motives mentioned in the literature such as: social networking (Bagchi-Sen, 2004), abstracting external investment (Caloghirou *et al.*, 2003), and exploiting research synergy (Fusfeld and Haklisch, 1985). The techniques in this study when applied to group these motives could produce useful information in similar research.

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