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Extreme internal–external industrial-service flexibilities and interfirm cooperative networks in high-technology machine manufacturing ☆

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ABSTRACT

Most interfirm studies focus only on the strategies of strategic partnerships, such as joint ventures, technology transferring agreements, licensing agreements; the study here provides interfirm-network knowledge protocols for designing interfirm-service processes in the high-technology machinery industry (HTMI) by small-and-medium enterprise (SME) networks from the perspectives of extremely-rapid industrial-service flexibility (X-ISF). Based on the decision system analysis (DSA) method, this study constructs an X-ISF research model consisting of major variables of extremely-rapid internal ISF (X-I ISF), extremely-rapid external ISF (X-E ISF), and cooperative networks. This study applies a mixed methods (qualitative and quantitative) research design to understand interfirm-network decision-making and the influence of the antecedent conditions of internal and external X-ISF and cooperative upstream-to-downstream networks on firms' X-ISF performance. The study finds that the mutual relationships between X-I ISF and X-E ISF are substantially unbalanced — the impact on firm X-ISF performance by the external-to-internal (X-in) ISF is substantially greater than the impact from the internal-to-external (X-out) ISF. Recognize the need to lead with external-to-internal X-ISF to sustain the adoption-implementation of superior high-technology is the principal take-away strategy implication.

1. Introduction

Accurately mapping configural antecedent conditions and outcomes of extremely-rapid industrial-service flexibility (X-ISF) and the recipes of alternative configurations of cooperative networks are new and major topics in industrial innovation and performance research. From the perspective of the high-technology machinery industry (HTMI), due to the high degree of similarity of machines made across several nations, Taiwan HTMI manufacturers confront difficult price-capability international competitions; new international competitors emerge annually that possess low-cost advantages that enable these firms to quickly catch-up both in quality and in market position via X-ISF, that is, extremely-fast ISF. (cf. Lai & Chang, 2009).

Small-and-medium enterprises (SMEs) and interfirm-external X-ISF networks represent the basic industrial structure and behavior of Taiwan machine manufacturing firms. Taiwan's machine-manufacturing interfirm (MMI) networks differs radically from other societies of East Asia—for example, Taiwan MMI network behavior is more conservative and consists of SMEs more often versus larger-size and more innovative, single-firm, machine manufacturing in Japan (see Hamilton & Biggart, 1988; Hamilton, Roas, & Carter, 1996; Winckler & Greenhalgh, 1988). Taiwan firms have small but substantial shares in the global HTMIs export markets—executives in these firms write vision statements for their firms that indicate serious commitments to radical innovations in designing-manufacturing machines using X-ISF with the principal objective to achieve success in global markets.

Since the net cost of key components is usually high (30+%) of the total manufacturing cost, the key components affect not only the performance of the machine but also the total cost of the machine. This configuration of antecedent conditions indicates that if the Taiwan HTMI firms are to sustain their competitive advantages, HTMI must acquire outside manufacturing resources, and thus the interfirm strategies in creating and implementing X-ISF via cooperative networks play an important role in the Taiwan HTMI. Hagedoorn (1990, p. 17) reports, "…the organizational design of [interfirm] co-operation can be expected to be related to the strategies and economic performance of companies, reflecting their ability to model their inter-firm relationships."

X-ISF is an important driving force for achieving high performance by firms in MMI networks. A gap exists between what executives in cooperative interfirm-networks are actually doing and academic

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discourse via survey reports on these networks (Huggins, 2001). In-depth research into such network behavior in the HTMI is essential but missing for capturing a clear understanding X-ISF's influence on firm and interfirm performance. The present article provides both maps of X-ISF processes and tests the impact of X-ISF in new machine processes in high-technology manufacturing. The study is unique in providing both qualitative and quantitative examinations of the influence of two X-ISF modalities (internal and external) and cooperative networks on X-ISF performance. X-ISF versus ISF is identifiable by the achievement of sustaining extremely rapid real-time (<48-h) high-technology machinery computer assistant designs (CADs) to mach-testing (experimental production runs) of new CADS. The findings in the present study show that successful implementation of X-ISF requires both external-to-internal X-ISF (X-in ISF) and internal-to-external X-ISF (X-out ISF) with X-in ISF directing such couplings.

2. Literature review

X-ISF is the ability to plan and implement a change-in-direction in manufacturing including responding to dramatic environmental events extremely-rapidly time with little penalty in effort, cost, or performance (cf. Upton, 1994, 1995). Creating X-ISF is not only one response to deal with challenges facing the global competition, rapidly changing technology and shorter product life cycles, but also one process for accomplishing extreme logistics flexibility among connections between suppliers, assemblers and markets (Aprile, Garavelli, & Giannoccaro, 2005).

2.1. Industrial Service Flexibility (ISF)

Flexibility can extend a firm's range of available products and can shorten the time that a firm needs to respond to demand. Flexibility refers to the capability, willingness, and behavior of reacting to the demand of modifications in a flexible manner (Ivens, 2005) and regards to be the incremental cost and time of modifying a design in order to respond to customers' changing needs or to discover a better solution for the design process (Thomke, 1997). Although researchers and manufacturers understand the flexibility concept, they struggle with its application to industry-wide standards (Gerwin, 1987; Sethi & Sethi, 1990). Newman, Hanna, and Maffei (1993) explain flexibility as a fundamental instrument for dealing with uncertainty. External uncertainty can stem from the demand or the supply of the market; internal uncertainty can arise from internal failure, lack of materials, and delay.

Numerous studies discuss the benefits of interfirm flexibility, sources of flexibility, and methods of flexibility from the viewpoints of technology and operations management. Hua, Huang, and Zhang (2008) indicate that any MMI firm that expands its size or scope must develop its ability of interfirm ISF, and that a key issue of such a firm's manufacturing strategy is the degree of interfirm ISF requirements by multi-purpose production sources. Therefore, interfirm ISF is drawing increasing attention from researchers and practitioners. Since flexibility is a complex and multi-dimensional concept, it is difficult to summarize all its contents (Gupta & Buzacott, 1996; Upton, 1994). Volberda and Rutges (1999) classify flexibility into internal and external types. They define internal flexibility as management's capability to adapt to environmental demands quickly; they define external flexibility as the capability to manage environmental influences and to reduce the firm's vulnerability to environmental changes. External flexibility is relative to customer requirements and thus to a firm's competitive advantage. This notion of flexibility is a “first-order flexibility” with regard to quality, cost, and time (Suarez, Cusumano, & Fine, 1996), or “market-based flexibility” (Chen, Calantone, & Chung, 1992).

Differentiating from the previously discussed flexibilities, X-ISF is to create and implement extremely-rapid (<48 h CAD-to-machine output) industrial flexibility strategies focusing on the core of services in cooperation interfirm networks (cf. Uzzi, 1997) of SMEs. Grönroos (2000) addresses that services are identifiable as **s**imultaneous production and consumption of intangible product that contain integrative characteristics with respect to external factors in the production process; X-ISF is explicitly recognizing and accomplishing such near-simultaneous processes in adopting new high-technology machine design-manufacturing. Interactions between service providers and customers in business markets increasingly take place in the form of extremely-rapid response relationships (cf. Heide & Stump, 1995; Ivens, 2005). Expanding on Volberda and Rutges's (1999) classification of flexibility, X-ISF is classifiable further into internal and external ISF (X-I and X-E). X-I ISF for machinery manufacturing includes rapid new reconfigurations of machinery that makes machinery; X-E ISF for machinery manufacturing is the rapid sharing of customers' orders by a “leader firm” with “satellite” firms—such rapid sharing is necessary when customers' purchase orders are substantially greater than the manufacturing capabilities of the leader firm.

2.1.1. The elements of extremely-rapid internal ISF (X-I ISF)

X-I ISF provides operational efficiency by means of rapid effective processes and infrastructure. Building Koste and Malhotra's (1999), Hyun and Ahn's (1992), and Upton's (1994) studies and the findings from the present study, X-I ISF is classifiable as coupling four elements of machine flexibility, material-handling flexibility, routing flexibility, and labor flexibility. Machine availability is the quantity and variety of operations that a machine can execute without incurring high transition costs or large changes in performance outcomes (Koste & Malhotra, 1999); material-handling flexibility is the ability to transport different work pieces between various processing centers over multiple paths economically and effectively (Koste & Malhotra, 1999); routing flexibility uses alternate routes to whatever extent is judged to deliver performance economically and effectively (Koste & Malhotra, 1999); labor availability provides flexible labor and guarantees the performance even when demand becomes unstable, and labor availability has good uniformity if the operators can maintain quality and efficiency across a variety of jobs (Hyun & Ahn, 1992; Upton, 1994).

2.1.2. The elements of extremely-rapid external ISF (X-E ISF)

X-E ISF includes rapid-coupling of the multiple linkages among corporate, marketing, and manufacturing strategies across interfirm networks of firms. Building on the foundations of earlier research, this study classifies X-E ISF into the four categories: product, modification, delivery, and volume. Product flexibility is defined as the capability of the manufacturing system to initiate production of new products, using existing facilities (Narasimhan, Talluri, & Das, 2004); modification flexibility refers to the ease with which a manufacturer can alter a product design to satisfy requests for customization and differentiation (Dixon, 1992; Gerwin, 1987); delivery flexibility is the ability to change the content of the order or the delivery date (Dixon, Nanni, & Vollmann, 1990); volume flexibility is the ability to operate at various batch sizes or at different production output levels economically and effectively (Gerwin, 1987).

2.2. Cooperative networks

Huggins (2001) addresses that essential need to create interaction and cooperation within firms in order to build a successful interfirm network in industries; however, the speed of interfirm interaction is generally low and unintensive due to a general absence of a supportive immediate-response interfirm culture. In Taiwan's cooperative networks, the manufacturer that receives orders is called “the mother factory”; the factory that actually does necessary work to complete