Reverse technology transfer from a dispersed, fragmented value chain

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ABSTRACT

A great deal has been written concerning the transfer of technology within a firm's boundaries and from a firm outward to partners and suppliers. But reverse technology transfer, the ability to transfer technology from partners and suppliers back to the focal firm, has become more critical with dispersion and fragmentation of the value chains on a global basis. The proposed basis for effective reverse technology transfer is a fit between the characteristics of the value chain and the characteristics of the technology being transferred. Hypotheses and a model of fit are developed, including moderating variables that can improve the fit. A brief proposal for empirical testing is presented, followed by conclusions and areas for further development.

Keywords: value chain fragentation, technology transfer, reverse technology transfer

INTRODUCTION AND CORE CONCEPTS

Firms transfer technology both internally and externally to increase innovation on existing products and services and to develop new products and services. Technology transfer occurs internally to the firm, for example between divisions or from R&D to product development teams. Likewise technology is transferred within the value chain network, for example within production clusters. Technology is also transferred outward from the firm to the value chain as the firm invests in plants, out-sources R&D and licenses technology. Of interest here is technology transfer from the value chain to the firm, often called reverse technology transfer.

The vast majority of the literature is concerned with technology transfer from the flagship firm outward to the value chain, and with access to technology from formal arrangements such as partnering and licensing. This literature is reviewed along with the concept of "fit" to develop a conceptual model of reverse technology transfer from the value chain to the firm.

Porter (1985) uses the five forces of suppliers, substitutes, new entrants, buyers and rivalry as a way of looking at the forces driving industry competition, and Porter uses value chain analysis as a tool for analyzing a firm's competitive advantage. Porter's value chain includes primary and support activities as it follows the steps of development, production and sales. More recently, the concept of the value chain has been expanded to include all external stakeholders, including suppliers and customers. McPhee and Wheeler (2006) use the term "added-value" chain in describing an extended view of the value chain including external networks and uses and reuses of the end products. The extended value chain, the core concept for this paper, includes buyers, suppliers, and competitors (Kaplinsky, 2000) and is represented in Figure One (Appendix).

The value chain is used by Dicken (2003) to understand the network of activities on a global basis that make up production of goods and services. Dicken adds that the flow of goods goes in one direction but that the flow of information about demand and supply status in the other direction serves to integrate the value chain.

Dispersion in the value chain comes as new markets open up, causing production investments in those markets and new, specialized manufacturing and service centers emerge in developing nations. Dispersion is illustrated in terms of a global component network for Ford's manufacture of the Escort, with parts of the automobile coming from fifteen different countries in Europe, Asia and the U.S. (Daniels et al., 2007).

Fragmentation in the value chain is defined as the ability to break up the integrated production and support process, moving the elements to lower cost locations. Fragmentation is facilitated by lowering trade barriers, by technology that assists in coordinating the value chain, and by the lowering of the cost of moving goods and information locations (Venables, 1999). Examples include the movement of software development to India, Russia, Malaysia, and central Europe and the movement of manufacturing into (and away from) the Mexican maquiladoras corridor as costs and capabilities change.

Fragmentation can occur with a single country, for example with the cluster of suppliers around Detroit, but is most often associated with TNCs and the rationalization of production and support activities. In the latter case, fragmentation of the value chain leads to competition for the production element and often to further cost competition (Venables, 1999).

This fragmentation has progressed to the point that the term value chain is being replaced by value grid (Pil & Holweg, 2006), with a recognition that companies cannot directly control either production or the customer. With product development now a global, fragmented process (Eppinger & Chitkara, 2006), companies are searching for new models of innovation and technology transfer.

The prevailing mode of technology transfer is that the technology developed in the home base of the firm is transferred to divisions and foreign subsidiaries and suppliers for exploitation in the interest of the firm (e.g. Porter, 1985). As shown in Figure Two (Appendix), technology is transferred both internally and externally to increase innovation on existing products and services and to develop new products and services.

Following the labels in Figure Two: Technology transfer occurs 1) internally to the firm, for example between divisions or from R&D to product development teams. Likewise 2) technology is transferred within the value chain network. Technology is also transferred outward from the firm to the value chain 3) as the firm invests in plants, out-sources R&D and licenses technology. Of interest here is technology transfer from the value chain to the firm 4), often called reverse technology transfer.

With decreasing product/process life cycles and the increase in technological change, it has become harder for any one company to support all of the agendas of innovation, and there has been a growing emergence of suppliers as sources of innovation (Perrons and Platts, 2004). One way to keep up with emerging technology regimes is to look to external partners as a source of R&D (Nicholls-Nixon & Woo, 2003). At the beginning of the 1990's only 20% of companies reported heavily relying on external sources for technology, but that had increased to 85% by 2000 (Schiele, 2006).

While the majority of the literature on technology transfer is concerned with transfer from a flagship firm to the global production network (Ernst and Kim, 2002), a growing number of papers are concerned with innovation as a system, including both outbound and reverse technology transfer. Open innovation (Chesbrough, 2003) is touted as the new way to make the firm more porous for the flow of innovations from outside partners, and Total Innovation Management (Xu, et al., 2007) is explained as an "ecosystem" of innovation by anyone at any time.

With the recent emphasis on a systems perspective, suppliers are recognized as a source of innovation (Witzeman et al, 2006; Perrons & Platts, 2004). Zhao et al. (2005) identify the value chain as one of four types of technology sourcing and Sawhney, Wolcott, and Arroniz (2006) advocate the supply chain as one of twelve ways to innovate. However, the complexity of the transactions and the capabilities of the supply base affect the transfer process (Gereffi, Humphry, & Sturgeon, 2005), as does the degree of integration in the value chain (Jacobes & Billinger, 2006), as does the relationship with the supplier and the type of technology (Steensma & Corley, 2000). For the transfer to be timely, cost effective and complete, the characteristics of the value chain, the technology and the transfer objectives all have to fit together.

RESEARCH QUESTIONS AND CONCEPTUAL MODEL

With the core concepts of reverse technology transfer from the supply chain established, some basic research questions can be raised:

- What are the characteristics of the value chain and its members that make it an effective source of technology?
- What are the types of technologies that can be transferred?
- How do the objectives of the transfer affect the transfer process?

- How do moderating forces affect the fit and the transfer process?

These research questions are reflected in the basic model for review in this paper, as shown below in Figure Three (Appendix). The model is based on the concept of “fit” a concept that is central to organization theory and strategic management and which will be explored as part of the literature review. The model also includes two key moderators between fit and transfer effectiveness, the governance structure of the value chain and communication tools. Other potential moderators, such as industry structure and internal capabilities of the firm, are beyond the scope of this paper.

Specific areas for examination in each area of the model include:

Value Chain Characteristics
- Specialization
- Location
- Linkage – tight/loose

Technology Characteristics
- Certainty
- Tacit/explicit

Transfer Objectives
- Exploration
- Exploration

The concept and application of “Fit”

Governance structures
- Equity
- Non-Equity

Communication
- Use of IT
- Interface design
- Communication density and frequency

Transfer Effectiveness
- Speed
- Cost
- Completeness

The research questions in this paper and the conceptual model are concerned with the identification and transfer of technology, NOT with whether the technology can be effectively used in an existing or new product or service. Therefore some important related concepts including learning and absorptive capacity are excluded from the model. These concepts would expand this model to the next step of implementing a transferred technology, an important area that applies to internal as well as externally sourced technology and innovation.

LITERATURE REVIEW AND HYPOTHESES

Each area of the model is expanded and hypotheses are developed from a review of the literature. The model is intended to guide the literature review to develop hypotheses concerning effective reverse technology transfer from the value chain members, particularly how to tailor the value chain for more effective reverse transfer.

Value Chain Characteristics

Characteristics of the value chain that affect the fit and reverse transfer effectiveness include characteristics of the supplier, management practices, value chain governance, and integrative mechanisms.

Important characteristics of the supplier include the specialization of the supplier, the complementary nature of the assets, and the supplier location. In general, the more specialized the supplier, the greater the likelihood that the supplier will be able to be a source of technology. Suppliers who are innovative are likely to be specialized, technically competent firms who are located in proximity to the buyer (Schiele, 2006). Specialization leads to higher investments in site, capital and human resources, leading to a higher capacity for innovation that meets the needs of the focal firm.

Gupta and Govindarajan (1991) developed a framework for subsidiary knowledge flows, with a subsidiary that had outflows of knowledge to the corporation but was not reliant on the corporation labeled a "global innovator" and subsidiaries with both inflow and outflow labeled an "integrated player." In both cases the subsidiary exhibited later interdependence and complementary assets.

In the auto industry, supplier networks that re tightly integrated and in proximity with a high degree of inter-firm specialization were found to be a superior source of innovation (Dyer, 1996). Proximity was explored by Harzing and Noorderhaven (2006) as a moderator for innovation in subsidiaries in terms of both physical and cultural proximity, finding that geographic distance was mitigated by modern communication capabilities, but that cultural distance was in inhibitor to knowledge flows.

Suppliers in the value chain are managed with a variety of tools and procedures that are designed to improve the reverse transfer of technology. R&D copractice (Ghoshal & Bartlett, 1998) is a way of insuring that goals are aligned and that communication flows are both from and back to the focal firm. Communication frequency and content are emphasized by a number of authors (e.g. Jacobes & Billinger, 2006; Ghoshal & Bartlett, 1998), as is movement of people as a way of enhancing communication (Frost & Zou, 2005). Overall supplier involvement is encouraged (Dyer, 1996) as a way to build supply chain capabilities and facilitate reverse transfers. The ultimate value chain design that enhances reverse transfers is call a "permeable vertical architecture" (Jacobes & Billinger, 2006) that promotes innovation and knowledge transfers in all directions.

The length of the term of a supplier relationship is also associated with a higher level of reverse transfer (Sawhney, Wolcott, & Arroniz, 2006), where information flows can be more open and with fuller content based on trust that is developed over time. Time increases the communication efficiency (Katobe, Martin, & Domoto, 2003).

Management forms and governance structures are used to enhance the information sharing and reverse technology transfer in value chains. Malhorta, Gosain, and Sawy, (2005) identified five different clusters on supply chain arrangements - collector, connector, cruncher, coercer, and collaborator – with variation in the level of knowledge creation and operational efficiency at each configuration. The highest level of knowledge creation in the value chain was from the coercer and collaborator configurations. In the coercer model, the information exchange was narrow whereas in the collaborator model the information flow was broad and there was joint decision making. A management structure that concurrently uses multiple forms was found to be most effective for information transfer in a study of European manufacturing firms (Jacobes & Billinger, 2006).

Rowleym, Behrens, and Krackhardt (2000) add the concept of embeddedness to the concept of structure in relationships in the value chain and the combined effect on information exchange. The greatest transfer of information came when there were strong ties and a greater degree of connection between the firms.

After reviewing the characteristics of the technology being transferred, these characteristics of the value chain are combined with technology characteristics in terms of fit and the impact on reverse technology transfer.

Technology Characteristics

Characteristics of the technology being transferred that affect the fit and effectiveness of the transfer include tacitness of the technology, simple versus complex technologies, newness to the focal firm, and incremental versus radical technologies.

The differences between tacit and explicit knowledge were explored by Nonaka and Takeuchi (1995). In general tacit knowledge can be documented and tacit knowledge cannot and includes both cognitive and technical information, plus tacit knowledge is "sticky" with the location of the knowledge. Transfer of knowledge can be one of four types, tacit to tacit, tacit to explicit, explicit to tacit, and explicit to explicit. While we are concerned with all four types of transfer, the most critical for reverse technology transfer is tacit to explicit.

Simple versus complex technologies in reverse transfer was explored in the US and Japanese automotive industries by Katobe, Martin, and Domoto (2003), where the difference was expressed as technique versus technology. A technique consists of discrete, explicit know-how while a technology encompasses a bundle of techniques along with how they can be applied to a broader set of problems.

The concept of incremental versus radical or disruptive technologies can be explained in terms of the technology "s-curve" (Foster, 1986) where incremental technologies apply to an existing s-curve moving the return from the technology up the curve. Radical or disruptive technologies represent a move to another s-curve with improved performance characteristics over the prior application.

These characteristics, along with newness to the focal firm, can be combined into a term that for this paper is called "technical uncertainty." Clearly, technologies with higher uncertainty are more difficult for reverse transfer than more certain technologies, and fit between the characteristics of the value chain and the technology becomes more critical to an effective reverse transfer.

Fit and Transfer Objectives

Fit is a concept that has a good deal of history in management literature, with fit between the organization and environment (Lawrence & Lorsch, 1986) and fit between internal resources and the external opportunities (Porter, 1985). When the parts of the construct fit together, then resources are optimally used and performance is optimal.

Here the concept of fit is used to evaluate the characteristics of the vale chain with the characteristics of the technology in terms of an effective reverse transfer from the value chain to the focal firm. A simple example of fit is the easy transfer of a very well understood technology from a member of the value chain to the focal firm through established channels without concern for loss of information or speed of the transfer. A better fit is associated with a more effective reverse transfer, while a less than perfect fit is associated with a less effective reverse transfer. Later in the model and paper, the ability to moderate the effects of a poor fit with governance and management techniques will be explored.

In the process of considering fit, a third variable is introduced in the form of the objectives of the transfer. Fit and efforts to moderate a less-than-perfect fit are based on a strategic objective of the reverse transfer, be it an incremental process or product improvement or a major change in a product or process. This is the "why" of the technology transfer.

Swan and Allred (2003) evaluated five different goals of external technology sourcing – differentiation, low cost, resource configuration, product dynamism, and speed. These objectives are comparable to the generic objectives of Porter (1985) of cost, differentiation, and focus with the addition of speed and resource configuration as added objectives. Another perspective on the goals of a reverse transfer is the difference between efficiency and learning and how those objectives affect the type of technical knowledge being sought and the sources in the value chain (Sobrero & Roberts, 2001).

Fit Between Value Chain and Technology Characteristics

Steensma and Corley (2000) examine the impact on performance of the type of technology transferred and the attributes of the relationship with tightly or loosely coupled partners as a contingency model. Unique and inimitable technologies are better transferred with tightly coupled relationships, while uncertain and dynamic technologies are better transferred with loosely coupled relationships. The result of this study indicated that the tacit nature of dynamic and uncertain technologies require less structured communication channels in order to be transferred. In the automotive industry a tightly integrated production network with close proximity and high inter-firm specialization outperforms a loosely coupled network (Dyer, 1996).

Relationship and structure are explicitly tied to the type of technology transfer in the steel and semiconductor industries by Rowleym, Behrens, and Krackhardt (2000). The authors found that loosely managed networks were better at transferring exploration technologies while strong ties were better at transferring exploitation technologies. The same study evaluated the density of the communication channels finding the inverse relationship so that dense but weakly integrated partners were better suited for exploration.

Matching level of interdependency with design scope is the key to effective efficiency and learning transfers according to (Sobrero & Roberts, 2001). The objectives of learning and efficiency are a tradeoff, with learning increased by a broader design scope and higher interdependency, but efficiency requiring limited design scope and less interdependency. This relationship defines two corners of a matrix, but clearly there are intermediate steps, if not a continuum in the tradeoffs.

A technology supply chain for new product development, as distinguished from a component supply chain, is described by Ettlie and Pavlou (2006) with highly specific technology transfers as opposed a continuous flow of materials. Transfers of technology are examined in terms of the uncertainty, that is the tacitness, novelty and complexity of the technology. Technologies with higher uncertainty require higher inter-organization communication, coordination, and cooperation for a successful transfer. For a new product, communication and management skills and techniques are required. This proposed relationship coincides with the reverse transfer of more tacit, uncertain technologies from a loosely coupled, specialized value chain member.

The relationship between supply chain characteristics, technology characteristics and transfer objectives is summarized in terms of fit in Figure Four (Appendix). Transfer of technologies that are more tacit and more uncertain is best accomplished with value chain partners who are specialized, have complementary assets and are in a loosely coupled but dense and long-term relationship. In general, reverse transfers in this category are intended to provide newer and more radical innovations (Upper right hand corner of Figure Four).

The fit between values chain characteristics and technologies being transferred is better in a diagonal from explicit and certain technologies and tightly coupled value chain members to the opposite corner of tacit, uncertain technologies and looser network.

The discussion above leads to the first hypothesis:

H1, H2, H3: When the characteristics of the value chain (H1) and the technology fit (H2) with the objectives of the reverse transfer (H3), as shown in Figure Four (Appendix), the result is the most effective reverse transfer.

Moderating Variables

Variables that moderate the fit are examined here in terms of the ability to make the fit better for a given reverse transfer process that is outside of the "best fit" area. In the upper left area of Figure Five (Appendix), labeled "B," technologies with high uncertainty, tacitness and radicalness are in a supply chain with tight coupling, assets that are not complimentary, and low socialization of the value chain partner. In the lower right hand corner, labeled "A," the reverse situation occurs for technologies that area best transferred by tight coupling.

The literature develops two potential moderators, governance structures that are focused on the architecture of the relationship with the supplier, and management tools that can change the information and knowledge interchange characteristics primarily through communication tools and information technology. As discussed above, Malhorta, Gosain, and Sawy (2005) identified five types of supply chain partners from collectors to collaborators. The authors also acknowledged that matching the supplier needs to the available suppliers was difficult and integrative mechanisms are often needed. Joint decision-making and modularity of the business processes can be assisted by standard business interfaces and electronic interchanges. This allows the value chain partner to respond quicker and more completely to short-term information needs and technology transfers.

Sobrero and Roberts (2001) found that there was an explicit tradeoff between efficiency and effectiveness in product development relationships, with type of problem being solved and interdependence as two key variables. For the mismatch in area B, the level of interdependence can be moderated by changing the governance, or structure of the relationship with the supplier. Gereffi et al. (2002) built a framework that links the complexity of transactions and the ability to codify transactions to the type of governance. In the terms of this paper, the architecture of the value chain needs to be changed from modular to relational, assuming that the supplier has the capabilities needed for tacit technology transfer. As industries become more complex, global, and fragmented, they generally move from vertical to a more open relational architecture.

For area A in Figure Five, the relationship can be adjusted to be tighter to provide for the flow of explicit, increment technologies through established communication channels. For area B, the relationship can be adjusted to be looser through change in the governance structure to allow for flow of tacit information and more radical technologies.

Thus:

H4: For reverse transfers that do not meet the criteria of best fit in that the technologies are incremental but the value chain structure is loose and remote, the fit can be adjusted to increase fit by tightening the communication, including through the use of IT.

And

H5: For reverse transfers that do not meet the criteria of best fit in that the technologies are radical and tacit, the fit can be adjusted by changing the governance structure of the relationship from tight coupling to loose coupling.

This model and these hypotheses summarize the relationships between technology, value chain, and objectives that are fit together to increase the effectiveness of reverse technology transfers. The fit can be improved through the changes in communication and governance.

EMPIRICAL RESEARCH

This model can be tested on individual or similar groups of reverse technology transfers through a questionnaire that would gather data on the variables of value chain characteristics and technologies being transferred and the corporate objectives of the transfer. The data could then be tested for the fit of the characteristics of according to the model. Data on governance structures and use of communication tools and IT would also be gathered to see if these factors acted as moderators when the data gathered did not fit the model. This model could also be tested across several industries and types of industries such as process and product and high technology and a mix of technologies.

CONCLUSIONS AND AREAS FOR FURTHER INVESTIGATION.

The growing use of global, fragmented value chains for innovation implies that a key success factor is the ability to transfer innovation and technology from the value chain to the focal firm – reverse technology transfer. This paper proposes a model of effective reverse technology transfer that considers the need for a fit between the characteristics of the value chain and the characteristics of the technology being transferred. As an example of reverse transfer fit, loose coupling in the value chain relationship is required in order to transfer tacit technology knowledge. A mismatch in fit can be moderated by either a change in the relationship governance or by a change in the rules and support for information exchange. If this model is empirically tested, the model can be used to design the value chain to increase the effectiveness of reverse technology transfer.

Areas for further investigation include the impact of uncertainty in the external environment on the model and extension of the model to include absorption and use of the transferred technology.

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APPENDIX

Figure One – The Extended Value Chain

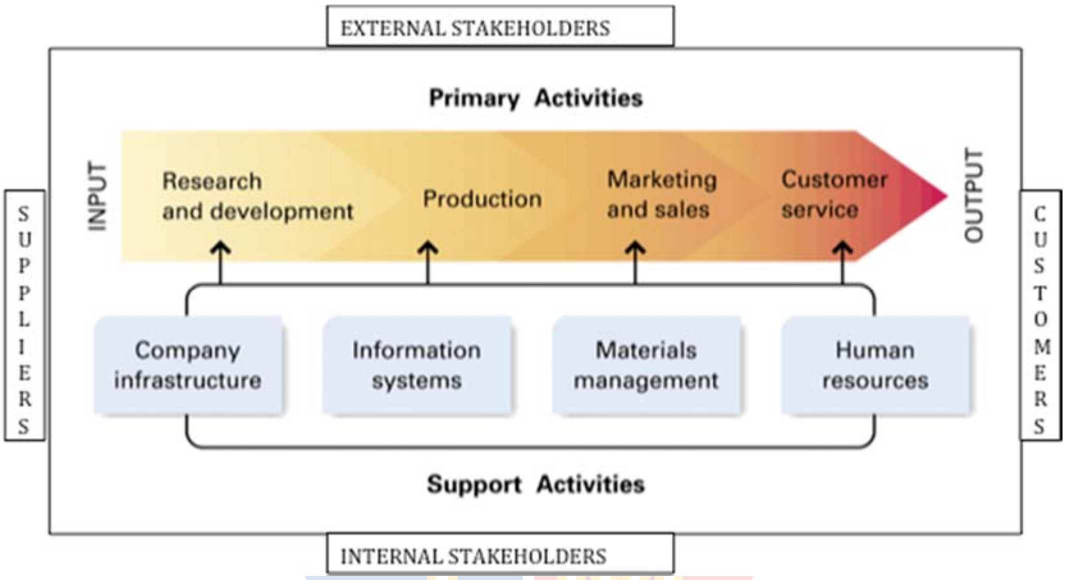

Figure Two: Overview Of Technology Transfer Paths

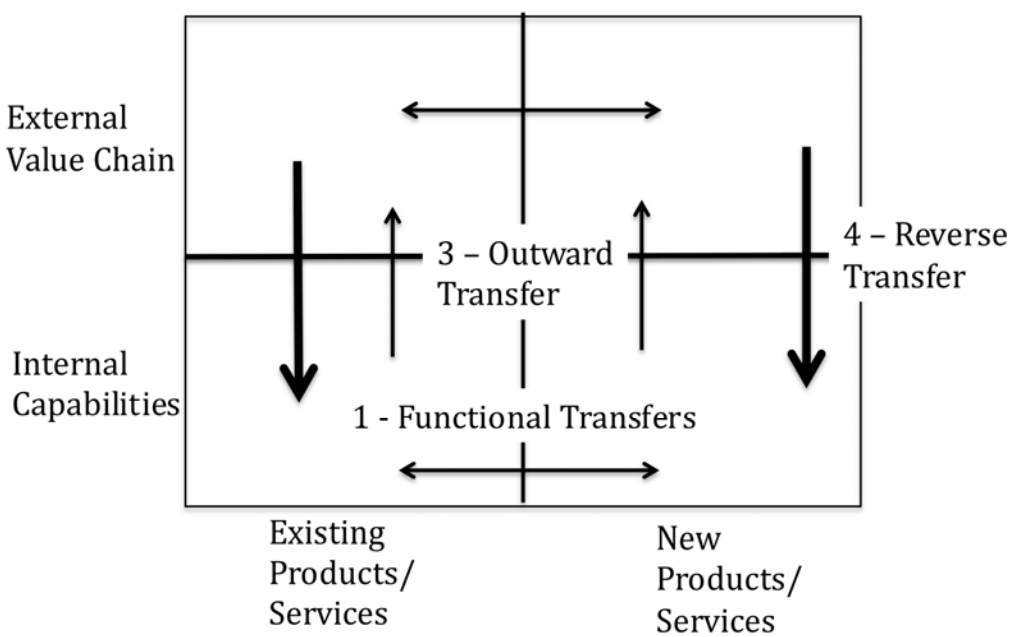

Figure Three - Conceptual Model - Reverse Technology Transfer From The External Value Chain

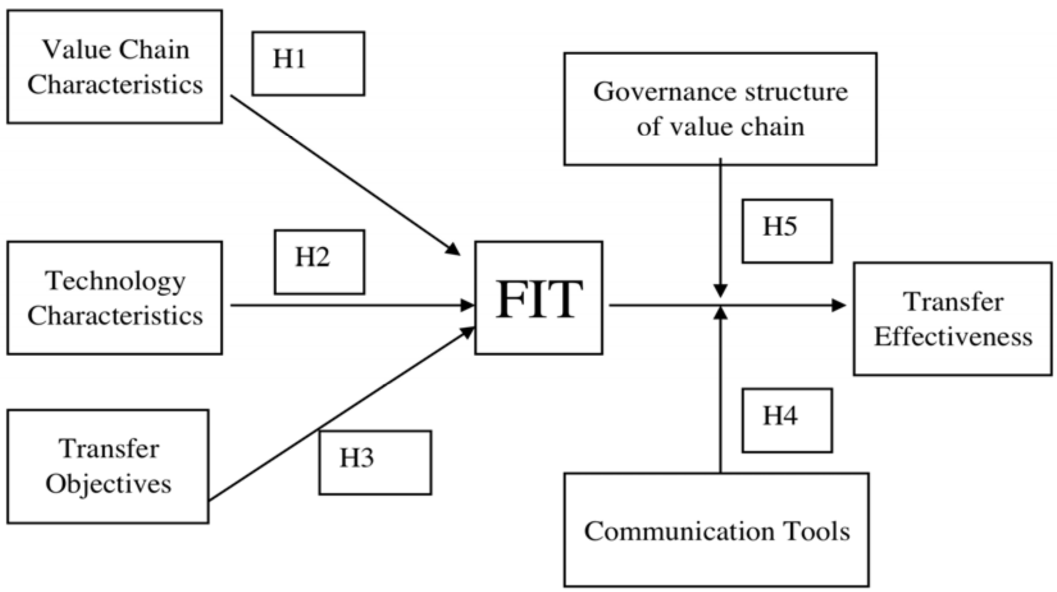

Figure Four – Hypothesis One: Reverse Technonlgy Transfer Fit

	Reverse Technology Transfer Objective	
	Incremental improvement to existing product/process, efficiency, exploitation	Radical, disruptive change or new product/process, learning, exploration
Value Chain Characteristics	• Any proximity • Complementary assets • Specialized capabilities • Tight network • Short term relationship	Best Valuse Chain Fit With Transfer Objectives: • Close to moderate proximity • Complementary or aligned assets • General capabilities • Loose network • Long term relationship
Technology Characteristics	Best Technolgy Fit With Transfer Objectives: • Explicit • Incremental • Certain • Known to focal firm	Best Technolgy Fit With Transfer Objectives: • Tacit • Radical • Uncertain • Not known to focal firm

Figure Five – Moderating Variables to Fit Model in Hypothesis One