# A Transaction Cost Economics Model of Vertical Integration Drivers for Remanufacturing Operations

by

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Submitted to the Department of Business Administration

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## Abstract

Despite recent attention to closed-loop supply chains and remanufacturing in the research literature, there is scant information about organization design for OEMs engaging in remanufacturing. Based on the research literature and six case studies we identify the drivers for organizational design and propose a framework for vertical integration for OEMs that offer remanufactured versions of their products. Our results show that brand name and intellectual property are powerful drivers favoring vertical integration. Additionally, we find that outsourcing activities for parts and components can have a profound impact on the potential profitability of OEM remanufacturing. Finally, we observe that most companies are still struggling with the question of vertical integration and there are many opportunities for further research.

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Milan, November 2008

*To my parents*

# Contents

# List of Figures

# List of Tables

# Chapter 1

# Introduction

## 1.1 Background

Today, both policy-makers and environmentally conscious customers demand that manufacturers reduce the waste generation from their products. Mainly motivated by the urge for a sustainable environment, in environmentally conscious systems the products return from end-users to the manufacturers for remanufacturing (Guide and Van Wassenhove 2001).

Until recently remanufacturing is not considered as a revenue generating industry, however with tight legislations and increasing value trapped in the products, it has become a profitable major industry. In United States, mostly small and medium sized remanufacturing businesses have estimated sales of $53 billion per year (Lund 1998) and a remanufactured product can cost consumers 50 to 75 percent less than a new product (National Center for Remanufacturing and Resource Recovery, 2006). US Department of Commerce estimates remanufacturing market to value around $100 billion.

Remanufacturing has the power of differentiating the firm cost and environmental-wise and this entails a significant impact on the bottom-line of the firm (Robotis, Bhattacharya, and Van Wassenhove 2005). Companies, especially in the capital goods industry, strategize using their remanufacturing capabilities to survive and to compete in the market. Yet, research is limited on the development of successful business models entailing remanufacturing as a competitive edge.

## 1.2 Scope and Objectives

This study attempts to contribute to the research on the organizational aspects of remanufacturing activities by proposing a model of vertical integration that portrays the firms' outsourcing decisions based on transaction cost theory. The main thrust in this study is that the uncertainty and asset-specificity is important drivers in the organizational choices of the companies who are interested in remanufacturing either because of legislations or profit-drive. Although the source of uncertainty can be contingent on the industry, product, and even country specific factors, transaction cost economics framework can incorporate environmental factors into the organizational decision making. Also, asset specificity by definition includes physical assets such as facilities as well as proprietary information, brand image, and know-how arising from disassembly.

In order to research these hypotheses, the study will concentrate on how and to what extent, certain transactional characteristics posited by transaction cost theory lead the vertical integration decisions in firms engaged in product recovery activities. First, a survey-based data collection methodology will be employed to explore the one way relationships between the transaction cost theory determinants of vertical integration in remanufacturing industry. The exploration of these one-way relationships could provide both academics and professionals in the industry with a roadmap while helping them explore the logic behind the organizational decisions for remanufacturing. Second, based on the inputs from the survey-based research, the proposed conceptual model will be refined using a series of case studies. Case studies help researchers understand why and how of the problems studied and therefore provide better understanding in revealing the causal relationships.

## 1.3 Structure of the Thesis

This thesis is divided into eight chapters. In Chapter 1, the background to the research is introduced followed by the objectives of this study, and a statement of the thesis structure. In chapter two the background on remanufacturing, and the interface between the transaction cost economics theory and remanufacturing operations will be explained. In this chapter, the study will be grounded on the previous literature and the motivation for the study and selected theoretical basis will be explored in detail. Chapter two will conclude with a clear statement of research questions and propositions.

After summarizing the background in remanufacturing literature, in chapter 3, a model of vertical integration will be proposed to identify the antecedents of the organizational decisions in product recovery environment. The constructs of the model will be explained in detail and the related hypotheses will be formulated. The research methodologies of the study and interview protocol development are discussed in Chapter 4. The two phased research approach will be discussed and each step to formulate this empirical research will be presented. Survey-based and case study methodologies and their advantages and disadvantages of will be discussed.

Chapter 5 presents the first phase of the dissertation: the survey study. In this chapter, measure development and survey administration will be discussed in detail. Moreover, the results of model estimation using partial least squares methodology and hypotheses testing will be discussed. Chapter 5 presents the overall data analysis process for survey-based part of this dissertation and discusses the results and findings of conceptual model estimation.

In chapter 6 results of the model estimation will be synthesized into an interview protocol to better understand the causal relation between the supported relationships. First data sources will be elaborated on multiple dimensions such as respondent title, industry, and product characteristics. Then, the development interview protocol and administration will be explained.

Chapter 7 presents the data analysis process for interviews and discusses the results and findings providing detailed explanations. In this chapter, the differences between the capital and consumer goods industries will be revealed based on interview results and three dominant organizational configurations will be discussed based on survey and case studies. We will propose a refined model of vertical integration for further empirical testing.

Finally, Chapter 8 summarizes and concludes the findings of this study, explores the managerial implications, and suggests recommendations for future research.

# Chapter 2

# Remanufacturing and Transaction Cost Economics

## 2.1 Introduction: The Remanufacturing Literature

Definitions of remanufacturing have evolved in time as its purpose and importance did. While remanufacturing is an industrial process in which worn-out products are restored to like-new condition (Guide 2000) in the recent past, it has quickly became a production strategy whose goal is to recover the residual value of unused products by reusing components that are functioning well (Debo, Toktay, and Van Wassenhove 2005). As a process the term "remanufacturing" refers to restoring a used product (or a component) to acceptable condition for resale. Therefore, it is different from the repair operations as it requires the product totally disassembled and all parts are returned to like-new condition (Guide 2000).

Remanufacturers may choose to process returned products (often called a "core") in two different ways: value-added recovery or material recovery (Thierry, Salomon, Van Nunen, and Van Wassenhove 1995). Product recovery value chain complements the flow of forward supply chains and closes the loop, and operates in the reverse order to deliver the residual value in the products from customers to manufacturers. Guide, Teunter, and Van Wassenhove (2003) identifies the common processes in the product recovery value chain as the product acquisition, reverse logistics, inspection, testing and disposition, remanufacturing, and selling and distribution.

The first stage, the product acquisition is equivalent to a raw material supply in a forward supply chain. Therefore, it is very important to acquire products of acceptable quality and with the right timing to guarantee an uninterrupted production process. Product acquisition efforts are affected by the system adopted: the waste stream or the market driven stream (Guide and Van Wassenhove, 2001). Waste stream is focused on passive collection of products by diverting them from landfills by enforcing manufacturer responsibilities. Under waste stream system returns are not controllable and firms act with minimize-loss objective. On the other hand, market driven stream proactively provides incentives to customers to control product returns. Guide *et al.* (2001) provide a detailed analysis of the effects of both systems on the firms' sort and test, and remanufacturing activities.

Unlike that of forward supply chain, the product acquisition process in reverse supply chains is characterized by high degree of variability in quantity, quality and timing (Guide 2000, Guide and Jarayaman 2000, Thierry *et al.* 1995). Therefore, uncertainty is a crucial element in vertical integration decisions and should be accounted for. The variability component is incorporated in many of the recent studies dealing with inventory planning and scheduling for remanufacturing. Guide (2000) discusses the impact of remanufacturing time variability on scheduling and planning and Stanfield, Wilson, and King (2004) model the variability in remanufacturing times. Fleischmann, Krikke, Dekker, and Flapper (2000) present a review of 9 case studies, which emphasizes uncertainty in different stages of remanufacturing as a common component. Forecasting and inventory model developed by Toktay, Wein, and Zenios (2000) also accounts for uncertainty in the form of delay between sale and return of the product. These studies treated uncertainty as the unpredictability resulting from returns, however technological uncertainty regarding products and processes are ignored. Also, the role of uncertainty in strategic management of reverse supply chains are not modeled nor empirically tested except for the game theoretic models for channel selection literature.

Product acquisition stage is followed by reverse logistics activities. Collected cores have to be returned to the facilities in a cost-minimizing manner. With any type of product to be retrieved from the market for remanufacturing purposes, a reverse logistics network, which implicates investment in certain assets, network should be designed. Reverse logistics activities include transportation but not limited to it; the network is also responsible for gathering the used items, classifying and segregating (Majumder and Groenevelt 2001). To achieve these tasks, physical locations, facilities and transportation links are needed. In the forward supply chain literature, to solve the logistics problems, or to conduct both production and distribution planning, quantitative modeling tools are widely used (Arntzen, Brown, Harrison, and Trafton 1995, Cohen and Lee 1988; Geoffrion and Graves 1974, Goetschalckx, Vidal, and Dogan 2002). In this sense, Jayaraman, Guide, and Srivastava (1999) provide a closed loop logistics mixed integer programming model (called REVLOG) to determine the optimal quantities of cores and products and locations for distribution, remanufacturing and transshipment. Solving the model for a set of test problems, authors found out that the quantity of available cores and demand for remanufactured products are the key decision variables. Fleischmann, Beullens, Bloemhof-Ruwaard, and Van Wassenhove (2001) present a mixed integer programming approach to reverse logistics network design in attempt to provide a standard model. The model is solved using data from copier manufacturing and paper recycling industries. Additionally, a detailed characterization of product recovery networks are articulated in Fleischmann *et al*. (2000) using case study methodology. Nine case studies from previous literature are compared and three generic characteristics are identified: (1) the coordination requirement between disposer and reuse markets, (2) supply uncertainty, (3) the dispositioning task. However, authors did not explore why and how coordination requirements arise or provide mechanisms for achieving coordination remained unclear.

In the reverse logistics stream, aside from planning and scheduling of reverse logistics activities, channel selection decisions also come into scene. These include decisions on the firms' boundaries on different tasks: core gathering, sorting and transportation. This study is relevant to the channel selection literature as it investigates the antecedents of the firm boundary decisions. When channel selection and coordination is considered, the problem of network design becomes a more strategic issue including decisions on outsourcing/insourcing, 3rd party logistics providers (3PL), incentive contracts and competition. There are several papers addressing channel selection and boundary issues from game theoretical perspective (Ferguson and Toktay 2006, Savaskan, Bhattacharya, and Van Wassenhove 2004, Savaskan and Van Wassenhove 2006). These models attempt to determine the optimal collection channel decisions and provide insights on how to develop incentive contracts among manufacturer, retailer, customer and third party providers. Savaskan *et al*. (2004) explicitly modeled the OEM's choice of reverse channel structure and considered direct collection, collection via retailer and collection via subcontracting to 3PL. Authors investigate how different channel structures affect remanufacturing profits and return rate. They show that retailer is the most effective collector, and profits can be increased by designing incentive contracts. In a 2006 paper, Savaskan and Van Wassenhove compared the direct collection with indirect collection when there is competition between retailers. They found out that competition between retailers can benefit the manufacturer and increase remanufacturing profits.

Competition also received considerable attention from scholars. Majumder and Groenevelt (2001) present two cases of competition between local firm and OEM, first in remanufacturing and second in procurement of cores from the market. Surprisingly, the authors found that in a competitive setting while OEM wants to increase remanufacturing costs, local firm tries to decrease these costs in an attempt to induce OEM to produce more. A very recent paper by Ferguson and Toktay (2006) considers the competition in the remanufactured product market, and the authors develop the conditions under which OEM takes remanufacturing or collection as an entry deterrent strategy.

Aside from developing models and methods, and evaluating optimal channel choices within remanufacturing, several papers recently pointed remanufacturing as a source of competitive strategy (Dowlatshahi 2000, Ferguson and Toktay 2006, Giuntini and Gaudette 2003, Robotis *et al.*, 2005, Klausner and Hendrickson, 2000, Stock, Speh, and Shear 2002) that can be used to deter entry, maintain brand loyalty, defend sales from lower price entrants and recover more value from end-of-life products in a demand driven product recovery market. In spite of these researches, why firms pursue different means for organizing product recovery operations remained uncertain. Thus, this study is relevant to a number of streams in the literature reviewed above. First, it relates to channel selection literature as it investigates how OEM's decide to develop remanufacturing competences internally, outsource or take collaborative actions by developing optimal incentive contracts. The contribution to this stream will be a thorough elaboration of drivers of remanufacturing decisions in the industry's inherent volatile setting (i.e. multiple sources of uncertainty such as technological and condition uncertainty), instead of settings of game theoretic models with rigid assumptions such as information symmetry, exogenous cost structures, and implicit returned product allocations. Although all operations research models provide useful insights about the ideal conditions and assumptions that are required to derive meaningful results, there is no strategic evaluation of the factors, except for cost, price and return rate that lead to OEM's decision to integrate remanufacturing internally, or contracting it to 3PL. These studies are concerned about optimizing a specific set of variables instead of exploring the relevant variables in the context of environmental and managerial factors.

Second, the study complements the research on operational aspects of reverse supply chain and progresses further as it develops an analytical framework of how to manage reverse supply chains strategically. The need for research on organizational and strategic management is pointed out in the literature (Flapper, Van Nunen, and Van Wassenhove 2005, Guide, Muyldermans, and Van Wassenhove 2005), some authors investigated the diverse aspects of reverse supply chains that affect strategy making process (Flapper 2003) and some authors developed theoretical models to in order to understand how different organizational forms should be selected (Toffel 2004). Guide and Van Wassenhove (2006) also draw attention to the need for developing integrated business models to reap the most from return streams and to encourage the development of closed loop supply chain competences among firms. However, the empirical testing of the hypotheses and research questions developed so far lagged behind the growth of the field. Moreover, important variables such as human assets and technological uncertainties in remanufacturing are ignored and a framework for strategic management of product recovery activities has not been proposed.

In addition to its testable model development to address above issues, this thesis adopts survey and case based data collection and empirical testing approach. The research on reverse supply chains concentrated in normative, theoretical and case study approaches. However, several authors iterated the need for empirical research in operations management field and the need for combining theory with empirics within the operations management field (Fisher 2007, Voss 2002, Meredith 1998). Roth (2007) proposes empiricism in operations management to augment traditional normative and analytic approaches. As Roth (2007) notes, '...manufacturing strategy is largely unstructured, complex, multi dimensional and less conducive to normative, analytic modeling.' Roth (2007) also emphasizes the importance of an empiricist perspective in revealing the emerging operations management practices within industry.

Additionally, Prahinski and Kocabasoglu (2006) addressed the need for empirical research in reverse supply chains and emphasized that empirical research can facilitate the understanding of reverse supply chain issues and help improve managerial aspects of reverse supply chains. We use an empirical approach, first a survey and follow-up case studies, to validate the conceptual relations proposed between organizational pattern and its drivers. To fill theory building and empirical testing gap in strategic management of product recovery activities, this study proposes a framework to reveal the important variables in strategic management of reverse supply chains and to provide a roadmap on how to utilize these variables to increase performance of reverse supply chains.

## 2.2 Transaction Cost Economics

Essentially, transaction cost economics theory (TCE) argues that certain exchange characteristics increase transaction costs and these problems can be remedied by different governance mechanisms that have different cost minimizing features (Williamson 1985). Foss (2003) argued that transaction cost approach has power to understand both the organizational structure as discussed in Williamson (1996) and strategizing. Its exploratory power arising from these aspects pointed out in Foss (2003) make transaction cost approach a viable and helpful theoretical approach for studying the organizational choices for remanufacturing operations.

Transaction costs may occur ex ante; as costs of drafting and negotiating contracts or ex post; such as costs of monitoring and enforcing agreements. Basic premise of TCE states that if costs of adaptation, coordination, performance evaluation and safeguarding assets are high to exceed the production cost advantages of market, firms will organize hierarchically (Rindfleisch and Heide 1997). TCE posits that such hierarchies offer greater protection for specific assets and provide relatively efficient mechanisms for responding to change when coordinated adaptation is necessary.

Transaction cost approach assumes bounded rationality and opportunism as a basis for the proposed relationships. Bounded rationality refers to limited cognitive ability of actors. Actors intend to behave rationally, however because of their limited ability to recognize all the ex-ante and ex-post consequences of contracts, all complex contracts become incomplete contracts. Second underlying assumption is opportunism, which Williamson (1985) defines as “self-interest seeking with guile.” Opportunism poses problems for relationships that have an asset valuable also outside the relationship. Aside from behavioral assumptions, TCE proposes the degree of relationship-specific assets involved, the frequency, the uncertainty about future and trading partners, and the complexity as transactional dimensions. The probability of observing a particular organizational form is a function of certain properties of underlying transactions; asset specificity, uncertainty, complexity and frequency (Table 2.1). The organizational forms range from pure market transactions to totally integrated firm structure. The properties of transactions in detail are discussed in the following sections.

Table 2.1 Governance Decisions in Transaction Cost Economics

<table>
<tr><td colspan="2" rowspan="2"></td><th colspan="3">Investment Characteristics (Asset Specificity)</th></tr>
<tr><td>Nonspecific</td><td>Mixed</td><td>Idiosyncratic</td></tr>
<tr><th rowspan="2">Frequency</th><td>Occasional</td><td rowspan="2">Market Governance</td><td>Trilateral Governance</td><td rowspan="2">Unified Governance</td></tr>
<tr><td>Recurrent</td><td>Bilateral Governance</td></tr>
</table>

*Efficient Governance*

## 2.2.1 Asset Specificity

Williamson (1985) refers to the asset specificity as the transferability of the assets that support a given transaction. Asset specificity is the most significant variable of interest in TCE studies. Williamson (1991) classifies asset specificity further into six categories: site specificity, physical asset specificity, human asset specificity, brand name capital, dedicated assets, and temporal specificity. First, site specificity is triggered by the need for minimizing transportation and inventory costs for highly immobile assets. Second, physical asset specificity refers to relationship specific equipments and machinery. And the third, human asset specificity refers to the transaction-specific knowledge or human capital achieved through specialized training or learning-by-doing (Shelanski and Klein 1995). When any kind of relationship specific assets are at stake, TCE proposes vertical integration since it provides more protection for the asset, and coordination if need be.

## 2.2.2 Uncertainty

Uncertainty is the second most important dimension of TCE. It is further classified into environmental and behavioral uncertainty, all of which have different consequences. Environmental uncertainty refers to “unanticipated changes in circumstances surrounding an exchange” (Noordewier, John, and Nevin 1990). Environmental uncertainty comprises of both technological and volume uncertainty. Demand, supply or volume uncertainty refers to inability to predict market requirements regarding a product (Walker and Weber 1984). Technological uncertainty can be observed from the frequency of changes in product specification and the probability of technological improvements. Finally, behavioral uncertainty arises from the difficulties associated with monitoring the contractual performance of exchange partners (Williamson, 1985). However, TCE proposes that uncertainty is a moderator between degree of hierarchical governance and asset specificity. In the lack of relationship specific assets, TCE does not predict that uncertainty leads to vertical integration.

## 2.2.3 Frequency

Frequency refers to the transaction repetitiveness. Frequency construct becomes more important in the case of scale economics. If transactions are occurring occasionally, transactions could be relatively inexpensive. However, if there are recurring transactions the parties should adopt procedures, and lower the cost of the transaction by negotiations.

TCE predicts that if the frequency of transactions is high, firms would tend to try to reduce their overall costs of going to the market repeatedly by vertically integrating (Williamson, 1985).

### 2.2.4 Product Complexity

Product complexity is defined across three dimensions: number of components, component interactions and product novelty (Novak and Eppinger, 2001). Product complexity can be measured in the component or product level. It is often argued that product complexity is a complement to vertical integration as it increases the coordination costs (Masten, Meehan, and Snyder 1989, Walker and Weber 1987).

## 2.3 Remanufacturing and Transaction Cost Economics Theory

The firms that successfully manage to create remanufacturing competence could be able to increase profits and better compete (Oster 2006, Brat 2006). The potential increases in profitability, sales, and brand name capital present an attractive rationale for OEMs to consider their remanufacturing options. Nevertheless, how, and in what situations, these competences can be developed remains a vague concept. The inherent complexity in remanufacturing operations as a result of uncertainty in product acquisition, remanufacturing lead times, and market segmentation makes it difficult to identify the driving forces and circumstances to develop competences.

TCE argues that certain exchange characteristics increase transaction costs, and these problems can be remedied by different governance mechanisms with different cost minimizing features (Williamson 1985). This exploratory power makes the TCE approach a viable and helpful theoretical approach to study the still unexplored domain of organizational choices for remanufacturing operations.

Moreover, TCE has been used to explore a number of supply chain management issues. Monteverde and Teece (1982) is the earliest systematic work that uses TCE to explain make-or-buy decision in automotive industry context. Walker and Weber (1984, 1987) explored the vertical integration decisions in auto industry context and provided empirical support for the uncertainty as a determinant for vertical integration. While there is mixed evidence on transactional variables' predictive ability in supply chain (e.g. McNally and Griffin 2004), TCE has proved to be an effective analytical framework to investigate both strategic, economic, and organizational questions about a firm's make-or-buy and vertical integration decisions.

TCE theory has also been used in environmental and closed-loop supply chain contexts. Rosen et al. (2001) tested the predictability of the transactional variables in computer industry supply chain. They found out that TCE hypotheses hold for inter-firm environmental management activities, and their results show that relational contracts with suppliers are more effective in managing closed loop supply chains. Rosen et al. (2001) also suggest TCE is a valuable lens for investigating reverse supply chain activities, and urge for broader empirical studies in environmental supply chains. In Toffel (2004), the remanufacturers' strategic choices are explored from a dynamic capabilities view, in addition to TCE and resource-based views. As opposed to previous studies using TCE from an environmental perspective, we adopt a business economics perspective to investigate the organizational problems in strategic management of remanufacturing activities.

## 2.4 Research Propositions

Several researchers have suggested that remanufacturing may serve as a competitive strategy to deter entry, maintain brand loyalty, defend sales from lower price entrants, and increase market share for OEMs that offer remanufactured version of their products (Ferguson and Toktay 2006, Klausner and Hendrickson 2000, Rogers and Tibben-Lembke 1999). However, why firms pursue different organizational structures for product recovery operations remains uncertain. Our research relates to strategic competition literature as it investigates how OEM's decide to develop remanufacturing competences internally, outsource, or take collaborative agreements with hybrid forms of governance. Our contribution is by the identification of drivers of remanufacturing decisions in the industry's inherent volatile setting (i.e. multiple sources of uncertainty such as technological). This study complements the research on the operational aspects of reverse supply chain and takes it one step further via the formulation of a theoretical framework on how to manage closed loop supply chains strategically.

The need for research on the organizational and strategic management of remanufacturing is identified in the literature (Flapper et al. 2005, Guide et al. 2005, Thierry et al. 1995). Other research develops theoretical models to understand how different organizational forms could be selected (Toffel 2004). Guide and Van Wassenhove (2006) also draw attention to the need for developing integrated business models to exploit the full potential from return streams and to encourage the development of closed-loop supply chain competences within firms. Important variables, such as human skills and technological uncertainties in remanufacturing are ignored and a framework for strategic management of product recovery activities has not been proposed. To address these issues, we provide insights on the following research questions:

1. What are the prevalent organizational patterns in governance of remanufacturing operations?

2. How and why do these patterns emerge?

3. What drivers help explain emergence of these organizational patterns?

We use an empirical approach, case studies, to validate the conceptual relations proposed between organizational pattern and its drivers. Several authors iterated the need for empirical research in operations management field and the need for combining theory with empirics within the operations management field (Fisher 2007, Voss 2002, Meredith 1998).

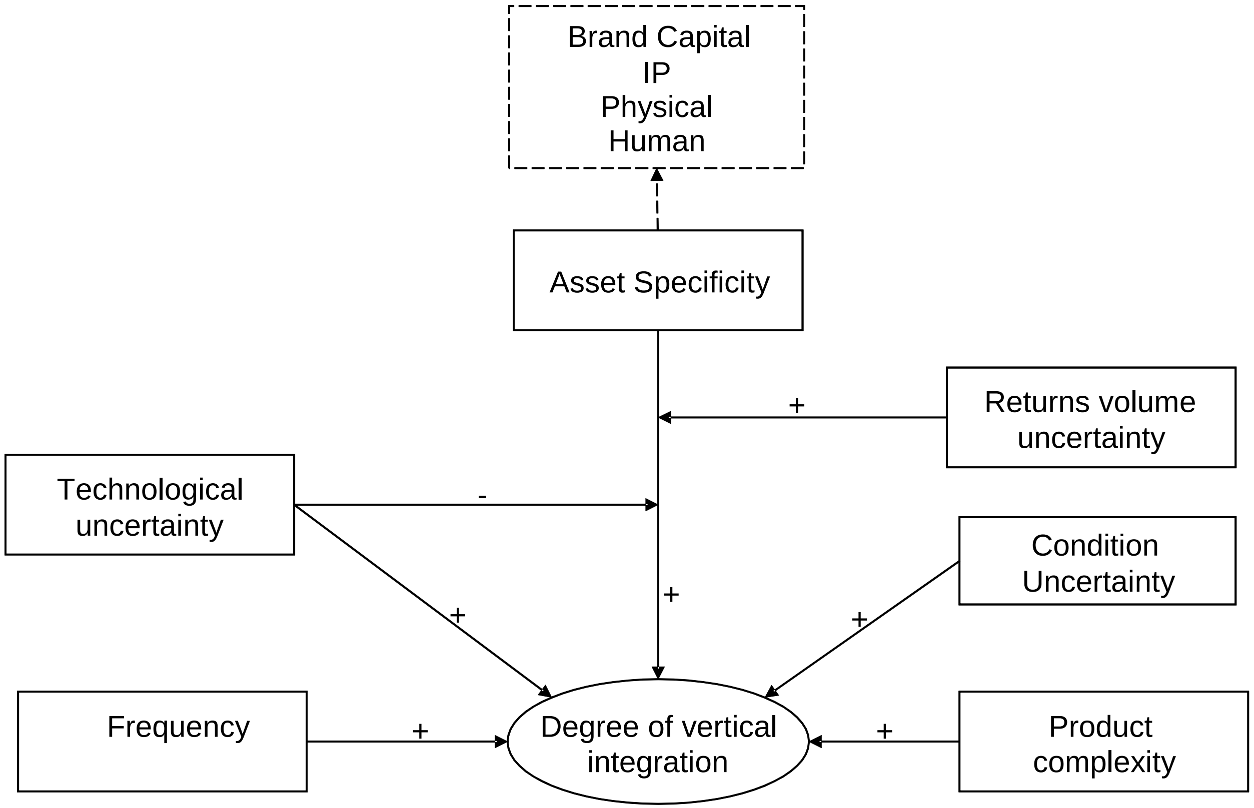
# Chapter 3

# Conceptual Framework and Research Hypotheses

## 3.1 Conceptual Framework of Vertical Integration in Remanufacturing

We propose a model (Figure 3.1) of vertical integration decisions in remanufacturing based on transaction cost economics theory, previous literature and interviews with managers.

Figure 3.1 The conceptual model



## 3.2. Preliminary Study

Before starting to sketch the model, unstructured interviews are conducted with 4 industry executives. These interviews are conducted to ensure that industrial reality is captured in the research question and reflected in the conceptual model. In these one- to two-hour interviews, managers from companies and trade and research organizations were asked questions on current organization of the remanufacturing operations and why they were organized in this particular form. These interviews also revealed organizational bottlenecks and the potential competitive benefits of remanufacturing. They were also asked to elaborate on the current state of the remanufacturing industry in general, the significant drivers for diverse organizational arrangements based on our preliminary model, and potential challenges. We discussed the industry-based differences in remanufacturing operations in consumer and capital goods companies, as proposed in previous literature (Guide and Van Wassenhove 2001).

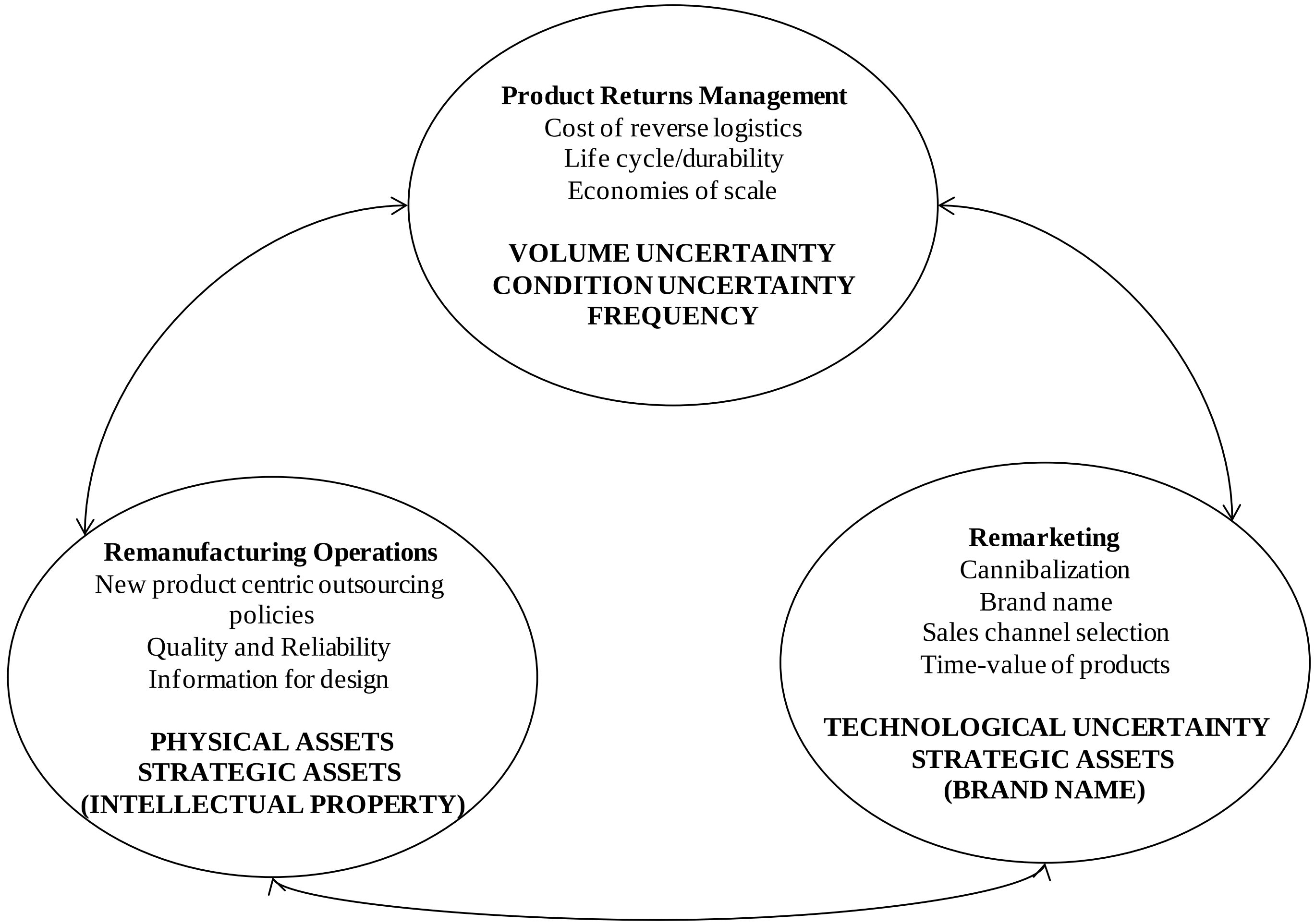
All the interviewees agreed the main drivers for OEMs engaging in remanufacturing activities are the potential for profits, and the market demand for remanufactured products. They also uniformly agreed that volume and condition certainty are two complicating variables at product acquisition stage. Volume and condition uncertainties affect economies of scale, especially when combined with durability issues. It became clear that product acquisition management efforts have a significant impact on the organizational design of remanufacturing.

The executives from Bosch Tools and Cisco Systems both expressed their concern for organizational decisions as the quality and reliability of remanufactured products. The utilization of dedicated remanufacturing lines represents a challenge for these companies since returns, and, in particular their condition uncertainty, presents a challenge for accurate planning of materials and labor, as reported in Guide (2000). Additionally, the use of disassembly knowledge to determine the causes for premature part failure data embodies another opportunity from product returns (Klausner and Hendrickson 2000). By having remanufacturing operations in-house Bosch also obtains critical warranty data and uses this data in improving current design of the product.

The executives from industry organizations (National Center for Remanufacturing and Resource Recovery and The Remanufacturing Institute) confirmed that there were differences in the objectives and motivation of remanufacturing operations between capital goods and consumer goods companies. Their experiences suggest that consumer goods companies perceive product returns as a cost center, and take actions to minimize their loss. At the other extreme, remanufacturing is cited as a major source of revenue by managers from capital goods companies. From a remarketing perspective, consumer goods companies fear that market cannibalization could be an issue and act cautiously in their secondary selling channels. Capital goods companies emphasize the functionality in the products and use remanufacturing also as a service competence (Guide and Van Wassenhove 2003). Brand name deterioration concerns and increasing time-value of products are other two variables that emerged from a remarketing perspective.

Figure 3.2 summarizes the salient drivers of different organizational forms revealed from our preliminary study and their fit with the previous literature and transaction cost theory variables. In the next section, we discuss how this fit emerges between preliminary data, the previous literature and transaction cost variables, and develop the conceptual model based on Figure 3.2.

Figure 3.2 Drivers of organizational decisions based on TCE, literature and preliminary interviews



## 3.3 Research Hypotheses

Research hypotheses are developed in the light of previous remanufacturing literature and findings of the preliminary study. After, these inputs are merged; the hypotheses are formulated based on TCE tenets.

### 3.3.1 Asset Specificity

Williamson (1985) defines asset specificity as the transferability of the assets that support a given transaction. Asset specificity can be observed in a firm's physical investments, skill and knowledge intensive operations, location choices and brand names (Williamson 1998). Product recovery requires investments to capitalize on these assets (e.g. transportation networks, test-sort-disassembly equipment, training programs, specialized facilities and learning curve effects). Assets involved in remanufacturing operations should be safeguarded to prevent relationship hazards. TCE posits that there exists an organizational arrangement that minimizes overall costs of governing these assets. In this thesis, each type of asset, that can expose firms to relationship hazards, is discussed exclusively in the context of product recovery operations.

#### 3.3.1.1 Physical Asset Specificity

Physical asset specificity refers to relationship specific equipments and machinery, or complex computer systems that are designed for a single purpose and have low value outside of the transaction relationship (Joskow 1988). Remanufacturing operations often require specialized physical assets, such as equipment, machinery or facilities for testing, sorting and processing product returns (Fleischmann et al. 2001). The assets required for remanufacturing that cannot be used for any other purpose outside processing a specific type, or brand, of product return are considered specific investments. These assets, unless kept internal, expose the firm to hold-up risks with contractors or partners. One of the most specific assets for remanufacturing operations can be observed in capital goods remanufacturing (Guide and Van Wassenhove 2003). The equipment and facilities where large scale capital goods (e.g., airframes, diesel locomotive engines, jet turbine engines) are remanufactured are specific to the product type and manufacturer. At the other extreme, for products that can be remanufactured with minimal investment by third parties and are readily accessible from the market (such as toner cartridge refilling), the relationship hazards are rather low since OEM has the option to switch partners, or bring the activity back into the firm with minimal investment. TCE proposes that hierarchical governance offers greater protection when coordination is essential regarding specific assets (Shelanski and Klein 1995). TCE predicts that in the cases where processing returned products requires specific physical investments, vertical integration will be favored instead of market transactions.

#### 3.3.1.2 Human Asset Specificity

Human asset specificity refers to the transaction-specific knowledge or human capital achieved through specialized training or learning-by-doing (Shelanski and Klein 1995). Remanufacturing operations are labor intensive and critically dependent on a supply of skilled labor (Hauser and Lund 2003). Further, they lack standardized work and material content since returned products varies in condition and are less amenable to automation (Ayres et al. 1997). Specialized training required for operators to disassemble and re-assemble recovered products, diagnostic skills to identify failed parts, and the effects of learning-by-doing constitute transaction-specific investments in remanufacturing. As the level of skill specialization, and learning by-doing effect increases, the cost of market mechanism in supplying the labor increases. Therefore, TCE favors increasing hierarchical governance.

### 3.3.1.3 Strategic Assets

Remanufacturing firms can be exposed to relationship hazards from two types of strategic assets. Brand-name capital specificity refers to investments in brand reputation. Brand name capital increases the probability of vertical integration as firms must maintain the reputation of a shared brand.  The OEM must control the quality and the reliability of remanufactured product to protect brand name capital. In addition, the need for coordination and monitoring is high (Klein 1980). During preliminary interviews, an executive expressed concern about the quality and reliability of third-party remanufactured products, and cited potential brand damage as a reason to vertically integrate into remanufacturing. Additionally, many firms manage product return initiatives in-house, or impose selling restrictions to re-sellers in order to prevent gray market sale of their products and the resulting (possible) damage to their brand name (Tibben-Lembke and Rogers 2003).

The second important strategic asset is proprietary technology embedded in OEM products and processes (Gatignon and Anderson 1986). Intellectual property (IP) is an asset that is hard to transmit across organizational boundaries, and when transmitted it is subject to hazards of sharing and valuation (Calvet 1981). In remanufacturing, products containing high levels of proprietary technology are subject to hazards of exposure during disassembly. Firms that use IP through patents to earn royalties are especially at risk. Ayres et al. (1997) points out the need for IP protection as one of the factors leading to vertical integration at Rank-Xerox. The knowledge pertaining to brand-specific production processes required for disassembly and remanufacturing, must be accounted for when designing the organizational arrangements. Therefore, we hypothesize that high intensity of IP in the products, and/or processes, leads to hierarchical organization of product recovery activities.

We propose the following hypotheses based on our discussion of asset specificity construct:

*Hypothesis 1a: The higher the specificity in machinery, equipment and facilities used in product recovery, the higher the degree of vertical integration.*

*Hypothesis 1b: The higher the need for skilled labor and know-how in disassembly, test and remanufacturing, the higher the degree of vertical integration.*

*Hypothesis 1c: The higher the brand reputation of the OEM, the higher the degree of vertical integration.*

*Hypothesis 1d: The higher the intensity of proprietary part/process technology used in core the higher the degree of vertical integration.*

## 3.3.2 Uncertainty

Uncertainty in the environment is the second important dimension of TCE and a significant variable in remanufacturing operations (Guide 2000, Fleischmann et al. 2001). Environmental uncertainty refers to "unanticipated changes in circumstances surrounding an exchange" (Noordewier et al. 1990). Environmental uncertainty creates adaptation problems, as agreements must be modified as the circumstances surrounding the exchange changes (Rindfleisch and Heide 1997). In this study, we consider environmental uncertainty in remanufacturing as a multidimensional construct that is composed of volume, and technological uncertainty based on Walker and Weber (1984) and condition uncertainty based on previous remanufacturing literature (Guide 2000, Guide and Van Wassenhove 2001, Galbreth 2006). Environmental uncertainty has been investigated as an interaction variable by Prahinski and Kocabasoglu (2006), but the direct effects of uncertainty on building product recovery strategies is not clear. The following section explores the role of volume, technological and condition uncertainty on firm's organizational choices in remanufacturing operations.

### 3.3.2.1 Volume Uncertainty

Volume uncertainty in remanufacturing is the inherent difficulty in predicting the number of cores returned. The availability of returned products can result in a high amount of variance, depending on the type of product recovery practiced (Thierry et al. 1995). Product returns in a waste-stream recovery system are highly uncertain with respect to the timing (frequency), quantity and quality of the product returns (Guide and Van Wassenhove 2001). However, if product returns are market-driven (the most common situation for remanufacturing in the US), the company can control the return stream with product acquisition management (Guide and Van Wassenhove 2001, Guide et al. 2003). These activities act to reduce the uncertainties with respect to volume, quality and timing for remanufacturing firms.

From a TCE perspective, uncertainty causes the company to continually update contracts and causes high coordination and renegotiation costs (Poppo and Zenger 1998). This uncertainty may cause suppliers to experience high production costs and excess capacity and OEMs can experience stock-outs, or excess inventory (Walker and Weber 1984). As the uncertainty increases, the frequency of updating and renegotiating increases and the firm seeks other means for coordinating these activities in order to minimizing the associated costs.

However, the role of volume uncertainty as a predictor of vertical integration remains insignificant until specific assets come into play (Williamson 1985, Walker and Weber 1984). In other words, if product returns are highly variable, but overhead costs do not increase transaction costs, the firm may choose not to vertically integrate and outsource remanufacturing. Therefore, increased transaction costs may motivate a firm to internalize remanufacturing operations so as to coordinate product returns more effectively, and decrease the safeguarding costs. We hypothesize an interaction effect between uncertainty and asset specificity as an antecedent to vertical integration.

*Hypothesis 2a: Volume uncertainty in returns and processing increases the degree of vertical integration in the presence of asset specificity.*

## 3.3.2.2 Technological Uncertainty

Technological uncertainty is the frequency of changes in product specification and the probability of technological improvements. When product specifications change frequently, or there are short product life cycles, technological uncertainty may pose a problem for remanufacturing, especially in the form of time-value lost during remanufacturing operations (Guide et al. 2003, Guide et al. 2006). To avoid high levels of returned product obsolescence firms must have agile remanufacturing operations and responsive disposition policies (Guide et al. 2003). From a TCE perspective, the difficulty in accurately forecasting new technical or design requirements for disassembly creates adaptation problems and incurs high renegotiation and coordination costs (Walker and Weber 1984). We hypothesize that increasing uncertainty in processing cores will motivate the firm to internalize remanufacturing to avoid repeated coordination costs required for sequential decision-making and to increase the agility of operations to prevent lost time-value.

*Hypothesis 2b: The higher the level of technological uncertainty the higher the degree of vertical integration.*

Moreover, rapid technological change increases the probability of obsolescence in investments on knowledge and routines (Balakrishnan and Wernerfelt 1986). A high risk of technological obsolescence may discourage a company from investing in specific assets (Heide and John 1990). Further, the firm may prefer to outsource product recovery activities to suppliers that already have the technology, or the scale to adopt new technological assets. Therefore, we hypothesize that technological uncertainty in the presence of highly specific assets decreases the probability of vertical integration, and favors market transactions.

*Hypothesis 2c: Remanufacturer firms prefer market transactions in order to avoid technological obsolescence when highly specific assets are required.*

## 3.3.2.3 Condition Uncertainty

Condition uncertainty is defined as the variability in the quality of returned products. Condition uncertainty impacts the planning of materials and labor and the resulting capacity management problems in remanufacturing facilities. Variability in the condition (quality) of products increases the variance of the expected processing times (Guide 2000) and the condition of the returned product is a leading variable in deciding for optimal recovery action (Bloemhof-Ruwaard et al. 1996). Moreover, when supplier relationships are used, determining the price becomes a problem since the product's condition is not visible to the OEM a priori. A low visibility of the condition, or quality, of product returns increases the risk of delays from suppliers, and also increases the costs of drafting the contract. Thus, condition uncertainty may pose problems when remanufacturing operations are in-house, or when outsourced. Based on the uncertainty construct in TCE, we hypothesize that condition uncertainty leads to vertical integration since the lack of information on the condition of the returned product makes drafting contracts costly and monitoring more difficult.

*Hypothesis 2d: The higher the uncertainty in quality (condition) of returns, the higher the degree of vertical integration.*

### 3.3.3 Frequency

In the TCE literature, frequency is referred to as the recurrence of transactions (Williamson 1985). In a remanufacturing context, frequency of remanufacturing as a combination of (1) the number of times a core can be remanufactured, and (2) the timing of returns. In other words, the potential frequency of transactions between the OEM and its supplier, the utilization of remanufacturing machinery, equipment and labor essentially depend on the timing of returns and number of times a product can be remanufactured. When remanufacturing transactions are not frequent enough, firms may prefer to outsource rather than investing in all the fixed assets and incurring operational costs of a rare occurring transaction. The frequency of product recovery activities may increase the probability of vertical integration since in-house remanufacturing may lead to lower production coordination costs compared to market coordination costs for outsourcing. TCE predicts that if the frequency of transactions is high, firms would tend to try to reduce their overall costs of going to the market repeatedly by vertically integrating (Williamson 1985).

*Hypothesis 3: The higher the remanufacturability and the more frequent return of the core stream, the higher the probability for vertical integration.*

### 3.3.4 Product Complexity

Product complexity is defined across three dimensions, the number of components, component interactions and product novelty (Novak and Eppinger 2001). Product complexity may have a twofold effect on vertical integration decisions. First, an increasing complexity of products requires more skilled labor and know-how to test, and increases the effects of learning-by-doing required to disassemble and remanufacture. Therefore, increasing product complexity leads to higher human asset-specificity for remanufacturing.

Second, product complexity creates a variety of internal transaction costs, such as the coordination costs between design and disassembly, and testing and remanufacturing. Lowering product complexity can aid to reduce test and manufacturing complexity and decrease coordination costs (Guide and Van Wassenhove 2003). When a large volume of cores are available for remanufacturing, there also exists the scale for altering the design for manufacture and assembly, and remanufacture. In the TCE literature, it is often argued that product complexity is a complement to vertical integration as it increases the coordination costs (Masten *et al.* 1989, Walker and Weber 1987). We believe that product complexity increases the probability of vertical integration as firms seek to capture the benefits of their investment in the skills needed to coordinate development and production of complex designs (Novak and Eppinger 2001).

*Hypothesis 4: The higher the complexity of the core, the higher the degree of vertical integration.*

# Chapter 4

# Research Methodology and Protocol Development

## 4.1 Methodology

This dissertation will concentrate on (1) establishing the relationships between the transactional attributes of product recovery operations and its competitive implications to determine an efficient form of organization for their operations through a survey study; and (2) revealing the causal relationships between the organizational arrangements through a series of theoretically sampled case studies. In the first phase of the study, transaction cost economics variables are operationalized in the remanufacturing industry context; a questionnaire is designed and administered among managers from remanufacturing industry. Data will be analyzed using partial least squares regression.

Survey study findings will then be used as an input to developing an interview protocol for case-studies. Results of survey-based empirical studies are easy to interpret and insightful for understanding one-way relationships. However, they cannot provide the researchers with insights on casual relationships, namely why and how aspects of the problem. Therefore the survey study will be complemented with case studies from companies.

## 4.2 Phase 1: Survey Study and Partial Least Squares Methodology

This part of the research aims to contribute to remanufacturing literature by developing a descriptive model of drivers of vertical integration decisions. Particularly, the study concentrates on identifying the antecedents of vertical integration decisions in remanufacturing by adopting an inductive approach. The main objective in this phase is determining the important drivers of in-sourcing and outsourcing decisions using transaction cost economics theory.

The data for testing the proposed model will be collected through a survey study among capital goods manufacturers. Capital goods remanufacturing not only includes life extension programs on locomotives, engines, mining and naval equipment, but also includes drive train remanufacturing, auto parts and office equipment such as copiers. Capital goods remanufacturing constitutes the biggest part of all remanufacturing activities in US (Giuntini *et al.* 2003) and unlike the recent awakening of interest in consumer goods remanufacturing, remanufacturing in this industry is more established. Table 4.1 presents a comparison of capital goods and consumer goods remanufacturing with respect to transactional characteristics.

Table 4.1 The Differences in Remanufacturing Operations between Capital Goods and Consumer Goods Industries.

| | **Capital Goods** | **Consumer goods** |
|---|---|---|
| Physical Asset | Highly specific machinery and equipment. | Low-to-moderate specific machinery and equipment. |
| Specificity | On-site manufacturing or very specific transportation network. | Generic transportation network. |
| Site Specificity | Specific site requirements | Depends on product-market characteristics |
| Human Asset Specificity | High specificity | Low-to-moderate specificity |
| Volume Uncertainty | Low-to-moderate (end-of-lease returns or scheduled life extension) | High (controllable by economic tools) |
| Product Value | High | Low-to-moderate |
| Product Complexity | High | Low-to-moderate |
| Frequency | High (reconditioning more than once) | Low (mostly remanufactured only once) |

The analysis of data and testing of the research hypothesis will be performed by applying partial least squares regression methodology. Partial least squares (PLS) approach is used to account for the effects of measurement error. In this approach, the predictor and dependent variables are viewed as latent constructs that cannot be observed directly. PLS is gaining active interest and used by virtue of it being able to model latent constructs under conditions of non-normality and small to medium sample sizes. Because it makes no distribution assumptions, it is robust to violations of multivariate normality. PLS is also preferable to other techniques, such as regression, that assume error free measurement.

Tests of significance were analyzed using a Bootstrap resampling procedure in SmartPLS software and 500 resamples were used. The software used for the analysis was SmartPLS version 2.0.

## 4.3 Phase 2: Case Study Methodology

The methodological approach is motivated by the potential of empirical research to develop new, managerially-relevant, theory (Voss *et al.* 2002). Additionally, this research is focused on revealing how and why elements of organizational patterns exist in remanufacturing operations. There are a number of capabilities that the selected research methodology should have. The first is to investigate the organizational decisions of companies in their own context, and to avoid rigid assumptions. Second capability is to be able to account for different sources of disturbances from external and internal environment and reach as close as possible to real-life circumstances. Third, this study follows a multivariate approach to analyzing the variables and their complex interactions. Case methodology is generally recognized as the most appropriate tool in this situation (Yin 1994, Meredith 1998).

Yin (1984) defines case study methodology as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used.” He suggests that case study methodology is appropriate for broader scope studies to cover multivariate complex conditions instead of isolated variables, and where there is need to use multiple sources of information (Yin 2002). Case studies are intended to take the audience of the research into the world of the subjects; therefore, they can provide a much richer and more vivid picture of the phenomena under study than other, more analytical methods (Marshall and Rossman 1999).

*A priori* specification of the conceptual framework and constructs is used to provide more accurate and precise measurement (Eisenhardt 1989). The multiple-case studies design allows the researcher to explore the phenomena under study through the use of a replication strategy and most likely to outperform single-case studies (Yin 2002). If all or most of the cases provide similar results, there can be substantial support for the development of a preliminary theory that describes the phenomena (Eisenhardt 1989). In this study, cases from multiple settings are used to increase the generalizability of the findings (Eisenhardt 1989, Meredith 1998). Major drawback related to using multiple cases is that it requires more resources to collect and analyze data. However, using multiple settings increase the external validity, and lower observer bias (Voss 2002). The case population is comprised of

OEMs that offer remanufactured versions of their products. Only OEMs in the United States is selected for case research, since the presence of environmental regulations that require product recovery (e.g., the WEEE in the EU) would introduce an additional level of complexity. The companies include three OEMs primarily in consumer goods and three capital goods OEMs to study the impact of different industries on vertical integration decisions. The objective is to detect the differences between, and the sensitivity of the results through this theoretical sample for the respective industries[1].

[1] The preliminary interviews with industry executives confirmed that consumer goods manufacturers and capital goods manufacturers view remanufacturing very differently.

# Chapter 5

# Survey Study: Measures, Administration and Results

## 5.1 Measure Development

Data for testing the proposed conceptual model will be collected through an industry survey among OEMs in the capital goods industry. Unfortunately, the transactional characteristics cannot be measured directly but must be inferred using other proxies (Spiller 1985). The measurement model developed based on the previous literature and measures are adapted to remanufacturing context (Table 5.1). However, some brand-new measures are developed since some other measures are not suitable for adapting to remanufacturing literature or they are not readily available in forward supply chain literature, too.

Asset-specificity construct’s measures are developed with respect to the source of the specificity. Two-item scale for physical asset specificity is adopted from Stump and Heide (1996). For human asset specificity construct two items are adopted from Lohtia et al. (1994) and one new item is developed to measure the extent employees develop remanufacturing-related skills specific to firm. Brand name capital can be indirectly measured using a proxy (Minkler and Park 1994, Gatignon and Anderson 1988) or directly using accounting methods. Since acquiring data on book value and marketing value of the brands is hard due to confidentiality concerns, this study uses proxy measures for brand name capital. First item is derived from Gatignon and Anderson’s (1988) advertising intensity measure and respondents are asked to rate advertising intensity. Similarly second item intended to measure the overall attitude towards brand name within the company. To measure the proprietary content of remanufactured product, item is adopted from Anderson and Gatignon (1986).

Technological and volume uncertainty are the environmental characteristics that affect the choice of organizational arrangement. Volume uncertainty is measured using two items; first one targeting the unpredictability of the returning cores based on Chen and Paulraj (2004), and second one measuring the changeability (Walker and Weber 1984). Technological uncertainty measures are adopted from Chen and Paulraj (2004). Condition uncertainty is defined as the variability in the quality of returned products. Condition uncertainty impacts the planning of materials and labor and the resulting capacity management problems in remanufacturing facilities. Thus, respondents are asked the ability to estimate material, labor and overall costs of remanufacturing a certain core. Product complexity measure is adopted from widely recognized study of Anderson (1985). Complexity refers to the degree of technical and engineering content, and sophistication and uniqueness in the remanufactured products. Additionally, to capture the product architecture and component level complexity two items are adopted from Hobday's (1998) study on development of complex products. Operationalization of the frequency construct is significantly different from the operationalization in forward supply chain literature. Therefore, this study proposes three new measures for measuring the frequency in remanufacturing context. The number of times a product can be remanufactured is captured with a dichotomous variable. Second measure aims to determine the timing of returned cores in order to assess the effect of product line utilization and third item measures the extent of economies of scale in processing returned cores.

Based on transaction cost economics theory, degree of vertical integration is used as a measure for inter-firm coordination. In line with previous literature, which employs continuous operationalization for vertical integration (Balakrishnan and Wernerfelt 1986, Masten et al. 1989), degree of vertical integration is measured as the percentage of integration, 0% indicating total outsourcing and 100% indicating complete vertical integration. On the other hand, respondents are also asked to choose their organization's structural arrangement from a set, which is adopted from Toffel (2002).

Table 5.1 Measures

| Asset Specificity |
| --- |
| Physical<br>• Remanufacturing of our products requires highly specialized tools and equipment.<br>• Our firm has unusual technological norms and standards, which require extensive adaptation in production systems. (Stump and Heide 1996)<br>Human<br>• In time, our employees develop test, disassembly, re-assembly related firm specific skills and knowledge.<br>• Compared to other companies, our company spends more time training our employees in how to test, disassembly and remanufacture a core. (Lohtia et al. 1994 )<br>• Training employees in the remanufacturing routines and procedures represents a large investment for our firm. (Lohtia et al. 1994 )<br>Brand Name<br>• Our company advertises remarkably to build a brand image (Gatignon and Anderson 1988)<br>• Our company values brand reputation and take actions in remanufacturing accordingly.<br>IP<br>• Our products and processes are highly proprietary (Anderson and Gatignon 1986)<br>• Disassembly of cores exposes proprietary information that can damage the firm. |
| Volume Uncertainty |
| • The volume and/or composition of supply of cores is difficult to predict. (Chen and Paulraj 2004)<br>• We expect significant fluctuations in monthly volume of returned products (Walker and Weber 1984) |
| Technological Uncertainty |
| • Our industry is characterized by rapidly changing technology.<br>• The rate of process obsolescence is high in our industry.<br>• The production technology changes frequently and sufficiently. (Chen and Paulraj 2004) |
| Condition Uncertainty |
| • How accurately can you estimate the cost of materials for remanufacturing?<br>• How predictable is the labor requirement for remanufacturing a certain core?<br>• How accurately can you estimate the overall cost of remanufacturing a certain core? |
| Product complexity |
| • Our remanufactured products are technical, have high engineering content, and change fast. (Anderson 1985)<br>• Our remanufactured products are sophisticated, customized, unique and complex (Anderson 1985)<br>• Our remanufactured products have high hierarchical systemic architectures (Hobday 1997) |

| |
|---|
| • Our remanufactured products have complex component interfaces (Hobday 1997) |
| Frequency |
| • Our products can be remanufactured more than once [c].<br>• Returned cores arrive to remanufacturing facility very frequently and in significant amounts.<br>• We have the economies of scale for processing returned cores in our premises. |
| Degree of Vertical Integration |
| • What is the percentage of the product recovery activity undertaken by your company (0% Total outsourcing of remanufacturing - 100% total integration of remanufacturing )<br>• Our company;<br>  o Outsources all activities related to product recovery.<br>  o Arranges long-term contracts to recycle, collect, test and remanufacture cores.<br>  o Engages in joint ventures with 3rd party recyclers, collectors and remanufacturers<br>  o Engages in joint ventures with competitors to undertake collection, test, and sort and remanufacture activities.<br>  o Vertically integrates into product acquisition and remanufacturing by developing necessary capabilities in-house |
| [a] All items used in the scale 7= strongly agree 4= neither agree nor disagree 1= strongly disagree unless otherwise indicated<br>[b] Item was reverse scored.<br>[c] Yes/No question |

## 5.2 Survey Administration

The survey is administered online on *www.questionpro.com* website. In the questionnaire, the items are written in the form of statements with which the respondent is to agree or disagree on a 7-point strongly agree-strongly disagree Likert scale. The target population was capital goods companies with active remanufacturing operations. Contact lists that are obtained from The Remanufacturing Institute, The Reverse Logistics Association and APRA are filtered to include only capital goods companies. An invitation letter is enclosed to e-mails and link to the survey is provided. In exchange for their cooperation respondents are offered a complimentary consulting report that benchmarks their remanufacturing performance with the average industry performance. Data is collected on-site on the www.questionpro.com website. Overall 88 respondents started the survey and 44 of them completed.

## 5.3 Data Analysis

This section provides a comprehensive discussion of the data analysis techniques utilized in the quantitative part of the study, and the results obtained. First, the data analysis technique is described. Second, the sample characteristics are reported. Third, the steps taken to establish validity and reliability of the survey instrument are explained. Fourth, the statistical analyses that are performed to test the research framework and hypotheses are discussed, and the results obtained from these tests are presented. Finally, the results are discussed and interpreted in greater detail.

## 5.4 Sample Characteristics

The sampling frame for this study consisted of capital goods companies that have remanufacturing operations. The survey is administered online and 88 companies started the questionnaire. Out of 88 companies, 44 completed the questionnaire. Of the 44 completed, 9 were incomplete and thus were dropped from subsequent analyses.

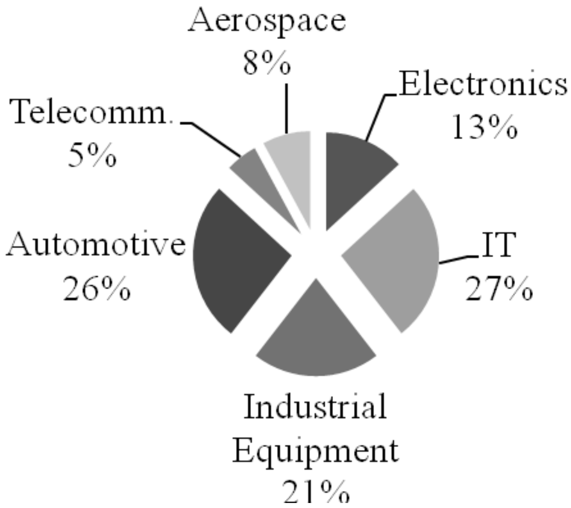
The final sample comprised of 35 companies with median sale of $300 million and mean sales of $6 billion. On average companies in the sample employ 10,583 employees and have annual sales of $6 million in remanufactured products. Table 5.2 summarizes the sample statistics. 26% of the companies come from automotive industry, followed by industrial equipment industry with 21% of all respondents (Figure 5.1).

Although the response rate is high, overall the number of data points is limited. Remanufacturing industry is dominated by predominantly small, independent, and privately owned companies and OEMs constitute a small percentage although they account for most of the market value. Unfortunately to date, there have not been many organizations that track OEM remanufacturing industry. Very little number of organizations is limited in scope, usually covering just one or two industries at a time, again restricting researchers' ability to reach to these companies and have a complete picture of OEM remanufacturing industry. These facts also constrain the ability to determine if the sample acquired in this research is representative of the OEM remanufacturing industry. A survey study conducted between 2000-2003 presents distribution of respondent companies with respect to annual sales and number of employees (Hauser and Lund 2003). In comparison with this study's descriptive statistics, the data provides an accurate representativeness of industry. Still precautions will be taken in developing conclusions from the results of model analyses and results will be used as input to the case study for additional testing.

Table 5.2 Sample Statistics

| | | |
|---|---|---|
| **Usable questionnaires**<br>**Response Rate** | 35<br>40% | |
| | **Mean** | **Median** |
| **Annual Sales** | $6 billion | $300M |
| **Annual Sales (Remanufactured Product)** | $131 million | $19.5 million |
| **Workforce** | 10,853 | 450 |

Figure 5.1 Industry Breakdown




## 5.5 Measurement Model

The adequacy of the measurement model is evaluated on the criteria of reliability, convergent validity and discriminant validity of the multi-item scales for the 10 model constructs. As part of the measurement purification process, two items were dropped from the analysis (see Table 5.3) because of not loading strongly on their constructs. As a result of exploratory factor analysis, human asset specificity and physical asset specificity loaded on one component. Therefore, two construct are combined into one construct and named operational assets for subsequent analyses. The analyses and criteria for reliability, convergent validity and discriminant validity of the scales will be further explained in the following sections.

### 5.5.1 Reliability

An important step in factor validation is to test the reliability to ensure measurement accuracy and minimize the measurement error. Factor reliability is a measure to ensure the variance captured by the factor is more than that by the error component (Hair, Anderson, Tatham and Black 1992). Several types of reliability are defined in the literature. Since most factors employed in this study were measured by multi-items, the assessment of factor reliability was based on the correlation between individual items that made up the factor, relative to the variances of the items. The minimum requirements for adequate factor reliability are that they are positive, have a sufficiently large item loading (larger than .70), and are statistically significant, with very small standard deviation (Bagozzi and Baumgartner 1994).

Consequently, Cronbach's alpha coefficients, which are calculated based on the average inter-item correlations, were used to measure internal consistency, and the guideline is that Cronbach's alpha coefficients should be greater than .70 for acceptable reliability (Bagozzi and Yi 1988).

Table 5.3 shows the final set of measures and results of the reliability analysis. The reliabilities of the individual scales are above recommended levels except for frequency, ranging from .70 to .94 for Cronbach's alpha coefficient providing evidence in favor of the reliability of the measurement model constructs. However, to obtain a more reliable set of frequency measures, one item with the lowest factor loading was excluded from this scale.

In addition, a more rigorous test of reliability, which involves assessing the amount of variance captured by a construct's measures in relation to the amount of variance due to measurement error, was also performed. In order to claim reliability, the average variance extracted (AVE) by the construct's measures should be greater than .50 (Fornell and Larcker 1981). As shown in Table 5.3, ranging from .74 to .90, all the AVE values for the constructs in the measurement model provide additional evidence for reliability. Since frequency scale shows an adequate level of AVE, it will be used in further analyses. In summary, all of the constructs demonstrate acceptable levels of reliability.

Table 5.3 Measurement Model Results

| | Factor Loadings | |
|---|---|---|
| **Operational Assets** | **Cronbach's α: 0.81** | **AVE: 0.83** |
| Remanufacturing of our products requires highly specialized tools and equipment. | 0.65 | |
| Our firm has unusual technological norms and standards, which require extensive adaptation in production systems. (Stump and Heide 1996) | 0.85 | |
| In time, our employees develop test, disassembly, re-assembly related firm specific skills and knowledge. | 0.73 | |
| Compared to other companies, our company spends more time training our employees in how to test, disassembly and remanufacture a core. (Lohtia et al. 1994 ) | 0.67 | |
| Training employees in the remanufacturing routines and procedures represents a large investment for our firm. (Lohtia et al. 1994 ) | 0.70 | |
| **Brand Name** | **Cronbach's α: 0.72** | **AVE: 0.78** |
| Our company advertises remarkably to build a brand image (Gatignon and Anderson 1988) | 0.88 | |
| Our company values brand reputation and take actions in remanufacturing accordingly. | 0.88 | |
| **IP** | **Cronbach's α: 0.89** | **AVE: 0.90** |
| Our products and processes are highly proprietary (Anderson and Gatignon 1986) | 0.95 | |
| Disassembly of cores exposes proprietary information that can damage the firm. | 0.95 | |
| **Volume Uncertainty** | **Cronbach's α: 0.71** | **AVE: 0.77** |
| The volume and/or composition of supply of cores is difficult to predict. (Chen and Paulraj 2004) | 0.88 | |
| We expect significant fluctuations in monthly volume of returned products (Walker and Weber 1984) | 0.88 | |
| **Technological Uncertainty**[1] | **Cronbach's α: 0.76** | **AVE: 0.81** |
| Our industry is characterized by rapidly changing technology. ***** | 0.42 | |
| The rate of process obsolescence is high in our industry. | 0.87 | |
| The production technology changes frequently and sufficiently. (Chen and Paulraj 2004) | 0.88 | |
| **Condition Uncertainty** | **Cronbach's α: 0.71** | **AVE: 0.63** |
| How accurately can you estimate the cost of materials for remanufacturing? | 0.74 | |
| How predictable is the labor requirement for remanufacturing a certain core? | 0.82 | |
| How accurately can you estimate the overall cost of remanufacturing a certain core? | 0.90 | |
| **Product complexity** | **Cronbach's α: 0.94** | **AVE: 0.76** |
| Our remanufactured products are technical, have high engineering content, and change fast. (Anderson 1985) | 0.92 | |
| Our remanufactured products are sophisticated, customized, unique and complex (Anderson 1985) | 0.85 | |
| Our remanufactured products have high hierarchical systemic architectures (Hobday 1997) | 0.91 | |
| | | |

| | | |
|---|---|---|
| Our remanufactured products have complex component interfaces (Hobday 1997) | 0.93 | |
| **Frequency** [1] | **Cronbach's α: 0.53** | **AVE: 0.68** |
| Our products can be remanufactured more than once. * | 0.58 | |
| Returned cores arrive to remanufacturing facility very frequently and in significant amounts. | 0.74 | |
| We have the economies of scale for processing returned cores in our premises. | 0.82 | |
| **Degree of Vertical Integration** | **Cronbach's α: 0.65** | **AVE: 0.74** |
| What is the percentage of the product recovery activity undertaken by your company (0% Total outsourcing of remanufacturing - 100% total integration of remanufacturing ) | 0.86 | |
| Our company; | 0.86 | |
| Outsources all activities related to product recovery. | | |
| Arranges long-term contracts to recycle, collect, test and remanufacture cores. | | |
| Engages in joint ventures with 3rd party recyclers, collectors and remanufacturers | | |
| Engages in joint ventures with competitors to undertake collection, test, and sort and remanufacture activities. | | |
| Vertically integrates into product acquisition and remanufacturing by developing necessary capabilities in-house | | |
| | | |
| **Excluded from the scale due to low factor loading* | | |
| [1] *Updated reliability scores* | | |

### 5.5.2 Validity

Factor validity was tested to ensure that the factor adequately measures the concept it is supposed to measure. Without assessing the factor validity, the hypotheses might be accepted or rejected when there is excessive error in factor measurement (Bagozzi 1994). In order to claim the validity of a construct, it is necessary to have both convergent and discriminant validity. Convergent validity refers to the state when items measure their intended construct and no other construct, whereas discriminant validity is confirmed when the construct as a whole differs from the other constructs.

#### 5.5.2.1 Convergent Validity

Convergent validity was assessed by two methods to ensure the extent to which measurement scales designed to measure the same factor are related. First, it is required that each item loaded highly on its hypothesized factor in the confirmatory factor analysis (CFA). All the measures loaded significantly on their intended latent constructs (Table 5.3 shows factor loadings), and after two items are dropped, all the factor loadings are substantively large (all 24 items have loadings above .70), demonstrating convergent validity (Bagozzi and Yi 1988).

Furthermore, if the average variance extracted (AVE) is less than .50 that is the variance due to measurement error is greater than that captured by the factor, the convergent validity of the factors is questionable (Fornell and Larcker 1981).

Based on this criterion, the AVE values ranging from .63 to .90 show convergent validity of the factors.

#### 5.5.2.2 Discriminant Validity

Discriminant validity was tested to ensure the degree to which measures of different factors are unique. The most common test of discriminant validity is to check whether the confidence interval around the correlation between any two latent constructs (as shown in the phi matrix) does not include 1 (Smith and Barclay 1997). In the cases tested, none of the intervals reached 1.

Second, discriminant validity can also be assessed by using a more rigorous test suggested by Fornell and Larcker (1981) that compares the average variance extracted (AVE) values associated with each construct to the correlations among constructs. Discriminant validity is achieved if the items share more common variance with their respective constructs than any variance that construct shares with other constructs. Therefore, square root of a construct's AVE should be higher than the correlation between that construct and any other construct. According to this criterion, each construct sufficiently differs from the other constructs, evidenced by the squared correlations between all latent constructs significantly less than the corresponding AVE values. Table 5.4 illustrates the test of discriminant validity with square root of AVE values presented in the diagonal of the matrix. All square rooted AVE values greater than correlation among the respective constructs provides further evidence on the discriminant validity of the constructs.

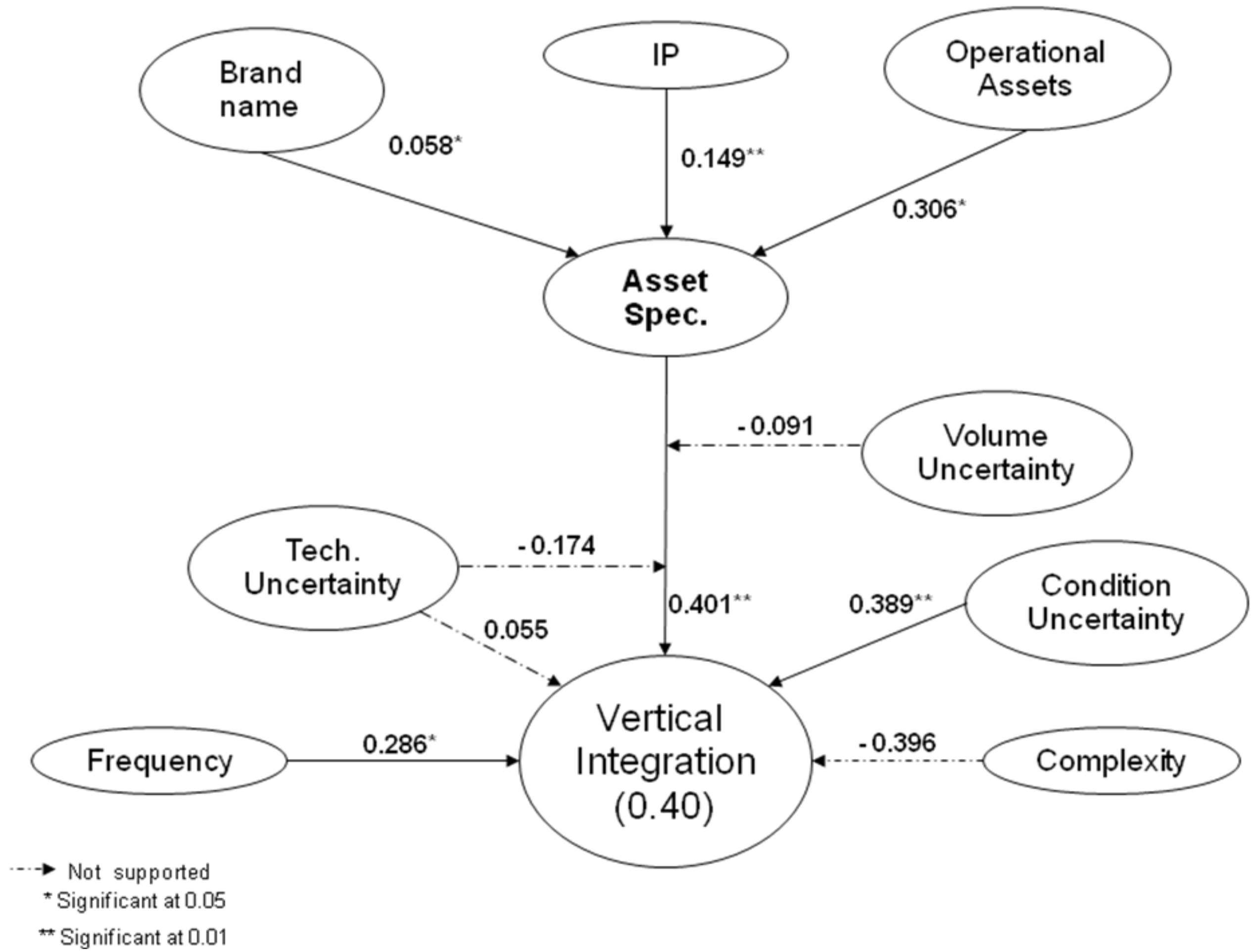
Table 5.4 Discriminant Validity Test

| Constructs | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Physical Asset Specificity | 1 | - | - | - | - | - | - | - | - |
| Brand name | 0.33 | ***0.88*** | | - | - | - | - | - | - |
| Complexity | 0.64 | 0.25 | ***0.87*** | - | - | - | - | - | - |
| Frequency | 0.42 | 0.18 | 0.35 | ***0.82*** | - | - | - | - | - |
| Human Asset Specificity | 0.92 | 0.12 | 0.65 | 0.32 | ***0.84*** | - | - | - | - |
| IP | 0.69 | 0.25 | 0.31 | 0.41 | 0.36 | ***0.95*** | - | - | - |
| Technological Uncertainty | 0.38 | -0.12 | 0.45 | 0.18 | 0.51 | 0.03 | ***0.90*** | - | - |
| Vertical Integration | 0.19 | 0.07 | -0.10 | 0.33 | 0.06 | 0.34 | -0.11 | ***0.90*** | - |
| Condition Uncertainty | 0.12 | 0.37 | 0.22 | 0.15 | -0.03 | 0.25 | -0.05 | 0.40 | 1 |

# 5.6 Model Estimation and Results

Once measurement model is validated, the conceptual model is estimated by partial least squares approach using SmartPLS version 2.0. Base model estimation can be found in Figure 5.2.

Figure 5.2 Base Model Estimation Results



Overall, results show that asset specificity is the most important reason that leads to vertical integration (total effect= .533). Operational assets, which are comprised of human specific assets and physical assets is the most powerful effect increasing tendency to vertically integrate (total effect= .306). High labor skills and the related search and training costs repeatedly urge companies to internalize remanufacturing activities. Moreover the level of sophistication and large initial investment to undertake capital goods remanufacturing increase the effect asset specificity on vertical integration.

Second most important asset that drives vertical integration is the intellectual property (IP) arising in disassembly (total effect= .149). In line with the exploratory interviews with managers in preliminary study, costs arising from protecting IP and costs of contracting to guard against the IP leaks motivates firm to internalize remanufacturing operations. IP concerns are followed by the impact of brand name capital construct. Although it has a small total effect (.058), the impact of brand name capital is significant at .01-level.

The hypotheses regarding the direct effects of volume and technological uncertainty on vertical integration are not supported. Initially, it is hypothesized that high technological uncertainty may lead to recurring coordination costs between the OEM and contractor, and therefore urges OEM to internalize the remanufacturing operations in a volatile environment. Although this holds in previous transaction cost literature, other complicating factors such as technological obsolescence of large investment assets exist. However, model estimation results show a non significant effect of technological uncertainty's moderation affect in the presence of highly specific assets.

Also, volume uncertainty in transaction cost literature is dealt in two ways: high uncertainty may increase costs of coordination, therefore increasing the degree of vertical integration or combined with disruptive flow (low frequency) may lead to lower utilization of machinery or inadequate economies of scale. Instead of developing in-house capabilities, firm choose to outsource this low-value adding operations to a third party remanufacturer.

In contrast to insignificant effects of technological and volume uncertainty, results show a highly significant overall effect for condition uncertainty (total effect= .389). Overall condition uncertainty is the second most important factor leading to vertical integration following asset specificity. Product remanufacturability or the frequency of remanufacturing has a significant effect on the degree of vertical integration. PLS results and the bootstrapping procedure with 500 resamples showed that the model explain 40% of the variance in the data. The significant and non-significant hypotheses are further elaborated and translated into an interview protocol in the next chapter. Furthermore, the interview administration and data coding will be explained.

Base model hypotheses and their estimated path coefficients are presented in Table 5.5.

Table 5.5 Base Model Hypotheses and Total Effects

| **Hypothesis** | **Total Effects**<br>**(t-value, p-value)** |
|---|---|
| Hypothesis 1a-b: The higher the specificity in operational assets used in product recovery, the higher the degree of vertical integration | .306<br>(2.47, 0.01) |
| H1c: The higher the brand reputation of the OEM, the higher the degree of vertical integration | .058<br>(2.02, 0.05) |
| H1d: The higher the intensity of proprietary part/process technology used in the core, the higher the degree of vertical integration. | .149<br>(2.57, 0.01) |
| H2a: Volume uncertainty in returns and processing increases the degree of vertical integration in the presence of asset specificity. | -.091<br>(0.78, ns) |
| H2b: The higher the level of technological uncertainty the higher the degree of vertical integration. | .055<br>(0.62, ns) |
| H2c: Remanufacturer firms prefer market transactions in order to avoid technological obsolescence when highly specific assets are required. | -.174<br>(0.59, ns) |
| Hypothesis 2d: The higher the uncertainty in quality (condition) of returns, the higher the degree of vertical integration. | .389<br>(3.81, 0.01) |
| H3: The higher the remanufacturability and the more frequent return of the core stream, the higher the probability for vertical integration. | .286<br>(2.18, 0.05) |
| H4: The higher the complexity of the core, the higher the degree of vertical integration. | -.396<br>(1.76, ns) |

# Chapter 6

# Case Studies

## 6.1 Data Sources

As primary data source structured one to two-hour interviews is conducted with experienced managers. However, there are also other sources of data to provide different perspectives, increase the richness of data, and achieve a greater degree of validity (Yin 1989, McCutcheon and Meredith 1993). Multiple sources also allows for triangulation, which is especially helpful in testing multiple sources of information, and eliminating alternative explanations of the phenomena (Eisenhardt 1989).

Additionally, unpublished case studies, white papers, presentations given by managers on the firm's remanufacturing operations are used in triangulation of findings. Moreover, multiple facility visits were conducted to Xerox, Pitney–

Bowes (P-B), Hewlett-Packard (HP), Bosch and Black and Decker (B&D). Table 2 summarizes additional data sources for each company.

Table 6.1 Population of Case Companies and Interviewed Managers

| | | | |
|---|---|---|---|
| **CONSUMER GOODS** | | | |
| **Companies** | Robert Bosch Tool, NA | Hewlett-Packard | Black and Decker |
| **Interviewee(s)** | Randy Valenta,<br>Director, Product Services<br>Hank Wolman Engineering | Dana Rysavy<br>North America<br>Returns Manager | Ron Walters<br>Director, North America Supply Planning<br>Dean Edwards, Engineering, Industrial Products |
| **Products** | Power tools | Printing and Imaging Products | Power tools |
| **Additional Data Sources** | Field visits<br>Unpublished case study<br>Company presentations | Company presentations<br>Field visits<br>Archival sources | Field Visits<br>Archival sources |
| **CAPITAL GOODS** | | | |
| **Companies** | GE Transportation | Pitney-Bowes | Xerox |
| **Interviewee(s)** | Matt Dickey<br>Services Growth Leader | Jerry O'Sullivan<br>VP, North America GMS Supply Chain Operations | Dave Whitmyre,<br>iGEN3 Plant Manager |
| **Products** | Diesel Engines | Postal products | Copying and printing equipment |
| **Additional Data Sources** | Archival sources<br>White papers | Field visits<br>Archival sources | Field visits<br>Archival sources |

## 6.2 Interview Protocol

The interview protocol is designed to gather information on multiple variables and had questions that can be manipulated according to managers' answers. As a next step to test the face and content validity of the instrument, a pilot study is performed among managers. This section describes the steps to development of the interview protocol and the administration of interviews.

### 6.2.1 Protocol Development

Interview protocol includes questions on four main variables: temporal, independent, dependent, and external forces. This serves to enhance the reliability of our case research (Yin 1994).

The temporal dimension questions are broad and open-ended to stimulate discussions of the path dependencies and provide an introduction to more specific questions (Meredith 1998). Managers are asked how they started their remanufacturing operations and the driving forces then and now. Additionally, they are asked to define the fit between remanufacturing operations and overall business model of their companies.

The second set of questions is related to the independent variables. The constructs are defined based on TCE and preliminary interviews are included in this portion of the protocol. The managers are first asked directly about the relationship between the variable and organizational arrangement, and then they are asked 'why' certain relationships occur in their companies. Some of the questions are manipulated according to the answers to previous ones ('what if' questions). For questions that reflect multiple dimensions (such as uncertainty), the managers are asked to compare the challenges brought by each dimension.

A third set of questions relates to dependent variable, and includes questions on current organizational arrangement (i.e., the 'why and how' this certain configuration for remanufacturing was chosen). Managers are also asked to identify the shortcomings of these configurations and what they would change to improve the profitability of remanufacturing.

Additional questions are included on external environmental forces, such as market structure for new and remanufactured goods, third-party remanufacturer competition, and available supplier base for manufacturing. The objective is to control for these factors in cross case analyses and employ this data in revealing differences between capital and consumer goods companies. Interview protocol is presented in Table 6.2.

Table 6.2 Interview Protocol

| **TEMPORAL DIMENSION** | |
|---|---|
| Open-ended | 1. Why does your company remanufacture?<br>2. How long has your company been remanufacturing? How did your company decide to remanufacture?<br>3. How does your remanufacturing operation add value to overall organization and how does it fit to your current overall business model?<br>4. How much outsourcing does your company do with regards to your new products? How does this affect your operations (remanufacturing)? How have your returns volume changed over time? How did your organization respond to this change?<br>5. How did you deal with your returned products before your start remanufacturing? |

| INDEPENDENT VARIABLE QUESTIONS (SIGNIFICANT RELATIONSHIPS) | |
|---|---|
| Frequency | 1. How does the number of times you remanufacture your products effect your outsourcing decision? Would be different if you remanufacture your products [more/less] than [once, twice or three times]?<br>2. Do you design your products for remanufacturing? |
| Condition Uncertainty | 3. How accurate can you estimate the condition of the returned products? Do you have information on the condition of returned products beforehand?<br>4. Can you use past experience to estimate the conditions of cores, is there a consistency in conditions instead of variance?<br>5. Which one is more problematic for your remanufacturing operations: inadequate information in the return volume of cores, or inadequate information regarding the condition of the core?<br>6. How do you deal with condition uncertainty?<br>7. Would you find it easier to (contract remanufacturing) outsource when you can't have any information, or does outsourcing make it harder to coordinate remanufacturing of cores in highly variable conditions? |
| Brand name capital | 8. What is the primary return from remanufacturing operations – cost recovery, profit stream associated with brand extension etc.<br>9. Are you using remanufacturing to extend your market share by providing lower-price products?<br>10. What would be the problems if independent 3rd party remanufacturers remanufactured your products instead of you [you don't have any control over the quality and reliability]? |
| Intellectual Property | 11. What is the possibility of IP leakage if a third party disassembles your products for your company?<br>12. What would be the damage on your company in case of IP leak?<br>13. Would you avoid third party involvement to protect your IP? |
| Operational Assets | 14. How hard is it to find the right workers to perform shop floor remanufacturing operations? How dependent are you on your workers and their skills, are these skills (or workers) easily replaceable from market?<br>15. How important are your workers skill sets in remanufacturing operations, would you be willing to outsource remanufacturing operations to another company if they were generic [specific]? |
| **INDEPENDENT VARIABLE QUESTIONS (NON-SIGNIFICANT RELATIONSHIPS)** | |
| Technological Uncertainty and Assets | 16. Are any of your assets (machinery, equipment) under risk of obsolescence because of the technological evolution in your products? If yes, what do you do to mitigate the risk?<br>17. How does changing technology in products and processes affect your organization, how would you act e.g. if you foresee fast tech. evolution in your industry? |
| Volume Uncertainty and Assets | 18. Do you use new product assembly and production lines for remanufacturing or do you have separate production equipment and lines for remanufacturing operations? Why?<br>19. Does uncertainty in returns volume affect utilization of machinery and equipment? |

| | |
|---|---|
| | 20. Do you have scale problems in remanufacturing cores? |
| Complexity | 21. What are the implications of remanufacturing such complex products? Do you do contract manufacturing for new products? Is the cause of that you do not have the production expertise because you outsource part of manufacturing new products?<br>22. Do you use reverse engineering knowledge or [part failure] data arising from remanufacturing to feed the design/improve the design of the product. |
| **EXTERNAL-INTERNAL ENVIRONMENT** | |
| Competition | 23. Do you think third party involvement in remanufacturing can provide incentives for these companies to become independent remanufacturers? Why?<br>24. How would remanufacturing market look like if you are not involved in remanufacturing your products?<br>25. Do you perceive your products' remanufacturing market as attractive to independent remanufacturing companies as it is to you? |
| Goal and Incentive Alignment | 26. How do your relationships with marketing and sales departments work? Are there any dependencies, i.e. for information flow, demand planning etc? Do you have any problems selling remanufactured products, or does marketing/sale have concerns?<br>27. Do you think your division gets the rewards it deserves related to remanufacturing activities?<br>28. What would be fair distribution of rewards from remanufacturing success? |
| **DEPENDENT VARIABLE QUESTIONS** | |
| Open-ended | 1. How do you organize your remanufacturing operations? Why?<br>2. How much outsourcing with regards to: Core collection, disassembly/remanufacturing, sort/test, remarketing/resale? Why?<br>3. How would you organize these operations if you were doing it from scratch today? Why?<br>4. What is the impact of remanufacturing in your company's bottom-line? How does remanufacturing operations impact performance outcomes and why?<br>5. How do you measure remanufacturing performance? What are key performance indicators for remanufacturing's financial and operational performance? |

## 6.2.2 Protocol Administration

Prior to the full set of interviews a pilot study is conducted with managers at three OEMs. Managers were asked to evaluate the face validity of questions, if the questions reflected the reality of the industry, and if the interviews could be completed with 75 minutes or so. After analyzing this input, more questions are added on forward supply chain policies and sales channel design. Overall, the managers who participated in the pilot found the protocol realistic and workable.

The interview protocol is administered in a pre-determined sequence. First, key managers from the population of companies were asked for one to two-hour interviews. Key managers are defined as the executive who has the senior responsibility for managing strategic aspects of remanufacturing operations. In four of six companies, the managers have been with their companies since the beginning of remanufacturing operations and they took part in the organization of remanufacturing operations. Therefore, there is a high degree of confidence that informants are the most qualified to answer our questions on organizational arrangements and capable of providing input on the temporal dimension. The remaining two managers have also been with their respective companies for a considerable amount of time, and are responsible for managing remanufacturing operations for North America. The managers were provided with the interview protocol in advance, and asked to invite other managers with in-depth knowledge for a particular issue. Each interview started with open-ended, broad questions and proceeded to more specific questions as in funnel model. The interviews were then transcribed, examined by the managers for accuracy, and then combined with other sources of information for each company.

# Chapter 7

# Results and Discussions

## 7.1 Data Analysis and Coding

The interviews were transcribed and coded with respect to thirty-eight dimensions, ranging from remanufacturing operations' fit to overall business model to remanufacturing market characteristics. Case coding can be found in Appendix. Three cases from consumer goods are grouped, and compared-contrasted with the second three-case group from capital goods. Eight dimensions that differentiate consumer goods from capital goods are identified. Second, the final framework is refined by doing in-depth within-case analyses to test the hypotheses. Lastly, data is analyzed in a cross-case manner to reveal the prevalent organizational patterns in the industry, and to identify how proposed constructs lead to emergence of these patterns. In the following sections detailed analyses of data is presented. Finally, how the findings lead to developing the final testable model of vertical integration in remanufacturing will be discussed.

## 7.2 The Differences between Capital and Consumer Goods Industry

Some key differences between the drivers of organizational decisions in capital goods and consumer goods industries became clear early in the analysis. Table 7.1 summarizes eight variables that differentiate remanufacturing operations between capital and consumer goods industries. The major difference between organizational arrangements in consumer and capital goods is their motive for engaging in remanufacturing operations. Capital goods OEMs' remanufacturing operations began as a way to satisfy customer service requirements, rapidly evolved into profitable businesses. Capital goods OEMs now recognize remanufacturing as a value-added part of their core business, and enjoy significant returns from remanufacturing operations.

In contrast, consumer goods OEMs remanufacturing operations developed in response to liberal reseller return policies that led to increasing quantities of returned products. Remanufacturing managers at consumer goods firms are charged the standard accounting costs for returned products. In addition to these standard accounting costs, are the costs of recovery activities (reverse logistics, credit issuance, remanufacturing and remarketing). Consumer goods firms turned to remanufacturing to recover some of the costs of these returns, but managers reported their best scenario would be to lose less money since making profits is not possible. For consumer goods OEMs, remanufacturing is part of an overall cost recovery strategy, with positive, but not significant returns to the company's bottom-line, and most of them foresee few, if any, strategic competencies sourced from remanufacturing.

The remarketing processes also exhibit different characteristics for consumer and capital goods OEMs. Managers at the consumer goods companies have a strong, pervasive, belief that remanufactured versions of their products cannibalize new product sales[2]. These firms are also very concerned over the firm's brand name and any possible negative associations with low-price point markets (e.g., liquidators). All the managers report using separate marketing channels for remanufactured products to minimize the potential for brand name erosion. As brand name capital increases, so does concern with cannibalization and brand name erosion. Consumer goods companies attempt to differentiate the new and remanufactured products with different warranties and offering incentives for new product purchases. In contrast, capital goods companies (e.g., GE and Xerox) have a customer service focus and emphasize functionality for both remanufactured and new products, providing both customers with the same warranty.

The returns channel is another differentiating factor between consumer and capital goods remanufacturing operations. Consumer goods OEMs report that no-defect returns (also referred to as false failures, see Ferguson *et al.* 2006) from retailers constitute the majority of returns. Their resellers must return the products to the

[2] Please note that the managers at the firms that are interviewed all admitted that there were no studies confirming that remanufactured products cannibalized new product sales. The belief is strongly held by market and sales staff and has become institutionalized.

OEM to get back the credit they issued to customers. This protects the company from potential brand name deterioration caused by low quality and reliability of third-party remanufactured products. Capital goods have significant value at the end of their lives and there is often fierce competition from third-party remanufacturers for the used assets. For example, Xerox faces vigorous competition from third-party remanufacturers for their used products that are sold (rather than leased). This competition can be a powerful motivation for an OEM to engage in remanufacturing since the third-party remanufacturer will reap the revenues from name brand remanufactured products. The OEM loses the revenue from the lost sale and the potential damage to their brand name from sub-standard remanufacturing processes. Product acquisition therefore brings competition to the market in capital goods industry and these companies compete both for supply of cores to remanufacture and sales.

Finally, these analyses shows that brand name capital is the most significant driver for vertical integration in both industries, followed by IP and customer service concerns in capital goods, and warranty data (e.g., information about how the product performed in the field) for consumer goods. In the following sections, the significant and non-significant drivers of vertical integration in remanufacturing will be discussed and the final framework will be proposed.

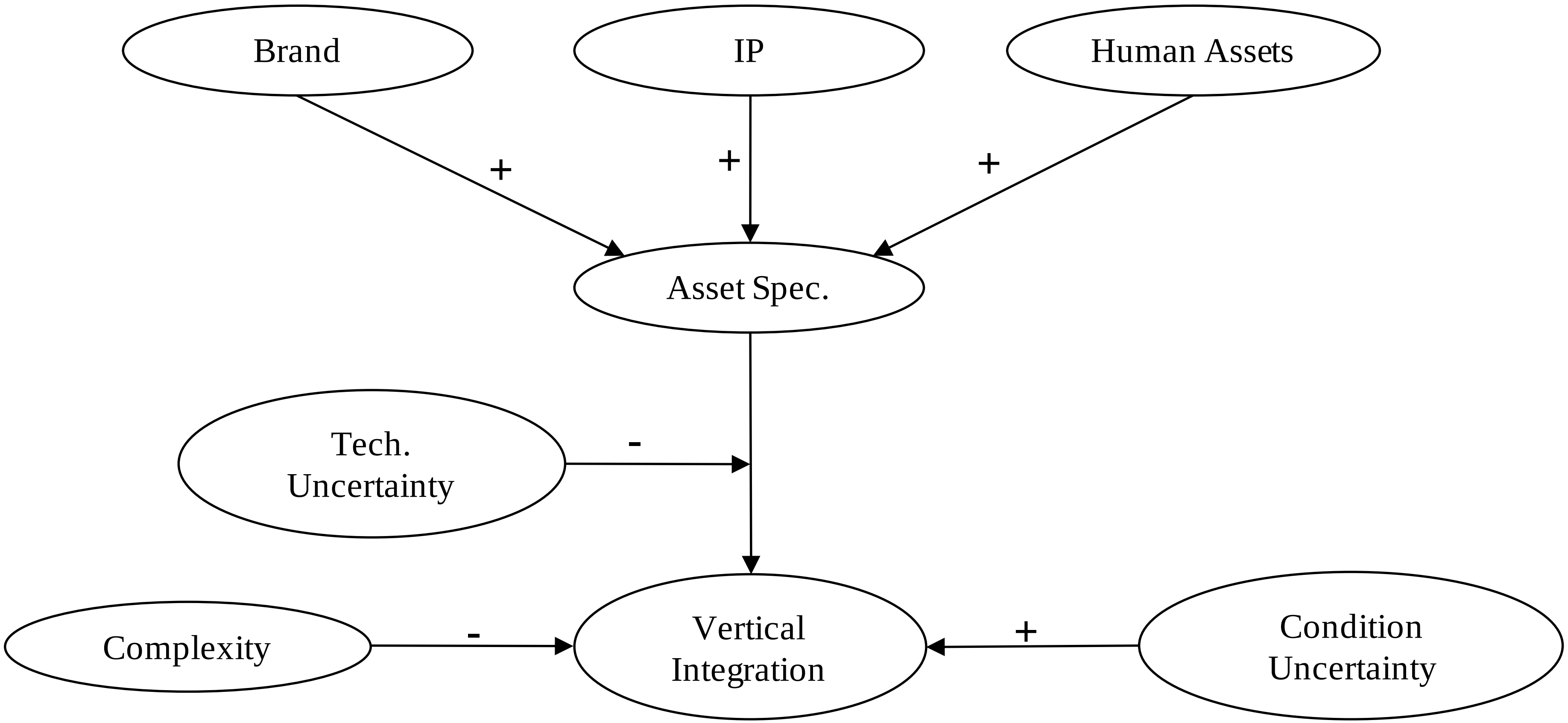
Table 7.1 Differences in Remanufacturing Operations between Capital and Consumer Goods Industries

| | **Capital Goods** | **Consumer Goods** |
|---|---|---|
| **Fit** | Core business | Service Operation |
| **Objective** | Profit | Cost recovery |
| **Driver** | Customer service and returns | Returns |
| **Contribution** | High and significant | Positive but not significant |
| **Third-party Competition** | Threat to market | Not a threat |
| **Returns Channel** | Not exclusive | Exclusively to OEM and authorized partners |
| **Sales Channel for Reman.** | Same | Differentiated (Secondary markets) |
| **Organizational Driver** | Brand name, IP, customer service | Brand name and warranty data |

# 7.3 Final Framework

Case transcriptions and coding are analyzed separately and then combined to analyze each hypothesis. The individual findings are merged and triangulated with the data from the secondary information sources, summarized in Table 6.1. Having the ability to filter the results with respect to industry bias, significant and non significant relationships are identified and a final testable framework of vertical integration is proposed for OEMs that offer remanufactured version of their products, Figure 7.1. In the following sections the hypotheses will be discussed and I will offer potential theories why the certain relationships hold for OEMs that remanufacture.

Figure 7.1 Final framework



### 7.3.1 Non-Significant Relationships

As a result of the analyses, the relationships between volume and technological uncertainty, frequency and physical asset specificity constructs and the degree vertical integration are not supported.

#### 7.3.1.1 Volume Uncertainty

In the previous literature volume uncertainty is cited a problematic aspect of product recovery (Fleischmann et al. 2001, Thierry 1995, Guide 2000). Our case data does not provide support for hypotheses on the positive effects of volume (H2a) and technological uncertainty (H2b) on vertical integration decisions. In interviews, managers from both capital and consumer goods companies expressed little concern over volume uncertainty, citing the value from leveraging past returns data and learning curve effects. In capital goods companies, besides use of past returns data, lease contracts, regular field maintenance records, and field workers convey more accurate data on returns volume and timing. Managers at consumer goods companies revealed that over time returns volume have stayed steady as a percentage of sales, and these companies keep extensive databases that are used to forecast future returns. However, companies, especially in consumer goods industry, cited the difficulties in estimating the labor and materials requirements for returned products, not only complicated by timing but also by the mix of returned products. There are potential explanations for this unexpected result. First, Fleischmann et al. (2001) and Thierry et al. (1995) both consider returns flows resulting from the waste stream. Guide (2000) mainly surveys third-party capital goods remanufacturers that do not offer leasing and must source used products from a variety of locations and end-users.

#### 7.3.1.2 Technological Uncertainty

Managers view technological uncertainty as a less serious concern than the other uncertainty variables. When asked about the actions that should be taken to sustain their market position in a fast technological pace environment, managers in capital goods companies stated the need for more supplier involvement for high investment remanufacturing assets. This supports technology uncertainty's moderation effect in vertical integration decisions (H2c). Managers in consumer goods companies stated they require more agile inventory policies to manage the increased obsolescence risk in high time-value consumer goods.

#### 7.3.1.3 Frequency

Frequency of remanufacturing construct is defined as the number of times products can be remanufactured and the timing of the returns volumes. For capital goods companies, remanufacturing serves as a customer service offering (such as GE Services housing remanufacturing operations), or as a primary means to satisfy demand for certain class of products such as Xerox DocuTech monochrome printer. Xerox introduced DocuTech products in 1987, and ceased manufacturing new products in 1997. The company has been satisfying market demand through remanufactured products for a decade by remanufacturing returned products, often more than once, adding new parts and components when necessary. Frequency does not emerge as a decision variable in organizational decisions in the capital goods industry due to nature of remanufacturing operations. Capital goods OEMs must assume remanufacturing responsibility to satisfy demand, or to service products, regardless of their frequency. For consumer goods companies, frequency did not emerge as a significant variable in vertical integration decision, since consumer goods are normally remanufactured once in their (short) product lifecycle. Overall, we did not find any support for the increasing role of frequency on vertical integration decisions (H3).

#### 7.3.1.4 Operational Assets

The analyses provided no support for operational assets (physical asset specificity and human asset specificity) positive effect on vertical integrations decisions (H1a-b). Remanufacturing lines are less complicated than new production lines, and designed generically to accommodate more than one product. Therefore, equipment and machinery are also generic and simple. Assets for remanufacturing are not intended to manufacture from scratch, but oriented towards disassembly, testing and calibrating, thus limiting physical assets potential impact on vertical integration, or on organizational decisions. In cases where a returned product requires remanufacturing operations that are outside the company's competence (e.g. Bosch radios or B&D laser tools), or that require high capital investment (some of P-B products), are outsourced to original suppliers.

The labor skills required for remanufacturing operations are usually less specific than manufacturing. However, workers require some specialized skills to diagnose returned products quickly and identify useful information for design improvements. Xerox and P-B have formal, established, procedures for disassembling and testing the equipment. Over time the learning effects increase for executing the procedures and processing times get shorter. Thus, we observed some dependency on the learning effects even when the skills required are generic (H1b). Gathering reverse engineering and part failure data, and the identification of problems in defective products are commonly cited reasons for internalizing remanufacturing operations. This provides additional support as to the significance of learning curve effects.

## 7.3.2 Significant Relationships

As results of survey study and case studies following it, brand name, intellectual property, product complexity, condition uncertainty and human assets are revealed to be important drivers of vertical integration. This section discusses these constructs and their impact on vertical integration.

### 7.3.2.1 Brand Name

Brand name protection is the leading driver for vertical integration decisions (H1c) for capital and consumer goods OEMs. Companies, fearing the potential negative image from poor quality remanufactured products, remanufacture in-house. This allows greater control and maintains the reputation of their brand. Brand name is also a driver for internalizing remarketing activities in consumer goods companies since they do not want to be associated with lower-priced, lower-end market segments. Keeping recovery activities in-house allows carefully differentiated sales channels.

#### 7.3.2.2 Intellectual Property

Although all companies involved in this research were heavily patented companies, IP is the second most important concern leading to vertical integration in capital goods companies (H1d). Xerox earns significant royalties through its patents and manufacturing and remanufacturing in-house are preferred when IP content is high. In cases where supplier involvement is required, geographical proximity and suppliers with long-term relationships are considered crucial for increased control. Previous research supports this finding by revealing IP as a factor in Rank-Xerox's vertical integration decision in the EU (Ayres et al. 1997).

#### 7.3.2.3 Product Complexity

Complexity is a neglected decision variable in the make-or-buy decisions for remanufacturing. Many companies employ simple, cost-driven make-or-buy decision analysis that fails to consider the potential costs of disassembling complex products and increased work content. When there are no concerns regarding brand name capital and intellectual property, labor and material costs are the driving force for outsourcing remanufacturing. Only P-B considers the complexity of products in their decision to outsource, providing only partial support to positive effect of complexity on vertical integration decision (H4). Moreover, at P-B, the complexity of the product is considered for scheduling remanufacturing jobs and simpler jobs are scheduled earlier to help lines run efficiently.

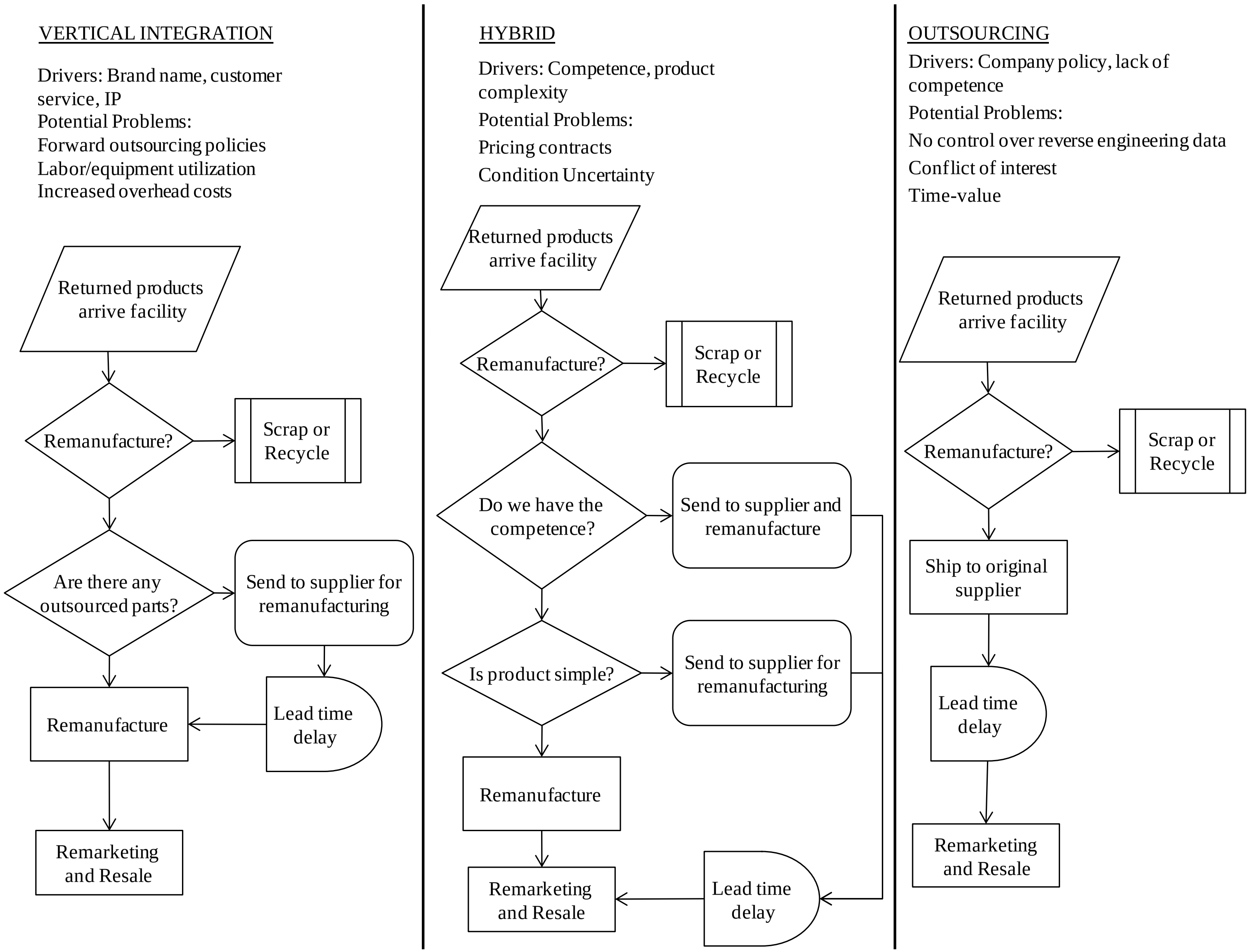
### 7.3.2.4 Condition Uncertainty

Condition uncertainty, which predicts labor and material requirements for a core, relates to returns volume and the mix of returned products. The majority of the managers reported problems in variability in the condition of returns, despite maintaining maintenance and repair databases. From a TCE perspective it is costly to design contracts for remanufacturing an unknown mix of cores, determine the pricing, and monitor the operations. Condition uncertainty is cited as an important driver leading to vertical integration decision as its complexity may result in poor coordination with outsourcing partners and higher costs (H2d).

## 7.4 Dominant Organizational Configurations

Three dominant organizational configurations are identified as a result of the interviews. A generic version of each configuration is illustrated in Figure 7.2

Figure 7.2 Dominant Organizational Configurations



### 7.4.1 Vertical Integration

Bosch and B&D (consumer goods) and GE and Xerox (capital goods) all organize their remanufacturing operations in-house. The common driving element for these companies is their concern for brand name capital. GE and Xerox are additionally motivated by customer service requirements.

Even though companies perform remanufacturing operations in-house, they are forced to outsource remanufacturing for outsourced components in new products since they do not have the equipment or the competencies. None of the companies interviewed has a policy to incorporate the remanufacturing costs in the make-or-buy decision for new products. These forward outsourcing policies increases the overall cost of recovery in many ways. Companies must incur high costs to maintain inventory for replacement parts and components that have long lead times from suppliers. For consumer goods companies, which generally have shorter life-cycles and higher time-value products, these longer lead times increases the likelihood that remanufactured goods will not be matched with demand. This implies higher lost time-value and an increased obsolescence and scrap rate.

Capital goods companies bear very high costs from scrapping a return due to parts or components unavailability, thus losing the high residual value of the equipment and future upgrade sales and service contracts. Since a capital good has approximately four times the lifecycle of a consumer good, end-of-life buys must be carefully planned. When production of a certain product is ceased, the OEM must ensure the availability of outsourced parts for future remanufacturing operations. However, the supplier often ceases the production of these parts with no consideration of an OEM's remanufacturing operations. End-of-life buys incur very high costs either because companies have to carry a very high inventory for a long time, or to compensate for the one-time set-up costs of suppliers in order to get parts needed for remanufacturing. Managers also reported large losses for residual inventories held for demand that never materialized. For these companies, parts and components that have the risk of unavailability, long procurement lead time, or high IP intensity should be manufactured and remanufactured in-house (or if scale does not permit could be sourced to local suppliers with long-term relationships) without losing control abilities.

Another problem in internalizing remanufacturing operations stems from the scale and scope of remanufacturing operations. Most lines are combined to serve more than one product, or a generic line serves for remanufacturing to balance their capacity utilization. High overhead costs due to low utilization driven by uncertainty in condition and demand for remanufactured products is common, and this overhead must be absorbed in recovery costs. These problems may be mitigated by adopting hybrid policies.

### 7.4.2 Hybrid Policies

P-B has a hybrid policy for remanufacturing that uses a selective algorithm to decide which products to remanufacture in-house, or outsource. This remanufacturing policy actively takes into account the company's forward policies similar to vertical integration policies that are passively bound to forward outsourcing practices. However, the decision criteria to outsource remanufacturing are not limited to forward outsourcing policies as in vertical integration policies. The competencies (assets and skills) required for remanufacturing, the complexity of the product, and the ability to diagnose the condition of the product beforehand, and remanufacturing cycle time are considered in the hybrid policy. When returned products are simpler, it is less costly to remanufacture in-house, as compared to sending it back to the original supplier of the product. However as the products get more complex, the capital investment for remanufacturing may increase. Instead of duplicating supplier's infrastructure, the products are sent to supplier for remanufacturing.

In P-B, this hybrid policy is coupled with an in-house scheduling rule for efficient management. For in-house remanufacturing, the products that can be remanufactured with minimum labor, material and cost are given priority in remanufacturing, while also accounting for the demand for product. The difference between a mixed and vertical integration policy is the mixed policy's ability to systematically differentiate between products and parts that will be sent to suppliers and those that will be remanufactured in-house.

This hybrid policy is constrained by condition uncertainty to a great degree. Although P-B has been leveraging past returns and quality data to develop averages for material and labor requirements to manage in-house remanufacturing, it still has to bring products back to distribution centers and inspect them to determine the exact condition. For in-house remanufacturing, these costs can be absorbed. However, when supplier involvement is required, it is challenging to develop pricing for the remanufacturing of a product in unknown condition, or monitor the supplier's performance to P-B standards. Moreover, the inability to tell the condition beforehand causes the company to incur transportation costs for a product that should have been scrapped on-site.

A similar hybrid organizational pattern is also described in Guide et al. (2005). The authors develop an integrated business model for HP to take advantage of the time value of returned notebooks and desktops. HP executes a centralized control for remanufacturing operations, but selectively outsources some remanufacturing operations. While high-touch (technical) remanufacturing is conducted in-house for desktops, HP outsources notebook remanufacturing to original supplier for both design and remanufacturing. Also, low-touch, simple operations such as cleaning and relabeling are performed in-house.

### 7.4.3 Outsourcing

It is observed that only HP uses a total outsourcing strategy for remanufacturing. However unlike operational or strategic forces that determine organizational decisions in the other firms, total outsourcing decision at HP was a company policy. HP outsources all manufacturing to its authorized suppliers. Lacking the manufacturing competence and to avoid duplicating the suppliers' investment, HP outsources the remanufacturing of returned products to its suppliers. In the same vein, Cisco Systems, one of the initially interviewed companies, uses the same organizational arrangement for remanufacturing its products. A common aspect of these companies is the fast paced technological evolution in their industries and short life-cycles of their products. These companies have strong working relationships with their suppliers in information sharing on reverse engineering and part failure data for design. Although remanufacturing of products is outsourced, the re-marketing processes are always kept in-house. The leading drivers for this decision are avoiding possible leakages to inappropriate sales channels, the desire to differentiate remanufactured products to prevent cannibalization, and to control reliability and quality.

# Chapter 8

# Conclusions and Further Research

## 8.1 Summary and Conclusions

This dissertation focuses on the drivers of organizational decisions and identifies the different organizational configurations of remanufacturing operations in the industry. TCE is utilized as a lens to investigate governance in remanufacturing operations and propose a conceptual model grounded in theory and with industrial reality. To author's knowledge, this is the first research that adopts a business economics perspective to strategic organizational research in remanufacturing literature. Moreover, with this research the focus moves from theoretical to empirical perspective, and provides researchers with a framework that is testable. Results suggest that strategic assets and the uncertainty in the condition of returned products are the primary drivers of vertical integration in remanufacturing. The management interviews shed light on the industrial differences and organizational drivers, and they helped us identify the inherent effect of forward supply chain policies on make-or-buy decisions.

The methodological approach follows the empirical research framework proposed by Fisher (2007). The research question in this dissertation is motivated by industry reality based on preliminary unstructured interviews with managers and a stylized version of the problem is then grounded on transaction cost economics theory. Adopting case study methodology, the relationships are validated and the "why" behind these relationships is revealed via in-depth data collected through interviews and secondary sources of information. Through within-case analyses, three organizational configurations are laid out as a roadmap for OEMs who perform remanufacturing operations. Within each organizational configuration we outlined the potential costs and benefits.

There are several interesting opportunities as a follow up to this research. First, the proposed model would benefit from extensive testing in different contexts. Using cross-sectional methods, researchers can test and further refine the model and we strongly encourage further empirical testing of our model. It is worthwhile to note that there is presently no trade association dedicated to remanufacturers and this makes the identification of OEMs that offer remanufactured versions of their products quite difficult. The remanufacturing industry was, until recently, dominated by third-party providers and there is increasing interest at OEMs that there is significant profit to be made from a product after the sale. The current model will help remanufacturing research to further evolve into a potentially fruitful domain of strategic organizational research with a business economics perspective. Second, a framework linking each organizational configuration to its performance metrics may be developed and tested. This could help identify high-formers and low-performers and increase the prescriptive power of model. Third, our scope was limited OEMs operating in the United States, since the presence of environmental regulations that require product recovery (e.g., the WEEE in the EU) would introduce an additional level of complexity. The extension of this study in the presence of environmental regulation would make for potentially insightful comparisons.

## 8.2 Managerial Implications

The drivers for organizing remanufacturing activities in capital goods and consumer goods share some similarities. The findings suggest that capital and consumer goods OEMs view brand name as a primary motivation to keep remanufacturing activities in-house (or at least under tight control). However, for capital goods OEMs, intellectual property concerns have a significant impact on internalizing remanufacturing operations. Consumer goods companies report brand name and possible customer service issues as a driver for in-house remanufacturing. Case studies do not provide support for the effects of technological and volume uncertainty on organizational structure.

It is very important that managers realize that remanufacturing not only benefits the company through tangible balance sheet assets. In the long term, remanufacturing can be one of the most significant value-adding “green” activity and can therefore be transformed into brand name capital and market value. There is an increasing scrutiny towards companies’ sustainability activities. Most of the time, the term sustainability relates to energy saving initiatives, use of alternative energy resources, safe disposal of potentially hazardous materials and recycling. Remanufacturing is a new and very aggressive addition to sustainable operations, often called the ultimate form of recycling. Remanufacturing operations can re-use materials, therefore decreasing the waste, but more importantly it conserves the value added (cost of labor and energy) by building on the existing product. Therefore, remanufacturing can conserve energy up to 80% in original product, materials and reduces the waste. In the long term, engaging in remanufacturing operations will be a considerable investment in environmental image of a company and increase its market value by positively contributing into its brand name capital.

Like other production operations, the feasibility of remanufacturing operations can be argued to be sensitive to the increases in the costs of labor, raw materials and energy. However compared to manufacturing, remanufacturing has been shown to remarkably robust to environmental cost changes. Remanufacturing a returned product through processes of disassembly, cleaning, remanufacturing costs typically 40-50% of the new product price. When energy costs is considered there is also a significant advantage due to energy savings. Over 80% of the energy required to manufacture the original product is typically contained in the core. With respect materials, remanufacturers have to add only 20% of virgin materials. Capital requirements are generally substituted with labor, which accounts for the biggest contribution, usually 40%-60% of original labor requirements.

Even though remanufacturing is a profitable business, in some consumer goods companies it is deliberately held back to avoid third party competition and the related brand damage and warranty problems. In the last few years, this phenomenon is observed in printing and imaging industry, namely ink and toner cartridge products. Many companies began designing manufacturing non-remanufacturable cartridges and replacement parts in order to avoid third part remanufacturer competition and protect their complementary revenue stream. Lexmark, the second largest printer manufacturer in U.S. started installing chips that prevent third party remanufacturers from filling the cartridges in 2002. This stirred a considerable deal of controversy in cartridge aftermarket and followed by lawsuits to Lexmark and Lexmark taking legal actions to third party remanufacturers for copyright violations. Therefore, it is also possible that intentional "design for non-remanufacturing" can be observed in some industries, especially in the ones that make much of their profits from complementary products and supplies. This strategy is seemingly the best one by means of cost to avoid third party competition.

Additionally, this research reveals the potential impact of forward supply chain outsourcing policies on remanufacturing operations. Even though many companies perform remanufacturing operations in-house, they are most often obliged to outsource remanufacturing for outsourced components from new products since they do not have the competencies to remanufacture. None of the interviewed companies has a policy that incorporates the remanufacturing costs in make-buy decision. The effects of these forward supply chain oriented policies on remanufacturing operations can be manifold. Managers at capital and consumer goods firms unequivocally stated that an outsourced component may lengthen the remanufacturing lead time, increase lost time-value in high-tech products, and increase buffer parts inventory. The overall costs of product recovery rises as more returned products become obsolete in the pipeline, or more parts become unavailable over time since the supplier does not foresee any customer issues related to remanufacturing. Although it might be cost prohibitive to consider these concerns in consumer goods companies due to low residual value of products, capital goods companies are well advised to incorporate remanufacturing operations to their outsourcing policies. For these companies, parts and components that are under risk of unavailability, have high procurement lead time, or have high IP intensity may be manufactured and remanufactured in-house. If scale does not permit, these parts and/or components could be sourced to local suppliers with long-term relationships, as one successful interviewed company does.

Finally, based on our study, three organizational configurations are identified and their potential benefits and drawbacks are discussed (Figure 7.2). Governance of remanufacturing operations is a complicated, multi-dimensional problem and is often an ignored process at many companies. Some of the managers interviewed (most often from consumer goods firms) admit that their current organizational structure arose as returns increased over time, and most of the time they responded to changes by using temporary patches instead of adopting a planned organizational arrangement to manage operations. Make-or-buy decisions are usually made based on myopic cost tradeoffs in forward supply chains that disregard the implications for remanufacturing operations. Hopefully, managers benefit from this study as a prescriptive framework in identifying the dominant driving force in their industry (market vs. operational), determining the variables that guide their organizational decisions and draw from organizational configurations discussed here in determining theirs.

## 8.3 Limitations and Future Research

Finally, I would like to acknowledge some limitations to this study. Methodologically this study is constrained by the limitations of case study methodology. Certain actions are taken to reduce the observer bias and increase the validity and reliability as proposed by Yin (1994). For example, interviews were tape-recorded to decrease interviewer bias, then the transcriptions were examined separately and our findings merged. From these transcribed interviews, we identified the conflicts and consensus, and triangulated with multiple sources of information for the hypotheses. We use multiple case studies to increase external validity, and examined OEM remanufacturing in two different settings: consumer and capital goods. We used multiple sources of information, in some case multiple informants, to increase the validity and reliability of our results.

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# Appendix

## Case Coding for Capital Goods Companies

Table A.1 Capital Goods Companies Case Coding

| | | | |
|---|---|---|---|
| | **GE** | **Xerox** | **Pitney Bowes** |
| **Industry** | **industrial** | **industrial** | **Industrial** |
| **Products** | **traction motors, diesel engines** | **Docutech and Igen copiers** | **Postal equipment** |
| **Driver** | **Profitable** | **Profitable** | **Profitable** |
| **First started remanufacturing operations because** | Customer Service | Returns+Customer Service | Customer Service |
| **Is it a core business?** | Yes | Yes | Yes |
| **Outsourcing policy for remanufacturing** | Cost-driven/FWD supply chain oriented outsourcing policy | Cost-driven/FWD supply chain oriented outsourcing policy | Cost-driven/FWD supply chain oriented outsourcing policy |
| **Outsourcing Unit** | Component/Subsystem | Component/Subsystem | Component/Finished Product |
| **Outsourcing Decision and Remanufacturing frequency** | Independent of each other | Independent of each other | Independent of each other |
| **Condition Uncertainty** | No problem | Problem | Problem |

| | | | |
|---|---|---|---|
| **Volume Uncertainty** | No problem | Problem | No problem |
| **Approaches for returns, material and labor estimation** | Field operations and maintenance data, part failure database | Lease/Rental agreement data, Ratio Management based on past experience and part failure | Lease agreement data |
| **Sales channel for remanufacturing** | Direct | Direct Sales, Authorized Resellers, Agents | Direct |
| **Is sales channel same with NEW?** | Same | Same | Same |
| **Compete with remanufacturing Product in lower-end market** | Never places remanufactured products in lower-end market | Never places remanufactured products in lower-end market | N/A |
| **Potential problems in 3rd party involvement problems** | Brand name | Customer service issues, Lost sales, brand name | Brand name, customer service, compliance to government contracts |
| **IP** | Very important | Very important | Important |
| **Actions for IP protection** | Confidentiality agreements, patents | Confidentiality agreements, patents, local sourcing for more control | Confidentiality agreements |
| **Labor quality and reliability in remanufacturing outsourcing** | Supplier Quality programs and Certifications | Training programs | Supplier Quality programs and Certifications |
| **Technological Uncertainty** | No problem | No problem now, but a big problem for future | No problem |
| **What happens if Tech uncertainty is a problem?** | More supplier involvement | More supplier involvement | Controlled environment |
| **Reverse engineering and design** | No | Yes | Yes |
| **How?** | Not enough, a concern | Extensive analyses in product labs. For both own and competitor products | Collaboration with suppliers |
| **Design for remanufacturing** | No | Yes | No |
| **How?** | Should do | Coding products, and designing for | Interested |

| | | | |
|---|---|---|---|
| | | (dis)assembly | |
| **Complexity** | Not a factor in outsourcing decision | Not a factor in outsourcing decision | Decision variable in outsourcing |
| **Remanufacturing Organization** | Mixed, some in the same production line, some in different facilities. No structured evaluation | Disassembly separate line, Reassembly same line with new products family | Mixed, some in-house some outsourced. Structured evaluation based on complexity, proximity |
| **Is market attractive** | Yes | Yes | Yes |
| **Market without you?** | Would be bigger and more fragmented. There would more competition and more players for GE's share of the market | n/a | More competitive |
| **Entrepreneurial Incentive** | A threat to market | A threat to market | A threat to market |
| **Marketing/Remanufacturing Interface** | No dependencies, Service organization makes demand planning and direct sales if used. No need for information sharing. | n/a | n/a |
| **Rewards Distribution** | Not fair at all | n/a | n/a |
| **Organization** | Vertical integration with component based outsourcing depending on the product | Vertical integration with component based outsourcing for parts coming from suppliers | Vertical integration with selective structured outsourcing policies based on parts and finished goods |
| **Manufacturing Outsourcing (New)** | High | High | |
| **Pitfalls** | Incentive schemes for suppliers should be reviewed | Stop-rule for remanufacturing. No end-of-life strategy | Uncertainty |

| | | | |
|---|---|---|---|
| **Ideal Organization** | Separate facilities for product families. An CAT-like separate business division might work well | Modeling whole remanufacturing process understanding the economics of it. No change at all in the technical side. | More organized approach, overall happy with the current organization |
| **KPIs** | None in place for remanufacturing, but should be | Cost of remanufacturing a product, material cost and labor, inventory: in-process inventory, inventory at the warehouse and finished goods inventory. Financials are the same | Same as manufacturing |
| **Quantitative contribution of the remanufacturing overall business** | 2/3 of the revenues GE transportation | Between 5-10 % ROS | 30% ROS |
| **Product life-cycle** | 20 years, extendable up to 30 | 3 years lease 5 year lifecycle remanufacturing up to 3-4 times | 7-10 year with typical leas terms of 48 months |

# Case Coding for Consumer Goods Companies

Table A.2 Consumer Goods Companies Case Coding

| | 58 | 60 | 50 |
|---|---|---|---|
| | **HP** | **Black and Decker** | **Bosch** |
| **Industry** | **commercial** | **commercial** | **commercial** |
| **Products** | **printing, imaging products** | **power tools** | **power tools** |
| **Driver** | **Minimize Loss** | **Minimize loss** | **Minimize loss** |
| **First started remanufacturing operations because** | Returns | Returns | Returns |
| **Is it a core business?** | No | No | Yes |
| **Outsourcing policy for Remanufacturing** | Company Policy | In-house (exceptions to products that are not core competence)+ Some outsourcing driven by FWD supply chain outsourcing policy | In-house (exceptions to products that are not core competence)+ Some outsourcing driven by FWD supply chain outsourcing policy |
| **Outsourcing Unit** | Product | Product | Product |
| **Outsourcing decision and remanufacturing frequency** | Independent of each other | Independent of each other | Independent of each other |
| **Condition Uncertainty** | Problem | Problem | Problem |
| **Volume Uncertainty** | Problem | Problem | Problem |
| **Approaches for returns, material and labor estimation** | Past experience, information sharing with remanufacturing partners | Past experience, part failure database | Past experience |
| **Sales Channel for Remanufacturing** | Resellers, authorized channels | Independent Channels | Secondary market for Skil, primary channel for Bosch |
| **Is sales channel same with NEW?** | No | No | Yes/No |
| **Compete with remanufactured products in lower-end market** | Never places remanufactured products in lower-end | Never places remanufactured products in lower-end | Yes |

| | | | |
|---|---|---|---|
| **Potential problems in 3rd party involvement problems** | Quality problems, Customer service issues | Brand name, market control | Brand name, warranty failure data |
| **IP** | Very important | Not important, generic accessible IP | Not important, generic accessible IP |
| **Actions for IP protection** | Confidentiality agreements, patents | Patents | Patents |
| **Labor quality and reliability in remanufacturing outsourcing** | Training and information sharing with partners | In-house remanufacturing | In-house remanufacturing |
| **Technological Uncertainty** | Problem | No problem | No problem |
| **What happens if Tech uncertainty is a problem?** | Dealing with Tech. evolution now, already in the business model | Speedup remanufacturing and pay attention to inventory | Should be more careful? |
| **Reverse engineering and design** | Yes | Yes | Yes |
| **How?** | Share quality and returns data with product group | Formal tear-down, product failure investigations (Open-to-improvement) | Formal tear-down |
| **Design for remanufacturing** | No | No | No |
| **How?** | - | design for assembly helps a little | it will help but not cost effective |
| **Complexity** | Not a factor in outsourcing decision | Not a factor in vertical integration decision | Not a factor in vertical integration decision |
| **Remanufacturing Organization** | Each product in separate facilities where they manufactured in the first place | Separate facilities and recon lines, generic for many products | Separate work cells, work benches and conveyors |
| **Is market attractive** | Yes | Yes | Yes it is profitable. No, too costly for a third party to bear |
| **Market without you?** | Don't know | n/s | Fragmented and competitive |
| **Entrepreneurial Incentive** | No | No | No |

| | | | |
|---|---|---|---|
| **Marketing/Remanufacturing Interface** | There is some dependency but In a working relationship. Information sharing and regular dialog | Mostly with sales and not dependencies and no problems | Some dependency but well working relationships |
| **Rewards Distribution** | Very fair | Not a lot of recognition | Recognition |
| **Organization** | All outsourcing except for remarketing/resale | Vertical integration with component based outsourcing for parts coming from outside suppliers | Vertical integration with component based outsourcing |
| **Manufacturing Outsourcing (New)** | 100% | 20% | 25-30% |
| **Pitfalls** | Decision making process for pricing remanufactured products could be more effective | Location problems and high transportation costs from that | None |
| **Ideal Organization** | Change the decision making process | Utilize outside companies more, outsource non-value adding operations | none |
| **KPIs** | repair, recovery, the cost of support returns as a percent of revenue, same KPIs as manufacturing | Efficiency of labor, recovery rate, budget, other manufacturing KPIs | Regular manufacturing KPIs and recovery rate |
| **Quantitative contribution of remanufacturing overall business** | Not significant but positive | Less than a percent in overall revenue | 15% off new product |
| **Product life-cycle** | 4 years | 5 years | 5 years |