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STRATEGIC INVESTMENTS IN THE RIGHT CRM TECHNOLOGIES, IN THE RIGHT AMOUNT, AND IN THE RIGHT ORDER

Valuing IT Opportunities

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Abstract

Although many companies have spent a great deal of money to adopt CRM (Customer Relationship Management) technologies, many have not seen satisfactory returns on their CRM installations. One of the reasons for such dissatisfaction and low ROI may be the lack of a comprehensive approach to evaluating the impact of CRM technologies, which are very different from traditional cost-cutting and quality-improving IT. To bridge the gap between the existing research stream on IT investment and firms' dissatisfaction with returns on CRM technologies, we aim to analyze the optimal CRM implementation strategy and the impact of CRM investments on a firm's profitability. For our analysis, we classify CRM technology into two broad categories, targeting-related CRM technology and support-related CRM technology. We find that the two types of CRM technologies are substitutive in generating firms' revenue rather than complementary. We also find that firms' investments in both targeting-related CRM and support-related CRM can decrease consumer welfare under certain conditions. We develop a model that not only considers different factors across industries and environments, but is also helpful in determining the right CRM technology, in the right amount, and in the right order.

Keywords: Customer Relationship Management, IT investments, consumer surplus

Introduction

Researchers have studied the impact of firms' IT (Information Technology) investments to increase productivity, to lower cost or to improve quality (e.g. Barua et al. 1991, 1995; Brynjolfsson 1996; Brynjolfsson and Hitt 1996; Demirhan et al. 2006; Mukhopadhyay et al. 1995, 1997; Thatcher and Pingry 2004). The vast literature has provided firms and managers interested in investing in IT with the knowledge of how to make IT investments under different conditions and the impact of such investments on profits and customers. Recently, more firms are attempting to adopt CRM (Customer Relationship Management) technologies, and the demand for more advanced CRM software has also grown rapidly. While one of the motivations to adopt CRM technologies includes saving the cost of marketing operations, such technologies are focusing on better understanding customers and enhancing the long-term relationship with customers (Dyche 2001; Rigby et al. 2004; Xu et al. 2001). According to IDC, the CRM market grew by 8 percent in 2004, resulting in total market revenues of 8.8 billion dollars; buyers' intentions to implement CRM and to focus on CRM initiatives remained high in 2005. Datamonitor also forecasted that the market for CRM software in the United States and major European countries is expected to increase by 9 percent annually over the next six years. [1]

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[1] This figure is comparable to 7 percent annual growth of ERP spending (IT Facts 2005).

Unfortunately, despite lots of money spent by companies (typically $5,000 a seat and $2 million to $5 million per deployment), many of them did not see a satisfactory return on their CRM installations (Fox 2001).[2] We attribute one of the reasons for such dissatisfaction and low ROI to the lack of understanding of the impact of CRM technologies, which are very different from traditional cost-cutting and quality-improving IT. On the one hand, due to the popularity of the CRM concept and the marketing efforts of CRM software vendors, firms are likely to make a biased decision to overinvest in the wrong CRM technologies and end up with low ROI unless a full consideration of their environments and customers is given. In fact, it has been often reported that many CRM features and much of the functionality is never used after implementation (Lacey 2002). On the other hand, firms are not choosing the appropriate implementation approach to maximize their returns. For the implementation of large-scale enterprise software such as ERP and CRM, firms may choose a phased implementation to avoid high risks posed by a large software project or choose an all-at-once approach (a.k.a. a big-bang approach), where every component is delivered at once (Fichman and Moses 1999). The pros of an all-at-once implementation cite early returns, faster implementation, lower cost, and better systems integration as its advantages, while the cons emphasize the learning, sustained momentum and lower risks of failure as the advantages of a phased implementation (Dennis et al. 2005; Duplaga and Astani 2003; Fichman and Moses 1999; Mabert et al. 2000). Despite the debate about which implementation approach is better, the literature has not considered the revenue aspect specific to CRM implementation. Furthermore, since ordinary CRM projects take years to complete, a firm's profit is subject to not only the implementation approach but also the order of implementing different CRM technologies. As a result, firms often revise their approach during CRM implementation, which is the greatest reason for cost escalation (CIO 2002).

To bridge the gap between the existing research stream on IT investment and firms' dissatisfaction with returns on CRM technologies, we study the optimal CRM implementation strategy and the impact of CRM investments on a firm's profitability. This study differs from the prior literature in two aspects. First, we address the new role of information technologies by analyzing the impact of customer-oriented technologies. Second, we attempt to capture the multi-faceted effects of CRM technologies and how these effects may interact in generating revenues. CRM software that can be purchased from commercial software vendors usually consists of various modules such as marketing automation, call-center, analytical, self-service, and sales force automation modules with distinct functionalities. Based on our analysis and interviews with CRM experts and consultants, we classify CRM software modules into two broad categories, targeting-related CRM modules and support-related CRM modules, to analyze the optimal CRM implementation strategy and their impacts on customers. This taxonomy is useful and essential in studying the optimal CRM implementation strategy because implementing each category of CRM technology not only requires different sets of knowledge and resources but also has distinct impact on a firm's profit and customers.

Since implementing support-related CRM technology should consider interactions with customers, training of employees and systems development should be done in a way to meet customers' individual expectations and maximize their value (Xu et al. 2002). On the outcome side, targeting-related CRM modules are associated with direct profit generation due to increased knowledge of customers and include marketing automation, analytics, and business intelligence modules. Support-related CRM modules are associated with relationship-building with customers by providing enhanced service; they include call-center, e-business, field service, and self-service modules. This taxonomy is similar to the industry view of CRM technologies as "front-office CRM" and "back-office CRM" (Dyche 2001). We conjecture that customers' willingness to pay increases with a firm's investments in targeting-related CRM technology, while the probability of high valuation of a product or service may improve with support-related CRM technology. Our main results can be summarized as follows.

- Different types of CRM investments can be substitutive from the revenue point of view. The conventional wisdom has been that computer assets are likely to be complementary. This substitution effect strengthens the possibility that a firm can specialize in one category of CRM technologies rather than choosing to be an all-

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[2] For example, when managers were asked to assess three key functions of CRM — marketing-campaign management, call-center management, and marketing analytics — no more than 35 percent of the respondents responded that their expectations had been met in any function (IDC 2001). A Merrill Lynch survey of CIOs at large companies found that 45 percent of those surveyed were not satisfied with CRM installations (ZDNet 2002). Nucleus Research, Inc. surveyed 23 CRM customers all selected by Siebel Systems, Inc. and reported that 61% of the surveyed CRM customers were yet to achieve anything close to an acceptable return on investment after two years with Siebel applications, which cost an average of about $6.6 million over a three-year period (Manakas 2002).

around player by investing in diverse CRM technologies. Misperceptions of the substitutive effect will lead to overinvestment (Siggelkow 2002) in CRM technologies, which may explain why firms do not receive as much benefit as they expect.

▪ The simultaneous implementation of both types of CRM technologies is likely to be optimal under stronger economies of scale or a vendor's discount on a bundled software purchase. When economies of scale or a vendor's discount are not sufficiently high, a firm endowed with a high portion of loyal customers may specialize in support-related CRM technology rather than targeting-related CRM technology.

▪ While more investments in targeting-related CRM technology decrease consumer surplus due to the increased capability to discriminate between loyal and non-loyal customers, investments in support-related CRM modules can either decrease or increase consumer surplus depending on the level of targeting-related CRM technologies. This result is interesting because a firm's efforts to maintain long-term relationship with customers may be merely a means of extracting maximum consumer surplus when coupled with proper customer analyzing technologies. Therefore, although IT investments at the aggregate level have increased consumer welfare (Brynjolfsson 1996), a firm's specific investments in CRM may decrease consumer welfare under certain conditions.

▪ While many firms select an all-at-once implementation to earn larger gains early, we find a counter-intuitive result. Since the two types of CRM technologies are substitutive by nature, a firm may prefer to concentrate on one type of CRM technology at the early period if a firm's discount factor is lower rather than to go with an all-at-once implementation.

The managerial implication of this paper is that the economic impact of different types of CRM technologies should be understood in order to decide its optimal implementation scope and strategies with a full consideration of market conditions, the degree of (dis)economies of scale, and the characteristics of goods sold. Since consumer welfare may even decrease with firms' investments in CRM technologies, using consumer surplus as a measure of IT value may have a limitation in the new era of CRM technologies.

Related Literature

This paper is related to several streams of IS and marketing literature. First, the IS literature has a well-established tradition of research on the impact of IT investments, optimal IT investments, and how different types of IT investments may become complementary. Barua et al. (1991) analyzed the strategic impact of IT investments that improve quality of service under a duopoly setting. Thatcher and Pingry (2004) studied the various impacts of IT investments that lead to a reduction in the design cost parameter or in the variable production cost parameter. Demirhan et al. (2006) examined IT investment strategies when IT investments improve the quality level of product and IT acquisition cost decreases over time. Firm-level empirical studies (Brynjolfsson 1996; Brynjolfsson and Hitt 1996) showed that IT investments increased firm's productivity and consumer surplus. Similarly studies of specific technologies (e.g. Kekre and Mukhopadhyay 1992; Mukhopadhyay and Kekre 2002; Mukhopadhyay et al. 1995; Riggins and Mukhopadhyay 1994; Srinivasan et al. 1994) and research at the process level (e.g. Ashworth et al. 2004; Davamanirajan et al. 2006; Mukhopadhyay and Mangal 1997; Mukhopadhyay et al. 1997) have quantified IT value at a finer level. Zhu (2004) found that e-commerce capability and IT infrastructure are complementary in creating business value measured by financial performance. On the implementation of large-scale enterprise software, there has been a debate about which implementation approach will work better, a phased approach or an all-at-once approach. The advocates of a phased approach argue that a big-bang approach is never a viable option or even results in as much as 20 percent drop in productivity level (Best 2003). Nevertheless, empirical evidence supports that a big-bang approach is often adopted and even successful in some cases. Especially, Duplaga and Astani (2003) found that 40 percent of the firms adopting ERP used a big-bang approach. They even found that smaller organizations implementing ERP with a big-bang approach proved more successful than larger firms using a gradual rollout.[3]

The term "CRM" emerged in the IT vendor and practitioner community in the mid-1990s and the terms "relationship marketing" and CRM are often used interchangeably in the academic community (Payne and Frow

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[3] For example, SAP, one of the largest enterprise software vendors of ERP and CRM, lists numerous success stories with a big-bang implementation of ERP and CRM packages on its Web site.

2005). The focus in the marketing CRM literature has been on how to optimize marketing mix in order to enhance relationships with customers and the longer term profit of a firm based on customers' life time value. For example, Rust and Verhoef (2005) addressed the issue of designing a mix of marketing interventions (e.g. direct mail, Internet contacts, personal selling contacts, telephone contacts, etc.) for each individual customer and showed that responses to marketing interventions is highly heterogeneous across customer characteristics and customers' past interactions with a company. Ho et al. (2006) incorporated customer satisfaction into a customer life time value model and analyzed the optimal investment in customer satisfaction. The latest review of the CRM literature by Rust and Chung (2006) suggests that it is useful to classify the literature on service and CRM into four categories: 1) managing service to addresses the strategic and tactical decisions (e.g. pricing) that a firm must make to acquire and retain customers effectively, 2) customizing service to study the firm's efforts to personalize and individualize service products and service delivery, 3) customer satisfaction and relationships to address the mechanisms that result in a successful, continuing customer relationship, and 4) the financial impact of customer relationships to quantify the profitability of its customer relationships.

In contrast to the rich literature of CRM that studies how to optimize marketing activities, relatively less effort has been made to study the role and impact of CRM technology (Mithas et al. 2005). This tendency is partly due to a "holistic" view of CRM beyond technology implementation (Payne and Frow 2005). Although CRM can be implemented without sophisticated technology (Rigby et al. 2002), technology is essential for successful CRM deployment at any firm with a significant size. Several studies have addressed the issue of investing in customer-oriented technologies. Chen et al. (2001) examined the impact of investing in targetability, a firm's ability to distinguish between its loyal and non-loyal customers, and the equilibrium investment amount. They showed that firms' investments in targetability will be determined by a number of loyal customers and the cost of acquiring targetability. Chen and Iyer (2002) labeled the ability to reach and customize price and other marketing efforts to the tastes of the individual consumer as consumer addressability. Given that information technology should improve a firm's addressability, it might not be desirable for all direct marketing firms to indefinitely pursue greater addressability under competition even if the costs of doing so decline. Villas-Boas (2004) studied an extreme case of a monopolist's customer recognition capability and found that the monopolist can be worse off if it could not recognize its previous customers. More recently, Jayachandran et al. (2005) showed that CRM technologies for sales support, marketing support, service support, analysis support, access support, and customer database are the facilitators of relational information processes and lead to increased customer relationship performance measured by customer satisfaction and customer retention. Srinivasan and Moorman (2005) showed that firms with more investments in CRM activities and technology achieved greater customer satisfaction. Mithas et al. (2005) showed that the use of CRM applications is associated with improved customer knowledge and greater customer satisfaction.

Overall, while the prior literature in IS has examined the impact of investments in IT that improve quality, increase productivity, or lower the marginal cost of quality and how such technologies should be obtained, a newer role of IT as a CRM enabler has not been studied much. The CRM literature has not also studied the technology aspect of CRM yet. Only a limited number of studies have examined how different technology-enabled CRM capabilities may influence competition and profits, but they lack the consideration of how such capabilities can be achieved in terms of investments in specific technologies and CRM modules. The gap between the literatures may be partly associated with dissatisfaction with CRM implementation. Our study will bridge the gap between the two streams of literatures by investigating what and how CRM technologies should be purchased and implemented under varying conditions and what the impact of such investments on consumer surplus is.

Model

CRM Classification from the IT Perspective

To analyze the effects of CRM technologies, we classify diverse CRM modules available from commercial software vendors into two broad categories: targeting-related and support-related CRM modules based on our analysis and interviews with CRM experts and consultants. This taxonomy is useful and essential in studying the optimal implementation strategy of CRM because implementing each category of CRM software technologies not only

requires different sets of knowledge and resources but also has distinct impact on a firm's profit and customers. For this reason, firms often choose to implement one type of CRM modules first and move to implementing the other type of CRM modules. We define targeting-related CRM modules as software components that involve analyzing customers' preferences and purchasing behaviors without direct interactions with customers. This type of CRM technology is often called "back-office" CRM (Dyche 2001). Though they may be sold by different names by different CRM vendors, examples of targeting-related CRM modules include marketing automation modules, analytical modules, and business intelligence modules. The expected benefit of implementing such modules is the enhanced ability to analyze customers' preference and better target those customers for future marketing activities. As we will see shortly, we model this benefit as a firm's increased accuracy in classifying customers as either loyal or non-loyal customers.

In addition, we define support-related CRM modules as software components that involve direct interactions with customers to provide customized service, which is often called "front-office" CRM. Examples of support-related CRM modules include call-center, e-business, sales force automation, and field service modules. These modules enable a firm to streamline communications from and to customers. Since implementing support-related modules should consider direct interactions with customers, training of employees and systems development should be done in a way to meet customers' individual expectations and maximize their value (Xu et al. 2002). The expected benefit of implementing these modules is the enhanced ability to support customers and derive higher customer satisfaction. We will model this benefit as an increased probability of customers to stay or become loyal after their purchases. Table 1 summarized our taxonomy of CRM modules. [4]

Table 1. Categorization of CRM Modules			
Category	Examples	Expected Benefit	Modeling
Targeting-related CRM Modules	Marketing Analytical modules Business intelligence	Enhanced targeting accuracy	Accurate classification of customers
Support-related CRM Modules	Call-center Sales force Field service Order management	Enhanced customer support quality	Higher probability of being loyal

Revenue from CRM Implementation

We assume that customers are heterogeneous in that there exist two types of customers: loyal (L) and non-loyal (NL) customers. Loyal customers are those who are insensitive to price and willing to repurchase whether they are offered any price promotion or not (Chen et al. 2001; Rigby and Ledingham 2004; Varian 1980). Non-loyal customers are those who are sensitive to price and willing to purchase a product only when they are offered price promotion. A product is priced at p , which is exogenously given throughout the paper. Let d denote a promotional discount and c denote the cost to reach one individual customer. This setting is congruent with common managerial practices of offering discounts to newer and vulnerable customers (Rigby and Ledingham 2004). Due to the cost of contacting an individual customer and the risk of offering a promotion to a loyal customer, a firm's objective is to contact only non-loyal customers and offer them a price promotion. This setting is more applicable to the industries where price variability is very low and an introductory rate is widely accepted without customers' resistance.

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[4] Although this classification is useful, this view has a limitation as well. The limitation and possible improvement will be discussed at the end of the paper.

Selected examples of such industries include those involved with broadband Internet connection service, cable TV service, credit card service with low APR and free balance transfer service (Villas-Boas 2004).

Let S denote the level of investments in support-related CRM modules defined over a continuous space $[S_0, \infty]$ and S_0 denote the level of pre-installed support-related CRM base.[5] We assume that the customers who purchased in the previous period can become either loyal or non-loyal in the next period and the probability of old customers becoming loyal is a function of a firm's support modules, which is $f(S)$. In fact, several research papers have found a link between CRM technology, customer satisfaction, and retention (Jayachandran et al. 2005; Mithas et al. 2005; Mittal et al. 2001; Rust and Zahorik 1993; Srinivasan and Moorman 2005). We will assume $f'(S) > 0$ and $f''(S) < 0$ so that a firm's support level increases with support modules implemented, but at a decreasing rate. [6]

We further assume that those who did not purchase in the previous period always remain non-loyal in the next period. This assumption is reasonable because a customer who did not purchase in the past is unlikely to be loyal in the current period. In the marketing literature, it has been well-known that a customer's choice is influenced by past purchase history due to the state dependence of customers, also known as purchase feedback, (Guadagni and Little 1983; Heckman 1981), habit-persistence (Heckman 1981), or unobserved heterogeneity (Roy et al. 1996). This type of state dependency of loyal customers is similar to the definition of loyalty in Guadagni and Little (1983). Each customer purchases at most one unit of a product or service every period from a single product monopolist (Villas-Boas 2004). We normalize the market size to 1 and denote the initial size of loyal segment in period 0 by l_0. The perceived size of a loyal segment in the n-th period is denoted l_n.

After the sizes of both loyal and non-loyal segments are determined by a firm's support level, it attempts to classify customers between loyal and non-loyal customers, which is congruent with the role of targeting and discrimination accuracy in the literature (Chen et al. 2001; Rigby et al. 2004). Again, we let T denote the level of targeting-related CRM modules defined over a continuous space $[T_0, \infty]$ and T_0 denote the level of pre-installed targeting-related CRM base. Now define $\Pr(i \mid j)$ as the probability that a firm classifies the customer from a segment j into a perceived segment i, where $i, j \in \{L, NL\}$. The revenue function can be derived as in Lemma 1.

Lemma 1   Suppose a firm attempts to provide a selective promotional offer only to the non-loyal segment of customers to avoid the cost of contacting an individual customer and the risk of offering a promotion to a loyal customer, its revenue in period n becomes $\pi_n = l_n p + (1 - l_n)\{\Pr(NL \mid NL)p - (c + d)\}$.

Since the revenue function only depends on $\Pr(NL \mid NL)$, we let $\Pr(NL \mid NL)$ the targeting accuracy of a firm as a function of the targeting modules implemented. That is, define $g(T) = \Pr(NL \mid NL)$. We assume $g'(T) > 0$ and $g''(T) < 0$ so that a firm's targeting accuracy increases with the scope of targeting modules implemented at a decreasing rate as in the case of support modules. Figure 1 describes the timeline of our model.

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[5] This assumption can be justified because the installation of one CRM module can be divisible into a number of features and functionalities that may be considered continuously defined. Therefore, while the modular investment in technology has been often adopted in the literature (e.g. Cyert et al. 1978), this context seems to be most appropriate to apply the approach. In addition, we can interpret the initial condition, S_0, as a firm's CRM capability to adopt new CRM systems.

[6] The concavity assumption represents decreasing returns to CRM investments. That is, firms can attain higher CRM capability as they invest more in CRM, but it becomes increasingly difficult to improve its level of service and targeting accuracy. This assumption is similar to the widely accepted assumption of the quadratic cost function of quality in the industrial organization literature, where it becomes increasingly difficult to improve product quality.
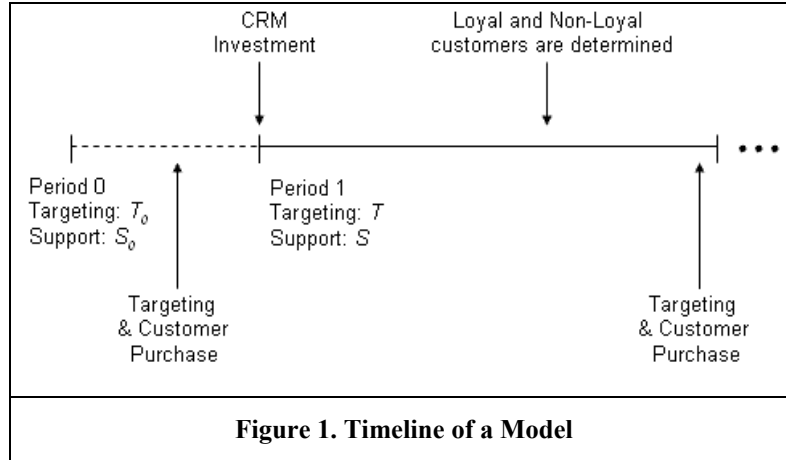
Figure 1. Timeline of a Model

The sizes of both segments can be represented as a Markov process. We define the transition matrix of a customer state as

$$\text{period } n+1$$

$$\text{period } n \quad M = \begin{array}{c} Loyal \\ Non-Loyal \end{array} \begin{array}{cc} Loyal & Non-Loyal \\ \begin{bmatrix} f(S_n) & 1-f(S_n) \\ g(T_{n-1})f(S_n) & 1-g(T_{n-1})f(S_n) \end{bmatrix} \end{array}$$

where S_n and T_{n-1} denote the level of support modules in period n and the level of targeting modules in period $n-1$, respectively. From the matrix above, as a non-loyal customer switches to a loyal customer, she should be classified correctly as a non-loyal customer and be offered a promotion in period $n-1$ with probability $g(T_{n-1})$, and then be supported by a firm as a legitimate customer and become loyal with probability $f(S_n)$. For example, if the size of the loyal segment in period $n-1$ was l_{n-1}, the size of loyal segment in the next period becomes $l_n = l_{n-1}f(S_n) + (1-l_{n-1})g(T_{n-1})f(S_n)$.

Cost of CRM Implementation

We assume that the cost of CRM implementation increases as more targeting- and support-related CRM modules are implemented. However, we assume that a certain level of pre-existing marketing applications enables a firm to save its implementation cost. That is, if a firm has already deployed basic marketing-oriented applications, it is likely to have more IT infrastructure, lower organizational resistance, and readiness to adopt more advanced CRM. For analytical tractability, we assume a simple form of the cost function that increases with number of modules implemented but decreases with pre-installed CRM base. For targeting-related CRM modules, we assume the cost of implementation to be $C_T = \alpha_T(T-T_0)$. Similarly, we assume $C_S = \alpha_S(S-S_0)$ for support-related CRM modules. The two coefficients, α_T and α_S, can be interpreted as marginal costs of unit module implementation. We assume that α_T and α_S are exogenously given constants with $\alpha_T > 0$ and $\alpha_S > 0$.[7] If a firm implements both types of modules simultaneously, we assume the cost of implementation to be

$$C(S,T) = (\alpha_T + K)(T-T_0) + (\alpha_S + K)(S-S_0).$$

K is a parameter that take effects only when the two types of modules are implemented in the same period. For instance, a CRM vendor may offer a discount on a bundled purchase of two types of modules, which will lead to a

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[7] We can expect that marginal costs of implementation, α_T and α_S, increase with the number of licensed users, the level of software customization, and required training during a CRM implementation project.

negative K.[8] In addition, if a firm can benefit from economies of scale for a simultaneous implementation, K can be further reduced. However, K can be also positive in case there exist diseconomies of scale for a simultaneous implementation. In fact, Siebel, the largest CRM vendor, has recommended a phased implementation rather than a big-bang implementation of CRM modules to its customers due to difficulties in managing a large software project.

CRM Implementation Strategy

Optimal Implementation Strategy

In this section, we consider that each consumer has only one purchasing incidence after CRM implementation and derive the optimal strategy. Therefore, the results in this section will be more applicable to durable goods because durable goods involve less frequent purchases by customers over their lifetime compared to non-durable goods. The purchase of durable products is characterized by buyers' purchasing a product and then staying away from the market for a long period, before they return to the market either to purchase an additional item or to replace an existing durable (Grewal et al. 2004). For service industries, the cycle of interactions with customers and the frequency of decisions on continued subscription may vary across industries as well. From our previous industry examples, we observe that the length of promotional credit card service tends to be longer than that of promotional discounts in cable TV. We consider that a firm can choose from one of three CRM implementation strategies: targeting-specialization, support-specialization, and simultaneous implementation strategy. First, for the targeting specialization strategy, the transition matrix is

$$A = \begin{bmatrix} f(S_0) & 1-f(S_0) \\ g(T_0)f(S_0) & 1-g(T_0)f(S_0) \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$$

and the revenue is

$$\pi_T = \{l_0 A_{11} + (1-l_0)A_{21}\}p + \{l_0 A_{12} + (1-l_0)A_{22}\}[g(T)p - (c+d)].$$

The support specialization strategy and the simultaneous implementation strategy shares the same transition matrix, which is

$$B = \begin{bmatrix} f(S) & 1-f(S) \\ g(T_0)f(S) & 1-g(T_0)f(S) \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}.$$

The revenue function for the support specialization strategy is

$$\pi_S = \{l_0 B_{11} + (1-l_0)B_{21}\}p + \{l_0 B_{12} + (1-l_0)B_{22}\}\{g(T_0)p - (c+d)\},$$

while the revenue function for the simultaneous implementation strategy is

$$\pi_{TS} = \{l_0 B_{11} + (1-l_0)B_{21}\}p + \{l_0 B_{12} + (1-l_0)B_{22}\}\{g(T)p - (c+d)\}.$$

From the first order conditions of three implementation strategies, we can obtain the optimal implementation scopes for each strategy. To obtain a closed form solution, we assume $f(S) = 1 - e^{-aS}$ and $g(T) = 1 - e^{-bT}$,[9] which satisfy our assumptions of $f'(S) > 0$, $f''(S) < 0$, $g'(T) > 0$, and $g''(T) < 0$. [10]

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[8] For example, some vendors such as Epicor and Oncontact explicitly offer quantity discounts.

[9] This form is the same as a CDF of an exponential distribution with rate S and T, respectively. This assumption not only models the state change of an individual customer in a unit time but also simplifies mathematical treatment significantly. The use of an exponential distribution to model the state change of a customer is often used for customer value analysis (e.g. Ho et al. 2006)

[10] a and b can be considered the effectiveness of CRM technology and we assume $a > 0$ and $b > 0$ so that investing in CRM technology does not lead to inferior performance. This assumption can be justified by latest

Lemma 2 If a firm chooses to implement only targeting-related CRM modules, the optimal implementation scope is given by $T^{**} = \log\left[bp\{1 - l_0 f(S_0) - (1 - l_0)g(T_0)f(S_0)\}/\alpha_T\right]^{\frac{1}{b}}$.

ii) If a firm chooses to implement only support-related CRM modules, the optimal implementation scope is given by $S^{**} = \log\left[a\{l_0 + (1 - l_0)g(T_0)\}\{p - g(T_0)p + (c + d)\}/\alpha_S\right]^{\frac{1}{a}}$.

iii) If a firm chooses to implement both types of CRM modules simultaneously, the optimal implementation scopes, denoted T^* and S^*, satisfy the following conditions: $T = \log\left[bp\{1 - l_0 f(S) - (1 - l_0)g(T_0)f(S)\}/(\alpha_T + K)\right]^{\frac{1}{b}}$ and $S = \log\left[a\{l_0 + (1 - l_0)g(T_0)\}\{p - g(T)p + (c + d)\}/(\alpha_S + K)\right]^{\frac{1}{a}}$.

Our first proposition determines on the optimal implementation strategy under varying conditions.

Proposition 1 The conditions under which each strategy dominates the others are given in Table 2. l^+, K^+, and K^{++} are provided in the Appendix.

Table 2. Optimal CRM Implementation Strategy		
	(Dis)economies of scale	Optimal Strategy
Smaller loyal segment $(l_0 < l^+)$	$K > K^+$	Targeting CRM Specialization
	$K < K^+$	Simultaneous
Larger loyal segment $(l_0 > l^+)$	$K > K^{++}$	Support CRM Specialization
	$K < K^{++}$	Simultaneous

Proposition 1 has several important implications. First, the simultaneous implementation strategy is optimal under strong economies of scale and the discount on a bundled software purchase, while the specialization strategies of either targeting or support modules are optimal under strong diseconomies of scale. It is interesting that a simultaneous implementation of both targeting and support modules is not always preferred even if there exist economies of scale (i.e., $K < 0$). In other words, in case K^+ or K^{++} is negative, specialization in targeting or support can dominate a simultaneous implementation even under economies of scale and the discount on a bundled purchase. Similarly, in case K^+ or K^{++} is positive, a simultaneous implementation can dominate targeting or support specialization strategy even in the presence of diseconomies of scale. Figure 2 illustrates Proposition 1 graphically.

Second, a firm in the industry with a large loyal customer base will prefer specialization in support-related CRM technology to targeting-related CRM technology. Thus, under a sufficiently large loyal customer base, a firm will choose between targeting specialization strategy and simultaneous implementation strategy while it will choose between support specialization strategy and simultaneous implementation strategy under a smaller loyal customer base. For example, when Union National Community Bank, a small regional bank in Mount Joy, PA, could not retain many customers, it decided to spend about $250,000 on a CRM package that allowed it to segment its 37,000 accounts by profitability using CRM analytics and business intelligence modules (Overby 2002). The implementation effort illustrates the targeting-oriented strategy under a small segment of loyal customers. As an example of support specialization, the CRM implementation in York International, a leading provider of heating,

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empirical studies (e.g. Jayachandran et al. 2005; Mithas et al. 2005; Srinivasan and Moorman 2005). This may not be true in case of mismanagement of CRM, which takes place in reality, but is not the focus of this paper.

ventilation, and air conditioning, focused more on call center, service sales, and service execution, which can be classified as support-related modules according to our categorization.

Figure 2. Optimal CRM Implementation Strategy on $l_0 K$ -plane
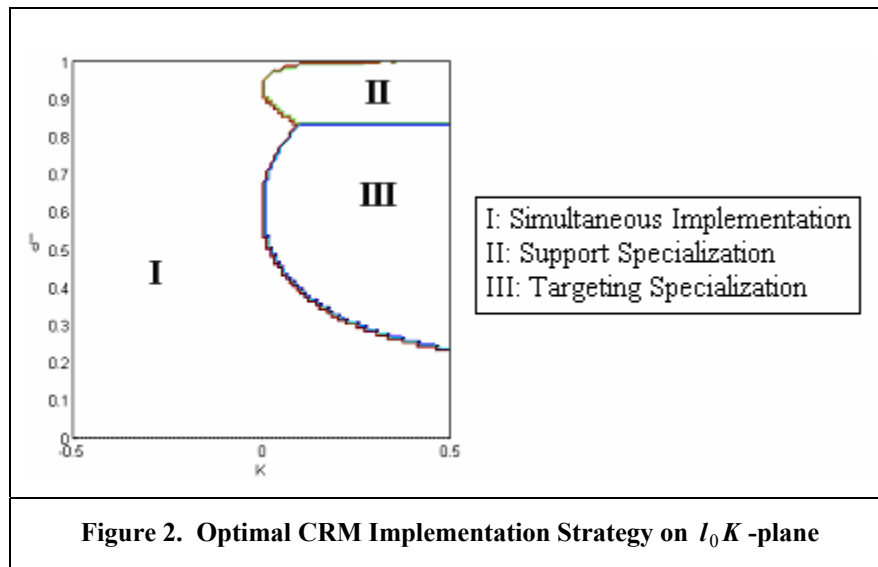
Strategic Implications of CRM Implementation

Proposition 2   When both targeting and support CRM modules are implemented simultaneously, the two types of CRM modules substitute the effect of each other. The degree of substitutability increases in S and T.

In recent years, the topic of interaction among activity choices of firms has received a burst of attention in the organization, economics, management, and IS literatures (Milgrom and Roberts 1990; Siggelkow 2002; Zhu 2004). Our interest in the CRM context is whether the investment in one type of CRM technology will increase (i.e., strategic complements) or decrease (i.e., strategic substitutes) the marginal return to the increase in the other type of CRM technology. Avoiding misperceptions of such interactions is important because such misperceptions are likely to lead to either underinvestment or overinvestment in CRM systems. Interestingly, we find that one type of CRM technology substitute the effectiveness of the other type of CRM technology and the degree of substitution increases in both S and T. The investment in support-related modules is likely to increase the size of loyal segment. However, the marginal benefit of targeting-related modules relies on the size of non-loyal segment. The more loyal customers there exist, the less incentive to invest in targeting-related modules a firm has because its ROI is likely to decrease. Therefore, when the level of support is high and there are more loyal customers, the marginal return to investing in targeting modules decreases as well. These interactions create a substitution effect of the investments in two types of modules. Thus, targeting-related and support-related CRM modules can be strategic substitutes in case of durable goods where customers' purchases are made infrequently over their life time. More traditional view on why too much investment in CRM at once may not work has focused on the ignorance of diseconomies of scale on the cost side, which is modeled as a positive K in this paper. Our finding suggests that a firm should pay attention to avoid overinvestment in CRM by considering the substitution effect on the revenue side as well. It is notable that this result is somewhat contradictory to Chen et al. (2001 p.37), who argued that at the industry level, the total investment in loyalty-building and the total size of loyal customers both increase with targetability. While a higher targetability increases the payoffs from loyal customers as argued in the paper, a more drastic reduction of the payoff from non-loyal customers may take place when we let the investments in support-related modules as loyalty-building technology and targeting-related modules be determined simultaneously.

Proposition 3   We have the following comparative statistics in the equilibrium.

i) For a simultaneous implementation, $\partial T / \partial K > 0$, if and only if $(\partial^2 \Pi / \partial T \partial S) < (\partial^2 \Pi / \partial S^2)$. Similarly, $\frac{\partial S}{\partial K} > 0$ if and only if $(\partial^2 \Pi / \partial T \partial S) < (\partial^2 \Pi / \partial T^2)$. In addition, $\partial \Pi / \partial K < 0$.

ii) For all three implementation strategies, $\partial \Pi / \partial T_0 > 0$, $\partial \Pi / \partial S_0 > 0$, and $\partial \Pi / \partial l_0 > 0$ in the equilibrium. In addition, $\partial \Pi / \partial l_0$ increases in S, while $\partial \Pi / \partial l_0$ decreases in T.

Interestingly, an increase in K does not always lead to a decrease in the optimal T and S in the simultaneous implementation strategy. That is, although a firm expects more diseconomies of scale, it may still increase the scope of its implementation projects when the substitution effect is very strong (i.e., under very low negative $\partial^2 \Pi / \partial T \partial S$). This result implies that CRM software vendor may be able to earn more profit by decreasing its discount on a bundled purchase, because this policy change can lead to larger implementation scopes by a CRM adopting firm. However, the profit of a client firm decreases in K.

We also found that a firm with higher capability in terms of T_0 and S_0 and a firm with more favorable market conditions in terms of l_0 will end up with more profits after its CRM implementation no matter what implementation strategy is chosen. These results predict that early adopters of CRM are likely to be the firms that had already invested more in front-office IT applications in the past, which is congruent with our observation that the heaviest and earliest investors in CRM have been from the financial and banking industry. Furthermore, loyal customers are important assets that make CRM more profitable. While a firm with a large loyal customer base may seemingly have little incentive to do CRM, ceteris paribus, a firm with a larger loyal customer base still has an incentive to implement CRM because $\partial \Pi / \partial l_0 > 0$. We can interpret $\partial \Pi / \partial l_0$ as the marginal value of having one more unit of loyal customer. Since $\partial \Pi / \partial l_0$ increases in S but decreases in T, we find that the shift of one non-loyal customer to a loyal one is more profitable for a firm when it has high support capability. This is because with the high level of support capability, a firm is more likely to retain the loyal customer and thus she is more valuable to a firm. However, when it has high targeting capability, it will have less incentive to obtain more loyal customers because a firm can more precisely tell to which segment their customers belong and thus its profit becomes less sensitive to the number of loyal customers. In other words, the marginal return on support modules increases as there exist more loyal customers, but the marginal return on targeting modules decreases as there exist more loyal customers.

Determinants of Implementation Scope

Proposition 4   Comparative statics for the optimal implementation scopes are given in Table 3.

Table 3. Comparative Statistics for the Optimal Implementation Scopes						
Effect / Strategy	∂T			∂S		
	∂S_0	∂T_0	∂l_0	∂S_0	∂T_0	∂l_0
Targeting	(-)	(-)	(-)	N/A	N/A	N/A
Support	N/A	N/A	N/A	0	(+)/(-)*	(+)
Simultaneous	0	(-)	(-)	0	(+)	(+)

* $\partial S / \partial T_0 > 0$ if and only if $T_0 < \log\left[2(1-l_0)p / \{p - (c+d)(1-l_0)\}\right]^{\frac{1}{b}}$. $\partial S / \partial T_0 \leq 0$, otherwise.

Next, we examine how various factors influence the optimal implementation scopes. Interestingly, the high level of pre-installed targeting induces less investment in targeting-related modules, while the high level of pre-installed targeting base induces more investment in support-related modules in the simultaneous implementation. This result is appealing because high S_0 leads to an increase in the current size of loyal segment, which reduces the

profitability of investments in targeting modules in turn. In contrast, high T_0 leads to more investments in support modules because a firm is likely to face more old customers who recently purchased and thus a larger loyal customer segment.

We also found that a firm in the industry with more loyal customers will implement more support-related modules rather than targeting modules. This becomes obvious when we compare specialized CRM modules for different industries offered by most large CRM software vendors. For example, in the financial industry, customers are price-sensitiv,e and CRM modules for the industry tend to include more targeting-related features. By contrast, CRM modules for the industrial manufacturing industry consist of more support-related features including service and order management.

CRM Technologies and Consumer Surplus

In this section, we examine the resultant consumer welfare when a firm adopts targeting and support-related CRM modules simultaneously. We will assume a utility function of an individual customer, which is consistent with our previous transition matrix. We propose the following.

$$U = v - \overline{P}$$

U : consumer utility

v : customers' valuation of a good determined by service quality, where [11]

$$v = \begin{cases} \overline{v} & \text{, if one is a loyal customer} \\ \underline{v} & \text{, if one is a non-loyal customer} \end{cases}$$

$\overline{P}$: price paid by a consumer, where $\overline{P} = \begin{cases} p - d & \text{, if a promotion is offered} \\ p & \text{, otherwise} \end{cases}$

We further assume that $\overline{v} \geq p$ and $p > \underline{v} \geq p - d$, to ensure that a loyal customer purchases even without any promotion, but a non-loyal customer purchases only when she is offered a promotional offer.[12] We obtain the following consumer surplus function.

$$CS = \{l_0 B_{11} + (1 - l_0)B_{21}\}(\overline{v} - p) + \{l_0 B_{12} + (1 - l_0)B_{22}\}[g(T)(\underline{v} - p + d) + \{1 - g(T)\}d].$$

That is, $\overline{v} - d$ is the amount of surplus that loyal customers receive when they purchase at p. Since $\{l_0 B_{12} + (1 - l_0)B_{22}\}$ customers receive a promotional offer, the additional surplus of loyal customers who are incorrectly classified as non-loyal customers is d for each customer. We reach Proposition 5.

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[11] This setting of two types of customer valuation level to analyze a firm's customer recognition capability can be found in the literature like Villas-Boas (2004).

[12] That is, if $\overline{v} < p$, even a loyal customer does not purchase a product at p. If $\underline{v} < p - d$, a non-loyal customer does not make a purchase even under a promotion. Moreover, if $p \leq \underline{v}$, a non-loyal customer makes a purchase even without a promotion.
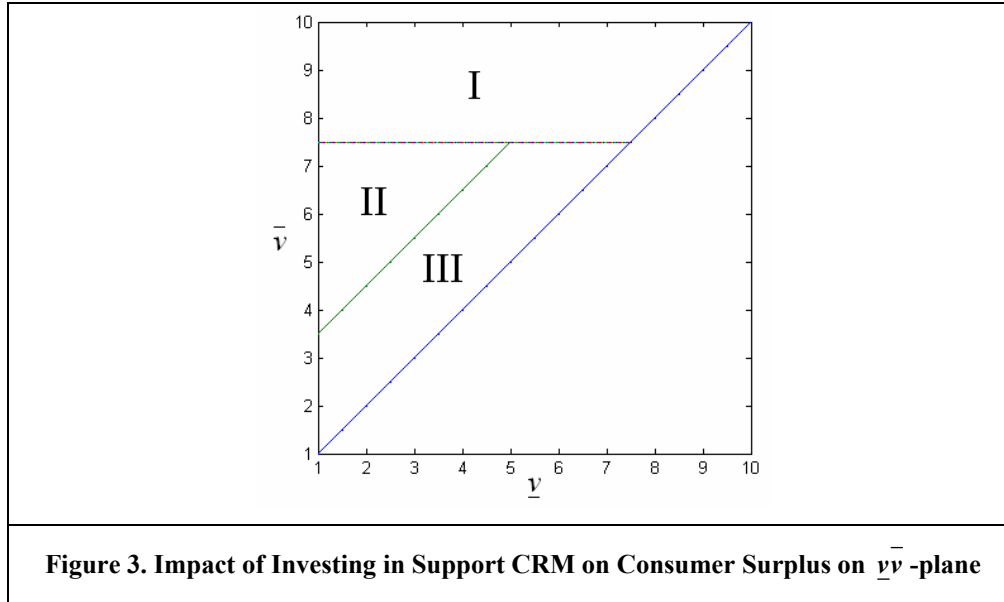
Figure 3. Impact of Investing in Support CRM on Consumer Surplus on $\underline{v}\bar{v}$ -plane

Proposition 5   For a simultaneous implementation of both targeting and support-related CRM technologies,

i) Enhanced targeting accuracy due to targeting-related technology decreases consumer surplus.

ii) If $\bar{v} > p + d$, then an increase in S leads to an increase in consumer surplus (Region I in Figure 3). If $\bar{v} < \underline{v} + d$, then an increase in S leads to a decrease in consumer surplus (Region III in Figure 3). In the less extreme case of $\underline{v} + d < \bar{v} < p + d$, consumer surplus increases in S under sufficiently high T , but decreases in S , otherwise (Region I in Figure II).

iii) If consumer surplus decreases in S , more surplus is extracted under higher T . If consumer surplus increases in S , marginal increase in surplus is higher under higher T .

Proposition 5-i) makes sense because a firm can extract more surplus from its perceived loyal customers as it improves its targeting accuracy with more sophisticated targeting-related CRM modules. Since enhanced targeting accuracy enables a firm to charge different prices to different segments of customers more precisely, consumer surplus from loyal customers who can purchase at lower price diminishes as a result of targeting modules. The effect of support-related CRM modules is mixed. The level of targeting modules does not matter in determining whether investing in support modules increase or decrease in two extreme cases. First, if the valuation of a loyal customer is very large such that $\bar{v} > p + d$, then an increase in S always leads to an increase in consumer surplus (Region I in Figure 3). Thus, when the valuation of a loyal customer is sufficiently large, customers can be also better off by a firm's efforts to build better relationship with its customers. Second, if the valuation of a loyal customer is very small and only slightly larger than that of a non-loyal customer such that $\bar{v} < \underline{v} + d$, an increase in S always leads to a decrease in consumer surplus (Region III in Figure 3). In this case, investing in support-related CRM technology can be viewed as a method to extract more surplus from customers.

In the intermediate case of $\underline{v} + d < \bar{v} < p + d$ (Region II in Figure 3), however, investing in support modules can either increase or decrease consumer surplus depending on the level of targeting modules to be implemented. Interestingly, raising S results in an increase in consumer surplus only when T is sufficiently high. The reason for this result can be explained as follows. Under low T , most surplus comes from the customers who are misclassified as non-loyal customers. Therefore, if S increases, the expected number of non-loyal customers decreases and thus the number of customers who can be potentially misclassified decreases, which leads to a decrease in consumer surplus. To the contrary, if T is high, the reduction in non-loyal customers due to increased S does not decrease consumer surplus much, but increases surplus from new loyal customers more drastically. Therefore, though a firm's advanced targeting capability reduces consumer surplus, customers can be better off from a firm's

implementation of targeting modules when the firm plans to further implement support modules. This result implies that while a firm can extract more consumer surplus by implementing targeting-related CRM technology, the upside effect of targeting on customers is that the positive effect of support-related CRM technology on consumer surplus can be augmented in the presence of a proper level of targeting technology. The fact that investments in both types of CRM technologies can decrease consumer surplus is very surprising. This suggests that while firm's investments in IT increase consumer surplus at the aggregate level as in Brynjolfsson (1996), there is a possibility that firms' CRM investments enable them to extract most surplus from consumers by building long-term relationship with customers and decrease consumer welfare in the end.

Order of CRM Implementation

For implementation of large-scale enterprise software like ERP and CRM, firms may either choose a phased implementation to avoid the high risk posed by a large software project or choose an all-at-once approach (Fichman and Moses 1999). The pros of an all-at-once implementation cite early returns, faster implementation, lower cost, better systems integration as the advantages of all-at-once implementation, while the cons emphasize learning, sustained momentum and lower risk of failure as advantages of a phased implementation (Dennis et al. 2005; Duplaga and Astani 2003; Fichman and Moses 1999; Mabert et al. 2000). In reality, CRM software vendors such as Siebel recommend that CRM modules should be implemented in a phased manner rather than in a big-bang manner to reduce the risk from radical changes and cost overruns. However, many firms still employ an all-at-once implementation (CIO 2002; Duplaga and Astani 2003; Mabert et al. 2000,). A firm's initial decision on an appropriate approach is important because a revision of the implementation approach, incurs budget increase and dissatisfaction with CRM (CIO 2002). Despite the debate on which approach in enterprise software implementation is better, an all-at-once or a phased implementation, there has been little research on the revenue aspect of implementation approach. Furthermore, since ordinary CRM projects take years to complete, a firm's profit is likely to be sensitive to not only the implementation approach but also the order of implementing different CRM modules in case a firm is selling non-durable goods with more frequent purchasing incidences by customers. That is, when implementation is to be phased, should a firm improve the relationship with customers through enhanced support-related CRM technology or adopt targeting-related CRM technology for immediate revenue generation? We will consider three implementation strategies over two periods as follows.

- Implement both support-related CRM modules and targeting-related CRM modules simultaneously in period 1 (All-at-once Strategy)

- Implement support-related CRM modules in period 1 and targeting-related CRM modules in period 2 (Support-to-Targeting Strategy)

- Implement targeting-related CRM modules in period 1 and support-related CRM modules in period 2 (Targeting-to-Support Strategy)

The last two strategies can be classified as phased implementation strategies. [13] We will assume that a firm makes a decision on the implementation strategy and scope at the beginning of period 1. Our main foci in this section will be 1) under what conditions one implementation strategy dominates others and 2) how a firm's time preference influences the its optimal implementation strategy and order of CRM implementation.

The strength of our model is that it is scalable to any number of periods and length of implementation periods so that we can consider non-durable goods. For example, the size of loyal and non-loyal customers can be decided by

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[13] Phasing CRM implementation by two types of CRM technologies is natural and reasonable because implementing each type of CRM technology requires different sets of skills and expertise. Another option when a firm has multiple remote locations is phasing CRM implementation by locations, but this approach is beyond the scope of this paper.

$$
M^n = \begin{bmatrix}
\begin{aligned}
& f(S)^n\{1-g(T)\}^{n-1} \\
& + \frac{g(T)f(S)\{f(S)^{n-1}\{1-g(T)\}^{n-1}-1\}}{f(S)\{1-g(T)\}-1}
\end{aligned}
&
\begin{aligned}
& \{1-f(S)\}f(S)^{n-1}\{1-g(T)\}^{n-1} \\
& + \frac{\{1-f(S)\}[f(S)^{n-1}\{1-g(T)\}^{n-1}-1]}{f(S)\{1-g(T)\}-1}
\end{aligned}
\\[2em]
\begin{aligned}
& g(T)f(S)^n(1-g(T))^{n-1} \\
& + \frac{g(T)f(S)\{f(S)^{n-1}\{1-g(T)\}^{n-1}-1\}}{f(S)\{1-g(T)\}-1}
\end{aligned}
&
\begin{aligned}
& \{1-g(T)f(S)\}f(S)^{n-1}(1-g(T))^{n-1} \\
& + \frac{\{1-f(S)\}[f(S)^{n-1}\{1-g(T)\}^{n-1}-1]}{f(S)\{1-g(T)\}-1}
\end{aligned}
\end{bmatrix}.
$$

As the period approaches infinity, the transition matrix converges to

$$
M^\infty = \begin{bmatrix}
\dfrac{g(T)f(S)}{1-f(S)\{1-g(T)\}} & \dfrac{1-f(S)}{1-f(S)\{1-g(T)\}} \\[1.5em]
\dfrac{g(T)f(S)}{1-f(S)\{1-g(T)\}} & \dfrac{1-f(S)}{1-f(S)\{1-g(T)\}}
\end{bmatrix} = \begin{bmatrix}
m_{11}^{(\infty)} & m_{12}^{(\infty)} \\[1em]
m_{21}^{(\infty)} & m_{22}^{(\infty)}
\end{bmatrix}.
$$

Thus, a firm will have loyal customers whose size is given by $\dfrac{g(T)f(S)}{1-f(S)\{1-g(T)\}}$ as $n \to \infty$. This size increases in both S and T. If a firm is more concerned about building a long-term relationship that involves more frequent purchases over a customer's lifetime and doesn't discount future profits very much, its initial capabilities like S_0 and T_0 will count less in making an implementation decision. In addition, since $\dfrac{\partial^2 m_{11}^{(\infty)}}{\partial S \partial T} < 0$, two types CRM technologies are likely to be strategic substitutes in the infinite time horizon case when δ, the discount factor $\delta \in (0,1)$, is sufficiently high. Therefore, for a firm that sells non-durable goods with more frequent purchases, the effect of one type of CRM modules is also likely to substitute the effect of the other type of modules as we observed in the previous section. This result highlights the substitutive nature of two types of CRM modules even when a firm is involved with more frequent interactions with customers through purchases.

Proposition 6   As δ decreases and a firm places less importance on the future, a firm's optimal implementation strategy can change from an all-at-once implementation to a phased implementation.

Figure 4 shows the result of our numerical analysis with a two period model. As Proposition 6 states, a decrease in the discount factor can lead to a transition of the optimal implementation strategy from an all-at-once implementation to a phased implementation. This is surprising because one of the greatest incentives for a firm to implement CRM in a big-bang manner is to realize larger profits as early as possible. With this incentive, a more plausible prediction would be the reverse case: moving from a phased implementation to an all-at-once implementation as its future profit becomes less important. However, since the two types of CRM technologies are substitutive by nature, a firm may prefer to concentrate on one type of CRM technology at the early period as a firm's discount factor decreases.

Figure 4. Optimal CRM Implementation Strategy on $l_0 K$ -plane (Left: $\delta = 0.95$, Right: $\delta = 0.5$)
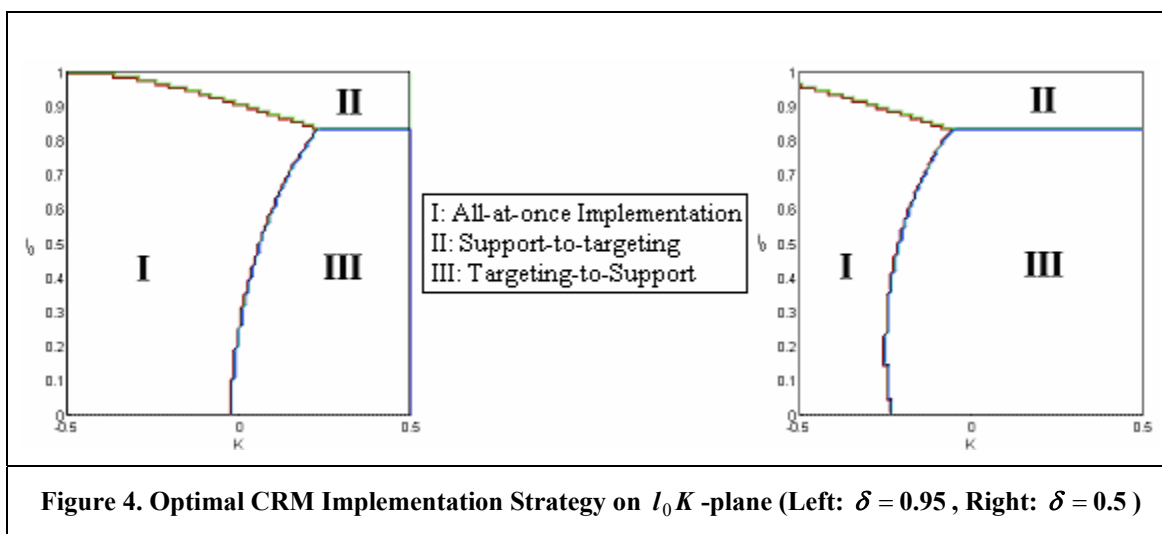
Figure 4 also shows other interesting points. First, the all-at-once implementation strategy is optimal under strong economies of scale or discount on a bundled purchase while phased implementation strategies are preferred under strong diseconomies of scale. If K is sufficiently large and diseconomies of scale are strong, then a firm will consider a phased implementation and choose between a targeting-to-support strategy and a support-to-targeting strategy depending on the given l_0. If there are more loyal customers, a firm will prefer to implement support-related CRM modules first and then move to targeting-related CRM modules. An example of the support-to-targeting strategy can be found in Heinz Company. As a dominant company in branded foods, Heinz has maintained a large loyal customer base. [14] We find that Heinz is considering more targeting-oriented CRM modules after its successful completion of support-oriented CRM (Clark 2004). Second, although economies of scale favor an all-at-once implementation, the simple existence of such economies of scale do not ensure that an all-at-once implementation is preferred. If l_0 is very small as in Figure 4, a firm can select the targeting-to-support strategy even in case K is negative. Furthermore, if l_0 is very high, a firm may prefer support-to-targeting strategy although K is negative. Therefore, even when a firm can benefit from economies of scale (i.e., $K < 0$), it may plan a phased implementation in consideration of increased revenues from focusing on one type of CRM technology first. To the contrary, a firm may prefer an all-at-once implementation even under diseconomies of scale with positive K. This is interesting when we consider the debate on the implementation strategy between an all-at-once and a phased implementation has been mostly centered on cost economics.

To summarize, our results suggest three new points to the debate on CRM implementation strategies. First, when a firm sells non-durable goods to customers, it should pay attention not only to the choice between a phased and an all-at-once implementation, but also to the order of implementing different types of CRM technologies. Second, an all-at-once implementation should not be selected only because a firm wants to reap large gains from CRM early. Third, the existence (dis)economies of scale in CRM implementation cost does not simply ensure that one approach is preferred to the other. The focus should be shifted to how large such effect is compared to the revenue side.

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[14] In an effort to assure customer satisfaction, Heinz created a customer relationship model called First Call to offer services and capabilities that makes Heinz its customer's "First Call," accompanied by CRM software. At its core, the CRM software automatically deposits funding into customer accounts by forecasting volume, promotions and spend, with updates on deductions and payment requests on a daily basis and up-to-the minute shipment and consumption information.

Discussion, Conclusions, and Future Research

In this paper, we developed a parsimonious model to investigate the optimal CRM strategy under various conditions. The main contribution of this paper is that instead of viewing CRM technology as a single composite innovation, we examined the interactive nature of different types of CRM technologies depending on its economic impact to open up the black box of CRM software implementation. Without consideration of the interactions between different types of CRM technologies, a firm may make a biased decision to either overinvest or underinvest in CRM systems. This may explain why many companies are not satisfied with their CRM investments. We investigated how a firm's profit and the optimal scopes of CRM implementation change under varying conditions. We also showed that a firm's investments in support-related CRM technology, which is seemingly to build better relationship with customers, may be a way to extract more surplus from consumers using its targeting-related CRM technology. In addition, while a firm can extract more consumer surplus by adopting advanced targeting-related modules, there is a case where consumer surplus increases in a firm's investments in support CRM modules only in the presence of a proper level of targeting-related CRM. We extended the issue of selecting the right implementation approach between an all-at-once and a phased implementation to selecting the right order of CRM implementation. Surprisingly, even when a firm places more importance on the early return, it can be optimal to choose a phased implementation. Our model framework is easily scalable to consider many important factors and helpful in determining the right CRM technology, in the right amount, and in the right order. Ultimately, this study is expected to bridge the gap between the existing research stream on IT investment and firms' dissatisfaction with returns on CRM technologies.

Despite the interesting results of this paper, the parsimony of our model had a tradeoff of making several restrictive assumptions for analytical tractability.[15] First, an important issue is the independence of two types of CRM technologies. It is possible that a firm benefits more from the integration of front-end and back-end CRM systems. For example, a firm will have better knowledge of customers with an analysis of call-center interactions. Second, targeting CRM in our model is mainly used for price discrimination, but it may be used for other purposes: cross-selling, up-selling, new product development, and so on. Third, the cost function takes a specific form, which may drive our results. The first and second limitations are related to whether the two categories of CRM technologies are mutually exhaustive and exclusive. In reality, they may not be perfectly exhaustive and exclusive. Nevertheless, the classification is useful, corresponds to the practitioner's view of CRM, and provides insights into what the firm's CRM implementation strategy should be. Our current work in progress focuses on incorporating a system integration parameter and generalizing the model in order to make our model applicable to a broader context.

This study can be improved and extended in several ways. First, while we fixed the number of customers over periods, we can also consider that the market size can change by allowing customers to enter or exit the market. In this case, a firm may have to use more advertising as a way to attract new customers rather than making targeted offers. Second, our model can be also extended to examine the effect of competition. An interesting question would be how the role of support and targeting-related CRM innovation changes under competition. Third, while we assumed that customers are not forward-looking, it is possible that customers' behaviors change when they can predict that they will be locked in as the cost of becoming loyal. For example, a rather extreme case can be found as in Villas-Boas (2004), where a monopolist can be worse off if it can not recognize its previous customers. Finally, empirical tests of the results in the paper may be also interesting. For example, we can study whether firms' IT spending in CRM has either increased or decreased consumer surplus. In addition, we can test whether firms' investments in CRM were influenced by their existing marketing-related applications and their market conditions. A number of possible extensions of our paper imply that it can inspire more research from the perspective of both information systems and marketing.

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Appendix

Proof of Lemma 1)

First, as a measure of probability, the following two regularity conditions must be satisfied.

$$\Pr(L \mid NL) + \Pr(NL \mid NL) = 1 \quad \text{and} \quad \Pr(L \mid L) + \Pr(NL \mid L) = 1 .$$

In addition, we assume that the perceived size of two segments ought to be equal to the corresponding sizes of the actual market as in Chen et al. (2001). That is,

$$l \cdot \Pr(L \mid L) + (1-l) \cdot \Pr(L \mid NL) = l \quad \text{and} \quad l \cdot \Pr(NL \mid L) + (1-l) \cdot \Pr(NL \mid NL) = 1-l .$$

Using these conditions, the profit and cost consists of three components as follows.

$$\begin{aligned}
\pi_n &= l_n \, \Pr(L \mid L)p + l_n \, \Pr(NL \mid L)(p-c-d) + (1-l_n) \Pr(NL \mid NL)(p-c-d) \\
&= l_n p + (1-l_n) \Pr(NL \mid NL)p - (1-l_n) \Pr(NL \mid NL)(c+d) - l_n \, \Pr(NL \mid L)(c+d) \\
&= l_n p + (1-l_n) \Pr(NL \mid NL)p - (1-l_n)(c+d) \\
&= l_n p + (1-l_n)\{\Pr(NL \mid NL)p - (c+d)\}.
\end{aligned}$$

Proof of Lemma 2 and Proposition 1)

For targeting specialization, since

$$A = \begin{bmatrix} f(S_0) & 1-f(S_0) \\ g(T_0)f(S_0) & 1-g(T_0)f(S_0) \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix},$$

$$\Pi_T = \pi_T - C_T = \{l_0 A_{11} + (1-l_0)A_{21}\}p + \{l_0 A_{12} + (1-l_0)A_{22}\}[g(T)p - (c+d)] - \alpha_T(T - T_0).$$

From FOC,

$$\frac{\partial \Pi_T}{\partial T} = \frac{\partial \pi_T}{\partial T} - \alpha_T = 0 \iff \{l_0 A_{12} + (1-l_0)A_{22}\}g'(T)p - \alpha_T = 0$$

$$\iff T^{**} = \log\left[\frac{bp\{1-l_0 f(S_0) - (1-l_0)g(T_0)f(S_0)\}}{\alpha_T} \right]^{\frac{1}{b}}$$

For support specialization, since

$$B = \begin{bmatrix} f(S) & 1-f(S) \\ g(T_0)f(S) & 1-g(T_0)f(S) \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix},$$

$$\Pi_S = \pi_S - C_S = \{l_0 B_{11} + (1-l_0)B_{21}\}p + \{l_0 B_{12} + (1-l_0)B_{22}\}[g(T_0)p - (c+d)] - \alpha_S(S - S_0).$$

From FOC,

$$\frac{\partial \Pi_S}{\partial S} = \frac{\partial \pi_S}{\partial S} - \alpha_S = 0 \iff \{l_0 B'_{11} + (1-l_0)B'_{21}\}p + \{l_0 B'_{12} + (1-l_0)B'_{22}\}[g(T_0)p - (c+d)] - \alpha_S = 0$$

$$\Leftrightarrow S^{**} = \log\left[\frac{a\{l_0 + (1-l_0)g(T_0)\}\{p - g(T_0)p + (c+d)\}}{\alpha_S}\right]^{\frac{1}{a}}$$

For a simultaneous implementation strategy,

$$\Pi_{TS} = \pi_{TS} - C(S,T)$$

From FOC,

$$\pi_{TS} = \{l_0 B_{11} + (1-l_0)B_{21}\}p + \{l_0 B_{12} + (1-l_0)B_{22}\}[g(T)p - (c+d)]$$

$$\frac{\partial \Pi_{TS}}{\partial T} = \frac{\partial \pi_{TS}}{\partial T} - \alpha_T - K = 0 \Leftrightarrow T = \log\left[\frac{bp\{1 - l_0 f(S) - (1-l_0)g(T_0)f(S)\}}{\alpha_T + K}\right]^{\frac{1}{b}}$$

$$\frac{\partial \Pi_{TS}}{\partial S} = \frac{\partial \pi_{TS}}{\partial S} - \alpha_S - K = 0 \Leftrightarrow S = \log\left[\frac{a\{l_0 + (1-l_0)g(T_0)\}\{p - g(T)p + (c+d)\}}{\alpha_S + K}\right]^{\frac{1}{a}}$$

Since $\dfrac{\partial^2 \Pi_{TS}}{\partial T^2} < 0$ and $\dfrac{\partial^2 \Pi_{TS}}{\partial S^2} < 0$, in order to satisfy the second-order conditions and ensure global concavity, the condition below must be satisfied.

$$\begin{vmatrix} \dfrac{\partial^2 \Pi_{TS}}{\partial T^2} & \dfrac{\partial^2 \Pi_{TS}}{\partial T\partial S} \\ \dfrac{\partial^2 \Pi_{TS}}{\partial S\partial T} & \dfrac{\partial^2 \Pi_{TS}}{\partial S^2} \end{vmatrix} = \frac{\partial^2 \Pi_{TS}}{\partial T^2} \cdot \frac{\partial^2 \Pi_{TS}}{\partial S^2} - \left(\frac{\partial^2 \Pi_{TS}}{\partial S\partial T}\right)^2 > 0.$$

Now

$$\Pi_{TS} - \Pi_T > 0 \Leftrightarrow K < \frac{V_1}{T^* + S^* - T_0 - S_0} = K^+$$

, where

$$V_1 = \{f(S^*) - f(S_0)\}\{l_0 + (1-l_0)g(T_0)\}p + \{l_0(1 - f(S^*)) + (1-l_0)(1 - g(T_0)f(S^*))\}[g(T^*)p - (c+d)]$$
$$- \{l_0(1 - f(S_0)) + (1-l_0)(1 - g(T_0)f(S_0))\}[g(T^{**})p - (c+d)] + \alpha_T(T^{**} - T^*) - \alpha_S(S^* - S_0)$$

In the same manner,

$$\Pi_{TS} - \Pi_S > 0 \Leftrightarrow K < \frac{V_2}{T^* + S^* - T_0 - S_0} = K^{++}$$

, where

$$V_2 = \{f(S^*) - f(S^{**})\}\{l_0 + (1-l_0)g(T_0)\}p + \{l_0(1 - f(S^*)) + (1-l_0)(1 - g(T_0)f(S^*))\}[g(T^*)p - (c+d)]$$
$$- \{l_0(1 - f(S^{**})) + (1-l_0)(1 - g(T_0)f(S^{**}))\}[g(T_0)p - (c+d)] + \alpha_S(S^{**} - S^*) - \alpha_T(T^* - T_0)$$

In addition,

$$\Pi_T - \Pi_S > 0$$

$$\Leftrightarrow l_0 \begin{bmatrix} \{f(S_0) - g(T_0)f(S_0)\}p + \{(1-f(S_0)) - (1-g(T_0)f(S_0))\}[g(T^{**})p - (c+d)] \\ -\{f(S^{**}) - g(T_0)f(S^{**})\}p - \{(1-f(S^{**})) - (1-g(T_0)f(S^{**}))\}[g(T_0)p - (c+d)] \end{bmatrix}$$
$$+ g(T_0)f(S_0)p + (1-g(T_0)f(S_0))[g(T^{**})p - (c+d)]$$
$$- g(T_0)f(S^{**})p - (1-g(T_0)f(S^{**}))[g(T_0)p - (c+d)] - \alpha_T(T^{**} - T_0) + \alpha_S(S^{**} - S_0) > 0$$

$$\Pi_T - \Pi_S > 0 \Leftrightarrow l_0 U_1 + U_2 > 0 \Leftrightarrow l_0 < -\frac{U_2}{U_1} = l_0^+,$$

where

$$U_1 = (1 - g(T_0))[\{f(S_0) - f(S^{**})\}p + f(S^{**})\{g(T_0)p - (c+d)\} - f(S_0)\{g(T^{**})p - (c+d)\}] < 0$$

and

$$U_2 = \{f(S_0) - f(S^{**})\}g(T_0)p + (1-g(T_0)f(S_0))[g(T^{**})p - (c+d)]$$
$$- (1-g(T_0)f(S^{**}))[g(T_0)p - (c+d)] - \alpha_T(T^{**} - T_0) + \alpha_S(S^{**} - S_0)$$

since

$$U_1 = \begin{bmatrix} \{f(S_0) - g(T_0)f(S_0)\}p + \{(1-f(S_0)) - (1-g(T_0)f(S_0))\}[g(T^{**})p - (c+d)] \\ -\{f(S^{**}) - g(T_0)f(S^{**})\}p - \{(1-f(S^{**})) - (1-g(T_0)f(S^{**}))\}[g(T_0)p - (c+d)] \end{bmatrix}$$
$$= (1-g(T_0))[\{f(S_0) - f(S^{**})\}p + [f(S^{**})[g(T_0)p - (c+d)] - f(S_0)[g(T^{**})p - (c+d)]]]$$
$$< (1-g(T_0))[\{f(S_0) - f(S^{**})\}p + [f(S^{**})[g(T^{**})p - (c+d)] - f(S_0)[g(T^{**})p - (c+d)]]]$$
$$= (1-g(T_0))\{f(S_0) - f(S^{**})\}[p\{1 - g(T^{**})\} + (c+d)] < 0$$

Proof of Proposition 2)

$$\frac{\partial^2 \Pi_{TS}}{\partial S \partial T} = \left\{ l_0 \frac{\partial B_{12}^{(1)}}{\partial S} + (1-l_0)\frac{\partial B_{22}^{(1)}}{\partial S} \right\} pg'(T)$$
$$= -[l_0 f'(S) + (1-l_0)g(T_0)f'(S)]pg'(T) < 0.$$

In addition, supposing $D = \frac{\partial^2 \Pi_{TS}}{\partial S \partial T}$,

$$\frac{\partial D}{\partial S} = -f''(S)[l_0 + (1-l_0)g(T_0)]pg'(T) > 0,$$

$$\frac{\partial D}{\partial T} = -[l_0 f'(S) + (1-l_0)g(T_0)f'(S)]pg''(T) > 0$$

Thus, D increases in both S and T.

Proof of Proposition 3)

i) Suppose $\Pi_{TS}^T = \frac{\partial \Pi_{TS}}{\partial T} = 0$ and $\Pi_{TS}^S = \frac{\partial \Pi_{TS}}{\partial S} = 0$. Taking the total derivative of the two equation,

$$\frac{\partial \Pi_{TS}^T}{\partial T}dT + \frac{\partial \Pi_{TS}^T}{\partial S}dS + \frac{\partial \Pi_{TS}^T}{\partial K}dK = 0,$$

$$\frac{\partial \Pi_{TS}^S}{\partial T} dT + \frac{\partial \Pi_{TS}^S}{\partial S} dS + \frac{\partial \Pi_{TS}^S}{\partial K} dK = 0 \,.$$

Thus, by applying Cramer's rule,

$$\frac{\partial T}{\partial K} = \frac{\begin{vmatrix} -\dfrac{\partial \Pi_{TS}^T}{\partial K} & \dfrac{\partial \Pi_{TS}^S}{\partial T} \\ -\dfrac{\partial \Pi_{TS}^S}{\partial K} & \dfrac{\partial \Pi_{TS}^S}{\partial S} \end{vmatrix}}{H(T,S)} = \frac{1}{H(T,S)}\left(\frac{\partial \Pi_{TS}^S}{\partial S} - \frac{\partial \Pi_{TS}^S}{\partial T} \right) \,.$$

Therefore, $\dfrac{\partial T}{\partial K} > 0$ if and only if $\dfrac{\partial^2 \Pi}{\partial T \partial S} < \dfrac{\partial^2 \Pi}{\partial S^2}$.

$$\frac{\partial S}{\partial K} = \frac{\begin{vmatrix} \dfrac{\partial \Pi_{TS}^T}{\partial T} & -\dfrac{\partial \Pi_{TS}^T}{\partial K} \\ \dfrac{\partial \Pi_{TS}^T}{\partial S} & -\dfrac{\partial \Pi_{TS}^S}{\partial K} \end{vmatrix}}{H(T,S)} = \frac{1}{H(T,S)}\left(\frac{\partial \Pi_{TS}^T}{\partial T} - \frac{\partial \Pi_{TS}^T}{\partial S} \right) \,.$$

Therefore, $\dfrac{\partial S}{\partial K} > 0$ if and only if $\dfrac{\partial^2 \Pi_{TS}}{\partial T \partial S} < \dfrac{\partial^2 \Pi_{TS}}{\partial T^2}$. Also, $\dfrac{\partial \Pi_{TS}^*}{\partial K} = -(T^* - T_0) - (S^* - S_0) < 0$.

ii) For targeting specialization, applying the envelope theorem,

$$\frac{\partial \Pi_T^*}{\partial T_0} = (1 - l_0)g'(T_0)f(S_0)p - (1 - l_0)g'(T_0)f(S_0)\big[g(T^{**})p - (c+d)\big] + \alpha_T$$

$$= (1 - l_0)g'(T_0)f(S_0)\big[p - g(T^{**})p + (c+d)\big] + \alpha_T > 0$$

$$\frac{\partial \Pi_T^*}{\partial S_0} = \left\{ l_0 \frac{\partial A_{11}}{\partial S_0} + (1 - l_0)\frac{\partial A_{21}}{\partial S_0} \right\}\big\{ p - g(T^{**})p + (c+d) \big\}$$

$$= \big\{ l_0 f'(S_0) + (1 - l_0)g(T_0)f'(S_0) \big\}\big\{ p - g(T^{**})p + (c+d) \big\} > 0 \,,$$

$$\frac{\partial \Pi_T^*}{\partial l_0} = (A_{11} - A_{21})p + (A_{12} - A_{22})\big\{ g(T^{**})p - (c+d) \big\}$$

$$= f(S_0)\{1 - g(T_0)\}p + f(S_0)\{g(T_0) - 1\}\big\{ g(T^{**})p - (c+d) \big\}$$

$$= f(S_0)\{1 - g(T_0)\}\big\{ p - g(T^{**})p + (c+d) \big\} > 0 \,.$$

For support specialization, applying the envelope theorem,

$$\frac{\partial \Pi_S^*}{\partial T_0} = \left\{ l_0 \frac{\partial B_{11}^*}{\partial T_0} + (1 - l_0)\frac{\partial B_{21}^*}{\partial T_0} \right\}p + \left\{ l_0 \frac{\partial B_{12}^*}{\partial T_0} + (1 - l_0)\frac{\partial B_{22}^*}{\partial T_0} \right\}\{ g(T_0)p - (c+d) \}$$

$$+ \big\{ l_0 B_{12}^* + (1 - l_0)B_{22}^* \big\}g'(T_0)p$$

$$= \left\{ l_0 \frac{\partial B_{11}^*}{\partial T_0} + (1 - l_0)\frac{\partial B_{21}^*}{\partial T_0} \right\}\{ p - g(T_0)p + (c+d) \} + \big\{ l_0 B_{12}^* + (1 - l_0)B_{22}^* \big\}g'(T_0)p > 0 \,,$$

$$\frac{\partial \Pi_S^*}{\partial S_0} = \alpha_s > 0 \,,$$

$$\frac{\partial \Pi_S^*}{\partial l_0} = \{B_{11} - B_{21}\}p + \{B_{12} - B_{22}\}\{g(T_0)p - (c+d)\}$$

$$= \{f(S) - g(T_0)f(S)\}p - \{f(S) - g(T_0)f(S)\}\{g(T_0)p - (c+d)\}.$$

$$= f(S^{**})\{1 - g(T_0)\}\{p - g(T_0)p + (c+d)\} > 0.$$

For a simultaneous implementation, applying the envelope theorem,

$$\frac{\partial \Pi_{TS}^*}{\partial T_0} = \left\{ l_0 \frac{\partial B_{11}^*}{\partial T_0} + (1 - l_0)\frac{\partial B_{21}^*}{\partial T_0} \right\}p + \left\{ l_0 \frac{\partial B_{12}^*}{\partial T_0} + (1 - l_0)\frac{\partial B_{22}^*}{\partial T_0} \right\}\{g(T^*)p - (c+d)\} + \alpha_T + K$$

$$= \left\{ l_0 \frac{\partial B_{11}^*}{\partial T_0} + (1 - l_0)\frac{\partial B_{21}^*}{\partial T_0} \right\}\{p - g(T^*)p + (c+d)\} + \alpha_T + K$$

$$= (1 - l_0)g'(T_0)f(S)\{p - g(T^*)p + (c+d)\} + \alpha_T + K > 0,$$

$$\frac{\partial \Pi_{TS}^*}{\partial S_0} = \alpha_S + K > 0,$$

$$\frac{\partial \Pi_{TS}^*}{\partial l_0} = (B_{11}^* - B_{21}^*)p + (B_{12}^* - B_{22}^*)\{g(T^*)p - (c+d)\}$$

$$= \{f(S^*) - g(T_0)f(S^*)\}p - \{f(S^*) - g(T_0)f(S^*)\}\{g(T^*)p - (c+d)\}$$

$$= f(S^*)\{1 - g(T_0)\}\{p - g(T^*)p + (c+d)\} > 0.$$

Proof of Proposition 4)

For targeting specialization, let $T^{**} = \log\left[\frac{bpV_1}{\alpha_T}\right]^{\frac{1}{b}}$, where

$$V_1 = \{1 - l_0 f(S_0) - (1 - l_0)g(T_0)f(S_0)\}.$$

Then,

$$\frac{\partial T^{**}}{\partial S_0} = \frac{1}{b} \cdot \frac{\partial \log V_1}{\partial S_0} = \frac{1}{bV_1} \cdot \frac{\partial V_1}{\partial S_0} = -\frac{1}{bV_1}\{l_0 f'(S_0) + (1 - l_0)g(T_0)f'(S_0)\} < 0.$$

Similarly,

$$\frac{\partial T^{**}}{\partial T_0} = \frac{1}{b} \cdot \frac{\partial \log V_1}{\partial T_0} = \frac{1}{bV_1} \cdot \frac{\partial V_1}{\partial T_0} = \frac{1}{bV_1}\{-(1 - l_0)\{g'(T_0)f(S_0)\}\} < 0$$

$$\frac{\partial T^{**}}{\partial l_0} = \frac{1}{b} \cdot \frac{\partial \log V_1}{\partial l_0} = \frac{1}{bV_1}\frac{\partial V_1}{\partial l_0} = \frac{f(S_0)}{bV_1}\{g(T_0) - 1\} < 0$$

$$S^{**} = \log\left[\frac{a\{l_0 + (1 - l_0)g(T_0)\}\{p - g(T_0)p + (c+d)\}}{\alpha_S}\right]^{\frac{1}{a}}$$

For support specialization, let $S^{**} = \log \left[\dfrac{aV_2 V_3}{\alpha_S} \right]^{\frac{1}{a}}$, where $V_2 = l_0 + (1-l_0)g(T_0)$ and $V_3(T_0) = p - g(T_0)p + (c+d)$. Then,

First, $\dfrac{\partial S^{**}}{\partial S_0} = 0$.

$$\frac{\partial S^{**}}{\partial T_0} = \frac{1}{a} \left(\frac{\partial \log V_2}{\partial T_0} + \frac{\partial \log V_3}{\partial T_0} \right) = \frac{1}{a} \left(\frac{1}{V_2} \frac{\partial V_2}{\partial T_0} + \frac{1}{V_3} \frac{\partial V_3}{\partial T_0} \right) = \frac{1}{aV_2 V_3} \left(V_3 \frac{\partial V_2}{\partial T_0} + V_2 \frac{\partial V_3}{\partial T_0} \right)$$

$$= \frac{1}{aV_2 V_3} \left(\{ p - g(T_0)p + (c+d) \} (1-l_0)g'(T_0) - \{ l_0 + (1-l_0)g(T_0) \} g'(T_0)p \right)$$

$$= \frac{1}{aV_2 V_3} \left(\{ p - g(T_0)p + (c+d) \} (1-l_0) - \{ l_0 + (1-l_0)g(T_0) \} p \right) g'(T_0)$$

Thus, $\dfrac{\partial S^{**}}{\partial T_0} > 0 \Leftrightarrow \{ p - g(T_0)p + (c+d) \}(1-l_0) - \{ l_0 + (1-l_0)g(T_0) \}p > 0 \Leftrightarrow T_0 < \log \left[\dfrac{2(1-l_0)p}{p - (c+d)(1-l_0)} \right]^{\frac{1}{b}}$.

$$\frac{\partial S^{**}}{\partial T_0} > 0 \quad T_0 < \log \left[\frac{2(1-l_0)p}{p - (c+d)(1-l_0)} \right]^{\frac{1}{b}} .$$

Also, $\dfrac{\partial S^{**}}{\partial l_0} = \dfrac{1}{a} \cdot \dfrac{\partial \log V_2}{\partial l_0} = \dfrac{1}{aV_2} \dfrac{\partial V_2}{\partial l_0} = \dfrac{1}{aV_2} \{ 1 - g(T_0) \} > 0.$

For the simultaneous implementation strategy,

$$\frac{\partial S^*}{\partial S_0} = \frac{\partial T^*}{\partial S_0} = 0.$$

In addition, by taking the total derivative of the two equation,

$$\frac{\partial \Pi_{TS}^T}{\partial T} dT + \frac{\partial \Pi_{TS}^T}{\partial S} dS + \frac{\partial \Pi_{TS}^T}{\partial T_0} dT_0 = 0 \quad \text{and} \quad \frac{\partial \Pi_{TS}^S}{\partial T} dT + \frac{\partial \Pi_{TS}^S}{\partial S} dS + \frac{\partial \Pi_{TS}^S}{\partial T_0} dT_0 = 0 ,$$

$$\frac{\partial T}{\partial T_0} = \frac{\begin{vmatrix} -\dfrac{\partial \Pi_{TS}^T}{\partial T_0} & \dfrac{\partial \Pi_{TS}^S}{\partial T} \\ -\dfrac{\partial \Pi_{TS}^S}{\partial T_0} & \dfrac{\partial \Pi_{TS}^S}{\partial S} \end{vmatrix}}{H(T,S)} = \frac{\begin{vmatrix} (+) & (-) \\ (-) & (-) \end{vmatrix}}{H(T,S)} < 0 \quad \text{and} \quad \frac{\partial S}{\partial T_0} = \frac{\begin{vmatrix} \dfrac{\partial \Pi_{TS}^T}{\partial T} & -\dfrac{\partial \Pi_{TS}^T}{\partial T_0} \\ \dfrac{\partial \Pi_{TS}^T}{\partial S} & -\dfrac{\partial \Pi_{TS}^S}{\partial T_0} \end{vmatrix}}{H(T,S)} = \frac{\begin{vmatrix} (-) & (+) \\ (-) & (-) \end{vmatrix}}{H(T,S)} > 0 ,$$

because

$$B = \begin{bmatrix} f(S) & 1 - f(S) \\ g(T_0)f(S) & 1 - g(T_0)f(S) \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}$$

$$\pi_{TS} = \{ l_0 B_{11} + (1-l_0)B_{21} \} p + \{ l_0 B_{12} + (1-l_0)B_{22} \} [g(T)p - (c+d)]$$

$$\Pi_{TS}^T = [l_0 \{ 1 - f(S) \} + (1-l_0) \{ 1 - g(T_0)f(S) \}] g'(T)p - \alpha_T$$

$$\Pi_{TS}^{S} = \{l_0 + (1-l_0)g(T_0)\}pf'(S) - f'(S)\{l_0 + (1-l_0)g(T_0)\}[g(T)p - (c+d)] - \alpha_S$$
$$= f'(S)\{l_0 + (1-l_0)g(T_0)\}\{p - g(T)p + (c+d)\} - \alpha_S$$

$$\frac{\partial \Pi_{TS}^{T}}{\partial T} = [l_0\{1 - f(S)\} + (1-l_0)\{1 - g(T_0)f(S)\}]g''(T)p < 0,$$

$$\frac{\partial \Pi_{TS}^{S}}{\partial S} = \{l_0 + (1-l_0)g(T_0)\}\{p - g(T)p + (c+d)\}f''(S) < 0,$$

$$\frac{\partial \Pi_{TS}^{T}}{\partial S} = \frac{\partial \Pi_{TS}^{S}}{\partial T} < 0,$$

$$\frac{\partial \Pi_{TS}^{T}}{\partial T_0} = -(1-l_0)\{g'(T_0)f(S)\}pg'(T) < 0,$$

$$\frac{\partial \Pi_{TS}^{S}}{\partial T_0} = (1-l_0)g'(T_0)f'(S)\{p - g(T)p + (c+d)\} > 0.$$

By taking the total derivative of the two equation,

$$\frac{\partial \Pi_{TS}^{T}}{\partial T}dT + \frac{\partial \Pi_{TS}^{T}}{\partial S}dS + \frac{\partial \Pi_{TS}^{T}}{\partial l_0}dl_0 = 0 \text{ and } \frac{\partial \Pi_{TS}^{S}}{\partial T}dT + \frac{\partial \Pi_{TS}^{S}}{\partial S}dS + \frac{\partial \Pi_{TS}^{S}}{\partial l_0}dl_0 = 0.$$

$$\frac{\partial S}{\partial l_0} = \frac{\begin{vmatrix} \dfrac{\partial \Pi_{TS}^{T}}{\partial T} & -\dfrac{\partial \Pi_{TS}^{T}}{\partial l_0} \\ \dfrac{\partial \Pi_{TS}^{T}}{\partial S} & -\dfrac{\partial \Pi_{TS}^{S}}{\partial l_0} \end{vmatrix}}{H(T,S)} = \frac{\begin{vmatrix} (-) & (+) \\ (-) & (-) \end{vmatrix}}{H(T,S)} > 0 \text{ and } \frac{\partial T}{\partial l_0} = \frac{\begin{vmatrix} -\dfrac{\partial \Pi_{TS}^{T}}{\partial l_0} & \dfrac{\partial \Pi_{TS}^{S}}{\partial T} \\ -\dfrac{\partial \Pi_{TS}^{S}}{\partial l_0} & \dfrac{\partial \Pi_{TS}^{S}}{\partial S} \end{vmatrix}}{H(T,S)} = \frac{\begin{vmatrix} (+) & (-) \\ (-) & (-) \end{vmatrix}}{H(T,S)} < 0, \text{ because}$$

$$\frac{\partial \Pi_{TS}^{T}}{\partial l_0} = \{g(T_0) - 1\}g'(T)f(S)p < 0, \text{ and } \frac{\partial \Pi_{TS}^{S}}{\partial l_0} = f'(S)\{1 - g(T_0)\}\{p - g(T)p + (c+d)\} > 0.$$

Proof of Proposition 5)

i) $CS = \{l_0 B_{11} + (1-l_0)B_{21}\}(\bar{v} - p) + \{l_0 B_{12} + (1-l_0)B_{22}\}[g(T)(\underline{v} - p + d) + \{1 - g(T)\}d]$

$$\frac{\partial CS}{\partial T} = \{l_0 B_{12} + (1-l_0)B_{22}\}(\underline{v} - p)g'(T) < 0$$

ii) $\dfrac{\partial CS}{\partial S} = \left\{l_0 \dfrac{\partial B_{11}}{\partial S} + (1-l_0)\dfrac{\partial B_{21}}{\partial S}\right\}(M - d) + \left\{l_0 \dfrac{\partial B_{12}}{\partial S} + (1-l_0)\dfrac{\partial B_{22}}{\partial S}\right\}[g(T)m + \{1 - g(T)\}d],$

$$\frac{\partial CS}{\partial S} = \left\{l_0 \frac{\partial B_{11}}{\partial S} + (1-l_0)\frac{\partial B_{21}}{\partial S}\right\}(\bar{v} - p) + \left\{l_0 \frac{\partial B_{12}}{\partial S} + (1-l_0)\frac{\partial B_{22}}{\partial S}\right\}[g(T)(\underline{v} - p + d) + \{1 - g(T)\}d]$$

$$= \left\{l_0 \frac{\partial B_{11}^{(1)}}{\partial S} + (1-l_0)\frac{\partial B_{21}^{(1)}}{\partial S}\right\}[g(T)(p - \underline{v}) + (\bar{v} - p - d)]$$

Therefore, $\dfrac{\partial CS}{\partial S} > 0 \Leftrightarrow g(T)(p - \underline{v}) + (\bar{v} - p - d) > 0 \Leftrightarrow g(T) > \dfrac{p + d - \bar{v}}{p - \underline{v}}$

(1) $\dfrac{p+d-\bar{v}}{p-\underline{v}} > 1 \Leftrightarrow \bar{v} < \underline{v} + d$. Then, since $g(T) < \dfrac{p+d-\bar{v}}{p-\underline{v}}$, $\dfrac{\partial CS}{\partial S} < 0$

(2) $\dfrac{p+d-\bar{v}}{p-\underline{v}} < 0 \Leftrightarrow \bar{v} > p+d$. Then, since $g(T) > \dfrac{p+d-\bar{v}}{p-\underline{v}}$, $\dfrac{\partial CS^{(1)}}{\partial S} > 0$

(3) Otherwise, $\dfrac{\partial CS}{\partial S} > 0 \Leftrightarrow g(T) > \dfrac{p+d-\bar{v}}{p-\underline{v}} \Leftrightarrow T > \log\left(\dfrac{p-\underline{v}}{\bar{v}-\underline{v}-d}\right)^{\frac{1}{b}}$.

iii) $\dfrac{\partial^2 CS}{\partial S \partial T} = \left\{ l_0 \dfrac{\partial B_{12}}{\partial S} + (1-l_0) \dfrac{\partial B_{22}}{\partial S} \right\} (p-\underline{v}) g'(T) = -f'(S) g'(T) \{ l_0 + (1-l_0) g(T_0) \} (p-\underline{v}) < 0$