IT Portfolio Selection and IT Synergy

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IT PORTFOLIO SELECTION AND IT SYNERGY

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ABSTRACT
This paper proposes the framework of IT portfolio selection and investigates the impact of IT synergy on a firm’s IT portfolio selection. IT resources can be distinguished from other forms of resources by their great potential of enhancing synergy between IT units. Based on prior discussion on types of IT synergy, we classify IT synergy into the three types and examine the effects of the different types of IT synergy on the IT portfolio selection. We found that firms of moderate and high risk tolerance are likely to obtain superior IT portfolio options by enhancing IT synergy, whereas firms of low risk tolerance may not benefit from enhancement of IT synergy.

Keywords
IT synergy, IT portfolio selection, IT investment

INTRODUCTION
Why should investors who purchase financial products know about Markowitz’s portfolio selection theory? Markowitz (1991, 1952) argues that investors can reduce portfolio risk simply by holding multiple stocks that are not perfectly correlated while expecting the same portfolio return from their investment. Markowitz theory provides investors with methods of selecting an optimal financial portfolio. Investors can use information about diversification of their investment portfolio to estimate and reduce the risk of their investment, by expanding their view from a level of individual units to a portfolio level. In this regard, diversification plays a critical role in the financial portfolio selection. This study extends the financial portfolio selection theory to the domain of IT portfolio selection. While Markowitz theory proposes how rational investors will diversify their investment to achieve an optimal portfolio, our study proposes how rational firms will use IT synergy to optimize their IT portfolio.

IT investments in a firm have continued to increase. Estimated 50 percent of U.S. capital investment is for IT (Lucas, 2005, p. 113). The amount of spending for IT in a firm today is critical for the business performance of the firm. According to our survey with CIOs (Chief Information Officers) in three US Fortune 100 firms, their annual IT spending ranges from tens of million dollars to one billion dollars. Along with this trend of growing IT investment, impact of IT of the firm and the role of the CIO who takes charge of IT investments have become increasingly important. However, there are few widely accepted methodologies with which IT managers can optimize their IT resources.

Weill and Vitale (2002) define IT portfolio of a firm as “its total investment in computing and communication technology.” Jeffery and Leliveld (2004) define IT portfolio management as “managing IT as a portfolio of assets similar to a financial portfolio and striving to improve the performance of the portfolio by balancing risk and return.” Maizlish and Handler (2005) classify the IT portfolio management problem into three different levels: the IT discovery portfolio, the IT project portfolio, and the IT asset portfolio. The decision unit in our study can be any IT investment unit, but the main focus of our study lies on the allocation problem that matters for CIOs or senior IT managers. For example, a CIO of the firm may have to allocate its total IT budget to IT organizations for individual business units in a multi-business firm, or for individual functional departments such as the marketing department and the operation department.

The synergy between IT investment units differentiates IT portfolio selection from the financial portfolio selection. Holding multiple financial products does not create additional return, whereas holding multiple IT resources may enable a firm to earn additional return from its IT investment. The synergy obtained from diversification has been discussed in strategy literature, particularly in the multi-business context (Tanriverdi and Venkatraman, 2005; Rumelt, 1982; Amihud and Lev, 1981; Christensen and Montgomery, 1981; Palepu, 1985; Robins and Wiersema, 1995; Farjoun, 1998; Miller, 2004). However,
there have been not enough studies of synergy in the domain of IT investment. The unique characteristics of IT resources other than non-IT resources motivated us to study IT synergy.

In this paper, we develop a framework of IT portfolio selection, and examine the effect of IT synergy on a firm’s IT portfolio selection within the framework. This paper provides the model of IT portfolio selection with which decision makers in a firm can attain optimal IT portfolio from their IT investment. We view IT investment of a firm from the perspective of the CIO, who desires to maximize return from IT investments with minimum risk. In particular, we investigate how different types of IT synergy affect on IT portfolio selection differently.

THEORETICAL BACKGROUND

Markowitz’s Portfolio Selection Theory

Financial theories have been applied in strategic planning of the firm. Meyers (1984) argues that finance theory must be extended in order to bring financial and strategic analysis together. This paper extends the Markowitz theory to apply it to IT portfolio selection problems. In Markowitz’s portfolio selection theory, an investor’s problem is viewed as a problem of balancing return and risk. The main benefit of using Markowitz’s portfolio selection theory in financial investment is that an investor can reduce portfolio risk simply by holding securities that are not perfectly correlated (Markowitz, 1991). This benefit acts as a strong incentive for investors to learn about the portfolio selection theory.

Figure 1 (a) and (b) illustrate the difference between Markowitz portfolio selection and IT portfolio selection. In financial portfolio selection, the portfolio management means the use of diversification to reduce portfolio risk. However, we argue that IT portfolio management implies the use of IT synergy as well as the use of diversification, where IT synergy affects both portfolio return and portfolio risk.

Synergy

Synergy refers to additional return when firms can achieve from multiple investment units, which cannot be attained from stand-alone individual units. Synergy between multiple investment units has been actively discussed in the corporate strategy and finance literature. It is argued that the wealth gain is attributed to the utilization of resources resulting in different types of synergies (Eckbo, 1983; Bradley et al., 1983). Economies of scope enable a firm to share or utilize related inputs, which enhance synergy (Teece, 1980, 1982; Willig, 1978).

The main concern of prior studies in the corporate strategy literature is whether a corporate should diversify in its businesses. It is assumed that synergism is given to firms depending on their corporate structure and diversification strategies in this literature. However, this assumption needs to be reexamined because some empirical studies showed that managers

![Figure 1(a). The Framework of Markowitz Portfolio Selection](image1)

![Figure 1(b). The Framework of IT Portfolio Selection](image2)
overestimate their ability to obtain synergies from diversification (Miller, 2004). To our knowledge, few studies tried to answer for whether a firm has an incentive to enhance a certain types of synergy by investigating their effect on portfolio return and risk. Moreover, in the domain of IT investment of the firm, synergy enhancement can be an option for CIOs or IT managers. Information technologies have enormous potential of synergy enhancement. Thus, the discussion of synergy in this paper has a different aim from the studies of the corporate diversification strategy. We view IT synergy as a choice of a firm to achieve an optimal portfolio.

For IT resources, two types of synergies, sub-additive cost and super-additive value synergies, have been discussed (Tanriverdi, 2005, 2006). First, sub-additive cost synergy has been explained by the economics of scope that can be attained through diversification (Willing, 1978; Panzar and Willing, 1981; Teece, 1980, 1982). The synergistic economies arise from inputs that are shared by related businesses and the synergistic benefits are distinguished from vertical economies and financial economies (Hill et al., 1987). Resource relatedness refers to the use of common resources across units. According to the resource-based view of the firm, the use of common factors of production across units in diversification creates synergies, which is sub-additive production cost synergies (Farjoun, 1998; Robins and Wiersema, 1995; Tanriverdi, 2006). Second, the super-additive value synergies can be derived from Edgeworth complementarities, which can be described as ‘doing more of one thing increases the returns to do more of another’ (Milgrom and Roberts, 1995). Resource complementary is a major source of cross-unit synergy (Tanriverdi and Venkatraman, 2005). According to the economic theory of complementarities (Milgrom and Roberts, 1995), a set of resource is complementary when the return to a resource varies in the levels of returns to the other resources. A complementary set of resources creates super-additive value synergies.

**IT Portfolio Selection**

Investment in various IT activities of the firm are to be managed aggregately and planned centrally due to the large amount of firms’ IT spending. To our knowledge, McFarlan (1974) firstly used the term IT portfolio to emphasize the issues of risk management in IT investment. But it is the late 1990’s when the IT portfolio management is fully gained attention by practitioners and researchers, mainly due to the radical increase of IT investment in firms. Although there are multiple levels of IT portfolio management (Maizlish and Handler, 2005), most of previous studies have focuses on the problem of IT project portfolio selection.

Several studies of IT project portfolio selection stressed project interdependencies among IT projects and proposed a mode to overcome challenges of classical models of project selection and proposed models of IT project selection (Santhanam and Kyparis, 1995; Santhanam and Kyparis, 1996; Lee and Kim, 2000; Lee and Kim, 2001; Dickinson et al., 1999). However, those studies address the impact of IT synergy only on portfolio return, not on portfolio risk. This paper studies the impact of IT synergy on portfolio risk as well as portfolio return, which will provide firms with more comprehensive information to make decisions on IT investment.

The research problem of our study is IT investment allocation, instead of IT project selection. IT investment allocation is the decision to be done prior to IT project selection to align IT investment with firm strategy. The top-down approach will enable firms to spend their IT budget according to their strategic priorities. However, there has not been enough discussion about methodologies of IT investment allocation.

**IT RESOURCES AND IT SYNERGY**

Similar to general concept of synergy, IT synergy refers to additional return that a firm can achieve from multiple IT investment units, which cannot be obtained from stand-alone individual units. We argue that IT resources have unique characteristics that bring greater potential of enhancing synergy than non-IT resources. In this section, we intend to justify this argument by discussing why IT resources are more significant sources of synergy than non-IT ones. This discussion will add importance of IT synergy in IT portfolio management.

**Characteristics of IT resources**

We address three unique characteristics of IT resources that is related to the great potential of synergy enhancement. First, IT resources can be used remotely. Most IT services are provided and shared through networks and geographic constraints in using resources are minimized. Computer machines and software programs may not need to be moved or re-installed to be used in a specific place, and developers can work remotely through computer networks. Second, IT resources can be used by multiple users simultaneously. As long as the traffic limit is not exceeded, many IT resources can be used whenever they are needed by many users. These first two features make IT resources much more sharable between different IT investment units and create greater synergy than non-IT resources. Thirdly, the integration of heterogeneous IT systems enables firms to share business processes and exchange data, which enhance complementarities between IT components. The data provided by an
information system makes other systems more valuable. Integrated business processes between multiple information systems can create additional sets of data.

The Uncertainty of IT Resources

Resources of a firm can be anything that is thought of as a strength and weakness of the given firm (Wernerfelt, 1984). According to RBV (Resrouce-Based View) of the firm, resources of a firm enable the firm to achieve competitive advantage, and to drive toward superior long-term performance (Barney 1991; Penrose 1959; Wernerfelt 1984). Using the criteria of strategic resources in RBV—valuable, rare, in-imitable, and non-substitutable (Barney, 1991), we can argue that a main role of the CIO of the firm is to develop strategic IT resources from IT investment, by making their IT resources valuable, rare, in-imitable, and non-substitutable. When the IT resources of the firm fit well with unique needs of the organization, the firm is able to achieve maximum value of the IT resources.

Here, we need to distinguish the existing IT resource, which is used as the input of an IT investment, and the prospect IT resource, which is the output of an IT investment. We assume that there is no uncertainty in using existing IT resources because firms have used the existing IT resources and probably know their values. However, the value of the prospective IT resource is uncertain; thus, there is uncertainty in the return of the IT investment.

Three types of IT synergy

Figure 2. (a) and (b) illustrate the differences between when two IT investment units are evaluated without any synergy, and when there is synergy. As we discussed earlier, by viewing IT units aggregately, a firm is able to take synergies into consideration in their IT portfolio selection. We classify IT synergies into three types: the sub-additive cost IT synergy (c-type synergy); the two-way super-additive value IT synergy (tv-type synergy); and the one-way super-additive value IT synergy (ov-type synergy). Table 1 summarizes the three types. To develop models of the three types of IT synergies, we use the following settings and notations.

- $x_i$: the proportion of IT investment unit $i$ out of the total IT investment ($i = 1, 2; 0 < x_i, x_j < 0; x_i + x_j = 1$)
- $r_i$: the expected return on investment (ROI) of IT investment unit $i$ when the two IT units are evaluated without any synergy
- $\alpha_i$: the marginal increase (decrease) of the ROI of the IT investment unit $i$ when the two IT units are evaluated without any synergy
- $\beta_i$: the maximum percentage of IT resource that IT investment unit $i$ can share out of the sum of required IT resources by the two investments ($\beta_i = \beta_i > 0$)
- $\delta_i$: the maximum percentage of additional value created when the two IT investment units are selected over the sum of stand-alone returns of individual IT resources ($\delta_i = \delta_i > 0$)

The Sub-additive Cost IT Synergy

The sub-additive cost IT synergy (c-type synergy) refers to additional cost saving when there is sharing of common IT resources between two IT units. The condition of sub-additive cost synergy is $\text{Cost}(A + B) < \text{Cost}(A) + \text{Cost}(B)$ (Teece, 1982). Examples of this type of synergy can easily be found. Hardware, software, network systems, IT human resources, and other IT resources can be shared across different business units or functional groups. In our model, we assume that the firm can estimate the maximum percent of IT resources that can be shared by two IT investment units.

In our model, we assume that the maximum percentage of IT resource shared between two IT investment units can be estimated by IT experts in the firm. The additional portfolio return will be the amount that the firm can save in sharing existing IT resources. The amount will be $\beta_{12} \cdot En(x_1, x_2)$, where $En(x_1, x_2)$ refers to an entropy function of which value is maximized when the investment is most diversified, here $x_1 = x_2$. A widely-used entropy function is Jacquemin-Berry entropy measure $\sum_{i,j} P_i' \ln(1 / P_i')$, where $P_i'$ is the share of the segment $i$ of group $j$ in total (Palepu, 1985). Then, when the sub-additive cost synergy exists and other types of IT synergy do not exist, the portfolio return, $RT$, will be:

$$RT = r_1 x_1 + r_2 x_2 + \beta_{12} \cdot En(x_1, x_2),$$

(1)

where $b$ is the total IT budget and $\beta_{12} = \beta_{21}$. We define portfolio risk as the standard deviation of portfolio return, as it is defined in financial literature. The sub-additive cost synergy appears not to affect portfolio risk because the additional return
is nothing to do with any ROI (Return on Investment) term that has uncertainty. The variance of portfolio return with the subadditive cost synergy is the same as that of portfolio return without the synergy. The portfolio Risk, \( RK \), will be:
\[
RK = \left[ \text{Var}(r_1 x_1 + r_2 x_2 + \beta_{12} En(x_1, x_2)) \right]^{1/2}
\]
\[
= \left[ \text{Var}(r_1 x_1 + r_2 x_2) \right]^{1/2}
\]

![Figure 2. (a). Evaluation of two IT investment units without consideration of IT synergy](image)

![Figure 2. (b) Evaluation of two IT investment units as a portfolio with consideration of IT synergy](image)

One-way Super-additive Value IT Synergy

The super-additive value IT synergy refers to additional value created by the complementary relationship between the two IT units. The condition of super-additive value synergy is \( \text{Value}(A+B) > \text{Value}(A) + \text{Value}(B) \) (Davis and Thomas, 1993). In this study, we distinguish one-way super-additive value IT synergy from two-way super-additive value IT synergy.

The one-way super-additive IT synergy (ov-type synergy) occurs when, between two IT investment units, the intrinsic value of the first IT investment unit affects the value of the second unit but is not affected by the value of the second unit. Zhu (2004) explains the effect of IT infrastructure with complementarities. We argue that the complementarities of IT infrastructure are different from the complementarities in which both units are mutually influenced. IT infrastructure affects the value of IT applications but it is hardly influenced by the value of IT applications. Thus, we extend Tanriverdi’s (2006) taxonomy of IT synergies and examine three types of IT synergies in our study.

For example, performance of most IT systems is influenced by performance of hardware and networks. As the performance of hardware and networks increase, productivity of IT applications will increase. If we consider a business unit whose operations heavily depend on various IT systems and IT machines, it is reasonable to think that the value of the IT infrastructure is positively related to the value of IT in the business unit.

We assume that, in the relationship between IT investment unit \( i \) and IT investment unit \( j \) \((i, j = 1, 2, i \neq j)\), the marginal increase (decrease) of the ROI of IT investment unit \( j \) over the marginal increase (decrease) of the value of IT investment \( i \), \( \alpha_{ij} \), is a constant parameter in the range of \( x_i \) and \( x_j \) specified by the firm. We assume \( \alpha_{ij} \geq 0 \) because IT managers would not integrate the two IT units when \( \alpha_{ij} < 0 \). When IT investment unit 1 has ov-type synergy on the IT unit 2, the firm will obtain the additional return \( \alpha_{12} (r_1 x_1) x_2 \).

Then, when ov-type synergy exists without any other types of IT synergies, the portfolio return of IT investment unit 1 and 2 will be:
\[
RT = r_1 x_1 + r_2 x_2 + \alpha_{12} (r_1 x_1) x_2
\]
In calculating portfolio risk, we assume that the firm can collect information about correlation between the ROI of two investment units, $\rho_{13}$, and standard deviation of the ROIs, $\sigma_{1}$ and $\sigma_{2}$. Then, when the super-additive value synergy exists, the portfolio risk will be:

$$RK = \sqrt{Var(r_{1}x_{1} + r_{2}x_{2} + \alpha_{12}(r_{1}x_{1})x_{2})}$$

$$= \left[ x_{1}^2 (1 + \alpha_{12}x_{2})^2 \sigma_{1}^2 + x_{2}^2 \sigma_{2}^2 + 2x_{1}(1 + \alpha_{12}x_{2})\sigma_{1}\sigma_{2} \rho_{12} \right]^{1/2}$$

<table>
<thead>
<tr>
<th>Types</th>
<th>Sub-additive cost IT synergy (c-type synergy)</th>
<th>One-way Super-additive Value IT synergy (ov-type synergy)</th>
<th>Two-way Super-additive Value IT synergy (tv-type synergy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Additional value created when there is sharing of common IT resources between two IT units.</td>
<td>Additional values created by the relationship between two IT units (A and B), where the value of one IT unit (A) is influenced by the value of the other IT unit (B), but the value of B is not influenced by the value of A.</td>
<td>Additional value created by the relationship between two IT units, where the return rate of one IT unit is affected by the value of the other IT unit.</td>
</tr>
<tr>
<td>Key characteristics of IT resource related to the synergy</td>
<td>Capability of the remote and simultaneous use</td>
<td>Heavy dependence of IT applications on IT infrastructure; Applicability across a wide range of businesses and industries</td>
<td>Integration; Applicability across a wide range of businesses and industries</td>
</tr>
<tr>
<td>Examples</td>
<td>IT machines, IT human resources, and other IT resources can be shared across different business units or functional groups.</td>
<td>The performance of software programs depends on hardware and networks on which the programs are running.</td>
<td>Marketing Information Systems, New Product Development Systems and Customer Service Systems can create additional information and value by exchanging data and business processes.</td>
</tr>
</tbody>
</table>

Table 1. Three Types of IT Synergies

The Two-way Super-additive Value IT Synergy

The two-way super-additive value IT synergy (tv-type synergy) occurs when the two IT units are mutually beneficial. It can be achieved when more than one enterprise systems share data and business processes. For example, marketing systems and new product development systems of a firm can exchange data about customers and their preference on quality attributes of a product. The data exchange can help the marketing systems do marketing research and find customers, and help new product development systems in designing new products.

We assume that a firm can estimate the ratio between maximum additional return created from tv-type synergy and the sum of expected return of the two IT investment units without the synergy. With this assumption, we formulate the additional
return from tv-type synergy as follows: The additional portfolio return will be the amount that the firm can attain the additional value and the amount will be \( \delta_{12} (r_{1x1} + r_{2x2})\mathit{En}(r_{1x1}, r_{2x2}) \), \( \delta_{12} = \delta_{12} \). Then, when tv-type synergy exists and other types of IT synergies do not exist, the portfolio return will be:

\[
RT = r_{1x1} + r_{2x2} + \delta_{12} (r_{1x1} + r_{2x2})\mathit{En}(r_{1x1}, r_{2x2})
\]

This type of IT synergy appears to change portfolio return because the additional term includes the ROIs that have uncertainty.

\[
RK = \left[ \mathit{Var}(r_{1x1} + r_{2x2} + \delta_{12} (r_{1x1} + r_{2x2})\mathit{En}(r_{1x1}, r_{2x2})) \right]^{1/2}
\]

**IT PORTFOLIO SELECTION MODEL**

**Research Problem and IT Efficient Frontier**

We intend to solve problems of IT investment allocation that CIOs or senior IT managers in a large-size firm face. IT organizations in a firm would have IT budget and the CIO needs to allocate the IT investment into multiple IT investment units for strategic IT spending. For example, a CIO in a firm needs to allocate IT budget for different functional divisions, such as operation, marketing and IT infrastructure. A CIO in a multi-business firm may need to allocate IT budget to different business units. Individual functional groups or business units may want to get IT budget for their unit as much as possible to implement IT projects and initiatives proposed by them. The IT investment unit, in our model, is a general unit. It refers to any decision making units that CIOs or IT decision makers may have. Our model can be applied to a problem of allocating IT budget for multiple business units, for different types of IT, such as hardware, software and network, for different functional groups such as IT for marketing group, IT for operation, and IT for customer service group.

To investigate IT portfolio selection problems of the firm, we apply the Markowitz’s mean-variance efficient frontier. The IT efficient frontier is a visual presentation of the balance between portfolio return and risk. We believe that the efficient frontier is a useful tool for CIOs because IT portfolio is an investment for them and every investment can be viewed as a problem of balancing return and risk. Similar to efficient frontier for security portfolio selection (Kroll, Levy, and Markowitz, 1984), IT efficient frontier can defined as the intersection of the set of portfolios with minimum variance and the set of IT portfolios with maximum return. However, we extend the original efficient frontier by incorporating the construct of IT synergy. The difference of IT efficient frontier from the Markowitz’s mean-variance efficient frontier is that the expected portfolio return is the function of synergies as well as individual units’ return. With the additional factors of expected portfolio return, the portfolio risk will be changed correspondingly because portfolio risk is defined as the standard deviation of portfolio return.

The objective of the CIO in the problem of IT investment allocation is to balance two sub-objectives: to maximize portfolio return and to minimize portfolio risk. Portfolio return is influenced by the return of individual IT investment units and synergies. The synergies include c-, ov- and tv-type synergy. We assume that ov-type synergy and tv-type synergy between the two IT units are exclusive. It means that there cannot be both ov- and tv-type synergy between the two units. In our model, we use synergy measured only between two units because practically it is very difficult to measure added value when more than three IT units interacts. The portfolio return, RT, can be represented as:

\[
RT = RT (\text{expected returns of individual IT units, synergies})
\]

The risk of an IT portfolio can be defined as the degree of uncertainty of the return, which, statistically, refers to the standard variation of the return. Thus, the portfolio risk, RK, can be represented as:

\[
RK = \left[ \mathit{Var}(RT(\text{expected returns of individual IT units, synergies})) \right]^{1/2}
\]

For example, the IT efficient frontier consists of two IT investment units, as illustrated in Figure 1. (b), can be plotted with the following formulas

\[
RT = r_{1x1} + r_{2x2} + \alpha_{12}(r_{1x1})x_{2} + \beta_{12} b\mathit{En}(x_{1}, x_{2}) + \delta_{12} b(r_{1x1} + r_{2x2})\mathit{En}(r_{1x1}, r_{2x2})
\]

\[
RK = \left[ \mathit{Var}(RT) \right]^{1/2}
\]

**Decision Variables**

The decision variable in the model is the proportion of investment for each IT investment units. The IT investment unit can be any level that CIOs or senior manager IT managers would allocate their IT budget. The amount of dollars in each IT
investment unit is normalized and \( x_i \) refers to the ratio of amount of dollar and the total amount of IT investment. The range of \( x_i \) will be ranged from zero to one.

**Constraints**

Constraints in the IT portfolio optimization model should address the unique problems of the firm or IT organization. These constraints may include the IT budget, resource restrictions, and interdependencies among IT projects, mandatory projects, and other restrictions that an organization may have.

**Models**

The optimization problem of balancing return and risk can be formulated to three optimization models and the three models produce an identical efficient frontier. The first model is to maximize portfolio return with constraints of portfolio risk. The second model is to minimize portfolio risk subject to a certain level of portfolio return. The third model can have an objective function of the linear combination of return and risk.

**Model 1:**

Maximize \( RT \)

Subject to \( RK \leq RK_0 \)

(8)

\( \text{subject to \hspace{0.5cm}} \) (other constraints)

, where \( RK_0 \) refers to the maximum level of portfolio risk that the firm can tolerate

**Model 2:**

Minimize \( RK \)

Subject to \( RT \geq RT_0 \)

(9)

\( \text{subject to \hspace{0.5cm}} \) (other constraints)

, where \( RT_0 \) refers to the minimum level of portfolio return that the firm must achieve

**Model 3:**

Maximize \( RT + w(RK - RK_0) \)

Subject to (other constraints)

(10)

\( \text{subject to \hspace{0.5cm}} \)

, where \( w \) is the parameter that represent weight attached to portfolio risk compared to portfolio return.

The bi-criteria linear programming in Model 3 can be theoretically explained by Lagrange relaxation of the optimization problem of maximizing portfolio return with the constraint of not taking a certain level of risk. Then \( w \) would be a Lagrange multiplier that represents the shadow price of the risk constraints. If we let \( L = RT + w(RK - RK_0) \), \( \frac{\partial L}{\partial RK} = w \), because \( \frac{\partial L}{\partial RK} = w \) and \( \frac{\partial L}{\partial RT} = 1 \). Therefore, the Lagrange multiplier \( w \) refers to the marginal increase of portfolio return over marginal increase of portfolio risk at a portfolio risk.

In the IT portfolio that consists of \( n \) IT investment units, the portfolio return and the portfolio risk are defined as:

\[
RT = \sum_{i=1}^{n} r_i x_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij}(r_i, x_j)x_j
\]

\[
+ \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij}(r_i, x_j)x_j En(x_i, x_j) + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \delta_{ij}(r_i, x_j + r_j, x_i) En(r_i, r_j, r_i, r_j)
\]

\[
RK = [Var(RT)]^{0.5}
\]

THE EFFECT OF IT SYNERGY ON IT PORTFOLIO SELECTION: COMPUTATIONAL STUDY

This section aims to examine the effects of the three types of IT synergies on a firm’s portfolio selection, using an IT portfolio for two IT investment units as described in Figure 2. (b). Firms can raise several questions. Do synergies always
offer better portfolio options? If not, under what conditions synergies enable firms to have superior portfolio options or inferior ones. By observing changes in the efficient frontier of the firm, we intend to discuss about those questions.

Since our model uses data of synergies and correlations measured between two IT units, not the data among more than three IT units, it is meaningful to investigate the efficient frontier for two IT units. The result of the efficient set for two units can be applied to the efficient set for many IT units. The main usage of the efficient frontier is to know feasible portfolios and the efficient set. We can obtain feasible portfolios and an efficient frontier for many units by combining feasible areas plotted by pairs of IT units, pairs of an IT unit and an aggregate IT unit, or pairs of aggregate IT units. We consider a firm’s problem of IT investment allocation with the following assumptions: (1) a firm needs to allocate IT budget for the two IT investment units; (2) the first IT investment unit is characterized as low-return and low-risk and the second unit as high-return and high-risk.

![Efficient Frontier](image1)

Figure 3. The change in efficient frontier with different degrees of sub-additive cost IT synergies

![Efficient Frontier](image2)

Figure 4. The change in efficient frontier with different degrees of one-way super-additive value IT synergies

![Efficient Frontier](image3)

Figure 5. The change in efficient frontier with different degrees of two-way super-additive value IT synergies

The computational experiment requires specification of project data. By using specific IT portfolio data, we intend to test the following propositions.

- **Proposition 1.** c-type synergy enables firms to obtain superior IT portfolio options.
- **Proposition 2a.** firms whose risk tolerance is relatively high will obtain superior IT portfolio options as the one-way super-additive value IT synergy becomes greater.
- **Proposition 2b.** firms whose risk tolerance is relatively low may not be able to obtain superior IT portfolio options as the one-way super-additive value IT synergy becomes greater.
- **Proposition 3a.** firms of relatively high risk tolerance will obtain superior portfolio options as the two-way super-additive value IT synergy becomes greater.
- **Proposition 3b.** firms of relatively low risk tolerance may not be able to obtain superior portfolio options as the two-way super-additive value IT synergy becomes greater.
If the coordination cost for enhancement of $c$-type synergy is negligible, $c$-type synergy is likely to be always beneficial because it does not affect portfolio risk but increases portfolio return. However, $ov$-type synergy and $tv$-type rely on the return rate of IT investment units. Because the return rate is uncertain, both types of IT synergy are likely increase portfolio risk as well as portfolio return. Firms of high risk tolerance would benefit from the additional return created by IT synergy though they have to take additional risk. To the contrary, firms of low risk tolerance might not be able to obtain superior IT portfolios from $ov$- and $tv$-type IT synergy because they will increase portfolio return. The changes of the efficient frontiers in Figure 3, 4, and 5 illustrate the different effects of $c$-, $ov$-, $tv$-types of IT synergy on a firm’s IT portfolio selection respectively.

**IMPLICATIONS**

This study makes contributions to IS fields in several points. First, this study provides a methodological framework that helps firms to find a practical solution for their IT portfolio selection problems. A firm can use the efficient frontier as a tool in selecting an optimal IT portfolio after evaluating its risk tolerance. This tool can also be used for finding a firm’s range of options and possible outcomes for different IT portfolio, and for recognizing marginal return they can earn by taking a unit of risk.

Second, this paper addresses three types of IT synergies and discusses their different effects of those three types of IT synergies on a firm’s IT portfolio selection. Although IT resources have been considered a major source of synergies due to its unique characteristics, few studies have articulated the effect of IT synergy on portfolio risk, though the impact on portfolio return have been addressed.

Third, this paper develops analytic models of IT synergy. Though there have been prior literature that tested effects of synergy empirically, there have been few studies that use analytic models to test effects of synergy. In the model, we use non-linear function of portfolio return, which is a major difference from models in financial portfolio selection.

To complete the research framework proposed in this paper, we need to find conditions when our propositions fail and when our propositions work. Then, the framework is able to provide guidelines that tell conditions when an IT organization should enhance a specific type of IT synergy and when should not. Even the conditions when our propositions fail will have managerial implications because those conditions will affect decisions of IT synergy enhancement.

**REFERENCES**


