

Impact of ICT Investment on Agricultural Sector: Analysis of Korean Corporations Based on IT Portfolio Framework

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Abstract In several industries, including the agriculture industry, information and communication technology (ICT) expenditure has been gradually increasing. This study explores the ICT investment of Korean agricultural corporations, and examines the effect of ICT investment on their profitability using an IT portfolio framework. As the organizational capabilities and environment in which ICT is used is critical in examining its impact, the IT-savvy level is used as a moderator. An increase in ICT investment size results in a significantly positive effect on profitability in organizations with higher IT-savvy levels, whereas there is no effect in organizations with lower IT-savvy levels. This study shows the necessity of understanding the structure of ICT investments in the agriculture industry, and suggests the importance of organizational capabilities and environment in making best use of ICT.

Keywords: information and communication technology, information and communication technology investment, IT portfolio, IT-savvy, Agriculture

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1. Introduction

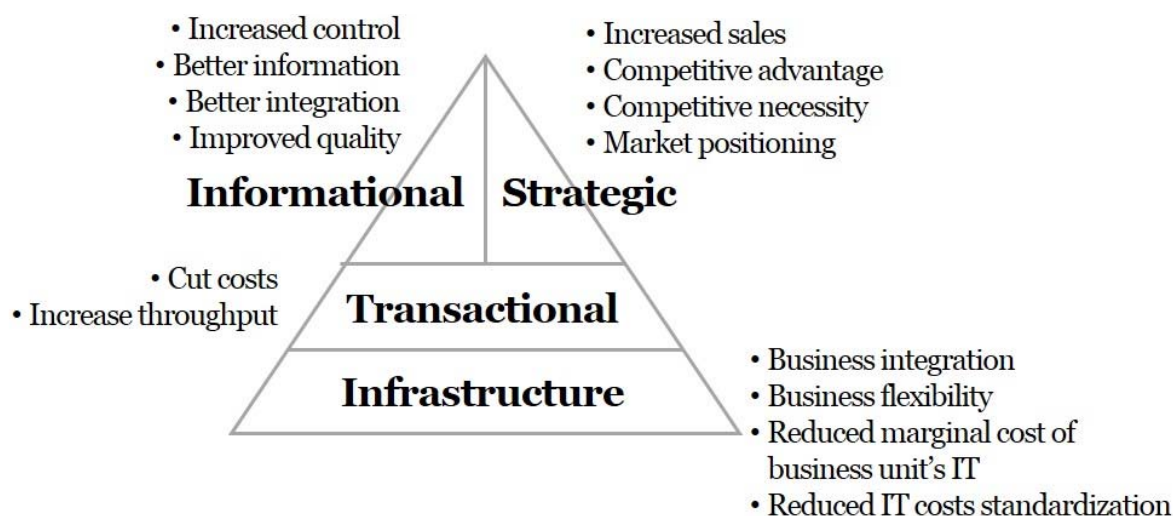
Recently, the application of information and communication technology (ICT) in agriculture has been diversified in an effort to address the industry's highly volatile production and market conditions, as caused by unpredictable environmental factors and long production cycles (Boehlje 2013). ICT has been penetrated into every part of the value chain of the agriculture industry: from production to sales-marketing. In the swine production industry, for example, the internet of things (IoT)-based electronic sow feeder has had a significant effect on productivity (Kang et al, 2015). Furthermore, electronic data interchange (EDI) has been applied to the agriculture industry supply chain. It facilitates logistics activities, reduces costs by improving supply chain coordination, and expands the target market (Manthou et al. 2005). The rapid expansion of Amazon Fresh (Gorczyński and Kooijman 2015) is an example of a successful sales and marketing IT application in the agriculture industry.

Together with the increase of ICT use and investment, IT managers are continuously under pressure to justify the effect of their ICT investments on organizational performance (Kumar et al. 2008). The use of IT in an organization is known to improve organizational efficiency and effectiveness and to help it establish a competitive advantage (Irani 2002; Powell 1992), but prior studies reveal mixed results in the debate on the IT productivity paradox (Soh and Markus 1995). In this regard, some authors have highlighted the importance of the effective management of ICT investment using the IT portfolio perspective (e.g. Kumar et al. 2008; Jeffery and Leliveld 2004; Weill et al. 2007). IT portfolio management is defined as managing ICT "to improve the performance of a portfolio by balancing risk and return" (Jeffrey and Leliveld 2004, p. 41), or "to maximize portfolio benefits, minimize risk and cost, and ensure alignment with organizational strategy over the long run" (Kumar et al. 2008, p. 65).

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Figure 1. IT portfolio (Weill et al, 2007)

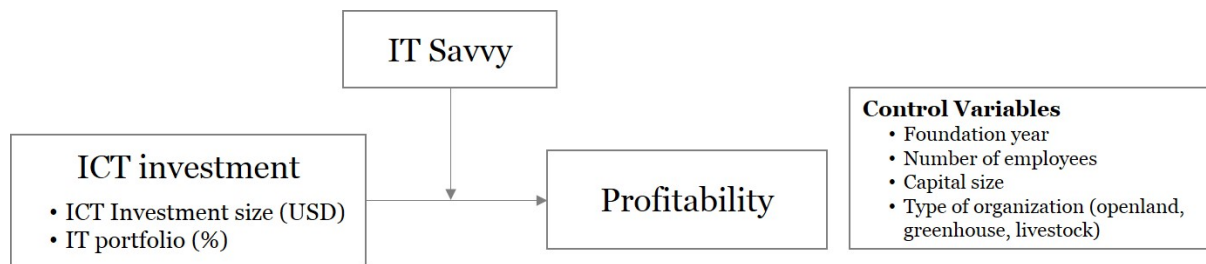
However, there is limited theoretical or empirical research on the effect of ICT investment in the agricultural sector; most previous studies address IT payoff in the manufacturing, service, government, or nonprofit sectors (Kohli and Devaraj 2003). This study attempts to fill the gap by exploring the IT portfolio of agricultural corporations, and examining the effect of ICT investment on the profitability of agricultural corporations. The concept of IT portfolios is employed in this study, like other financial investments, with the assumption that companies have IT portfolios (Kumar et al. 2008) to effectively manage their ICT investment.

We view an organization's IT portfolio as having four asset classes, based on Weill and Broadbent's study (1988); these are transactional, informational, strategic, and infrastructure assets (Figure 1). The infrastructure asset is "the base of the portfolio, providing IT capability to support the applications above" (Weill et al. 2007, p. 3); such applications include transactional, informational, and strategic assets. Using the capabilities of infrastructure assets, investing in transactional assets aims to cut costs and increase the productivity of organizational activities. Informational assets are used to provide more and better information to manage, monitor, or analyze customer needs, and to use in the decision-making process. Typically, informational systems provide a summary of transactional assets. Lastly, the intent of investing in strategic assets is to obtain a competitive advantage or fulfill a need in the market place, which is known as the most risky asset in which to invest. Overall, the relative proportions of these four assets are related to different corporate strategies (Kumar et al. 2008), such as cost leadership or differentiation.

Regardless of the amount of ICT investment or the balance of the IT portfolio, it is critical to have the proper organizational capabilities and environment to use IT. The concept of "IT savvy" has been proposed to achieve the effective implementation of IT in an organization (Weill et al. 2007); it is defined as "a characteristic of firms and their managers reflected in the ability to use IT to consistently elevate firm performance" (Weill and Ross 2013, p. 4). Weill et al. (2007) suggested five inter-related characteristics that constitute IT-savvy: use of IT for internal and external communication, Internet use, digital transactions, company-wide IT skills, and management involvement. They empirically derived results proving that higher levels of IT-savvy demonstrate higher organizational performance. This study uses the IT-savvy variable as a moderator, following Weill et al.'s (2007) approach.

2. ICT investment on Korean agricultural sector

ICT convergence is one of the key strategies to increase efficiency of the agricultural sector in Korea. The policy of technology development and ICT convergence in the agricultural sector was started by the Ministry of Information and Communication in 2004, and has been implemented by the Ministry of Agriculture (now Ministry of Agriculture, Food and Rural Affairs, MAFRA) from 2010 (Kim et al. 2014). The Korean government invested over 136 million dollars in R&D projects for ICT in the agricultural sector for last 10 years and its annual investment size increased gradually (MAFRA 2016) (Figure 3). With R&D projects for ICT convergence, MAFRA implemented poli-

Figure 2. Research model

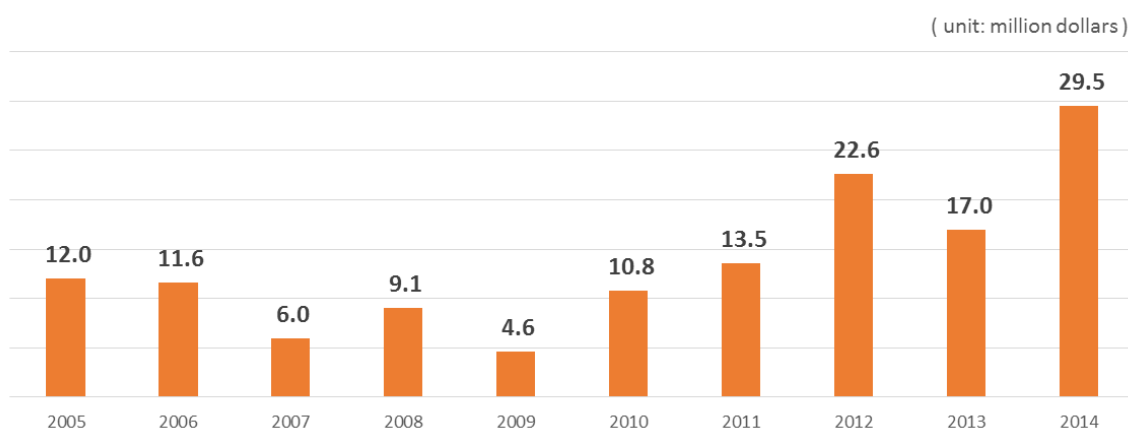
cies to facilitate comprehensive informatization in agricultural and rural areas since the 1990s. Initially, the government focused on infrastructure development, such as household personal computer penetration, internet use, and broadband internet access (Moon et al. 2012).

3. Research Model

In the present study, we developed a research model (Figure 2) to identify the effect of ICT investment on the profitability of companies, as moderated by IT-savvy levels. The variable of ICT investment was included as a predictor of profitability using the size of investment and the relative proportions of IT portfolio elements. The IT-savvy level was considered as a moderator. Several control variables were also considered, such as foundation year, number of employees, capital size, and type of organization.

Education, Promotion, and Information Service in Food, Agriculture, Forestry, and Fisheries). The agency collected responses from the CIOs or CEOs of Korean agricultural corporations regarding their ICT investment in 2015, and categorized Korean agricultural corporations into three types – cultivating, processing, and retailing – based on their role in the value chain. This study focuses only on the cultivating agricultural organizations (e.g. grain, vegetable, fruit, and livestock). Adequate responses from 473 corporations were selected for this analysis: 328 corporations using open-field farming systems, 125 corporations using greenhouse farming system, and 20 corporations using livestock farming system.

The correlation between variables used in the analysis was appropriate for use in a regression model (less than |0.4|). Variables used in the analysis were measured as follows:

Figure 3. Investment on ICT convergence in agricultural sector in Korea (2005 – 2014) (MAFRA 2016)

4. Methodology

We used survey data for ICT investment by Korean agricultural corporations gathered by EPIS (Korean Agency of

- **Dependent Variables:** Profitability was measured on a five-point Likert scale based on the statement, “Please rate the effectiveness of ICT investment on profit.”
- **Independent Variables:** ICT investment size was taken as the total amount of investment in 2015 (in USD).

The IT portfolio was measured in terms of the ratio of expense for each of the four IT assets to total ICT investment, based on Weill and Broadbent's (1998) categorization. Using a relative proportion scale, we discovered the priority of the four asset classes regardless of total investment size.

- **Control Variables:** Foundation year, number of employees, capital size, and type of organization were used as control variables. Agricultural organizations were sub-categorized into three farming types and dummy-coded: open-field farming, greenhouse farming, and livestock farming.
- **Moderator:** Weill et al.'s (2007) IT-savvy self-assessment tool was modified to be more suitable in the context of agricultural corporations. Based on their scores, the top 30% of organizations were interpreted as "high IT-savvy corporations," while the other 70% were considered "low IT-savvy corporations."

5. Results and discussion

5.1. IT Portfolio of Agricultural Corporations

Table 1. IT portfolios in different agricultural sub-sectors.

		Open-field farming (n=328)	Greenhouse farming (n=125)	Livestock farming (n=20)	F
Elements of IT portfolio	Infrastructure	56.8	50.7	72.5	2.724**
	Transactional	11.2	11.1	10.5	5.678*
	Informational	21.2	21.3	12.0	.886
	Strategical	10.8	16.9	5.0	.009
ICT investment size (USD)		3,857	6,436	3,062	1.193

Significance levels: **: $p < .05$, *: $p < .10$

Table 1 shows the average IT portfolio for the different types of agricultural corporation, together with details of the ICT investment size. One-way ANOVA was used to see the statistically significant difference in means between 3 types of agricultural corporations.

Corporations using open-field farming systems invested USD 3,857 in 2015, with a portfolio of 56.8% infrastructure, 11.2% transactional, 21.2% informational, and 10.8% strategic.

Corporations using greenhouse farming systems invested USD 6,436 in IT assets. Their average IT portfolio was constituted as follows: 50.7% infrastructure assets, 11.1% transactional assets, 21.3% informational assets, and 16.9% strategic assets. This shows that the percentage of strategic assets (16.9%) is statistically higher for green-

house systems ($p < .05$) than for open-field (10.8%) or livestock farming systems (6.9%). Greenhouse farming is productive and stable in terms of production, but more risky than open-field production due to its higher initial investment and operating costs (Asci et al, 2014).

Livestock farming systems have IT portfolios with 72.5% infrastructure, 10.5% transactional, 12.0% informational, and 5.0% strategic assets. They invested USD 3,062 in 2015 on average. The proportion of strategic, informational, and transactional IT assets is lower than for open-field or greenhouse farming systems, which means these corporations have lower-risk business strategies. This is due to the structure of the livestock industry. In the United States, for instance, no one can sell meat unless the animal was slaughtered and graded in a facility inspected by the U.S. Department of Agriculture (Harris and Tan 2004). Thus, there is no strong need for individual farmers or corporations to obtain a competitive advantage in the marketplace. Quality is determined largely by the grading system of slaughterhouses, and there is no advantage to be gained from investing in risky IT assets.

5.2. Effect of ICT Investment on Organizational Profitability

Two multiple regression analyses were conducted, one with ICT investment size as the independent variable and another with the relative proportions of each IT portfolio element as independent variables.

First, the amount of ICT investment (USD) was examined (Table 2). Corporations with higher levels of IT-savvy gain significant positive effects on profitability when their ICT investment size increases ($p < .05$). However, in corporations with lower levels of IT-savvy, the level of ICT investment does not have a significant effect on their profitability ($p = .390$).

Table 3 shows the estimated effects of IT portfolios on profitability. As the total of the relative proportions of all

Table 2. Effect of ICT investment size on profitability.

Variables	High savvy (n=156, Adj R ² =0.06)			Low savvy (n=318, Adj R ² =0.0001)		
	β	SE	t-value	β	SE	t-value
Constant	58.920*	27.280	2.160	3.169***	.245	12.944
Foundation year	-.028*	.014	-2.034	.000	.000	-1.295
Capital size (USD)	.000	.000	-1.417	.000	.000	-.084
Number of employees	.000	.004	.086	.001	.002	.583
Type: Greenhouse farming	-.097	.169	-.575	.253	.144	1.759
Type: Livestock farming	-.346	.341	-1.015	.448	.516	.867
ICT investment size (USD)	.000*	.000	2.334	.000	.000	.862

Significance levels: ***: $p < .001$, *: $p < .05$

elements of the IT portfolio is 100%, only the ratios of transactional, informational, and strategic assets are included. Both in corporations with higher levels and lower levels of IT-savvy, profitability increases when the ratio of transactional and strategic assets is larger than that of infrastructure. Conversely, low IT-savvy corporations should decrease the relative proportion of informational assets to increase profitability ($p < .10$).

6. Conclusion

This study may provide a guideline on where to invest for agribusiness managers in different type of cultivating agricultural organizations. The descriptive data (Table 1) shows that the percentage of strategic assets is higher for greenhouse systems (16.9%) than other types of agricultural corporations. Livestock farming systems have a small proportion of strategic, informational, and transactional IT assets because individual farmers or corporations do not have a strong need to obtain a competitive advantage (i.e.

strong brand equity) in the marketplace, as quality is determined largely by the slaughterhouse grading system.

Moreover, the analysis revealed findings consistent in the agriculture industry with previous literature about the moderating role of IT-savvy levels (Weill 2007). Practical policy recommendations for IT support or IT education can be drawn to maximize the benefit from IT investment. In terms of IT portfolio, profitability increases when the ratio of transactional and strategic assets grows compared to that of infrastructure. Interestingly, corporations with low IT-savvy levels should decrease the ratio of informational assets to increase profitability. This result demonstrates that the informational investment may result in the adoption of software or an IT device that primarily aims to improve the quality of information, but which has a negative possibility on profitability.

Although this study has several findings, there are also some limitations. After Brynjolfsson (1993), prior research on the effects of ICT investment was not fully mirrored in the real world due to (1) the mismeasurement of outputs

Table 3. Effect of IT portfolio on profitability.

Variables	High savvy (n=156, Adj R ² =0.11)			Low savvy (n=233, Adj R ² =0.08)		
	β	SE	t-value	β	SE	t-value
Constant	58.500*	26.460	2.211	3.100***	.251	12.341
Foundation year	-.028	.013	-2.092	.000	.000	-1.265
Capital size (USD)	.000	.000	-.877	.000	.000	-.078
Number of employees	.002	.004	.462	.001	.002	.923
Type: Greenhouse farming	.009	.164	.056	.227	.141	1.611
Type: Livestock farming	-.373	.332	-1.122	.499	.501	.997
Ratio of transactional asset	.010**	.003	3.248	.008**	.003	2.661
Ratio of informational asset	.000	.003	-.159	-.004°	.002	-1.849
Ratio of strategic asset	.008*	.003	2.572	.007*	.003	2.367

Significance levels: ***: $p < .001$, **: $p < .01$, *: $p < .05$, °: $p < .10$

and inputs, and (2) lag due to learning and adjustment. First, several variables should be used in any future study (e.g. ROA, net margin, Tobin's q, COGS) for output measurement in order to measure input and output measurements precisely. In the present study, profitability is surveyed from CIOs or CEOs, which might have some limitations. Second, future research may also use a longitudinal method to gain a deeper understanding of ICT investment. The accurate effects of ICT investment may take several years to show results on the "bottom line" (Brynjolfsson 1993). As this study uses cross-sectional data of 2015, the results may not fully represent the effects of ICT investment. Moreover, future studies should include important variables that affect profitability, other than investment size or IT portfolio ratio. For instance, variables related to characteristics of ICT (i.e., ease of use, usefulness) are critical to achieving higher performance from each IT dollar invested. Lastly, future research may compare the relative proportions of IT portfolio elements among diverse industry sectors. Prior literatures addressed the differing results of IT payoff in different industry sectors (Kohli and Devaraj 2003) or the differed effect size of IT due to the differed competitive nature of the industry (Kohli and Devaraj 2003, p. 129). Our findings showed a clue that IT portfolios in the agriculture industry differ from those found in other industries.

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