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A Study On The Relationships Between Software Engineering Capabilities And Business Performance Of Japanese It Firms Through Longitudinal Modeling

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A STUDY ON THE RELATIONSHIPS BETWEEN SOFTWARE ENGINEERING CAPABILITIES AND BUSINESS PERFORMANCE OF JAPANESE IT FIRMS THROUGH LONGITUDINAL MODELING

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Abstract

This study aims at better understanding the long-term relationships among the software engineering capabilities and business performance of the representative IT firms in Japan. We conducted longitudinal analyses on standardized software engineering capability scores of three surveys and ten-year business performance from 151 firms. Through panel analyses of the best Akaike Information Criteria model, we found that IT firms maintaining high levels of deliverables, derived from high levels of human development, quality assurance, project management and process improvement, tend to sustain high profitability, while IT firms with high levels of project management and customer contact tend to be highly productive and increasingly improve the productivity in the long-term. Concerning business performance, profitable IT firms tend to be stable and this tendency accelerates progressively due to the enhancement of deliverables and R&D. However, productive IT firms are not necessarily profitable likely because of the multi-layered industry structure in Japan.

Keywords: Software engineering, Enterprise systems, Business performance, Longitudinal modeling.

1 INTRODUCTION

The management of software engineering is one of the most important issues of contemporary business. However, many companies that use enterprise systems in Japan have not been satisfied with the quality, cost, speed and productivity of software that IT vendors deliver (Kadono 2007). Simultaneously, IT vendors in Japan are facing drastic changes in their business environment, such as technology innovations and new entrants from China, India and other countries. Also, the issues in the IT industry in Japan, such as the multilayer subcontractors and the business model depending on custom-made applications for domestic market orientation, have been pointed out over times (Cusumano 2004).

The information service industry is a 10.5 trillion yen market in Japan, which includes 7.6 trillion yen in software development and programming. In 2009, orders for software totaled 6.4 trillion yen, accounting for 60.3% of the entire information service industry, while the software products market was 1.2 trillion yen (Ministry of Economy, Trade and Industry, Japan 2010). Therefore, we think the longer the information service sector in Japan neglects the issues, the more costly the solution will be. Then, we address these issues as a problem of management of software engineering innovation in Japan.

Regarding the issues above, we learn several insightful lessons from previous relevant studies. For example, according to the empirical study on critical success factors in the competitive advantage of an organisation, organisational learning directly influences performance through innovation, and organisational learning is essential for continuous performance improvement and long-term competitiveness (Pastuszak et al. 2012). Also, useful information for businesses in building critical capabilities to create and maintain competitive positions in the marketplace are provided by examining key determinants of firm competitiveness along three capability-based constructs, i.e., quality, marketing, and knowledge management systems (Yee et al. 2012). Furthermore, the exploratory study on the relationships between innovation and organisational performance suggests that an innovation orientation is related to overall organisational performance and that the high innovating firms had a positive relationship with the top line growth, and customer satisfaction, and bottom line growth, and profitability (Dobni, 2011).

In order for the IT industry in Japan to meet these challenges, an important step is to understand how software engineering capability is significant as a core competence for achieving medium- and long-term success. Therefore, we designed the research on software engineering excellence and conducted it in 2005, 2006 and 2007 with Ministry of Economy, Trade and Industry, Japan (METI). As shown in Figure 1, the objectives of the survey were to:

- assess the achievements of the software engineering discipline, as represented by IT vendors in Japan, and
- better understand the mechanisms of how software engineering capabilities relate to IT vendors' business performance and business environment.

To achieve these objectives, we developed a measurement tool called Software Engineering Excellence (SEE), which can evaluate the overall software engineering capabilities of IT vendors from the viewpoint of deliverables, project management, quality assurance, process improvement, research and development, human development, and contact with customers. Also, we introduced other indicators: business performance and business environment. We assume that the business environment complements the relationship between SEE and the business performance of the software vendors.

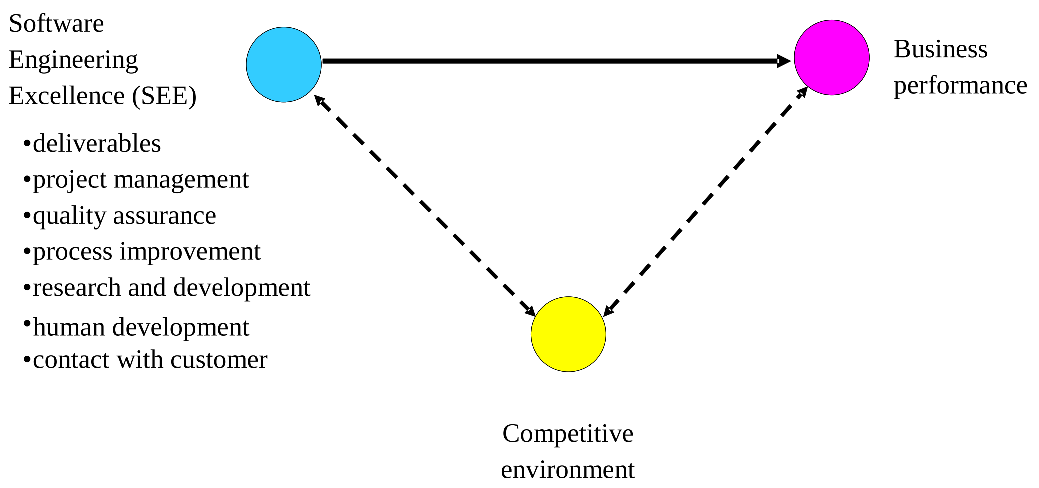

Figure 1. *Conceptual Model of SEE Research.*

In the SEE2005 survey, we analyzed the relationship among SEE, business performance and business environment based on the data collected from 55 major IT vendors in Japan. We conducted the cross-section analysis (Bollen 1989), during which we found that SEE characteristics have a direct positive impact on business performance and that the competitive environment directly as well as indirectly affects business performance in the same year (Kadono et al. 2006).

In the SEE2006 survey, we increased the number of surveyed Japanese IT vendors from 55 to 78 in order to more deeply investigate the impact of software engineering on business performance and the business environment. In particular, in this study we focus on the relationships among the SEE factors, the business environment, and business performance as measured by operating profit ratio in the same year. By analyzing the data collected from 78 major IT vendors in Japan, we found that superior deliverables and business performance were correlated with the effort expended particularly on human resource development, quality assurance, research and development and process improvement at 5% significance in Figure 2 (Kadono et al. 2007; Information-Technology Promotion Agency, Japan et al. 2007).

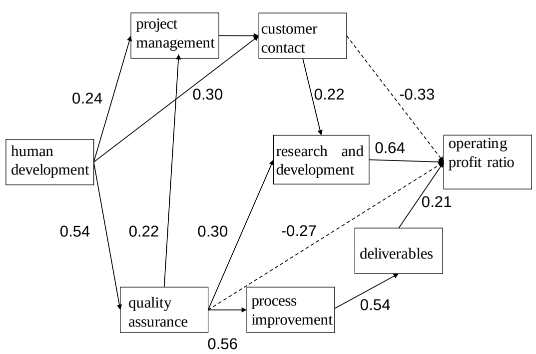

Figure 2. *Path Analysis Results at SEE survey in 2006.*

In 2007, we analyzed the data collected from 100 major IT vendors in Japan. At that time, we reproducibly observed that the level of effort expended on human resource development, quality assurance and project management improved the performance of the IT vendors in Japan in customer contact, research and development and process improvement, the same tendency we found in 2006. However, we also observed that the causal relationships differ significantly depending on the vendors' origin, i.e., whether a business is a makers-turned-vendor, a user-turned-vendor or an independent vendor (Kadono et al. 2009).

Thus, in these papers, we found the base model derived from the three innovation paths, i.e., 1) service innovation: project management to customer contact, 2) product innovation: research and development, 3) process innovation: quality assurance to process improvement, through a cross-section analysis on the seven SEE factors and operating profit ratio year by year.

On the other hand, we integrated 233 valid responses to the SEE surveys received over the three years into a new database and identified 151 unique IT firms. Through a panel analysis of the seven SEE factors of 151 unique IT firms, we empirically verified the series correlation among the seven SEE factors year-to-year (Kadono et al. 2010).

Based on the above previous analysis results and the literature search, the research question in the present paper is to investigate the relationships among the seven SEE factors and business performance, e.g., productivity, profitability, and stability, in the long-term as shown in Figure 3. In other words, we would empirically verify the series correlation of the relationships between the seven SEE factors and the financial performance through a longitudinal analysis by making best use of the data of the 151 unique IT firms who responded to the SEE surveys, i.e., the standardized seven SEE scores for three years and business performance for ten years.

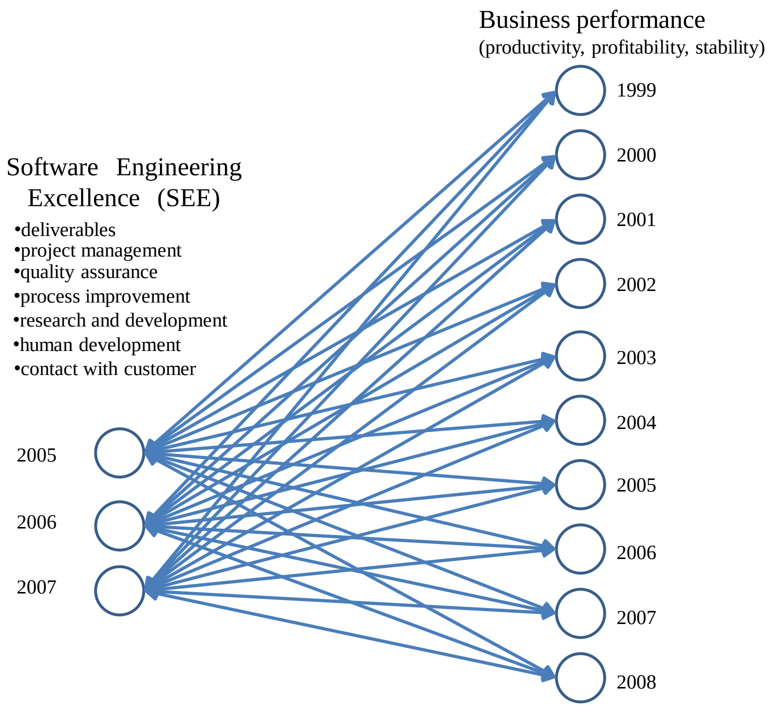

Figure 3. Research Question.

2 RESEARCH MODEL

We introduce the structural model and the measurement model of the research on software engineering capabilities and business performance in this section.

To characterize both intra-class and serial correlation among the repeated measurements of each firm effectively, we adopt a latent growth curve model (Meredith and Tisak, 1990) including two latent factors corresponding to the level (intercept) and the growth (slope) of the seven standardized SEE factors for three years and three financial performances such as productivity, profitability, and stability for ten years.

2.1 Structural Model

We assume a structural model of SEE and business performance as shown in Figure 4. In this paper, the SEE factors are measured by intercepts and slopes of the seven concepts, i.e., human development, project management, customer contacts, R&D, quality management, process improvement, and deliverables from 2005 to 2007, and business performances are measured by intercepts and slopes of productivity, profitability, and stability from 1999 through 2008.

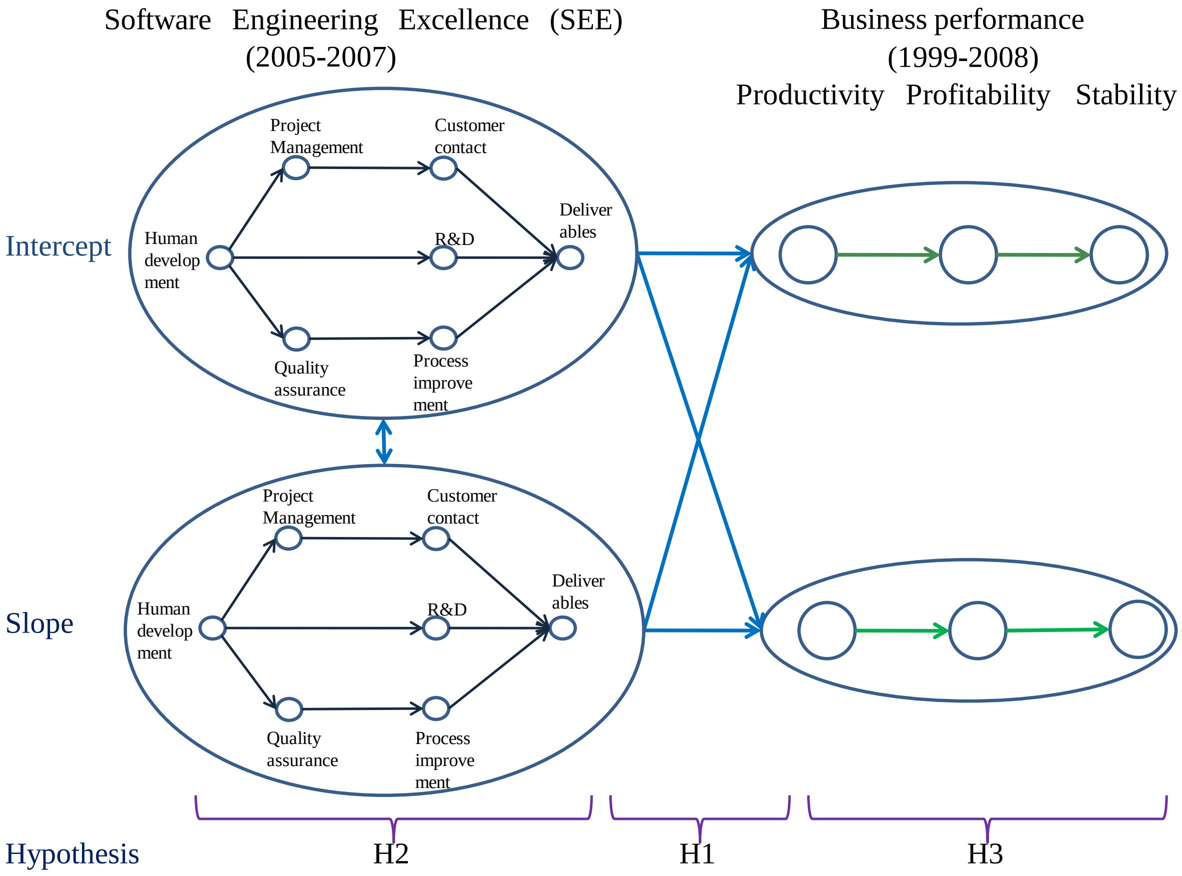

Figure 4. Research Model.

Based on the interviews with successful IT vendors in Japan, we hypothesize that firms who have excellent software engineering capabilities tend to improve their business performance in a medium- and long-term standpoint. Hereby, we assume the following three hypotheses, i.e., H1, H2, and H3 in Figure 5.

H1: software firms with high level (intercept) and high growth (slope) of the software engineering capabilities (SEE), which are core competences for them, tend to improve the level (intercept) and growth (slope) of their business performance in the long-term.

H2: regarding SEE, based on the interviews with successful IT vendors in Japan, we identified three key factors for successful vendors: efficient sales force management, effective operational improvement and excellent R&D. First, vendors who manage their sales force effectively succeed in efficiently assigning their software engineers to upcoming customer projects. As a result, one such vendor operates at an average of 90% capacity. Second, some profitable vendors have accumulated data on quality, cost, delivery and productivity for more than 30 years in order to improve their operations (Kaizen). Third, most large-scale system integrators in Japan are working very hard on R&D activities in addition to effectively managing their sales force management and efficiently improving their operations. The hypothetical structure is consistent with the empirical cross-section analysis results (Figure 2) and the panel analysis results based on the SEE 2006 and 2007 surveys.

Therefore, concerning the relationships among the seven SEE factors in Figure 4, we assume three paths to improvement of deliverables. In other words, there are three paths toward deliverables: the upper path from human development to project management and customer contact suggests service innovation, the middle path from human development to R&D suggests product innovation, and the lower path from human development to quality assurance and process improvement suggests process innovation (Dodgson et al. 2008).

H3: within the business performances, the higher productivity leads to the higher profitability and the higher profitability leads to the higher stability in the long-term. In fact, the successful IT firms we interviewed with in the above cases tend to increase in capital gradually, based on the established high-profit structure by improving productivity.

2.2 Measurement Model

Our measurement model of SEE was developed through interviews with over 30 industry experts in Japan and the U.S. as well as literature searches (Fujimoto 2003; Matsumoto 2005; Ministry of Economy, Trade and Industry 2005). Since this research intends to encourage innovation, we surveyed state-of-the-art cases from the viewpoints of marketing, process, and product in order to develop our measurement model. Therefore, the scope of the survey includes intangible resources of vendors based on the resource-based view (Barney, 2007).

The SEE measurement model has a hierarchical structure with three layers: observed responses to question items, seven detailed concepts, and SEE as a primary indicator (Kadono et al. 2006). The measurement models for 2006 and 2007 were updated slightly based on the response rate of each question item, the statistical significance of each observed response to the 2005 and 2006 SEE surveys, and changes in technology and market trends.

SEE as we have defined it consists of the following seven concepts:

- deliverables: achievement ratio of quality, cost, speed, and productivity, grip on project information.
- project management: project monitoring, assistance to project managers, project planning capability, ratio of PMP(Project Management Professional).
- quality assurance: organization, method, review, testing, guideline, management of outsourcers .
- process improvement: data collection, improvement of estimation, assessment method, CMM/CMMI (Carnegie Mellon University’s Capability Maturity Model Integration).

- research and development: strategy, organization, sharing technological skills, learning organization, development methodology, intellectual assets, commoditized software, readiness to state-of-the-art technology.
- human development: training hours, skill development systems, incentive schemes, measure of human development, moral support.
- contact with customers: ratio of prime contracts, scope of service offered, direct communication with customer's top management, deficit prevention, clarification of user specification.

Regarding the operating profit ratio as a representative profitability of business performance, we uniquely identified 151 IT firms responding to the three SEE surveys and calculated their operating profit ratios from 1999 to 2008 according to the corporate information of a Japanese credit research firm. Based on the time series data, we estimate the intercepts and the slopes of the operating profit ratios of the respondents for ten years.

In terms of productivity and stability, we measure sales per person and capital adequacy ratio for ten years respectively. Similarly to the operating profit ratio, we estimate the intercepts and the slopes of sales per person and capital adequacy ratio of the 151 respondents to the SEE survey.

3 SURVEY ON SOFTWARE ENGINEERING EXCELLENCE

Based on the measurement model, we conducted surveys on Software Engineering Excellence in 2005, 2006 and 2007 with Japan's Ministry of Economy, Trade and Industry (METI). We designed a questionnaire on the practice of software engineering and the nature of the respondent's company. This questionnaire was sent to the CEOs of major Japanese IT vendors with over 300 employees as well as the member firms of the Japan Information Technology Services Industry Association (JISA), and was then distributed to the departments in charge of software engineering.

Responses were received from 117 companies with a total of 100 valid responses to the 2007 survey, a response rate of 10%. There were 55 valid responses, a response rate of 24%, for the 2005 survey and 78 (response rate of 15%) for 2006. For this paper, we integrated the 233 valid responses received over the three years into a new database including 151 unique companies consisting of 42 maker-turned vendors, 33 user-turned vendors and 76 independent vendors (Table 1).

Year	2005	2006	2007	2005/06/07
Questionnaires sent	230	537	1000	NA
Valid responses	55	78	100	151
Maker-turned User-turned Independent	17 15 23	27 15 36	27 20 53	42 33 76
Response rate (%)	24	15	10	NA

Table 1. Software engineering excellence surveys.

For example, the score of deliverables of SEE is estimated by observed response to the relevant question items, such as achievement ratio of quality, cost, and delivery (QCD), and productivity, and grip on project information. Regarding the achievement ratio of QCD, the median achievement ratios of QCD are higher than 70% in any types of vendors, i.e., maker-turned, user-turned and independent vendors, as shown in the boxplot in Figure 5. Also, the achievement levels of QCD at the user-turned vendors tend to be higher than those of the maker-turned vendors and the independent vendors.

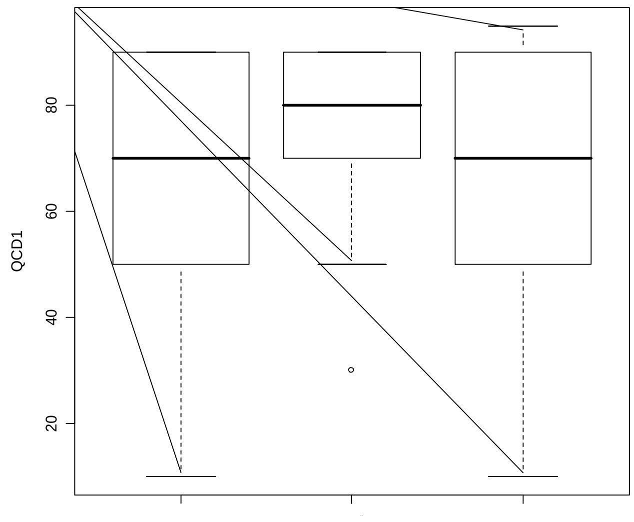

Figure 5. Achievement Ratio of Quality, Cost, and Delivery in SEE2007 (%).

After collecting data from the vendors in 2005, 2006 and 2007, we calculated the factor loadings and standardized factor scores of the seven factors in each year: deliverables, project management, quality assurance, process improvement, research and development, human development and customer contact, based on the responses received to the questions relevant to the measurement model described in the previous section.

4 RESULTS

First, on the basis of the preliminary analyses of intercepts and slopes of the seven SEE factors, the latent factors corresponding to slopes of human development (HD), quality assurance (QA), process improvement (PI) and R&D are considered to be single factor, and the slope factors of project management (PM) and customer contact (CC) can be ignored since the variance components are not statistically significantly positive.

Then, based on the structural model hypothesis in Figure 4 that is consistent with a series of empirical results, we conducted several panel analyses (Bollen 1989) of the data from the 233 valid responses we had received to the 2005, 2006, and 2007 surveys from 151 unique firms and selected the best panel model in terms of Akaike Information Criteria (AIC) (Akaike, 1974), as shown in Figure 6 (AIC=5945.81).

Therefore, based on the hypothetical model (H1, H2, H3) in Figure 4 and the path analysis results in Figure 6, we found the following to be characteristics of the relationships among the intercepts and the slopes of the seven SEE factors over the three years from 2005 to 2007 and the ten-year business performance from 1999 through 2008:

- Regarding the positive relationships among the intercepts of the SEE factors and the business performance (H1), the intercept path (H2) from project management (I-PM) to customer contact (I-CC) has significant influence on the intercept of productivity (I-1). Also, the intercept paths (H2) from human development (I-HD), quality assurance (I-QA), and from project management (I-PM) through process improvement (I-PI) toward deliverables (I-D) influence the intercept of profitability (I-2) significantly.

- Adding the positive interactions among the intercepts and the slopes to the above (H1), the intercept path (H2) from project management (I-PM) through customer contact (I-CC) has significant positive influence on both of the intercept of productivity (I-1) and the slope of productivity (S-1). And, the intercept path (H2) from human development (I-HD) to R&D (I-RD) has significant positive influence on the slope of profitability (S-2).
- On the contrary (H1), the slope of SEE factors (S-0) that consists of human development (S-HD), quality assurance (S-QA), process improvement (S-PI) and R&D (S-RD), has positive impact on the intercept of profitability (I-2) through the intercept of deliverables (I-D).
- Concerning the positive slope relationship (H1), the slope of deliverables (S-D) has positive impact on the slope of stability (S-3).
- Within the business performance (H3), productivity leads to profitability and profitability leads to stability significantly positively such as the paths from the intercept of profitability (I-2) to the intercept of stability (I-3), from the slope of productivity (S-1) to the slope of profitability (S-2), and from the slope of profitability (S-2) to the slope of stability (S-3),except the negative path from the intercept of productivity (I-1) to the intercept of profitability (I-2).
- In terms of the relationships among the intercepts of the seven SEE factors (H2), there is another negative path from the intercept of R&D (I-RD) to the intercept of deliverables (I-D).

These results suggest the following*:*

- From the viewpoint of Deliverables (D), IT firms who keep high levels of deliverables (D), which is an outcome factor of the SEE factors and relevant to human development (HD), quality assurance (QA), project management (PM) and process improvement (PI), tend to maintain high profitability in the long-term, i.e., high operating profit ratio.
- In addition, improving human development (HD), quality assurance (QA), process improvement (PI) and R&D is effective for the enhancement of the level of deliverables (D).
- Regarding project management (PM) and customer contact (CC), IT firms who are active in sales and marketing, i.e., high levels of project management (PM) and customer contact (CC), tend to be at high level of productivity, i.e., sales per person, moreover, they become increasingly likely to improve the productivity in the long-term.
- Although the level of R&D negatively influences the level of deliverables (D), the level of R&D likely leads to the growth of profitability in the long-term.
- Concerning business performance, the profitable IT firms tend to be stable and this tendency accelerates increasingly, i.e., higher capital adequacy ratio, due to the enhancement of the levels of deliverables (D) and R&D.
- The productive IT firms, i.e., high level of sales per person, are not necessarily profitable, i.e., high level of operating profit ratio. This suggests that the established big IT firms tend to be less profitable due to the multi-layer subcontractor industry structure in Japan. In contrast, the growth of productivity likely lead to the growth of profitability for the emerging firms.

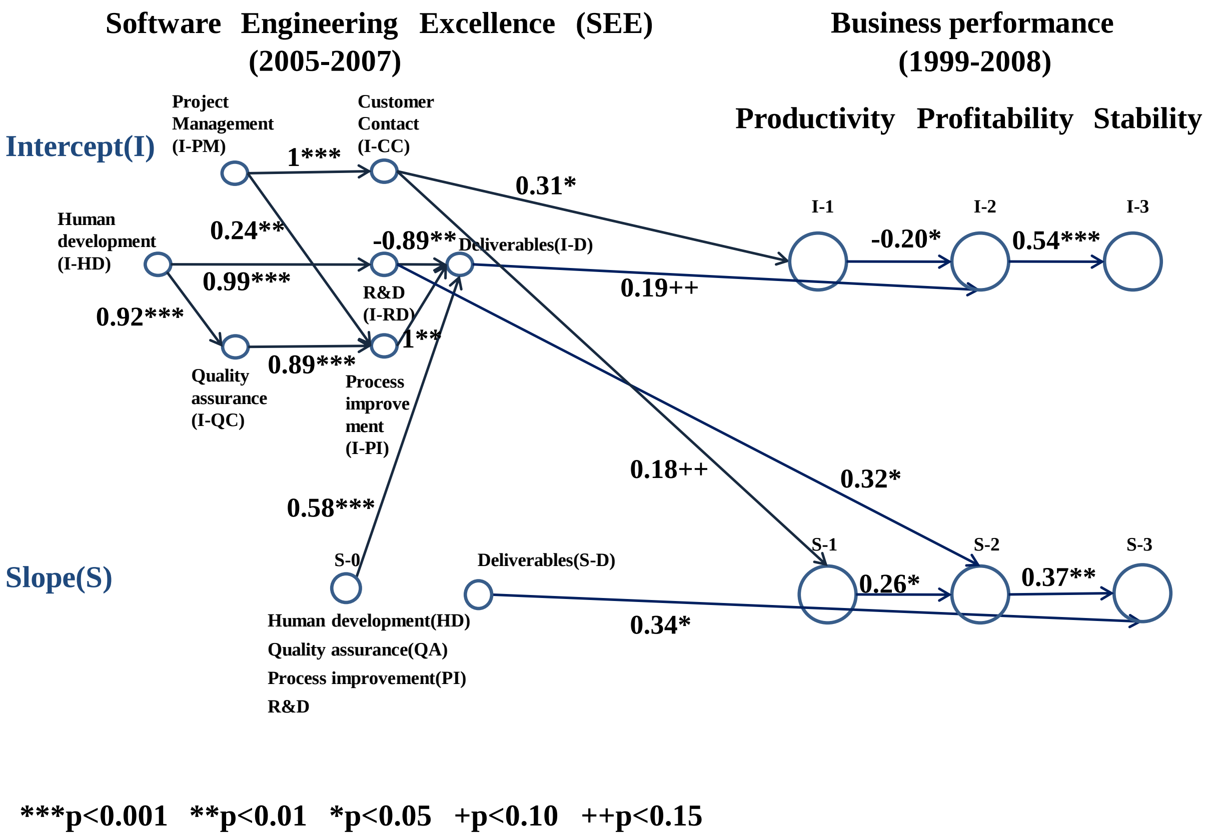

Figure 6. *Longitudinal Analysis Results*.

5 CONCLUSIONS AND FUTURE WORK

In order for the enterprise software industry in Japan to meet such challenges as technology innovation, legacy systems, custom-made applications, and multi-layer subcontractor industry structure, an important step is to understand how software engineering capabilities are significant as a core competence for achieving medium- and long-term business success. Therefore, we designed the research on software engineering excellence and conducted it in 2005, 2006 and 2007 with Ministry of Economy, Trade and Industry, Japan (METI), then 233 Japanese representative IT firms were surveyed totally.

Based on the structural model hypothesis in Figure 4, which is consistent with a series of empirical results, our research question in this paper is to investigate the relationships among the seven SEE factors and business performance in the long-term. Then, we conducted longitudinal analyses of the standardized data from the 233 valid responses we had received to the 2005, 2006, and 2007 surveys from 151 unique firms and newly introduced business performance data of the 151 firms, and selected the best panel model in terms of Akaike Information Criteria (AIC).

Through the panel analysis of the best longitudinal model, we found the following to be characteristics of the relationships among the intercepts and the slopes of the seven SEE factors over the three years from 2005 to 2007 and the ten-year business performance from 1999 through 2008. First, IT firms maintaining high levels of deliverables, which are derived from high levels of human development, quality assurance, project management and process improvement, tend to sustain high profitability in the long-term, e.g., operating profit ratio. Second, regarding the sales and marketing activities, IT firms with high levels of project management and customer contact tend to be highly productive, e.g., sales per person. Moreover, such firms increasingly improve the productivity in the long-term. Third, concerning business performance, the profitable IT firms tend to be stable and this tendency accelerates progressively due to the enhancement of the levels of deliverables and R&D. The productive IT firms are not necessarily profitable since the established big IT firms in Japan tend to be less profitable because of the multi-layer subcontractor industry structure.

Regarding the competitive environment, in the previous paper on the types of Japanese software vendors (Kadono et al. 2009), we found that the software maker-turned-vendors tend to significantly expand business with well-resourced R&D, while the user-turned-vendors seem to depend heavily on the demand of the parent companies. Therefore, some of user-turned-vendors are thought to gain inimitable capabilities. In contrast, many of the independent vendors serve as non-principal contractors that supply people without specific strengths as temporary staffing. However, some of the independent vendors with inimitable assets are thought to be the role models of software vendors in Japan (Barney 2007). For future study, we suggest considering the relationship among the types of Japanese software vendors as representatives of the competitive environment, software engineering capabilities, and business performance of the firms.

Furthermore, we would pursue the following for future work: continuous social research such as SEE survey, global comparison of the enterprise software industry and enterprise software development culture with the U.S., China, India, and the rest of the world, and the future estimation of the enterprise software industry in Japan through the simulations.

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