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Understanding Innovative Investment: Intangible Investment and R&D Expenditures of Korean Firms

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ABSTRACT

This study examines firms' propensity for innovative investment, such as intangible investment and R&D expenditures, by using rich panel data of Korean firms from the Survey of Business Activities. This topic has not been documented as much as the contribution of innovative investment to economic performance. The dynamic random effects probit estimations show not only that firms' propensity for intangible investment is persistent and dependent on firms' characteristics, but also that the dependence on firms' factors varies across sectors. On the one hand, estimations show that the propensity for intangible investment is complementary with internal R&D expenditures, except among ICT manufacturing firms. Among intellectual property rights, patents (trademarks) are positively associated with intangible investment in the non-ICT manufacturing (service) sector. In general, firms' affiliation with a parent company, or their status as listing companies, affects firms' propensity for intangible investment positively. On the other hand, firms' propensity for R&D expenditures exhibits stronger persistence than that for intangible investment. Non-ICT manufacturing firms exhibit the strongest persistence of R&D expenditures. While intangible investment is associated positively with propensity for R&D, patent rights are the only intellectual property rights showing positive connection to R&D expenditures. This effect is clearest among ICT manufacturing firms. In conclusion, this study contributes toward a better understanding of Korean firms' innovative investment by highlighting the role of firm-level characteristics, but also by demonstrating the heterogeneity of factors across sectors.

Keywords: Intangible investment, R&D expenditures, Heterogeneity, Dynamic random effect probit

JEL Classifications: D22, L21, O32

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I. INTRODUCTION

Korea is known for its strength in information and communication technology (henceforth ICT) and intensive research and development (henceforth R&D) investment, but studies have suggested that innovative investment, such as intangible investment and R&D investment, has been concentrated to a small part (Chun & Nadiri, 2016; Jung, 2018). This implies that Korean economy needs to spread innovative investment to sustain economic growth in the future, and this motivates this study to understand of determinants and properties of intangible investment in Korea. While contribution of intangible capital or R&D to economic success has been well documented (Corrado, Hulten, & Sichel, 2005; Corrado, Haskel, Jona-Lasinio, & Iommi, 2013; Corrado, Haskel, Jona-Lasinio, & Iommi, 2018; OECD, 2013), there is relatively fewer research on determinants of intangible capital accumulation at firm-level (Arrighetti, Landini, & Lasagni, 2014) and it is even more so compared to the study of R&D determinants (Brown, Martinsson, & Petersen, 2012; Czarnitzki, 2006; Czarnitzki & Toole, 2011; Lee, M. & Hwang, 2003; Lee, S., 2012). As innovation is found to be persistent (Antonelli, Crespi, & Scellato, 2012; Clausen, Pohjola, Sapprasert, & Verspagen, 2011; Ganter & Hecker, 2013), there can be potential persistence in innovative investment as well.

Thus, this study aims to analyze the propensity of innovative investment under firm heterogeneity by using a rich set of Korean firm-level panel data from Survey of Business Activities. The panel data allows to learn firm-level intangible and R&D investment in Korea with firm-level characteristics, such as affiliation, participation to international trade, and intellectual properties. To consider unobserved heterogeneity, the dynamic random effect probit model proposed by Wooldridge (2005) is applied. The probit estimations show persistence in innovative investment decision and effects of unobserved heterogeneity, but also different firm characteristics affect intangible investment and R&D investment. Furthermore, estimations for different industries indicate industry characteristics.

On the one hand, estimations on intangible investment propensity show size effect, positive associations with internal R&D expenditures, affiliation with a parent company, and listing status. A positive effect of patent rights on intangible

investment propensity is found from manufacturing firms, particularly non-ICT manufacturing firms, while that of trademark rights is observed from non-ICT service firms. Interestingly, association of intellectual property rights with intangible investment is not found significant for ICT firms. On the other hand, R&D investment is positively associated with intangible investment, patent rights, outsourcing, and export, but negatively associated with existence of parent company. In contrast to intangible investment, patent rights are positively associated with R&D investment for ICT firms, particularly ICT manufacturing firms. And the negative effect of parent company on R&D investment propensity is concentrated to manufacturing.

In sum, this study shows that innovative investment decision is affected by past innovative investment decision and firm characteristics. From the way firm heterogeneity influences innovative investment differently across industry (manufacturing versus services, ICT versus non-ICT), this study suggests influences of industry characteristics. This study contributes to existing literature on the determinants of intangible and R&D investment, but also to understanding the innovative investment in Korea. The firm-level analysis can provide interesting perspectives that may not be provided by aggregate approach.

Rest of this paper is organized as follows. In section 2, literature on intangible capital and R&D investment is reviewed. In section 3, the data for empirical analysis, and the empirical model are explained, followed by empirical results. This is followed by concluding remarks in the final section.

II. LITERATURE REVIEW

Reflecting importance of intangible capital, many studies document contribution of intangibles to economic growth, productivity or firm's value (Bontempi & Mairesse, 2015; Corrado et al., 2018; Haskel & Westlake, 2017; Hulten & Hao, 2008). Similarly, contribution of R&D investment to economic performance has been examined actively (Bilbao-Osorio & Rodriguez-Pose, 2004; Coad & Rao, 2010; Hong, 2017; Kim, 2011).

Micro-level intangible capital studies focus on contribution of intangible capital to economic performance such as firm's value or productivity. Intangible

assets help to analyze market value of firms (Hulten & Hao, 2008), and trademarks positively affect market value of firms (Sandner & Block, 2011). Intellectual capital (R&D and patents) and customer capital (trademarks and advertising) can improve the productivity significantly (Bontempi & Mairesse, 2015). And determinants and dynamics of intangible capital accumulation reflects firm-level characteristics (Arrighetti et al., 2014; Arrighetti, Landini, & Lasagni, 2015). Arrighetti et al. (2014) show association of human capital, organizational complexity, and cumulative dynamics with intangible capital, while Arrighetti et al. (2015) display persistence of intangible capital accumulation under firm heterogeneity.

Innovative activities are revealed to be persistent (Antonelli et al., 2012; Clausen et al., 2011; Ganter & Hecker, 2013), the persistence also can be observed both in innovative inputs (Máñez, Rochina-Barrachina, Sanchis, & Sanchis, 2009; Peters, 2007) and innovative outputs (Cefis, 2003; Roper & Hewitt-Dundas, 2008). Many empirical studies of persistent innovation rely on the dynamic probit model and highlight unobserved firm heterogeneity (Arrighetti et al., 2014; Ganter & Hecker, 2013; Peters, 2007; Triguero & Córcoles, 2013; Wooldridge, 2005; Wooldridge, 2010). Precisely the persistence of innovative activities is closely related to R&D activities (Antonelli et al., 2012; Clausen et al., 2011), and past innovation experience is an important determinant for current innovation, i.e. true state dependence (Máñez et al., 2009; Peters, 2007). Such persistence of innovation is likely to be strong among high-tech industries or intensive patent applicants (Cefis, 2003; Raymond, Mohnen, Palm, & van der Loeff, Sybrand Schim, 2010; Roper & Hewitt-Dundas, 2008).

In a related manner, cooperation with external agents may boost effectiveness of innovation due to potential spillover effects. R&D cooperation with external organizations or agents can improve individual firm's innovative output by the spillover effects. For instance, an inverted U-shape relation between extramural R&D and innovation performance is discovered (Wadhwa, Freitas, & Sarkar, 2017). There is a trade-off in the extramural R&D, since firms recognize the extramural R&D is risky due to potential knowledge leak, leading to firms' value protection strategies including employee retention or secrecy policy. Therefore, benefit from the extramural R&D is small when level of the extramural R&D is low, then it increases as the extramural R&D level rises due to spillover effects.

Eventually, the benefit eventually ceases increasing due to the value protection strategies when the extramural R&D further increases (Wadhwa et al., 2017). On the other hand, an analysis of intramural and extramural R&D by IT firms shows that internal R&D contributes to process innovation, the internal R&D without external members leads to product innovation, and the internal R&D and co-work with external members do not necessarily result in innovative outcomes (Jha & Bose, 2016). Their findings on innovation stemming from in-house R&D have an interesting implication to Montresor & Vezzani (2016), who display importance of internal intangible asset accumulation. They indicate that developing intangibles internally is the most innovation-impacting except in manufacturing, but intangible resource intensity is substantial for innovation in manufacturing (Montresor & Vezzani, 2016).[1] Additionally, there is a finding that knowledge spillovers on R&D cooperation is stronger for smaller firms than larger ones (Chun & Mun, 2012).

Listing status may affect investment decisions due to potentially different cost and incentives for external finance (Asimakopoulos, Asimakopoulos, & Fernandes, 2019; Asker, Farre-Mensa, & Ljungqvist, 2015). Listed firms tend to show more intensive and persistent R&D investment than unlisted firms (French, Fujitani, & Yasuda, 2020). In addition, R&D decisions by group-affiliated firms may be affected by internal finance availability from other firms within the group, possibly coordinated by group-level R&D activities (Beneito, Rochina-Barrachina, & Sanchis-Llopis, 2015). Thus, the same might be found from intangible investment.

In addition, industry-level characteristics can be crucial to firms' incentive to

[1] About specific partnership of R&D cooperation, Belderbos, Carree, & Lokshin (2004) examine effects of R&D cooperation to firm performance, labor productivity and productivity of innovative sales, by distinguishing partnership of R&D cooperation. They show partnership with competitors or suppliers contributes to incremental innovation, partnership with competitors or universities/research institutes contributes to innovative sales, and partnership with customers or universities/research institutes contributes to developing sources of knowledge for radical innovation (Belderbos, Carree, & Lokshin, 2004). R&D partnership also involves foreign investors. Multinational companies (MNC) parents ownership strategy and subsidiary experience plus majority owned affiliates determine foreign affiliates' performance (Contractor, Yang, & Gaur, 2016), which show routes that MNC parents' intangible assets contribute to performance of foreign affiliate.

invest in intangible capital. For instance, industry-level patent protection is positively influential to firm's stock market value if a firm performs R&D (Cockburn & Griliches, 1988), because it can affect firm's incentive to invest in R&D. When it comes to innovation beyond R&D, innovation in service sector needs to be analyzed differently from manufacturing. On characteristics of innovation in the service sector, "softer" aspects of innovation based on skills and inter-organization cooperation practices must be emphasized in the service sector than the manufacturing (Tether, 2005). This implies different types of intangibles might be involved with innovation in the service sector, as Montresor & Vezzani (2016) point out internal development of intangibles is an impactful aspect except in the manufacturing.

Studies of intangible capital also emphasize complementarity with ICT (Basu, Fernald, Oulton, & Srinivasan, 2003; Chen, Niebel, & Saam, 2016; Corrado, Haskel, & Jona-Lasinio, 2017). For example, Basu, Fernald, Oulton, & Srinivasan (2003) point out availability of cheap ICT capital and complementary investment in intangibles enhanced productivity growth. Similar complementarity between ICT and intangible capital is displayed at industry level (Chen et al., 2016), and ICT's role on productivity growth is found to be enhanced via spillover effects of knowledge (Corrado et al., 2017). The complementarity suggests that ICT intensive firms are likely to invest in innovative capital as well. From this perspective, ICT firms might show different patterns of innovative investment from firms in other industries.

Finally, there are findings that only a handful of manufacturing sectors in Korea heavily invests in innovative assets while service sector shows much smaller investment in innovative intangible assets (Chun & Nadiri, 2016; Jung, 2018). Chun & Nadiri (2016) show that contribution of intangible-intensive industries to aggregate productivity growth has increased in Korea and innovation in the intangible-intensive industries could be significant source of productivity growth. In addition to firm-level heterogeneity, Jung (2018) shows sectoral heterogeneity in Korea, which will be considered in this paper as well. However, in my knowledge, there has not been many studies on determinants of the firm-level intangible investment of Korean firms, compared to R&D investment. Mostly empirical studies on intangible assets and intangible investment in Korea are concentrated to their contribution to firm value or firm performances from

perspective of accounting and management (Chung & Cho, 2004; Cho, Park, & Kim, 2014; Ha & Yi, 2013; Lee & Og, 2015; Piao & Yang, 2011).

Based on the review of literature, this study contributes to firm-level research on determinants of intangible investment and R&D investment in Korea by adopting the approach of Arrighetti et al. (2014) and the methodology of Peters (2007), Triguero & Córcoles (2013), and Wooldridge (2010). Particularly, findings on the firm-level determinants of intangible investment are relatively novel in Korea. The findings from this study provide evidence of firm and sectoral heterogeneity in intangible and R&D investment from available interesting data of Korean firms, but also enriches existing literature on Korean intangible capital (Chun & Nadiri, 2016; Jung, 2018) by showing firm-level determinants of intangible accumulation.

III. EMPIRICAL ANALYSIS

1. Data

The panel data is from Survey of Business Activities annually conducted by Statistics Korea, the Korean government's statistics agency, which can be obtained via a platform called MDIS (Microdata Integrated Service). The survey covers both of listed and unlisted firms in all industries, but only firms hiring more than 50 permanent employees and assets value higher than 300 million Korean Won are included in the data. Intangible assets in the database are defined as "assets without physical shape but identified, and non-monetary assets with expected economic returns in the future, which are controlled and owned by firms for production of products or provision of services, rental to others, or management. Intangible assets include industry intellectual property such as patent rights, design rights and trademarks rights; expenditures for software development; purchase of software; and others as expenses for franchise or license" (Korean Statistics).[2]

[2] This is translated by author from the Korean glossary in Korean Statistics website because English version is not provided. (Link: http://www.narastat.kr/metasvc/svc/SvcMetaDcDtaPopup.do?confmNo=101066)

While the panel data from Survey of Business Activities does not provide specific components of intangible investment, nor values of tangible and intangible assets, total value of intangible investment and numbers of intellectual property rights held by firms are available. The data also contains number of employees,[3] sales, exports, intramural and outsourced (extramural) R&D expenditures, in addition to information of expenditures for outsourcing, existence of parent company and subsidiaries, and participation of foreign capital. Compared to another popular firm-level panel data from KIS-Value, Survey of Business Activities has advantage over KIS-Value as it provides information beyond corporate finance data. For example, information on intellectual property rights, external R&D expenditures, and existence of parent company and its share is available from Survey of Business Activities. Recently the survey has added questionnaire of strategic alliance and the 4th Industrial Revolution technology. Eventually, a balanced panel data for period of 2010~2016 is used since a balanced panel data is required for the dynamic probit analysis (Antonelli et al., 2012).

From the summary statistics in the left panels of <Table 1A and 1B>, several significant differences between manufacturing and service sector emerge. The numbers of observation vary across variables due to missing values. Expectedly manufacturing firms invest in tangible assets more heavily than service firms and conduct R&D investment more actively, whereas the scale of tangible and intangible is larger for manufacturing firms than service firms. The manufacturing firms also own more intellectual property rights than service firms, and their intellectual property rights are concentrated to patent rights. On the contrary, service firms relatively invest heavily in intangible assets, and trademark rights are their main intellectual property rights. And manufacturing firms are more likely to engage in international competition by exporting than service firms.[4]

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3 In the analysis, only regular employees are considered, even though some firms report temporary employees and daily workers.

4 As total R&D investment is defined as sum of intramural R&D expenditure and extramural R&D expenditure outsourced to external agents in this study, and there are observations with positive intramural R&D and missing extramural R&D expenditure or vice versa, missing R&D expenditures are treated as zero. However, this transformation does not alter qualitative results of estimation, while observations included in the estimation increase.

Within manufacturing sector in <Table 1A>, ICT manufacturing firms tend to be larger than non-ICT manufacturing firms. ICT manufacturing firms invest more in intangible capital and R&D and own more intellectual property rights than non-ICT manufacturing firms, on average. Within service sector in Table 1B, ICT service firms tend to employ less workers than non-ICT service firms. Average sales and export of ICT firms are also smaller than those of non-ICT firms. However, ICT service firms are more likely to invest in intangible capital and R&D than non-ICT service firms. Finally, <Table1A and 1B> suggest that non-ICT firms are more likely to have subsidiaries than ICT firms, even though it would be hasty to make any further conclusion at this stage.

<Table 1A> Summary statistics for manufacturing

	Manufacturing			**ICT Manufacturing**		
Variable	**Obs**	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
Employment	27,817	372.3	2238.9	3,108	752.9	5274.1
Tangible investment	27,726	18567.6	255356.7	3,105	58328.5	671809.9
Intangible investment	24,954	1835.8	29632.9	2,873	5829.3	67001.3
Positive intangible investment dummy	27,817	0.49	-	3,108	0.63	-
Internal R&D expenditures	21,806	9531.7	221673.7	2,649	48922.71	624606.0
Extramural R&D expenditures	5,475	1900.7	-	650	3952.43	-
Positive R&D expenditures dummy	27,817	0.76	-	3,108	0.83	-
Patents rights	22,602	79.5	1129.8	2,755	340.31	3009.0
Design rights	17,609	26.3	304.8	2,025	67.03	805.8
Trademark rights	19,894	52.9	358.0	2,213	43.30	460.9
Subsidiary dummy	27,817	0.48	-	3,108	0.36	-
Parents dummy	27,809	0.82	-	3,107	0.87	-

<Table 1B> Summary statistics for service sector

	Manufacturing			ICT Manufacturing		
Variable	**Obs**	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
Employment	23,572	407.3	1275. 1	4,148	339.76	1427.9
Tangible investment	22,841	9759.5	90917.1	4,026	17103.9	166124.2
Intangible investment	20,247	2120.2	37886.6	3,779	6042.00	79936.0
Positive intangible investment dummy	23,572	0.40	-	4,148	0.63	-
Internal R&D expenditures	8,075	2398.2	16147.3	2,429	4860.8	26918.3
Extramural R&D expenditures	3,304	513.2	3624.9	597	1312.87	6681.4
Positive R&D expenditures dummy	23,572	0.25	-	4,148	0.54	-
Patents rights	14,397	13.75	154.4	3,070	39.07	326.1
Design rights	11,965	3.04	21.8	2,210	4.83	27.5
Trademark rights	14,884	32.30	160.99	3,263	48.10	228.63
Subsidiary dummy	23,572	0.64	-	4,148	0.49	-
Parents dummy	23,560	0.74	-	4,148	0.76	-

2. Model

The objective of this study is to examine what characteristics lead to innovative investment, and the data suggests that not all firms invest in innovative capital. Thus, a random effect probit model can be chosen to analyze propensity of innovative investment (Arrighetti et al., 2014; Ganter & Hecker, 2013; Peters, 2007). For firm *i=1, …., N* in period *t=1, …, T*,

$$y_{it}^{*} = X_{it}\beta + u_i + \varepsilon_{it}$$
$$\varepsilon_{it} \sim N(0, \sigma^2) \quad (1)$$

, where $y_{it} = 1$ if $y_{it}^{*} > 0$, and $y_{it} = 0$ otherwise. X_{it} represents a vector of exogenous explanatory variables, u_i denotes the firm-specific time-invariant term

to represent unobserved firm characteristics, and ε_{it} is an idiosyncratic error. In this study, the dynamic random effect probit model is applied to consider potential persistence of innovative investment decision, which adds previous decision $y_{i,t-1}$ to equation (1) as equation (2) (Arrighetti et al., 2014; Ganter & Hecker, 2013; Peters, 2007; Triguero & Córcoles, 2013).[5]

$$y_{it}^{*} = \gamma y_{it-1} + X_{it}\beta + u_i + \varepsilon_{it} \quad (2)$$

, where $y_{it} = 1$ if $y_{it}^{*} > 0$ or a firm *i* invests in innovative capital in period *t*, and $y_{it} = 0$ otherwise. X_{it} is assumed to be strictly exogenous, and conditional on the unit-specific unobserved u_i. Assumptions on initial observation $y_{i,0}$ and correlation with the individual characteristics u_i are required to estimate the model. On this matter, a simplified method has been proposed by using initial observation $y_{i,0}$ and time-averaged covariates as predictors of the individual effect (Arrighetti et al., 2014; Peters, 2007; Wooldridge, 2005).

The distribution of u_i is assumed to be conditional on $y_{i,0}$ and $\overline{X}_\iota$ (Wooldridge, 2005), and specified as $u_i = \alpha_0 + \alpha_1 y_{i0} + \alpha_2 \overline{X}_\iota + \alpha_3 X_{i0} + c_i$ with $\overline{X}_\iota \equiv \frac{1}{T}\sum_{t=0}^{T} X_{i,t}$ by Grotti & Cutuli (2018). In this specification, c_i is the unit-specific time-constant error term, normally distributed with mean zero and variance σ_a^2. Therefore, the dynamic random effect probit model (2) becomes

$$y_{it}^{*} = \gamma y_{it-1} + X_{it}\beta + \alpha_0 + \alpha_1 y_{i0} + \alpha_2 \overline{X}_\iota + \alpha_3 X_{i0} + c_i + \varepsilon_{it} \quad (3)$$

, which would be estimated by conditional maximum likelihood estimation (Arrighetti et al., 2014; Wooldridge, 2005).

For estimation of propensity of intangible investment, explanatory variables consist of employment, binary indicator variables of internal and external R&D expenditures, intellectual property rights for each type of rights, affiliation with

[5] The model here is estimated by STATA's xtpdyn proposed by Grotti & Cutuli (2018), who applied Wooldridge's idea to the dynamic probit model (Grotti & Cutuli, 2018; Wooldridge, 2005; Wooldridge, 2010).

subsidiaries and parent company, foreign capital participation, listing status, and export. On the other hand, for estimation of propensity of R&D expenditures, explanatory variables consist of employment, binary indicator variables of intangible investment, intellectual property rights for each type of rights, affiliation with subsidiaries and parent company, foreign capital participation, listing status, and export.

Employment represents firm size, whereas the binary indicators for reporting positive internal and external R&D expenditures (intangible investment) are included to investigate potential complementarity with intangible investment (R&D expenditures). The indicators of owning intellectual property rights are included to find if a specific type of intellectual property right is associated with intangible investment (R&D expenditures). While external R&D represents R&D cooperation with external agents (Montresor & Vezzani, 2016), affiliation with subsidiaries and/or a parent company (Beneito et al., 2015), and foreign capital participation reflect organizational complexity related to innovative investment (Arrighetti et al., 2014). The listing status is included to capture the status' implications to investment decisions, such as access to external finance (French et al., 2020). Finally, another binary indicator of export is added, since the close association of R&D investment with export has been reported (Aw & Song, 2013).

3. Empirical results: intangible investment

<Table 2 and 3> show the average marginal effects of the dynamic random effects probit estimations of intangible investment and R&D expenditures, respectively. First and second columns show estimation results of manufacturing and service firms. In consideration of complementarity of innovativeness and ICT, estimation results of ICT and non-ICT firms are displayed separately. Full tables of estimation results with initial values and within-unit averages are exhibited in Appendix to save space and improve readability.

<Table 2> shows that intangible investment is significantly persistent, and firm size is positively associated with the propensity of intangible investment.[6] Also

[6] According to Tables in Appendix, some of the time-averaged variables in the Wooldridge

listing status is significantly associated with intangible investment, showing more likelihood of intangible investment by listed firms than unlisted firms. Intangible investment is positively associated with the internal R&D expenditures, and the association is stronger than the external R&D expenditures. And affiliation with a parent company is more likely to lead to intangible investment. Between manufacturing and service firms, some notable differences emerge. Association of internal R&D with intangible investment is stronger for service than manufacturing firms. Among intellectual property rights, patent rights are positively associated with intangible investment in manufacturing, but trademark rights in service sector. Subsidiary matters only in the service sector intangible investment, while parent company does in both sectors. Expectedly, intangible investment in manufacturing is positively linked to export.

Next two columns in <Table 2> compare ICT and non-ICT firms. While the internal R&D expenditures are significant, intellectual property rights are not significant factors of intangible investment in either sector. Existence of a parent company and listing status positively affect the propensity of intangible investment in general, but outsourcing improves the propensity of intangible investment of only ICT firms. Foreign capital participation negatively influences intangible investment of non-ICT firms.

In <Table 3>, ICT and non-ICT firms are contrasted within manufacturing and service sector. Non-ICT manufacturing firms exhibit stronger persistence of intangible investment than ICT manufacturing firms. Somewhat surprisingly, none of internal R&D expenditures, patent rights and export are significant factors of intangible investment of ICT firms. On the contrary, non-ICT manufacturing firms show positive associations of internal and external R&D expenditures, patent rights, and export with their intangible investment. Affiliation with a parent company and listing status are common positive factors of intangible investment for both groups of manufacturing firms.

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approach show opposite signs associated with the corresponding year-specific variables, thus it can be interpreted as existence of unobserved heterogeneity in this sample (Triguero & Corcoles, 2013).

<Table 2> Estimation of the average marginal effects: Intangible investment

	Manufacturing	**Service**	**ICT**	**Non-ICT**
	(1)	**(2)**	**(3)**	**(4)**
Lagged intangible inv dummy	0.209***	0.165***	0.159***	0.193***
	(0.0143)	(0.0154)	(0.0255)	(0.0112)
Log(employment)	0.0811***	0.0410***	0.119***	0.0466***
	(0.0166)	(0.0120)	(0.0235)	(0.0107)
Internal R&D dummy	0.0265**	0.0737***	0.0386*	0.0382***
	(0.0125)	(0.0155)	(0.0231)	(0.00989)
External R&D dummy	0.0256	0.0155	0.0386	0.0208
	(0.0172)	(0.0237)	(0.0283)	(0.0141)
Patent dummy	0.0238*	-0.00291	-0.0207	0.0168
	(0.0135)	(0.0162)	(0.0248)	(0.0108)
Utility dummy	-0.0115	0.00343	-0.0294	-0.00395
	(0.0115)	(0.0200)	(0.0259)	(0.00986)
Design dummy	-0.0126	-0.0109	-0.0195	-0.0145
	(0.0126)	(0.0189)	(0.0234)	(0.0107)
Trademark dummy	0.00991	0.0367***	0.0286	0.0134
	(0.0121)	(0.0124)	(0.0223)	(0.00896)
Subsidiary dummy	0.0119	0.0339***	0.0120	0.0250***
	(0.00793)	(0.00850)	(0.0144)	(0.00608)
Parent dummy	0.0326***	0.0623***	0.0319*	0.0485***
	(0.0105)	(0.0102)	(0.0175)	(0.00784)
Foreign capital dummy	-0.00470	-0.0292***	0.00714	-0.0131*
	(0.0103)	(0.0105)	(0.0204)	(0.00777)
Listed dummy	0.0860***	0.0797***	0.0989***	0.0807***
	(0.0108)	(0.0148)	(0.0181)	(0.00924)
Outsourcing dummy	0.0148	0.0103	0.0408**	0.0127
	(0.0117)	(0.00911)	(0.0179)	(0.00780)
Export dummy	0.0195*	-0.00451	0.0191	0.00794
	(0.0107)	(0.00986)	(0.0188)	(0.00780)
N	18130	14624	4450	30340
Log likelihood	-7848.778	-5429.957	-1747.901	-12365.271
χ^2	4140.685	3889.783	912.972	8940.040

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are omitted in the report.

<Table 3> Estimation of the average marginal effects: Intangible investment

	ICT manufacturing (1)	**Non-ICT manufacturing (2)**	**ICT services (3)**	**Non-ICT services (4)**
Lagged intangible inv	0.130***	0.209***	0.146***	0.163***
	(0.0275)	(0.0151)	(0.0318)	(0.0171)
Log(employment)	0.103***	0.0760***	0.131***	0.0259**
	(0.0385)	(0.0179)	(0.0293)	(0.0126)
Internal R&D dummy	-0.00340	0.0297**	0.0621**	0.0748***
	(0.0389)	(0.0131)	(0.0281)	(0.0185)
External R&D dummy	-0.0187	0.0370*	0.109**	-0.0140
	(0.0331)	(0.0192)	(0.0452)	(0.0263)
Patent dummy	0.0134	0.0240*	-0.0347	0.00955
	(0.0422)	(0.0143)	(0.0310)	(0.0193)
Utility dummy	-0.0584*	-0.00333	0.0389	0.000670
	(0.0301)	(0.0124)	(0.0498)	(0.0213)
Design dummy	-0.00845	-0.0135	-0.0259	-0.00515
	(0.0286)	(0.0137)	(0.0419)	(0.0215)
Trademark dummy	-0.00141	0.0101	0.0480	0.0337**
	(0.0330)	(0.0128)	(0.0293)	(0.0136)
Subsidiary dummy	0.00643	0.0121	0.0126	0.0389***
	(0.0213)	(0.00841)	(0.0195)	(0.00944)
Parent dummy	0.0582**	0.0288***	0.0184	0.0698***
	(0.0280)	(0.0111)	(0.0227)	(0.0113)
Foreign capital dummy	0.0279	-0.00803	-0.0116	-0.0311***
	(0.0265)	(0.0110)	(0.0314)	(0.0110)
Listed dummy	0.0873***	0.0793***	0.119***	0.0675***
	(0.0224)	(0.0118)	(0.0270)	(0.0173)
Outsourcing dummy	0.0161	0.0175	0.0487**	0.00114
	(0.0335)	(0.0124)	(0.0208)	(0.00996)
Export dummy	0.0184	0.0207*	0.0186	-0.0125
	(0.0307)	(0.0115)	(0.0253)	(0.0107)
N	1981	16149	2469	12155
Log likelihood	-735.484	-7067.736	-992.330	-4393.359
χ^2	436.028	3675.618	507.066	3153.331

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are omitted in the report.

On the other hand, in (3) and (4) of <Table 3>, both of internal and external R&D expenditures are significant for intangible investment of ICT service firms, whereas only internal R&D expenditures are significant for non-ICT service firms. While intangible investment by ICT service firms is positively associated with outsourcing, intangible investment by non-ICT service firms is positively associated with trademark rights and existence of affiliated firms (subsidiary or parent company) but negatively with foreign capital ownership. Finally, listed firms are more likely to invest in intangible capital than unlisted firms in both sectors.

4. Empirical results: R&D expenditures

<Table 4> displays estimation results of R&D expenditures propensity, and R&D expenditures show substantial persistence. The coefficients on the lagged R&D decision are larger than the coefficients on the lagged intangible investment from previous estimations of marginal effects (<Table 2>), and it implies that R&D expenditures tend to be more persistent than intangible investment.

When separately estimated for the manufacturing and service firms in (1) and (2) of <Table 4>, R&D persistence is stronger in the manufacturing than the service sector, and intangible investment is more strongly associated with R&D propensity in the service sector. Expectedly, patent rights are positive factors to R&D expenditures, as they are likely to represent outputs of past R&D expenditures. While outsourcing and export improve the R&D propensity, affiliation with a parent company does not.

Seemingly, the result on the parent company affiliation contrasts with the previous results on intangible investment propensity. It is possibly because R&D expenditures are measured from input side of innovation, while intangible investment is measured from output side of innovation since intangible investment is measured by increments (acquisition) in intangible assets. Thus, for example, affiliation helps spread allocation of within-group R&D resource (a negative coefficient on the parent company dummy), but intangible assets are outputs shared by firms within a group (a positive coefficient). However, precise conclusion on the parent company and R&D expenditure propensity has to derived after further investigation.

<Table 4> Estimations of average marginal effects: R&D expenditures

	manufacturing **(1)**	**services** **(2)**	**ICT** **(3)**	**non-ICT** **(4)**
Lagged R&D dummy	0.360***	0.226***	0.275***	0.315***
	(0.0220)	(0.0229)	(0.0376)	(0.0168)
Log(employment)	0.0224*	0.0112	0.0295	0.0221***
	(0.0122)	(0.00772)	(0.0196)	(0.00684)
Intangible inv dummy	0.0194***	0.0344***	0.0243*	0.0249***
	(0.00685)	(0.00658)	(0.0138)	(0.00506)
Patent dummy	0.0174*	0.0245**	0.0550**	0.0161**
	(0.00922)	(0.0105)	(0.0242)	(0.00695)
Utility dummy	0.00799	-0.00377	-0.0100	0.00444
	(0.00874)	(0.0106)	(0.0208)	(0.00686)
Design dummy	0.00803	0.00390	-0.00615	0.00833
	(0.00941)	(0.0112)	(0.0208)	(0.00755)
Trademark dummy	-0.0135	0.00576	-0.0125	-0.00263
	(0.00830)	(0.00755)	(0.0165)	(0.00600)
Subsidiary dummy	-0.00169	0.00759	0.00700	0.00267
	(0.00526)	(0.00514)	(0.0110)	(0.00388)
Parent dummy	-0.0321***	-0.00881	-0.0243*	-0.0222***
	(0.00735)	(0.00600)	(0.0138)	(0.00513)
Foreign capital dummy	-0.00609	-0.00673	-0.0119	-0.00491
	(0.00731)	(0.00642)	(0.0140)	(0.00533)
Listed dummy	0.00131	0.00659	0.0222	-0.00541
	(0.00703)	(0.00718)	(0.0142)	(0.00540)
Outsourcing dummy	0.0813***	0.0581***	0.0828***	0.0720***
	(0.0106)	(0.00736)	(0.0153)	(0.00698)
Export dummy	0.0183**	0.0164**	0.0407**	0.0137**
	(0.00744)	(0.00687)	(0.0160)	(0.00533)
N	18130	14624	4450	30340
Log likelihood	-4740.973	-3002.620	-1236.653	-7179.261
χ^2	4355.498	3087.427	941.202	8904.115

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are omitted in the report.

When ICT and non-ICT firms are compared in the third and fourth columns of <Table 4>, R&D expenditures are found to be persistent. Intangible investment, patent rights, outsourcing, export, and listing status are all positively associated with R&D expenditures in both of ICT and non-ICT firms. But the size effect on the R&D propensity is significant only for non-ICT firms, and patent rights are more substantially significant to the R&D propensity of ICT firms than non-ICT firms. Finally, export has stronger effects on the R&D propensity of ICT firms than non-ICT firms.

Within manufacturing ((1) and (2) of <Table 5>), ICT manufacturing and non-ICT manufacturing firms are compared. The coefficient on the lagged R&D expenditures indicator implies non-ICT firms' R&D expenditures are more persistent than ICT firms. But ICT firms' R&D propensity is substantially associated with intellectual property of patent rights. This could reflect that ICT-related patents rights are critical to Korean ICT manufacturing firms. On the other hand, outsourcing and export have significantly positive association with R&D propensity of non-ICT manufacturing firms, while they have positive but not significant relation with R&D propensity of ICT manufacturing firms.

Subsequently in the next two columns ((3) and (4) of <Table 5>), ICT service firms exhibit stronger persistence of R&D expenditures than non-ICT service firms. Furthermore, ICT service firms show closer connection between intangible investment and R&D expenditures than non-ICT service firms. Contrary to the manufacturing firms, R&D propensity of ICT service firms is positively associated with both of outsourcing and export, while that of non-ICT service is positively associated with only outsourcing.

In sum, it is non-ICT manufacturing firms whose R&D expenditures are the most persistent. Investing in intangible capital is positively associated with propensity of R&D expenditures in general, but size effect is observed only in manufacturing. Among intellectual property rights, only patent rights are positively associated with propensity of R&D expenditures, and this reflects the technical property of R&D expenditures. In contrast to intangible investment, affiliation with a parent company does not positively affect R&D expenditures but outsourcing positively affects it.

<Table 5> Estimations of average marginal effects: R&D expenditures

	ICT manufacturing (1)	non-ICT manufacturing (2)	ICT services (3)	non-ICT services (4)
Lagged R&D dummy	0.142***	0.358***	0.293***	0.221***
	(0.0230)	(0.0228)	(0.0478)	(0.0271)
Log(employment)	0.0473**	0.0152	0.0233	0.00890
	(0.0202)	(0.0135)	(0.0319)	(0.00739)
Intangible inv. dummy	0.000442	0.0227***	0.0499**	0.0297***
	(0.0184)	(0.00732)	(0.0201)	(0.00688)
Patent dummy	0.0571**	0.0117	0.0426	0.0240**
	(0.0223)	(0.00970)	(0.0366)	(0.0110)
Utility dummy	-0.00689	0.00914	-0.0116	-0.00316
	(0.0181)	(0.00945)	(0.0402)	(0.00999)
Design dummy	0.0244	0.00580	-0.0487	0.0133
	(0.0177)	(0.0104)	(0.0362)	(0.0124)
Trademark dummy	-0.0172	-0.0134	-0.0119	0.00738
	(0.0189)	(0.00895)	(0.0256)	(0.00754)
Subsidiary dummy	0.0165	-0.00295	0.00663	0.00942*
	(0.0120)	(0.00568)	(0.0181)	(0.00512)
Parent dummy	-0.0230*	-0.0327***	-0.0257	-0.00558
	(0.0135)	(0.00800)	(0.0218)	(0.00584)
Foreign capital dummy	0.000649	-0.00743	-0.0190	-0.00344
	(0.0152)	(0.00803)	(0.0241)	(0.00619)
Listed dummy	0.0158	-0.00305	0.0188	0.00369
	(0.0175)	(0.00768)	(0.0224)	(0.00739)
Outsourcing dummy	0.0291	0.0872***	0.115***	0.0457***
	(0.0210)	(0.0115)	(0.0205)	(0.00789)
Export dummy	0.0252	0.0169**	0.0507**	0.00833
	(0.0202)	(0.00777)	(0.0222)	(0.00693)
N	1981	16149	2469	12155
Log likelihood	-370.277	-4333.964	-845.726	-2125.433
χ^2	488.310	3899.128	541.061	2320.191

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are omitted in the report.

IV. CONCLUDING REMARKS

This study aims to inspect propensity of innovative investment at the firm level, which has become a critical factor of economic success. The dynamic random effects probit model is applied to examine the effects of firm-level characteristics on the propensity of innovative investment by adopting the approach of Arrighetti et al. (2014) and the methodology of Peters (2007), Triguero & Córcoles (2013), and Wooldridge (2010). Further estimations are performed on different sectors to further investigate the effects of sectoral characteristics. Examining the decision of intangible investment and R&D expenditures, persistence is found in both types of investment, but R&D expenditures are more persistent than intangible investment. In either type of innovative investment, it is the non-ICT manufacturing firms that show the strongest persistence. Furthermore, estimations show strong complementarily between intangible investment and internal R&D expenditures.

On the one hand, patents rights and trademark rights are positively associated with intangible investment in manufacturing and service sector, respectively. Additionally, affiliation with a parent company and status as a listed firm are positive factors for the propensity of intangible investment, but the positive effects of export are limited to manufacturing firms. On the other hand, only patents rights show positive connection with R&D expenditures propensity, and ICT manufacturing firms exhibit the strongest association between patents rights and R&D expenditures propensity. This reflects the technical properties of R&D expenditures and patent rights. Size effect on R&D propensity is limited to manufacturing firms, and export increases R&D propensity of non-ICT manufacturing and ICT service firms.

In conclusion, this study contributes to the study of innovative investment in Korea by spotlighting firm heterogeneity in innovative investment decisions, which has been documented much less than contribution of innovative investment to firm value or other firm performances. And estimations across different sectors exhibit additional influences of industry level characteristics, which can enrich existing finding on sectoral intangible capital accumulation (Chun & Nadiri, 2016; Jung, 2018). Finally, this study suggests that policies promoting innovation through accumulation of intangibles accommodate not only firm-level demands but also industry-specific characteristics.

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<Appendix> Full estimation tables of Table 2~5

<Table 2A> Estimation of the average marginal effects: Intangible investment

	Manufacturing	**Service**	**ICT**	**Non-ICT**
	(1)	**(2)**	**(3)**	**(4)**
Lagged intangible inv dummy	0.209***	0.165***	0.159***	0.193***
	(0.0143)	(0.0154)	(0.0255)	(0.0112)
Log(employment)	0.0811***	0.0410***	0.119***	0.0466***
	(0.0166)	(0.0120)	(0.0235)	(0.0107)
Internal R&D dummy	0.0265**	0.0737***	0.0386*	0.0382***
	(0.0125)	(0.0155)	(0.0231)	(0.00989)
External R&D dummy	0.0256	0.0155	0.0386	0.0208
	(0.0172)	(0.0237)	(0.0283)	(0.0141)
Patent dummy	0.0238*	-0.00291	-0.0207	0.0168
	(0.0135)	(0.0162)	(0.0248)	(0.0108)
Utility dummy	-0.0115	0.00343	-0.0294	-0.00395
	(0.0115)	(0.0200)	(0.0259)	(0.00986)
Design dummy	-0.0126	-0.0109	-0.0195	-0.0145
	(0.0126)	(0.0189)	(0.0234)	(0.0107)
Trademark dummy	0.00991	0.0367***	0.0286	0.0134
	(0.0121)	(0.0124)	(0.0223)	(0.00896)
Subsidiary dummy	0.0119	0.0339***	0.0120	0.0250***
	(0.00793)	(0.00850)	(0.0144)	(0.00608)
Parent dummy	0.0326***	0.0623***	0.0319*	0.0485***
	(0.0105)	(0.0102)	(0.0175)	(0.00784)
Foreign capital dummy	-0.00470	-0.0292***	0.00714	-0.0131*
	(0.0103)	(0.0105)	(0.0204)	(0.00777)
Listed dummy	0.0860***	0.0797***	0.0989***	0.0807***
	(0.0108)	(0.0148)	(0.0181)	(0.00924)
Outsourcing dummy	0.0148	0.0103	0.0408**	0.0127
	(0.0117)	(0.00911)	(0.0179)	(0.00780)
Export dummy	0.0195*	-0.00451	0.0191	0.00794
	(0.0107)	(0.00986)	(0.0188)	(0.00780)
Initial intangible inv	0.309***	0.279***	0.339***	0.294***
	(0.0150)	(0.0171)	(0.0315)	(0.0118)
Initial internal R&D dummy	-0.0136	0.00586	-0.0259	-0.00347
	(0.0138)	(0.0177)	(0.0255)	(0.0111)
Initial external R&D dummy	-0.0315*	0.0222	-0.0170	-0.0144
	(0.0171)	(0.0251)	(0.0365)	(0.0141)

Initial patent dummy	-0.0158	-0.0456***	-0.00619	-0.0304***
	(0.0140)	(0.0174)	(0.0302)	(0.0111)
Initial utility dummy	-0.00586	-0.0269	-0.0666**	-0.00307
	(0.0133)	(0.0219)	(0.0313)	(0.0117)
Initial design dummy	-0.0342**	-0.0498**	-0.0274	-0.0292**
	(0.0141)	(0.0224)	(0.0328)	(0.0122)
Initial trademark dummy	0.0113	0.0407***	0.0387	0.0141
	(0.0128)	(0.0154)	(0.0245)	(0.0102)
Initial outsourcing dummy	0.0122	-0.0220*	-0.0186	-0.00134
	(0.0140)	(0.0113)	(0.0205)	(0.00983)
Initial export dummy	0.00448	-0.0228*	0.00485	-0.00979
	(0.0124)	(0.0132)	(0.0232)	(0.00949)
Initial log(employment)	-0.0536***	-0.0296**	-0.0389	-0.0381***
	(0.0173)	(0.0118)	(0.0252)	(0.0105)
Avg. internal R&D dummy	0.0531**	-0.0190	0.0496	0.0200
	(0.0234)	(0.0284)	(0.0429)	(0.0185)
Avg. external R&D dummy	0.0661*	-0.0384	0.00741	0.0164
	(0.0347)	(0.0461)	(0.0662)	(0.0282)
Avg. patent dummy	0.0550**	0.0827***	0.107**	0.0553***
	(0.0234)	(0.0293)	(0.0470)	(0.0187)
Avg. utility dummy	0.0373	0.0572	0.136***	0.0197
	(0.0228)	(0.0399)	(0.0526)	(0.0199)
Avg. design dummy	0.0825***	0.0377	0.0692	0.0695***
	(0.0227)	(0.0350)	(0.0483)	(0.0192)
Avg. trademark dummy	0.0405**	0.0319	0.00994	0.0553***
	(0.0206)	(0.0215)	(0.0371)	(0.0157)
Avg. outsourcing dummy	-0.0179	0.0209	-0.0201	-0.000663
	(0.0237)	(0.0192)	(0.0363)	(0.0164)
Avg. export dummy	-0.0206	0.0834***	-0.0115	0.0285*
	(0.0217)	(0.0237)	(0.0411)	(0.0166)
Avg. log(employment)	0.0219	0.0177	-0.0428	0.0302*
	(0.0268)	(0.0185)	(0.0364)	(0.0166)
N	18130	14624	4450	30340
Log likelihood	-7848.778	-5429.957	-1747.901	-12365.271
chi2	4140.685	3889.783	912.972	8940.040

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are included in the estimation but omitted in the report.

<Table 3A> Estimation of the average marginal effects: Intangible investment

	ICT manufacturing (1)	Non-ICT manufacturing (2)	ICT services (3)	Non-ICT services (4)
Lagged intangible inv	0.130***	0.209***	0.146***	0.163***
	(0.0275)	(0.0151)	(0.0318)	(0.0171)
Log(employment)	0.103***	0.0760***	0.131***	0.0259**
	(0.0385)	(0.0179)	(0.0293)	(0.0126)
Internal R&D dummy	-0.00340	0.0297**	0.0621**	0.0748***
	(0.0389)	(0.0131)	(0.0281)	(0.0185)
External R&D dummy	-0.0187	0.0370*	0.109**	-0.0140
	(0.0331)	(0.0192)	(0.0452)	(0.0263)
Patent dummy	0.0134	0.0240*	-0.0347	0.00955
	(0.0422)	(0.0143)	(0.0310)	(0.0193)
Utility dummy	-0.0584*	-0.00333	0.0389	0.000670
	(0.0301)	(0.0124)	(0.0498)	(0.0213)
Design dummy	-0.00845	-0.0135	-0.0259	-0.00515
	(0.0286)	(0.0137)	(0.0419)	(0.0215)
Trademark dummy	-0.00141	0.0101	0.0480	0.0337**
	(0.0330)	(0.0128)	(0.0293)	(0.0136)
Subsidiary dummy	0.00643	0.0121	0.0126	0.0389***
	(0.0213)	(0.00841)	(0.0195)	(0.00944)
Parent dummy	0.0582**	0.0288***	0.0184	0.0698***
	(0.0280)	(0.0111)	(0.0227)	(0.0113)
Foreign capital dummy	0.0279	-0.00803	-0.0116	-0.0311***
	(0.0265)	(0.0110)	(0.0314)	(0.0110)
Listed dummy	0.0873***	0.0793***	0.119***	0.0675***
	(0.0224)	(0.0118)	(0.0270)	(0.0173)
Outsourcing dummy	0.0161	0.0175	0.0487**	0.00114
	(0.0335)	(0.0124)	(0.0208)	(0.00996)
Export dummy	0.0184	0.0207*	0.0186	-0.0125
	(0.0307)	(0.0115)	(0.0253)	(0.0107)
Initial intangible inv	0.250***	0.314***	0.318***	0.280***
	(0.0239)	(0.0160)	(0.0411)	(0.0189)
Initial internal R&D dummy	-0.0761	-0.0110	0.00124	0.00943
	(0.0468)	(0.0146)	(0.0326)	(0.0219)

Initial external R&D dummy	-0.0430	-0.0283	0.00385	0.0245
	(0.0423)	(0.0187)	(0.0609)	(0.0271)
Initial patent dummy	0.00444	-0.0143	-0.00992	-0.0571***
	(0.0464)	(0.0148)	(0.0412)	(0.0193)
Initial utility dummy	-0.0561	0.000830	-0.108*	-0.000946
	(0.0349)	(0.0145)	(0.0603)	(0.0253)
Initial design dummy	-0.0438	-0.0331**	0.00557	-0.0618***
	(0.0365)	(0.0153)	(0.0568)	(0.0234)
Initial trademark dummy	0.0335	0.00723	0.0567*	0.0410**
	(0.0333)	(0.0136)	(0.0340)	(0.0174)
Initial outsourcing dummy	0.0143	0.0124	-0.0386	-0.0152
	(0.0386)	(0.0149)	(0.0245)	(0.0130)
Initial export dummy	0.00710	0.00125	0.00219	-0.0278*
	(0.0325)	(0.0132)	(0.0321)	(0.0143)
Initial log(employment)	-0.0403	-0.0523***	-0.0243	-0.0279**
	(0.0371)	(0.0195)	(0.0344)	(0.0124)
Avg. internal R&D dummy	0.170**	0.0416*	-0.00478	-0.0249
	(0.0738)	(0.0245)	(0.0538)	(0.0342)
Avg. external R&D dummy	0.119	0.0405	-0.117	-0.00322
	(0.0767)	(0.0377)	(0.111)	(0.0503)
Avg. patent dummy	0.0707	0.0502**	0.125**	0.0588*
	(0.0734)	(0.0247)	(0.0622)	(0.0333)
Avg. utility dummy	0.147**	0.0159	0.118	0.0379
	(0.0586)	(0.0247)	(0.108)	(0.0431)
Avg. design dummy	0.0768	0.0827***	0.0164	0.0381
	(0.0586)	(0.0244)	(0.0809)	(0.0387)
Avg. trademark dummy	0.0134	0.0454**	-0.0116	0.0432*
	(0.0558)	(0.0217)	(0.0498)	(0.0235)
Avg. outsourcing dummy	0.0189	-0.0296	-0.0430	0.0295
	(0.0666)	(0.0251)	(0.0437)	(0.0213)
Avg. export dummy	-0.0290	-0.0207	0.00827	0.102***
	(0.0598)	(0.0230)	(0.0600)	(0.0255)
Avg. log(employment)	-0.0537	0.0338	-0.0441	0.0254
	(0.0602)	(0.0293)	(0.0461)	(0.0195)
N	1981	16149	2469	12155
Log likelihood	-735.484	-7067.736	-992.330	-4393.359
chi2	436.028	3675.618	507.066	3153.331

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are included in the estimation but omitted in the report.

<Table 4A> Estimations of average marginal effects: R&D expenditures

	manufacturing	**services**	**ICT**	**non-ICT**
	(1)	**(2)**	**(3)**	**(4)**
Lagged R&D dummy	0.360***	0.226***	0.275***	0.315***
	(0.0220)	(0.0229)	(0.0376)	(0.0168)
Log(employment)	0.0224*	0.0112	0.0295	0.0221***
	(0.0122)	(0.00772)	(0.0196)	(0.00684)
Intangible inv dummy	0.0194***	0.0344***	0.0243*	0.0249***
	(0.00685)	(0.00658)	(0.0138)	(0.00506)
Patent dummy	0.0174*	0.0245**	0.0550**	0.0161**
	(0.00922)	(0.0105)	(0.0242)	(0.00695)
Utility dummy	0.00799	-0.00377	-0.0100	0.00444
	(0.00874)	(0.0106)	(0.0208)	(0.00686)
Design dummy	0.00803	0.00390	-0.00615	0.00833
	(0.00941)	(0.0112)	(0.0208)	(0.00755)
Trademark dummy	-0.0135	0.00576	-0.0125	-0.00263
	(0.00830)	(0.00755)	(0.0165)	(0.00600)
Subsidiary dummy	-0.00169	0.00759	0.00700	0.00267
	(0.00526)	(0.00514)	(0.0110)	(0.00388)
Parent dummy	-0.0321***	-0.00881	-0.0243*	-0.0222***
	(0.00735)	(0.00600)	(0.0138)	(0.00513)
Foreign capital dummy	-0.00609	-0.00673	-0.0119	-0.00491
	(0.00731)	(0.00642)	(0.0140)	(0.00533)
Listed dummy	0.00131	0.00659	0.0222	-0.00541
	(0.00703)	(0.00718)	(0.0142)	(0.00540)
Outsourcing dummy	0.0813***	0.0581***	0.0828***	0.0720***
	(0.0106)	(0.00736)	(0.0153)	(0.00698)
Export dummy	0.0183**	0.0164**	0.0407**	0.0137**
	(0.00744)	(0.00687)	(0.0160)	(0.00533)
Initial R&D	0.169***	0.173***	0.233***	0.164***
	(0.0147)	(0.0169)	(0.0334)	(0.0114)
Initial intangible inv	-0.0137*	-0.000560	-0.0158	-0.00910
	(0.00810)	(0.00772)	(0.0178)	(0.00588)

Initial patent dummy	-0.00634	-0.0139	-0.0134	-0.0130*
	(0.00867)	(0.00941)	(0.0202)	(0.00672)
Initial utility dummy	-0.00932	0.00563	0.000732	-0.00681
	(0.00887)	(0.0116)	(0.0242)	(0.00705)
Initial design dummy	-0.0113	-0.0145	0.0138	-0.0121
	(0.0101)	(0.0122)	(0.0230)	(0.00809)
Initial trademark dummy	0.00256	0.0137	0.0448**	-0.00192
	(0.00856)	(0.00887)	(0.0190)	(0.00638)
Initial outsourcing dummy	-0.0319***	-0.00253	-0.0188	-0.0183***
	(0.00893)	(0.00668)	(0.0150)	(0.00608)
Initial export dummy	-0.0236***	-0.0106	0.0147	-0.0247***
	(0.00757)	(0.00753)	(0.0173)	(0.00566)
Initial log(employment)	-0.0147	-0.0102	-0.0149	-0.0107*
	(0.0116)	(0.00641)	(0.0207)	(0.00617)
Avg. intangible inv	0.0175	-0.00942	0.0410	0.00249
	(0.0135)	(0.0128)	(0.0283)	(0.00989)
Avg. patent dummy	0.0601***	0.0475***	0.0331	0.0624***
	(0.0146)	(0.0161)	(0.0349)	(0.0113)
Avg. utility dummy	0.0226	0.0222	0.0656	0.0217*
	(0.0163)	(0.0207)	(0.0416)	(0.0131)
Avg. design dummy	-0.00229	-0.00478	-0.000267	-0.00838
	(0.0159)	(0.0189)	(0.0365)	(0.0127)
Avg. trademark dummy	0.0325**	-0.00722	-0.0145	0.0270***
	(0.0145)	(0.0135)	(0.0309)	(0.0104)
Avg. outsourcing dummy	-0.00663	-0.0144	-0.00492	-0.00997
	(0.0161)	(0.0116)	(0.0267)	(0.0107)
Avg. export dummy	0.0488***	0.0309**	0.0179	0.0441***
	(0.0138)	(0.0139)	(0.0327)	(0.0103)
Avg. log(employment)	-0.00360	-0.000913	-0.0259	-0.00698
	(0.0187)	(0.0116)	(0.0333)	(0.0104)
N	18130	14624	4450	30340
Log likelihood	-4740.973	-3002.620	-1236.653	-7179.261
chi2	4355.498	3087.427	941.202	8904.115

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are included in the estimation but omitted in the report.

<Table 5A> Estimations of average marginal effects: R&D expenditures

	ICT manufacturing (1)	**non-ICT manufacturing (2)**	**ICT services (3)**	**non-ICT services (4)**
Lagged R&D dummy	0.142***	0.358***	0.293***	0.221***
	(0.0230)	(0.0228)	(0.0478)	(0.0271)
Log(employment)	0.0473**	0.0152	0.0233	0.00890
	(0.0202)	(0.0135)	(0.0319)	(0.00739)
Intangible inv. dummy	0.000442	0.0227***	0.0499**	0.0297***
	(0.0184)	(0.00732)	(0.0201)	(0.00688)
Patent dummy	0.0571**	0.0117	0.0426	0.0240**
	(0.0223)	(0.00970)	(0.0366)	(0.0110)
Utility dummy	-0.00689	0.00914	-0.0116	-0.00316
	(0.0181)	(0.00945)	(0.0402)	(0.00999)
Design dummy	0.0244	0.00580	-0.0487	0.0133
	(0.0177)	(0.0104)	(0.0362)	(0.0124)
Trademark dummy	-0.0172	-0.0134	-0.0119	0.00738
	(0.0189)	(0.00895)	(0.0256)	(0.00754)
Subsidiary dummy	0.0165	-0.00295	0.00663	0.00942*
	(0.0120)	(0.00568)	(0.0181)	(0.00512)
Parent dummy	-0.0230*	-0.0327***	-0.0257	-0.00558
	(0.0135)	(0.00800)	(0.0218)	(0.00584)
Foreign capital dummy	0.000649	-0.00743	-0.0190	-0.00344
	(0.0152)	(0.00803)	(0.0241)	(0.00619)
Listed dummy	0.0158	-0.00305	0.0188	0.00369
	(0.0175)	(0.00768)	(0.0224)	(0.00739)
Outsourcing dummy	0.0291	0.0872***	0.115***	0.0457***
	(0.0210)	(0.0115)	(0.0205)	(0.00789)
Export dummy	0.0252	0.0169**	0.0507**	0.00833
	(0.0202)	(0.00777)	(0.0222)	(0.00693)
Initial R&D	0.0900***	0.181***	0.293***	0.165***
	(0.0177)	(0.0161)	(0.0492)	(0.0192)
Initial intangible inv	-0.0235	-0.0143	-0.0128	0.00128
	(0.0208)	(0.00876)	(0.0293)	(0.00729)

Initial patent dummy	-0.0164	-0.00639	-0.0256	-0.0139
	(0.0231)	(0.00935)	(0.0314)	(0.00938)
Initial utility dummy	-0.0118	-0.0105	0.0265	-0.00559
	(0.0202)	(0.00973)	(0.0453)	(0.0105)
Initial design dummy	0.0360*	-0.0156	-0.0237	-0.0132
	(0.0209)	(0.0112)	(0.0441)	(0.0118)
Initial trademark dummy	0.0238	0.000356	0.0828**	0.00492
	(0.0208)	(0.00924)	(0.0324)	(0.00851)
Initial outsourcing dummy	-0.0410**	-0.0327***	-0.00510	-0.00307
	(0.0185)	(0.00993)	(0.0235)	(0.00651)
Initial export dummy	0.00859	-0.0294***	0.0134	-0.0173**
	(0.0191)	(0.00817)	(0.0279)	(0.00711)
Initial log(employment)	0.0181	-0.0188	-0.0397	-0.00699
	(0.0208)	(0.0133)	(0.0345)	(0.00556)
Avg. intangible inv	0.0621*	0.0101	0.0192	-0.0131
	(0.0345)	(0.0145)	(0.0445)	(0.0125)
Avg. patent dummy	-0.00191	0.0686***	0.0913	0.0389**
	(0.0378)	(0.0157)	(0.0567)	(0.0161)
Avg. utility dummy	0.0504	0.0215	0.0593	0.0229
	(0.0345)	(0.0177)	(0.0792)	(0.0202)
Avg. design dummy	-0.0463	0.000973	0.0401	-0.0130
	(0.0331)	(0.0175)	(0.0649)	(0.0191)
Avg. trademark dummy	0.0353	0.0305**	-0.0782	0.000225
	(0.0349)	(0.0155)	(0.0501)	(0.0130)
Avg. outsourcing dummy	0.0377	-0.0119	-0.0180	-0.0132
	(0.0354)	(0.0176)	(0.0399)	(0.0115)
Avg. export dummy	-0.0155	0.0552***	0.0605	0.0305**
	(0.0361)	(0.0147)	(0.0533)	(0.0133)
Avg. log(employment)	-0.0697**	0.0112	0.00143	-0.000708
	(0.0332)	(0.0208)	(0.0544)	(0.0106)
N	1981	16149	2469	12155
Log likelihood	-370.277	-4333.964	-845.726	-2125.433
chi2	488.310	3899.128	541.061	2320.191

*Note: ***, **, * denote significance at 1%, 5% and 10%, respectively. 2-digit industry dummies are included in the estimation but omitted in the report.