Internalization of R&D Outsourcing

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Abstract
To be written

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Absorptive Capability,

1. Introduction

R&D outsourcing is acknowledged as a key measurement for increasing the firm’s competitiveness through internalizing external expertise. It is because that the scope of firms’ having knowledge, its proprietary technologies and capability of accessing to external knowledge can be limited. So, the generation and transfer of knowledge are keys to sustainable competitive advantage, and knowledge management is fundamental to firm survival and growth in a globally competitive environment (Foss and Pedersen, 2002; Grant, 1996; Mudambi, 2002). This trend is also in collusion with recent open innovation framework. Accordingly, R&D outsourcing is one of effective selectable strategies that firms can use external knowledge through open innovation such as technology acquisition, alliance, R&D cooperation and etc. In most Organization for Economic Co-operation and Development (OECD) countries, for instance, the share of business expenditure on external R&D has gradually increased since the 1980s. In countries such as the UK and Germany, business expenditure on external R&D doubled in proportion to total expenditure on R&D, over a 10-year period (Howells, 1999; Bonte, 2003). Actually, the CAGR (Continuous Average Growth Rate) of internal expenditure for R&D was 16.0% in 2002-2007, while CAGR of outsourcing R&D fund in 2002-2007 was higher about 8% than internal ones. And
many previous studies also suggested that R&D outsourcing be fit for innovation of firms. Huang et al. (2009) tried to investigate the impact of such strategies on organizational consequences in terms of development costs and financial profits during the new product development (NPD) process. Results from 121 Taiwanese IT firms indicate that R&D outsourcing is effective in lowering development costs and in lifting financial profits.

As the R&D outsourcing becomes more common practice, a theoretical and empirical literature has been developed on the factors determining external knowledge acquisition and its effects on firms’ innovative performance. The first one is which determinants of R&D outsourcing can be identifying. And second is whether external knowledge acquisition through R&D outsourcing is always conductive higher performance of firms. Several studies have provided some results to these two issues. For example, Love and Roper (2001) have noted that the scale of plant and R&D input as well as appropriability conditions are the key determinants of the R&D mode when using a sample of innovating UK manufacturing. And related to effects of R&D outsourcing, Caudy (2001), Howells (1999), and Watanabe and Hur (2004) point out that R&D outsourcing can help to maximize innovation and overall company performance when properly planned and executed.

Although the determinants and effects of R&D outsourcing are well discussed, little is known about what factors of firms affect to performance through internalization of R&D outsourcing. So, this study constructs a more accurate framework to examine the impact of R&D outsourcing on firm performance with panel data which can control for firm effects and time effects, and after that the moderating effect of R&D organization features for internalization will be investigated. The research results will enrich the understanding of the relationship between R&D outsourcing and firm performance, and identify the moderating effect of R&D organization features.

The remainder of the article is organized as follows. Next section addresses literature review of R&D outsourcing effects on firm performance and internalization of external knowledge. Section 3 addresses theory development which consist conceptual model and some proposed hypothesis. Section 4 addresses variable construction, the data set, and the research methodology and model which can control firm effects and time effects. Section 5 describes empirical result. We discuss the findings such as conclusion and limitation section 6 concludes.
2. Background

2.2 R&D outsourcing Strategies

Links to recent open innovation paradigm, we can distinguish different strategies that can be employed to acquire and internalize technological knowledge for firm’s innovation strategy. Firms can decide various combinations of different strategies to perform innovation. First, firms select to do internal R&D for developing their own demand technology. But firms can select alternatively to do R&D outsourcing for acquiring and internalizing external knowledge. The last alternative is to form cooperative organization – R&D consortium, R&D joint venture, Research contract, and Licensing. There are ample theoretical literatures that focuses the choice between R&D sourcing and internal R&D as substitutes, i.e., the classical MAKE or BUY.

Recent research in motivation of R&D outsourcing strategy can be classified into three categories. The first is a transaction cost analysis perspective (Howell, 1999; Brusoni et al., 2001; Narula, 2001; Yasuda, 2005). This perspective suggests that in the presence of asset specificity, uncertainty and opportunistic behavior, transactions take place more efficiently and hierarchically within the firm than via the market (Williamson, 1985). Related to uncertainty and complexity, R&D outsourcing is difficult to be implemented because of a high degree of complexity and uncertainty associated with the nature of R&D (Howell, 1999). So, in the context of R&D activities, technologies that cannot be codified tend to be viewed as a candidate for in house research and development activities (Tidd and Trewhella, 1997, Narula, 2001) while R&D outsourcing is one of strategic decision making options when firms deploy open innovation strategy or complement NPD process with external technology. It means that the more technology can be codified (described in terms of formulae, blueprint and rules) the easier it is to be contracted out (Brook and Plugge, 2011). Actually, the demand technology of firms can be high or low level relatively. It was depended on how important the task or technology for firms. From a transaction cost point of view, external knowledge sourcing and in-house R&D are considered as substitutes and, in considering costs and risks, firms opt for either a make or a buy strategy (Veugelers and Cassiman, 1999; Beneito, 2003). Firms are thus confronted with the management of internal and external innovation strategies and must decide which technologies to develop in-house and which to source externally.
(Vega-Jurado et al., 2009). Many previous researches focused on factors affecting the decision-making of external knowledge acquisition through R&D outsourcing. Veugelers and Cassiman (1999) characterizes the innovation strategy of manufacturing firms such as classical MAKE or BUY strategy for acquiring demanded technology and examines the relation between the strategy and industry-, firm- and innovation-specific characteristics using Belgian company data from the Eurostat Community Innovation Survey CIS. The result shows that small firms are more likely to restrict their innovation strategy to an exclusive make or buy strategy, while large firms are more likely to combine both internal and external knowledge acquisition in their innovation strategy. Jones et al. (2001) investigate the impact of three variables (technological change life cycle stage, intellectual protection and internally available resources) on the propensity of U.S.-based multinational firm subsidiaries to acquire technology externally. Yoshikawa (2003) explores the key factors (such as time pressure and technology importance) that affect choices among external technology acquisition modes.

The second research perspective is a core competence perspective (Prahalad and Hamel, 1990). It is based on the idea that firms with high levels of R&D competence are likely to enhance their technological competencies that are needed for competitive advantage (Brook and Plugge, 2011). It means that firms are doing internal R&D or R&D outsourcing for increasing the technological competence and supplement of insufficient. In this context, many literatures argued that outsourcing R&D enables a firm to benefit from complementary resources and technology capabilities from external parties (Nohria and Garcia-Pont, 1991; Teece, 1986; Tidd and Trewhella, 1997; Kessler et al., 2000; Yasuda, 2005; Chesbrough, 2003). For example, Kessler et al. (2000) have found that external sourcing is positively related to lower competitive success and slower innovation speed. However, Tidd and Trewhella (1997) noted that that R&D outsourcing is a better and quicker option than building the required skills internally where suitable in-house capabilities are lacking. As the demand of consumer and competition in market increase more, firms tend to secure the technology which they don’t have or need to acquire as a shot.

The third is cost advantage perspective. It argues that R&D outsourcing can reduce the costs of new product development (Quinn, 1992; Quinn, 2000; Piachaud, 2002; Chesbrough, 2003). This notion is related to time and resource for innovation which firms does not have yet, so need to acquire external expertise. For example, firms which are doing R&D
outsourcing are not able to prevent the accumulation of internal bureaucracies and inefficiencies (Quinn, 2000). Chesbrough (2003) have found that using external technologies for internal product development is an efficient way of offsetting the rising cost of technology development. Firms can also use external knowledge through R&D outsourcing because of time consuming for internal R&D. However, Kessler et al. (2000) suggest that R&D outsourcing can create hidden cost. One of hidden cost is coordination cost which is occurs when firms attempt to integrate external knowledge into their knowledge base. The costs of R&D outsourcing can be high if the external technology is difficult to coordinate (Huang et al., 2009). The other hidden cost is related to the complexity of R&D outsourcing. As mentioned earlier, it can be linked transaction cost perspective. For example, completion of R&D outsourcing contract will be more likely to take a long time, if the complexity of R&D outsourcing is high. That can be increase the cost of R&D outsourcing totally. Therefore, total cost of R&D outsourcing is likely to be lower, when the target technology for R&D outsourcing can be easily defined and the relationship between firms and supplier is well established. So, firms need to consider doing R&D outsourcing carefully.

2.3 Recognition and Internalization of external knowledge

In R&D outsourcing, employees of R&D organization firstly recognize necessary technology and after that, define it. And after done R&D outsourcing, employees can identify, interpret using with exiting internal technology, or regenerating some new technology which are combined exiting and external knowledge. We can assume these internal activities as a internalization of external knowledge. According to the knowledge chain model (Holsapple and Singh, 2001), learning projection for increasing competitiveness is constituted acquisition, selection, generation, internalization, and externalization primarily. The secondary activities are leadership, coordination, control, and measurement. This model explains what activities come up for using internal and external knowledge for learning. They also suggest that knowledge internalization can be defined “Altering the state of an organization’s knowledge resources by distributing and storing acquired, selected, or generated knowledge”. Sub-activities of internalization include: Assessing knowledge to be internalized with requisite cleansing, refining, and filtering; targeting knowledge resources that are to be impacted by internalization; structuring
knowledge to be conveyed into representations appropriate for the targeted resources, including abstracting, indexing, sorting, labeling, categorizing, and integrating; delivering the knowledge representations to targeted knowledge resources.

![Fig. 1 The knowledge chain model. Source: Holsapple and Singh (2001)](image)

Internalizing knowledge is a culminating activity in organizational learning (Holsapple and Singh, 2001). This notion will be accompanied with our research issues that specific organizational factors of firm have relationship with performance through R&D outsourcing. So, the internalization of externalization might be more important than R&D outsourcing in itself. Because there are many variables those can affect to transfer process of external knowledge. It can be specified next section as followed.

From a R&D outsourcing point of view, the results of R&D outsourcing is new external knowledge for firms. Firms have to learn them with exiting knowledge for using effectively. It will be likely to link performance of firms direct or indirectly. During learning process of external knowledge through R&D outsourcing, internalization will be key process for using it. So, we focus to investigate what organizational factors of firms affect to internalization of external knowledge through R&D outsourcing.
Table 1. Primary and secondary activities in the knowledge chain model

<table>
<thead>
<tr>
<th>Primary</th>
<th>Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge acquisition</td>
<td>Knowledge leadership</td>
</tr>
<tr>
<td>Acquiring knowledge from</td>
<td>Establishing conditions that enable</td>
</tr>
<tr>
<td>external sources and</td>
<td>and facilitate fruitful conduct of KM</td>
</tr>
<tr>
<td>making it suitable for</td>
<td>Knowledge coordination</td>
</tr>
<tr>
<td>subsequent use</td>
<td>Managing dependencies among KM</td>
</tr>
<tr>
<td>Knowledge selection</td>
<td>Knowledge coordination</td>
</tr>
<tr>
<td>Selecting needed knowledge from internal sources and making it suitable for subsequent use</td>
<td>Ensuring that needed knowledge processors and resources are available in sufficient quality and quality, subject to security requirements</td>
</tr>
<tr>
<td>Knowledge generation</td>
<td>Knowledge control</td>
</tr>
<tr>
<td>Producing knowledge by</td>
<td>Knowledge measurement</td>
</tr>
<tr>
<td>either discovery or</td>
<td>Assessing values of knowledge resources,</td>
</tr>
<tr>
<td>derivation from existing knowledge</td>
<td>knowledge processors, and their deployment</td>
</tr>
<tr>
<td>Knowledge internalization</td>
<td>Altering the state of an organization's knowledge resources</td>
</tr>
<tr>
<td>Externalization</td>
<td>Embedding knowledge into organizational outputs for release into the environment</td>
</tr>
</tbody>
</table>

Source: Holsapple and Singh(2001)

3. Conceptual framework and theoretical hypotheses

![Conceptual Framework Diagram]

Fig. 2 Conceptual Framework

Figure 2 shows the framework proposed and investigated in this paper. The model means that R&D outsourcing and organizational features of firm have an effect on firm performance. And it proposes that the relationship between R&D outsourcing and firm performance is moderated by organization features of firm in internalization process. The specific relationship hypotheses and their underlying rationale will be followed.
3.1 Effects of R&D outsourcing on Firm Performance

What we firstly examine hypothesis is the effects of R&D outsourcing to firm performance. As a matter of fact, there are ample empirical studies, performed at firm level. Bönte(2003) investigated the productivity effects of investment in external vs. internal R&D in a sample of West-German Manufacturing Industries. The results provided strong evidence of a positive relationship between productivity and the share of external R&D in total R&D. And in 2003, he have proved that the productivity impact of internal and external R&D using an industry-level panel data set and found a positive relationship between the share of the external R&D and productivity. Gullec et al.(2004) also analyzed that R&D outsourcing is a significant factor in deciding the rate of long term productivity growth. Schmiedeberg (2008) have found that contracted R&D is only significant for the probability of patenting, but with a larger estimate than for internal R&D. Huang et al.(2009) have examined the effect of R&D outsourcing on NPD cost and firms performance. The result showed that Results from 121 Taiwanese IT firms indicate that R&D outsourcing is effective in lowering development costs and in lifting financial profits when products are developed under adaptive innovation. Conversely, Coombs (1996), Gilley and Rasheed(2000), and Kessler et al.(2000) have found that R&D outsourcing may not increase a firm’s profitability or performance. Bounfour(1999) has noted that R&D outsourcing may be negatively associated with financial performances. Bergman(2011) also pointed out that External R&D is generally found to have a negative effect on productivity.

Summarizing, the previous literature suggests that only a few econometric studies with panel data controlling for firm effects and time effects have explored the effects of R&D outsourcing on firms’ performance. And the results are mixed that Sometimes external R&D is found to have a larger productivity effect than internal R&D; sometimes the effect is smaller, and often not significant (Bergman, 2011). Therefore, it is proposed that, by doing R&D outsourcing, firms can achieve higher level of performance.

Hypothesis 1(H1) : More R&D outsourcing ratio of firms is associated with better performance
3.2 Effects of Organization features on Firm Performance

As many previous researches pointed out, internal R&D input is a crucial factor for internalization of external knowledge. Cohen and Levinthal (1989, 1990) suggest that prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends. These abilities collectively constitute what we call a firm's 'absorptive capacity'. This concept emphasizes on the firm’s pre-existing knowledge in the tasks of identifying, assimilating, and exploiting external knowledge. On the basis of this concept, several studies have found that absorptive capacity is generated in a variety of ways and firms which conduct their own R&D are better able to use externally available information (Tilton, 1971; Allen, 1977; Mowery, 1983). Internal R&D efforts also improve a firm's exploitation of technological knowledge and its conversion to innovation (Griliches, 1979; Cohen and Levinthal, 1990; Stock et al., 2001). Moreover, many previous empirical research have found that a higher level of R&D effort improves a firm's ability to convert external technical knowledge into innovation activities (Gambardella, 1992; Mowery et al., 1996; Helfat, 1997). Griffith et al. (2004) show that R&D investment not only stimulates innovation but also strengthens absorptive capacity to enhance technology acquisition. Tsai and Wang (2008) have found that external technology acquisition does not provide a significant contribution to firm performance per se; however, the positive impact of external technology acquisition on firm performance increases with the level of internal R&D efforts. Therefore it is proposed that, by investing more R&D input, firms can achieve higher levels of performance.

Hypothesis 2(H2-1) : More R&D intensity of firms is associated with better performance

And remains are competition, financial soundness, and openness of firms. The level of market competition is usually associated with firm performance. So we propose that, by increasing more level of competition, firms can achieve lower levels of performance.

Hypothesis 2(H2-2) : More level of market competition is associated with lower performance
Financial soundness is also considered a positive factor on firm performance. And higher level of firm openness can be likely to catch more innovation opportunities.

Hypothesis 2(H2-3) : A firm have more sound financial position is associated with lower Performance

Hypothesis 2(H2-4) : More level of openness is associated with higher performance

3.3 Moderating effect of organizational features for internalization

As we reviewed above section, there are many studies about the relationship between R&D outsourcing and firm performance. However, most previous literatures have not investigated the moderating roles of internal R&D input and organizational features in R&D outsourcing. For example, Jones et al. (2001) have examined that the moderating effects of internally available resources on the relationship between external technology acquisition and firm performance, they have not specified internally available resources, their moderator, as internal R&D efforts. And Tsai and Wang (2008) have also investigated that the extent to which external technology acquisition effects a firm's performance, and how this effect is moderated by internal R&D efforts. But they just focused only internal R&D input which is usually acknowledged a so called ‘Absorptive Capacity’. Specific organizational variables have to be considered when investigates the effect of R&D outsourcing on firms performance in internalization process of external knowledge. Kessler et al. (2000) argued that R&D outsourcing can be treated as an external learning process. So, the internalization process which firms interpret the external knowledge to new internal R&D assets for innovation with exiting knowledge is more important than R&D outsourcing in itself. And internal efforts of firms have been considered that it can enhance its identification and use of external technological knowledge (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Kim, 1999). It means that internal R&D efforts have a moderating effect on the relationship between external technology acquisition and firm performance. So we propose

Hypothesis 3(H3-1) : The greater the level of a firm's internal R&D efforts, the stronger the positive effect of R&D outsourcing on a firm's performance
And we assume that high qualified R&D employee can higher contribute to internalize the external knowledge through R&D outsourcing. The specific factors are ratio of R&D employee, ratio of full time R&D employee, and ratio of Ph. D R&D employee. For example, Rothwell (1992) highlights that links to external scientific and technical knowledge sources are effective only if the organization is well prepared and open to external ideas, and has skilled scientific and technical staff.

Hypothesis 3(H3-2) : The greater ratio of R&D employee, the stronger the positive effect of R&D outsourcing on a firm's performance

Hypothesis 3(H3-3) : The greater ratio of full time R&D employee, the stronger the positive effect of R&D outsourcing on a firm's performance

Hypothesis 3(H3-4) : The greater ratio of Ph. D R&D employee, the stronger the positive effect of R&D outsourcing on a firm's performance

4. Research Method

4.1 Variable and measure

The variables used in the analyses are defined as follows. Firm performance as a dependent variable is measured by sales amount in this study because the purpose of R&D outsourcing is to enhance their amount of sales through developing new technology and product. The level of market competition is measured by CR4 which is sum of market share of 4 largest firms in KSIC 2 digit. The financial soundness is measured by capital adequacy ratio which is calculated by stockholder’s equity divided total asset. R&D outsourcing is measured by R&D outsourcing intensity. It is calculated by amount of R&D outsourcing divided by amount of sales. Internal R&D effort is measured by R&D intensity which is calculated by R&D expenditure divided by amount of sales. Openness is measured by export/sales which is calculated by amount of firm export divided by amount of sales. And the moderating variables are measured by each ratio. The ratio of R&D employee is calculated by number of R&D employee divided by total employee.
Table 2. Variable definition and data sources

<table>
<thead>
<tr>
<th>Category</th>
<th>Variables</th>
<th>Definition</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>performance</td>
<td>Sales</td>
<td>KIS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>amount of sales</td>
<td></td>
</tr>
<tr>
<td>Competition</td>
<td>CR4</td>
<td>The sum of market share of 4 largest firms in KSIC 2 digit</td>
<td>KIS</td>
</tr>
<tr>
<td>Financial soundness</td>
<td>capital adequacy ratio</td>
<td>stockholders' equity/total asset</td>
<td>KIS</td>
</tr>
<tr>
<td>R&amp;D Input</td>
<td>R&amp;D Outsourcing intensity</td>
<td>amount of R&amp;D outsourcing/ Total R&amp;D expenditure</td>
<td>R&amp;D Activity Survey</td>
</tr>
<tr>
<td></td>
<td>(t-2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R&amp;D intensity(t-2)</td>
<td>R&amp;D expenditure/ amount of sales</td>
<td>KIS</td>
</tr>
<tr>
<td>Openness</td>
<td>export/sales</td>
<td>Amount of export/amount of sales</td>
<td>KIS</td>
</tr>
<tr>
<td></td>
<td>R&amp;D intensity(t-2)</td>
<td>R&amp;D expenditure/ amount of sales</td>
<td>KIS</td>
</tr>
<tr>
<td>Organizational features</td>
<td>R&amp;D employee Ratio</td>
<td>No. of Researcher and assistant/Total employee</td>
<td>R&amp;D Activity Survey</td>
</tr>
<tr>
<td>variables (Moderating variables)</td>
<td>FTE Researcher Ratio</td>
<td>No. of FTE of Researcher/Total employee</td>
<td>R&amp;D Activity Survey</td>
</tr>
<tr>
<td></td>
<td>PhD. Researcher Ratio</td>
<td>No. of PhD. Researcher/Total employee</td>
<td>R&amp;D Activity Survey</td>
</tr>
<tr>
<td>Control variables</td>
<td>Size</td>
<td>Size</td>
<td>KIS</td>
</tr>
<tr>
<td></td>
<td>year dummy</td>
<td>year dummy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>year dummy</td>
<td>year dummy</td>
<td></td>
</tr>
</tbody>
</table>

The ratio of full time research employee is calculated by number of full time research employee divided by total employee. The ratio of Ph. D R&D employee is calculated by Ph. D R&D employee divided by total employee. Finally, our model used in this study adopts year dummy and size variable for controlling the firm size. The size variable is measured by amount of firms’ capital.
4.2 Data

In this paper, we use a merged data set which is constituted financial data of Korea Investors Service (KIS) and the survey of R&D in science and technology. Korea Investors Service (KIS) is a company which provides financial information service of firms in Korea. And the survey of R&D in science and technology is investigated by the Ministry of Education, Science and Technology in accordance with the OECD Frascati Manual on the equivalent year.

Table 3. Data Set(2002-2007)

<table>
<thead>
<tr>
<th>Financial Statement Data</th>
<th>R&amp;D Activity Survey</th>
<th>Merged dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>year</td>
<td>No. of firms</td>
<td>year</td>
</tr>
<tr>
<td>2003</td>
<td>14,973</td>
<td>2003</td>
</tr>
<tr>
<td>2004</td>
<td>15,588</td>
<td>2004</td>
</tr>
<tr>
<td>2006</td>
<td>17,788</td>
<td>2006</td>
</tr>
<tr>
<td>2007</td>
<td>18,083</td>
<td>2007</td>
</tr>
<tr>
<td>Total</td>
<td>97,407</td>
<td>Total</td>
</tr>
</tbody>
</table>

First, we prepare the survey of R&D in science and technology 2002-2007. These survey data include 59,911 companies with separate R&D organizations. After that, we have matched the 97,407 firms’ financial data of Korea Investors Service (KIS) to the survey of R&D in science and technology 2002-2007 by registered business number of firms. Because of merging these two datasets, we can retain objectivity and revising the objectivity of survey data for analysis. Finally, a data pool was written by integrating these two sets of data and an empirical study was conducted on 19,695 firms from the two data.
4.3 Empirical model

We have examined the hypotheses with unbalanced panel data set. Panel data are most useful when we suspect that the outcome variable depends on explanatory variables which are not observable but correlated with the observed explanatory variables. If such omitted variables are constant over time, panel data estimators allow to consistently estimate the effect of the observed explanatory variables. (Kurt, 2011)

Consider the multiple linear regression model for firm $i = 1\sim N$ which is observed at each year $t = 1\sim T$.

$$y_{it} = \alpha + x'_{it} \beta + \nu_i + \varepsilon_{it} \quad i = 1,2,\ldots, N$$
$$t = 1,2,\ldots, T$$
$$\varepsilon_{it} \sim i.i.d.(0, \sigma^2)$$

where $y_{it}$ is the dependent variable, $x_{it}$ is a independent variables excluding the constant, $\alpha$ is the intercept, $\beta$ is a parameters, $\nu_i$ is an unobservable individual and firm-specific effect as a time invariant, and $\varepsilon_{it}$ is an idiosyncratic error term.

Using panel analysis is for correcting the estimation bias from unobservable exogeneity instead of cross-section analysis. In, It is matter for performing the panel analysis whether $\nu_i$ is correlated with independent variables or not. An unobservable individual and firm-specific effect is usually not changed by time. We can examine the analysis with random effect model, if we assume that $\nu_i$ is uncorrelated with independent variables. But if $\nu_i$ is correlated with independent variables, the random effect model is not suitable for estimating the efficient estimates. So we have performed with Hausman specification test whether $\nu_i$ is correlated with independent variables or not. The result showed that we have to adopt Fixed effect model.
<table>
<thead>
<tr>
<th>Variables</th>
<th>Number of Firms</th>
<th>Mean</th>
<th>std dev</th>
<th>Min</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>19,695</td>
<td>10.223</td>
<td>1.603</td>
<td>-6.908</td>
<td>17.961</td>
</tr>
<tr>
<td>CR4</td>
<td>19,695</td>
<td>0.355</td>
<td>0.177</td>
<td>0.078</td>
<td>0.975</td>
</tr>
<tr>
<td>capital adequacy ratio</td>
<td>19,695</td>
<td>0.464</td>
<td>0.310</td>
<td>-9.523</td>
<td>1.000</td>
</tr>
<tr>
<td>R&amp;D Outsourcing intensity</td>
<td>19,695</td>
<td>0.098</td>
<td>1.255</td>
<td>0</td>
<td>131.241</td>
</tr>
<tr>
<td>R&amp;D intensity</td>
<td>19,695</td>
<td>0.025</td>
<td>0.056</td>
<td>0</td>
<td>0.997</td>
</tr>
<tr>
<td>export/sales</td>
<td>19,695</td>
<td>0.087</td>
<td>0.284</td>
<td>-0.011</td>
<td>23.816</td>
</tr>
<tr>
<td>R&amp;D employee Ratio</td>
<td>19,695</td>
<td>0.166</td>
<td>0.161</td>
<td>0</td>
<td>1.000</td>
</tr>
<tr>
<td>Researcher Ratio</td>
<td>19,695</td>
<td>0.138</td>
<td>0.141</td>
<td>0</td>
<td>1.000</td>
</tr>
<tr>
<td>FTE Researcher Ratio</td>
<td>19,695</td>
<td>0.141</td>
<td>0.145</td>
<td>0</td>
<td>1.000</td>
</tr>
<tr>
<td>PhD. Researcher Ratio</td>
<td>19,695</td>
<td>0.007</td>
<td>0.026</td>
<td>0</td>
<td>0.781</td>
</tr>
<tr>
<td>Size</td>
<td>19,695</td>
<td>7.969</td>
<td>1.507</td>
<td>3.912</td>
<td>17.082</td>
</tr>
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5. Result *(Planned to be examine again and written)*
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<tr>
<td><strong>Sales(t-2)</strong></td>
<td>0.377***</td>
<td>0.375***</td>
<td>0.378***</td>
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<td><strong>capital</strong></td>
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<td>0.094</td>
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<td>(1.18)</td>
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<td>0.366***</td>
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<td>-0.131***</td>
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<td>(2.7) (2.7) (-0.31) (-0.92) (-0.87)</td>
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<td>Adjusted-R2 0.911 0.795 0.839 0.892 0.911</td>
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<td>F-Value for Δ Adjusted-R2 2.52 *** 2.47 *** 2.19 *** 2.93 *** 3.49 ***</td>
<td>F-Value for Δ Adjusted-R2 2.52 *** 2.47 *** 2.19 *** 2.93 *** 3.49 ***</td>
<td>F-Value for Δ Adjusted-R2 2.52 *** 2.47 *** 2.19 *** 2.93 *** 3.49 ***</td>
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6. Conclusion *(To be written)*
References


