MONASH BUSINESS SCHOOL

DEPARTMENT OF ECONOMICS

ISSN 1441-5429

DISCUSSION PAPER 25/15

Determinants of R&D intensity and its impact on firm value in an innovative economy in which family business groups are dominant: The case of South Korea

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Abstract:

We examine both the determinants of corporate research and development (R&D) intensity, and its impact on firm value, in Korea, a country in which family business groups are dominant and in which corporate-funded R&D intensity is one of the highest in the world. We find that growth opportunities, size of the firm and payment to executive board members have a positive effect on R&D intensity, while leverage has a negative effect on R&D intensity. When leverage is at an extremely high level, the relationship between growth opportunities and R&D intensity turns from positive to negative. The positive effect of firm size on R&D intensity is larger, the greater the number of subsidiaries the firm has, consistent with the firm engaging in cross-subsidisation. The positive effect of payments to executive board members on R&D intensity is smaller for chaebol affiliates than for stand-alone firms. Using instrument variables we find that R&D generates an increase in firm value.

Keywords: family business; R&D; innovative economy; firm value; chaebol

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1. Introduction

Despite the importance of innovation in family-controlled business groups across the globe, existing studies of business groups have largely ignored the role of research and development (R&D) (Belenzon and Berkovitz, 2010). The case of South Korea (hereafter Korea) provides an excellent opportunity to examine the role of R&D in a family business dominant economy. The Korean economy is dominated by family-controlled business groups (chaebol), which have been the main drivers for Korean exports and growth since the 1970s (Amsden, 1992).

Korea, as a late industrialised country, is one of the few nations that has successfully transformed from imitator to innovator (Amsden, 1992; Kim, 1998). Korea has a very high level of investment in R&D. Korea's R&D expenditure-to-GDP ratio in 2012 was 4.36 per cent, which was the second highest in the world after Israel (Ministry of Science, 2013). The Bloomberg Rankings in 2014 placed Korea first in the world in terms of level of innovative activities and third in the world in terms of R&D intensity.[1] Korea's total R&D expenditure in 2012 was 55,450.1 billion won (equivalent to $US49.2 billion dollars), an 11.1 percent increase on a year earlier, indicating that Korea successfully expanded its R&D investment, despite facing difficult economic conditions (Ministry of Science, 2013).

As a result of the high level of investment in innovation, many Korean brands have established global reputations. According to Interbrand's list of the Best Global Brands, Samsung Electronics was ranked as one of the top 10 global brands in 2012 (Kim, 2013). According to Interbrand, other Korean firms ranked in the world's top 100 firms in terms of brand name recognition were Hyundai Motors and Kia Motors. Notably, the Interbrand report found that brand value for all three of these companies went up by more than 15 per cent

[1] See http://www.bloomberg.com/rank

from the previous year, indicating that the brand value of Korean companies is growing rapidly. In addition, in a survey released by the Nikkei, Japan's leading economic newspaper, Korean companies ranked third overall in terms of global market share for 50 categories of major goods and services in 2012 with Korean companies coming out top in terms of global market share for eight of the major goods and services surveyed (Kim, 2013).

In contrast to many other countries, Korea's R&D intensity is largely driven by corporations (Ministry of Science, 2013). Corporations spent 43,222.9 billion won in 2012, representing 77.9 per cent of total R&D investment, compared to public research institutions and universities, which spent 6,950.3 billion won (12.5 per cent) and 5,276.9 billion won (9.5 per cent) on R&D, respectively. The corporate sector's share of total R&D expenditure (77.9 per cent) matched, or surpassed, that in the major G7 countries such as the United States (US) (68.3 per cent), Japan (77.0 per cent), and Germany (67.3 per cent) (Kim, 2013).

That the corporate sector's share of total R&D expenditure in an innovative economy such as Korea is so high poses two interesting questions that we address in this study. First, what are the factors affecting firms' R&D intensity in an economy in which family business groups are dominant? There is much evidence on the factors that explain differences in R&D intensity between countries. Among other factors, differences in R&D intensity across countries have been attributed to education (Griliches, 2000) and national culture (Versakelis, 2001). However, these findings are not necessarily apposite for understanding differences in R&D intensity at the firm level. David *et al.* (2000) and Garcia-Quevedo (2004) find that public R&D differs from private R&D. Examination of the determinants of R&D at the firm level is largely restricted to studies of US firms (see Griliches, 1986, among others), for which the corporate sector's share of total R&D expenditure is not as large as in Korea.

The second question we address in this study is do company level R&D activities increase firm value? This is important because decisions on where to invest, including whether to invest in R&D, should ultimately be based on their impact on firm value. Existing studies focus on the impact of R&D on exports (Wakelin, 1998; Aw *et al.*, 2011), economic growth and spill over effects (Brautzsch *et al.*, 2015; Cassiman and Veugelers, 2002; Frantzen, 2000; Scherer, 1982) or productivity (Griliches, 1979, 1998). Several studies have examined the impact of R&D on firm value in the US (see eg. Jaffe, 1986 and Pakes, 1985). There are, however, few, such studies for Asia (Xu and Zhang, 2004 is an exception).

A feature of our study is that we pay particular attention to the role of family business groups in investing in R&D. Family business groups are more pervasive in the global market than the diversified Anglo-Saxon ownership form (La Porta *et al.*, 1999). Most large listed firms in Asia, with the exception of those in Japan, are family businesses (Young *et al*., 2008; Claessens *et al.*, 2000). However, existing firm level studies have not considered the role of business groups in investing in R&D. Instead the focus of studies on business groups has largely been on whether internal finance via business groups and (external) capital markets are substitutes (see eg Mahmood and Mitchell 2004, Chang *et al.* 2006).

In particular, we pay attention to the following three key issues which are directly associated with family business groups with a view to adding value to existing studies. First, we examine the relationship between leverage and R&D investment and the extent to which the effect of growth opportunities on R&D investment is moderated by leverage. The incentive for family business is to leverage to finance growth and build business empires. This is because equity financing dilutes family ownership, which aggravates principal agent problems (Young *et al.*, 2008). Leverage is also important in understanding business group

strategies (Khanna and Yafeh, 2007). How does leverage affect R&D intensity? Schmookler (1966) argued that growth opportunities are an important determinant of R&D intensity. Does leverage moderate the effect of growth opportunities on R&D intensity?

Second, we investigate the role of large business conglomerates (i.e., chaebol) in determining R&D investment in conjunction with corporate governance. Honore *et al*. (2015) find that corporate governance has an important effect on R&D intensity. The role of the board is crucial as it makes strategic decisions, which include R&D investment (Bertrand and Mullainathan, 2001). Do board members respond to financial incentives to decide R&D investment? If so, is there any difference between chaebol and non-chaebol firms?

Third, we examine whether cross-subsidisation across members of a business group affects R&D intensity within the business group. This issue is an extension of the notion that deep-pocket internal capital markets are factors affecting the emergence of business groups (Khanna and Tice, 2001). Existing studies have examined the deep-pocket hypothesis largely from the perspective of diversification (Khanna and Palepu, 1997; Khanna and Yafeh, 2007). Belenzon and Berkovitz (2010) is an exception in that they report a positive relationship between group affiliation and corporate innovation in Europe. We extend on the approach in Belenzon and Berkovitz (2010) by examining whether the relationship between firm size and R&D intensity is moderated by the number of business group affiliates. In contrast to Belenzon and Berkovitz (2010), who use patent numbers as a measure of innovative activity, we use R&D intensity. Pakes (1985) criticised using patents as a measure of innovation because not all useful inventions are patented. Rather, the economic value of patents varies depending on technological, institutional and market circumstances.

With respect to examining the effect of R&D intensity on firm value we use stock returns to measure firm value. The advantage of using stock returns, vis-à-vis using profits or productivity as in Jaffe (1986) and Belenzon and Berkovitz (2010), is that it captures change in the market value of the firm instantly. As such, using stock returns minimises noise in the estimates. Endogeneity is an issue when attempting to establish a causal relationship between R&D intensity and firm value (Harris and Li, 2008; Ito and Lechevalier, 2010). In contrast to existing studies, which largely focus on export outcomes using instruments from inside of the system estimation, we employ two-stage least squares (2SLS) estimation, focusing on firm value after carefully identifying the instruments in the first stage estimation.

Foreshadowing the main results, we find that growth opportunities, size of firm and payment to executive board members have a positive effect on R&D intensity, while leverage has a negative effect on R&D intensity. The positive effect of firm size on R&D intensity is larger for firms belonging to business groups that have a large number of subsidiaries, possibly reflecting the internal-insurance role against the failure of R&D investment provided by other affiliates within the group. The positive relationship between payment to board members and R&D intensity is smaller for chaebol affiliates than stand-alone firms. When leverage is at an extremely high level, the relationship between growth opportunities and R&D intensity turns from positive to negative. Using the estimation results identifying the determinants of R&D intensity from the first-stage estimation, the 2SLS estimates in the second-stage suggest that company's R&D intensity generates an increase in firm value.

2. Hypotheses

In this section we propose several hypotheses concerning the determinants of R&D intensity and the relationship between R&D intensity and firm value, which we test below.

We begin with the relationship between growth opportunities and R&D intensity. Schmookler's (1966) demand-pull hypothesis contends that market demand plays an important role in the magnitude of R&D investment. The demand-pull hypothesis posits that growth opportunities "call forth" an innovation (Mowery and Rosenberg, 1979). In other words, growth opportunities for a firm create potential demand for a product and this provides firms with the incentive to invest in R&D to develop, and streamline, those products. The larger the potential growth opportunities, the higher the potential profits from developing the product and, hence, the greater the incentive to invest in R&D. While the demand-pull hypothesis has been criticised (see Mowery and Rosenberg, 1979), it has received empirical support in studies using US data (see eg. Scherer, 1982).

H1: R&D intensity is higher in firms with more growth opportunities.

Next, we examine the relationship between debt financing and R&D intensity. We expect debt financing to be inversely related to R&D intensity for several reasons. First, transaction cost theories of the firm propose that whether a project should be financed by debt or equity depends on the degree of asset specificity. Equity funding will be preferable to debt financing where asset specificity is high, such as with R&D investment (Williamson, 1988). Second, debt financing reduces free cash flows, forcing managers to act in the best interests of stockholders (Jensen, 1986). This may limit the ability of mangers to invest in excess in R&D, particularly if this does not generate immediate returns for stockholders (Galade Del Canto & Suarez-Gonzalez, 1999). Third, external sources of capital impose demands for information. Firms may be reluctant to provide such information with respect to their R&D activities because it may result in the loss of control over its innovative activities. Hence, investment in R&D may be inhibited (Galade Del Canto & Suarez-Gonzalez, 1999).

H2: Leverage has an inverse relationship with R&D intensity.

Bringing the first two hypotheses together, our third hypothesis is that leverage will moderate the relationship between growth opportunities for the firm and R&D intensity. Specifically, if a firm debt finances its growth opportunities the effect of potential growth opportunities/market demand on R&D intensity will be accentuated by leveraging.

H3: The positive relationship between growth opportunities and R&D intensity will be moderated by leverage, such that it will be smaller in debt-financed firms.

Firm size is expected to be positively related to R&D intensity for a number of reasons (Galade Del Canto & Suarez-Gonzalez, 1999; Graves & Langowitz, 1993; Hitt *et al.*, 1990). There are economies of scale and scope in investing in R&D. Larger firms are more likely to employ a higher number of scientists who develop new ideas through interacting with each other and have the infrastructure (eg. laboratories), conducive to successfully investing in R&D. Large firms are more likely to possess market power, making it easier for them to capture the economic rents from investing in R&D. Large firms are also more likely to be able to diversify R&D projects and be able to absorb the costs if the R&D fails.

H4: Firm size is positively related to R&D intensity

We next consider the number of subsidiaries that the firm has as a variable moderating the relationship between firm size and R&D intensity. We posit that the positive relationship between firm size and R&D intensity will be strengthened, the larger the number of subsidiaries that a firm has. In many respects, the effects of the number of subsidiaries that a firm has reinforce the effect of firm size on R&D intensity. Diversification in large business groups allows members to insure against the uncertainties associated with investing in R&D (Khanna and Yafeh, 2007). Internal financing for R&D activity from within the business group is preferable to external financing because the firm does not need to disclose information about its innovative activities to potential competitors. Thus, large firms that

have more business group affiliates are better placed to access capital to finance R&D investment than standalone firms at lower cost (Belenzon and Berkovitz, 2010). Large firms with subsidiaries are also able to benefit from knowledge spillovers that large standalone firms cannot and these spillovers have a positive effect on R&D intensity (Scherer, 1982a).

H5: The positive relationship between firm size and R&D intensity is moderated by the number of subsidiaries that a firm has, such that it will be stronger the larger the number of affiliates in the business group to which the firm belongs.

All things being equal, for a given fixed compensation, the incentive for board members is to play it safe and not engage in risky activities, such as investing in R&D. If compensation is increased, board members will have more incentive to undertake investment in R&D. One reason is that paying board members more will attract individuals with higher cognitive ability. Individuals with higher cognitive ability have been found to be more willing to take risks and evaluate prospects over longer time horizons (Dohmen *et al.*, 2010).

Another reason is that assuming board members are paid their marginal product, if board members are paid more, shareholders will expect board members to perform better, commensurate with higher compensation. If shareholders have an expectation of better performance, to meet this expectation we conjecture that board members will be more likely to engage in risk taking behavior. This follows because sticking with the status quo, (ie not taking risks), implies that there is zero probability of achieving better outcomes.

H6: Payment to board members is positively related to R&D intensity

We now turn to the situation in which the board's decisions are influenced by controlling shareholders (as in the case of the chaebol). In such circumstances, if board members invest more in R&D, the controlling shareholders will reap the benefits and the association between compensation paid to board members and investment in R&D will be weakened.

H7 : The positive relationship between payment to board members and R&D intensity will be weaker in chaebol affiliate than in stand-alone firms.

Investment in R&D represents an activity that can increase the value of a firm's intangible assets. The market value of a firm represents the market valuation of expected future profit streams generated from investment in R&D. These, in turn, are based on an assessment of the market return to the firm's tangible and intangible assets. While not all investments in R&D generate profits (Jensen, 1993), on average, any investment in a firm's intangible assets should be expected to increase the firm's market value (Bosworth & Rogers, 2001).

H8 : There is a positive relationship between R&D intensity and firm value

Figure 1 shows that our strategy consists of first- and second-stage estimation. The first-stage is to identify factors affecting R&D intensity (H1-H7). The second-stage is to examine the impact of this estimated R&D intensity on firm value, which is measured by stock returns (H8). R&D intensity in the second-stage estimation is a covariate which is endogenously determined in the first-stage. As such, we need to use 2SLS, which uses the determinants of R&D intensity as instrumental variables. We explain further in the method section below.

Figure 1 here
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3. Model

The fixed effects model is used to address estimation bias associated with omitted variables. Macroeconomic variables affect all firms (*i*) irrespective of industries. Thus, we consider the following fixed effects model, which includes time effects, θ_t. Time effects, θ_t, are denoted by a series of binary variables. For example, θ_2 equals unity if the year is two (i.e., $t = 2$) and zero otherwise. The time effect variable does not include firm-level information (i.e., i). Thus, it captures changes in macroeconomic variables in the particular year (in this case if $t =$

2) that affect R&D intensity across firms. In the results reported below we drop θ_1 to avoid multicollinearity with the constant α. This can be denoted as follows:

$$Y_{it} = \alpha + \beta_1 x_{1,it} + \beta_2 x_{2,it} + ... + \beta_k x_{k,it} + \theta_t + \varepsilon_{it} \quad (1)$$

R&D intensity can vary at the industry (*j*) level (Cohen and Klepper, 1992; Pavitt, 1984). Thus, identification based on the average of two industries has little meaning. As such, we consider the following extended model to control for variations due to industries. The identification of coefficients in Equation (2) is based on variation within an industry. This is because the variation across firms is controlled for in the estimation.

$$Y_{ijt} = \alpha + \beta_1 x_{1,it} + \beta_2 x_{2,it} + ... + \beta_k x_{k,it} + \theta_t + \phi_j + \varepsilon_{it} \quad (2)$$

We include industries at the Korea Standard Industry Classification 2-digit level. This classifies all listed firms into thirteen industries where firms are relatively equally distributed. Equation (2) controls for time-invariant industry-specific fixed effects. However, the remaining concern is time-variant industry-specific fixed effects. An industry can enjoy an upward swing in a given year, which other industries do not. If this occurs, firms in this specific industry may increase R&D intensity more than firms in other industries. In Equation (3) we also include industry-year effects ($\theta \times \phi_{jt}$) to address this issue.

$$Y_{ijt} = \alpha + \beta_1 x_{1,it} + \beta_2 x_{2,it} + ... + \beta_k x_{k,it} + \theta_t + \phi_j + \theta \times \phi_{jt} + \varepsilon_{ijt} \quad (3)$$

Equation (3) includes second-order industry-fixed effects in addition to the primary industry-fixed effects in Equation (2). In estimates reported below, we added a vector of interaction variables between time-effects and the industry variable. All standard errors (p-values) in our estimates are also robust against auto-correlation at the firm level.

Armed with the identified determinants of the R&D intensity from Equations (1)-(3), we use 2SLS to examine the impact of R&D intensity on firm value (R_{ijt}).

$$R_{ijt} = const + \delta_1 \hat{Y}_{ijt} + \sum_{i=2} Others_{it} + \theta_t + \psi_j + \theta \times \psi_{jt} + \xi_{ijt} \qquad (4)$$

$\hat{Y}_{ijt}$ in Equation (4) is the estimated variable from Equations (1) - (3). As such, the variable is endogenous and the standard error of the variable estimated by ordinary least squares (OLS) will be biased. To address endogeneity, we use 2SLS using excluded instruments identified by Equations (1) - (3). Standard errors are robust against auto-correlation at the firm level.

4. **Data**

Our sample consists of a panel of all firms listed on the Korea Stock Exchange between 2007 and 2012 obtained from three different sources. Data on executive compensation and outside directors are from the reports on the Electronic Disclosure System (DART). All other firm characteristics except stock return are obtained from the KIS-Value database for Korea. Stock return is obtained from the Korea Listed Company Association (KLCA) by averaging monthly compounded share price. We censored all continuous variables at the 1st and 99th percentiles to eliminate extreme values. As a result, we have 3,403 firm-year observations.

Table 1 defines each of the variables and presents the main descriptive statistics for each. Our main variable is R&D intensity. It is calculated by expressing R&D investment as a percentage of firm assets. Its mean (median) value is 0.6 (0.03) with standard deviation of 1.36. The maximum value of R&D intensity is 10.34 percent of total asset value. R&D intensity varies depending on the specific industry. The electronics industry, which includes Samsung Electronics, has the largest R&D intensity in Korea. It is to allow for this feature of the data that we included industry and year-industry effects in our model.

Growth opportunities are proxied by the market price of equity divided by the book value of equity (i.e., the price to book ratio). The mean (median) value is 1.11 (0.78) which means that the average stock price of our sample is slightly overvalued (undervalued) compared to the reference value of unity. However, it is not desirable to compare directly firms with large R&D intensity with firms with long-term fixed assets. This is because firms with large long-term fixed assets tend to exhibit big differences between book and market values. Again, this is another reason why we include industry and year-industry effects in our model. Leverage is defined as total debts divided by total assets. Payment to the board is defined as the average payment to registered board member divided by total assets.

Table 2 presents the correlation matrix. It shows that the debt to asset ratio is positively correlated with growth opportunity, firm size, executive (board) payments, operating cash flow, foreign ownership, audit committee, outside board members and number of subsidiaries. In contrast, the debt to asset ratio is negatively correlated with leverage and controlling shareholder ownership. Interestingly, controlling shareholder ownership is negatively correlated with all the other variables in the model. The correlation matrix, however, is limited in the information it provides. This is because pairwise correlations fail to address simultaneity due to omitted variables. For example, the positive correlation between R&D intensity and foreign ownership is biased when there is a third variable affecting both R&D intensity and foreign ownership concurrently. If an economy enjoys a boom in the business cycle, both foreign ownership and R&D intensity will rise. Our estimations are based on multiple regression that addresses estimation bias due to omitted variables.

Tables 1 & 2 here

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5. Results

Table 3 shows that the effect of growth opportunities on R&D intensity is positive and statistically significant, irrespective of model specification. All included time-varying regressors are values at the end of the previous year to mitigate reverse causality. The results imply that a one standard deviation in growth opportunity leads to an increase in the ratio of R&D to assets by 0.177-0.208. Considering that the mean value of R&D intensity is 0.60, these estimates suggest the effect of growth opportunities on R&D intensity is also economically significant. These findings are consistent with our first hypothesis, which predicts a positive relationship between firm growth opportunities and R&D intensity.

Table 3 here

Growth opportunity is an ex ante concept. Realised growth does not necessarily coincide with growth opportunity. Results in columns 2, 3 and 5, 6 of Table 3 include actual growth, proxied by sales growth and change in number of subsidiaries. The results indicate that the positive effects of growth opportunities on R&D intensity are robust, controlling for actual growth. The significant interactions between time effects and industry dummies (at the KSIC 2 digit level) imply that time effects, which are varying at the industry level, such as business cycles at the industry level, are also important determinants of R&D intensity.

Table 4 examines the relationship between leveraging and R&D intensity. In specifications (1) to (6), firm leveraging has a negative sign and is statistically significant, consistent with hypothesis 2. The average of the estimated coefficient of leverage for Models 1-6 is -0.72. That is, a one standard deviation increase in leverage decreases R&D intensity by 0.142, which is 23 percent of average R&D intensity. This indicates that the leverage effect is both statistically and economically significant. To test our third hypothesis, we interacted leverage

and growth opportunity (i.e., growth x leverage). The negative sign on the interaction term in specifications 7-9 indicate that the positive effect of growth opportunity on R&D intensity is attenuated by leverage. To illustrate the magnitudes, results in the final specification indicate that a one standard deviation increase in leverage attenuates the positive effect of growth opportunities on R&D intensity by 27 per cent, consistent with our third hypothesis.

Table 4 here

Most Korean firms have experienced financial distress in the aftermath of the Asian financial crisis. Growth strategies associated with high levels of debt and the absence of appropriate risk management increased the vulnerability of the Korean economy before the onset of the crisis. One of the lessons of the Asian financial crisis that Korean firms learned was to recognise the importance of risk management and to re-evaluate their growth strategy (Mishkin, 1999). Post-crisis, a debt-ridden growth strategy is no longer valued. Considering that R&D is a risky investment, our results suggest that Korean firms seek to avoid debt financing of R&D as part of improved risk management. This helps to explain why the leverage variable attenuates the positive effects of growth opportunities on R&D intensity.

To examine our third hypothesis further, we split our sample into quartile-basis subsamples based on the leverage variable. We then generate four binary variables indicating each interval of the sub-samples. Leverage25 (leverage2550) refers to a binary variable equal to unity if a firm belongs to the 25 percentile (low quartile) and zero otherwise. In the same way, leverage5075 and leverage75 indicates that a firm belongs to the third and fourth quartile respectively. Then, we generated four interaction terms between these binary variables and growth opportunity. This allows us to examine any potential non-linearities.

The results in column 1 in Table 5 are the same as the results in column 9 in Table 4, in order to facilitate comparison. The results in columns 2-5 in Table 5 indicate that only growth x leverage75 is negative and statistically significant. That is, the estimated coefficients in model 5 imply that a one standard deviation increase in leverage attenuates the positive effect of growth opportunities on R&D intensity by around 20 percent. The signs on the other interaction variables shown in columns 2-4 are positive, but not statistically significant. These findings suggest that at an extreme level of leverage, the relationship between growth opportunities and R&D intensity turns from being positive into negative. In our sample, in the highly leveraged firms the ratio of total borrowing to assets is at least 0.58.

Table 5 here

Figure 2 shows the moderated effect of growth opportunity on R&D intensity by leverage. Estimated coefficients from Table 5 (Model 1 and Model 5) are used to calculate the changing marginal effects of growth opportunity on R&D intensity when leverage increases. Firstly, it confirms that the positive effect of growth opportunity on R&D intensity is attenuated when firm's leverage increases both for the average firm (Model 1) and highly leveraged firms (Model 5). Secondly, the magnitude of attenuation of highly leveraged firms is smaller than that of average firms. This implies a version of diminishing marginal returns for leverage, diluting the positive effect of growth opportunities on R&D intensity. This finding is consistent with our calculation of the attenuation effect of leverage above: 20 percent for high quartile sub-groups versus 27 percent for all (average) firms.

Figure 2 here

To examine the fourth and sixth hypotheses, we include the logarithm of assets and logarithm of payment to registered board members (scaled by assets in millions), (ln(board payment)),

in our model. The results in Table 6 support the fourth and the sixth hypotheses as firm size and log of executive payment are positive and statistically significant.

Next we consider whether the positive effect of the size of the business group on R&D intensity differs depending on a firm's capability to absorb the negative impact of potential failure of R&D investment (hypothesis 5). If a firm belongs to a group that has a large number of subsidiaries, it may increase its R&D intensity because of the possibility of cross-subsidisation among affiliates, particularly when R&D investment fails.

In our estimates, we split our sample into two sub-groups: one for a group with firms with subsidiaries greater than the mean value of the (log of) number of subsidiaries (columns 1-3) and the others for the rest (columns 4-6). The dividing value in our sample was 0.467.

Table 6 here

The results in Table 7 show that the size variable is positive and significant only if a firm's number of subsidiaries is equal to, or greater than, the mean value of the number of subsidiaries. This finding supports our prediction that the positive effect of size of business group on R&D intensity is more evident when a firm belongs to a business group which has a large number of subsidiaries. The chi-squared statistics indicate that the coefficients range between 46.52 (p-value =0.00) for the pair of models 2 and 5 and 57.09 (p-value=0.00) for the pair of models 3 and 6, meaning that the coefficients between the paired model samples statistically differ. Table 7 suggests these differences are due largely to the substantial differences in the size variable (i.e., log of asset) between the two sub-samples.

Table 7 here

The association between firm size and R&D characterises the vertical dimension in that size changes over time within a firm, whereas the number of affiliations characterise the horizontal dimension. Our results suggest that the cross-sectional dimension strengthens the effect of within firm characteristics on R&D intensity. The traditional deep-pocket hypothesis explains why business groups appear. The key idea is that cross-financing among affiliates helps to overcome market failure. The traditional deep-pocket hypothesis is used to explain the horizontal dimension. Our findings indicate cross-subsidies among affiliates assist firms to undertake risky investment, such as R&D, within the firm. This explains the strengthening effect of cross-sectional characteristics on within-firm R&D intensity.

Table 8 here

To test whether the positive relationship between payment to board members and R&D intensity is smaller for chaebol affiliates than stand-alone firms, we firstly used the unrestricted sample with a binary variable for chaebol and its interaction with the ln(board payment) variable (model 1 in Table 8). Then, we split the sample into two groups: one for the chaebol affiliate (models 2-3) and the other for stand-alone firms (models 4-5). We followed the 2001 Korea Fair Trade Commission's classification for chaebols and non-chaebols (i.e., stand-alone firms). The results in Table 8 indicate that the behaviour of chaebol affiliates is different from stand-alone firms. The chi-square statistics (with p-values) on the lowest row strongly reject the null hypothesis of equality of the estimated coefficient from the paired groups. The magnitudes of the estimated coefficient of the size variables (log of assets) for chaebol affiliates are greater than those for stand-alone firms by approximately 14 percent. The finding that firm size has a bigger impact on R&D intensity for chaebol affiliates is consistent with our finding in Table 7, which indicates that the effect of firm size is greater for firms with a larger numbers of subsidiaries (hypothesis 5).

The positive effect of board payment on R&D intensity is not significant for chaebol affiliates. Our results imply that a financial incentive for board members to undertake R&D investment can be distorted for chaebol affiliates where controlling shareholders have exercised strong powers on strategic decisions and corporate governance has been poor. Controlling shareholders often make intuitive and charismatic decisions that may sometimes work in a small firm and/or in a less developed economy. However, as the size of firms grows and the market matures, the probability that controlling shareholder's intuition will lead to better outcomes than board decisions diminishes (Mishkin, 1999). This is because of the complexity of technologies and the market environment. Our findings imply that reforms to the corporate governance system to strengthen board functions in Korea following the 1997 crisis have yet been effective with respect to R&D investment, particularly in chaebols.

Next, we employed 2SLS to examine the impact of R&D intensity on stock returns. Excluded instruments are the major explanatory variables to determine R&D intensity in Tables 3-6, which are reported as the first-stage on the lower panel of Table 9. The p-values of the estimated coefficients, R-squared, and F-values illustrates that the instruments are valid.

The upper panel of Table 9 reports that the impact of R&D intensity on stock returns is positive and statistically significant, irrespective of model specification (Models 1-4) and different sub-samples (Models 5-8) consistent with hypothesis eight. The results indicate marginal effects of R&D intensity on stock returns range between 7 percent and 16.7 percent. The marginal effects of R&D intensity on stock returns for chaebols (Models 5 and 7) are slightly greater than non-chaebols (Models 6 and 8), albeit statistical significance dropped. In model (2) we controlled for foreign equity ownership, but the sign of the coefficient was somewhat counter-intuitive. As such, we replaced lagged foreign ownership with one-period

leading foreign ownership in models 3 and 4 (and 5 and 6). The negative sign in model 3 implies foreign investors reduced their ownership in firms which had a positive stock return in the previous period. This may imply foreign investors in Korea are myopic, rather than pursuing fundamental analysis using a buy and hold strategy. The estimation of our main regressor (i.e., R&D intensity) is consistently positive and significant throughout.

Table 9 here
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6. Conclusion

Korea has one of the highest levels of R&D investment in the world. Most of the R&D activity is corporate funded. Motivating this paper were the research questions: What explains the determinants of R&D intensity; and what is the impact of R&D intensity on stock returns in a late industrialising economy dominated by family controlled business groups, which has emerged to be one of the world's most innovative nations?

In terms of the first research question, results using an industry-fixed effects model suggest that growth opportunities, size of the firm and payment to executive board members have a positive effect on R&D intensity, while leverage has a negative effect. A feature of the study is that we wanted to explore the effect of the interaction between leverage and growth opportunities on R&D intensity in the aftermath of the Asian financial crisis. Our conjecture was that leverage would accentuate the demand-pull effect of growth opportunities as Korean firms tightened their risk management strategies. We found that leverage does accentuate the positive effect of growth opportunities on R&D intensity and that that when leverage is at an extremely high level, the relationship between growth opportunities and R&D intensity turns from positive to negative. Another feature of the study is that we examined how firm size and

cross-shareholdings within business groups in Korea interacted to affect R&D intensity. We found that the positive effect of firm size on R&D intensity is larger, the greater the number of subsidiaries the firm has, consistent with the firm engaging in cross-subsidisation. Finally, we examined how payments to executive board members impacted on R&D intensity between chaebols and stand-alone firms. We found that the positive effect of payments to executive board members on R&D intensity is smaller for chaebol affiliates than for stand-alone firms, reflecting the influence of controlling shareholders in chaebols.

To address the second research question, we used 2SLS to examine the impact of R&D intensity on stock returns. The 2SLS results suggested that R&D intensity increases stock returns, which, in turn, imply an increase in firm value. This finding is important given that the stock return captures expected cash flows in the future, which, in turn, influence corporate strategic decisions. Our results suggest that high levels of corporate expenditure on R&D activities in Korea are paying off for the firms in the form of higher stock returns.

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Table 1
Summary statistics

Variable	Mean	Sd	p50	p25	p75	min	max	N	Definition
R&D intensity	0.60	1.36	0.03	0	0.53	0	10.34	3403	R& D expenditure as a percentage of assets
Growth opportunity	1.11	1.05	0.78	0.5	1.29	0.14	7.25	3403	The price to book ratio =market price of equity divided by book value of equity
Leverage	0.44	0.2	0.45	0.29	0.58	0.04	0.94	3403	Debt divided by assets
Firm size	26.66	1.53	26.4	25.59	27.48	22.91	32.52	3403	Natural logarithm of assets
Board payment	1.01	1.23	0.61	0.28	1.26	0	16.06	3403	Payment to registered board members divided by assets in million.
CSH	0.43	0.16	0.43	0.31	0.53	0.06	0.89	3403	Controlling shareholder equity ownership
Operating cash flow	0.05	0.09	0.04	0	0.09	-0.31	0.53	3403	Cash flows from operations divided by assets
Foreign ownership	0.1	0.14	0.04	0.01	0.14	0	0.73	3403	Foreigner equity ownership
Audit committee	0.3	0.46	0	0	1	0	1	3403	A binary variable equal to 1 if a firm has an audit committee; zero otherwise
Outside director	0.38	0.16	0.33	0.25	0.5	0	1	3403	Outside directors divided by board members
Subsidiary number	6.98	16.7	2	0	7	0	250	3403	Number of subsidiaries
Stock return	0.18	0.58	0.09	-0.14	0.40	-0.93	3.7	3403	Continuously compounded return based on average of monthly data

Table 2
Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)R&D intensity	1										
(2)Growth opportunity	0.181*	1									
(3)Leverage	-0.059*	0.104*	1								
(4)Firm size	0.053*	0.139*	0.187*	1							
(5)Board payment	0.052*	0.011	-0.148*	-0.547*	1						
(6)CSH	-0.106*	-0.175*	-0.106*	-0.105*	-0.045*	1					
(7)Operating cash flow	0.097*	0.227*	-0.206*	0.120*	-0.034*	0.003	1				
(8)Foreign ownership	0.099*	0.249*	-0.124*	0.462*	-0.213*	-0.132*	0.235*				
(9)Audit committee	0.087*	0.191*	0.121*	0.553*	-0.254*	-0.140*	0.090*	0.293*	1		
(10)Outside director	0.028*	0.154*	0.077*	0.318*	-0.095*	-0.129*	0.030*	0.202*	0.404*	1	
(11)Subsidiary number	0.067*	0.100*	-0.018*	0.509*	-0.173*	-0.118*	0.044*	0.272*	0.324*	0.191*	1
(12) Stock return	-0.003	0.190*	-0.005	-0.081*	0.072*	-0.011	0.078*	-0.042*	-0.051*	-0.043*	-0.024*

Note: * denote statistical significance at the 5 percent level.

Table 3
Effects of growth opportunities on R&D intensity

	1	2	3	4	5	6
Growth opportunity	0.188***	0.198***	0.169**	0.171**	0.205***	0.169**
	[0.009]	[0.008]	[0.016]	[0.014]	[0.006]	[0.016]
CSH	-0.725**	-0.726**	-0.451	-0.491	-0.782**	-0.450
	[0.031]	[0.031]	[0.151]	[0.118]	[0.020]	[0.152]
Foreign ownership	0.540	0.542	0.501	0.626	0.565	0.501
	[0.196]	[0.197]	[0.183]	[0.131]	[0.179]	[0.184]
Sales growth		-0.0652			-0.0899	
		[0.396]			[0.250]	
Subsidiary number			0.00482			0.00483
			[0.318]			[0.318]
time2Xindustry				-0.034***	-0.033**	-0.0235*
				[0.001]	[0.037]	[0.054]
time3Xindustry				-0.0202*	-0.0254	-0.0149
				[0.053]	[0.120]	[0.237]
time4Xindustry				-0.0244**	-0.0326**	-0.0224**
				[0.014]	[0.028]	[0.039]
time5Xindustry				-0.028***	-0.043***	-0.036***
				[0.005]	[0.003]	[0.001]
time6Xindustry				-0.0203**	-0.0367**	-0.0304**
				[0.049]	[0.018]	[0.012]
Industry effects	No	Yes	Yes	Yes	No	Yes
Time effects	No	No	Yes	No	Yes	Yes
Constant	0.653***	0.682***	0.235	0.263	0.867***	0.188
	[0.000]	[0.000]	[0.230]	[0.196]	[0.000]	[0.355]
R^2 _ *adjusted*	0.0395	0.0395	0.12	0.117	0.0462	0.119
N	2701	2701	2701	2701	2701	2701

Notes: Figures in parenthesis are p-values. ***(**) (*) denotes significance at 1(5)(10) per cent. CSH refers to controlling shareholders.

Table 4

Leverage effects on R&D intensity

	1	2	3	4	5	6	7	8	9
Growth opportunity	0.218***	0.228***	0.205***	0.204***	0.235***	0.205***	0.646***	0.634***	0.644***
	[0.002]	[0.002]	[0.004]	[0.004]	[0.001]	[0.004]	[0.004]	[0.006]	[0.004]
CSH	-0.836**	-0.840**	-0.579*	-0.576*	-0.899***	-0.578*	-0.479	-0.812**	-0.482
	[0.014]	[0.014]	[0.068]	[0.069]	[0.008]	[0.068]	[0.126]	[0.016]	[0.124]
Leverage	-0.692***	-0.710***	-0.496**	-0.492**	-0.716***	-0.498**	0.514	0.172	0.506
	[0.004]	[0.004]	[0.049]	[0.050]	[0.004]	[0.048]	[0.134]	[0.619]	[0.141]
Growth x Leverage							-0.881***	-0.794**	-0.876***
							[0.009]	[0.023]	[0.009]
Industry effects	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes
Time effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Industry-time effects	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
_cons	1.025***	1.070***	0.563**	0.545**	1.250***	0.513**	0.013	0.780***	-0.0265
	[0.000]	[0.000]	[0.011]	[0.016]	[0.000]	[0.026]	[0.964]	[0.007]	[0.925]
$R^2_adjusted$	0.0458	0.0463	0.118	0.118	0.0527	0.117	0.133	0.0656	0.132
N	2701	2701	2701	2701	2701	2701	2701	2701	2701

Notes: as per Table 3

Table 5
Non-linear effects of leverage on R&D intensity

	1	2	3	4	5
Growth opportunity	0.644***	0.143**	0.190***	0.142**	0.310***
	[0.004]	[0.021]	[0.006]	[0.049]	[0.003]
CSH	-0.482	-0.504	-0.544*	-0.564*	-0.512*
	[0.124]	[0.111]	[0.081]	[0.072]	[0.100]
Leverage	0.506				
	[0.141]				
Growth x Leverage	-0.87***				
	[0.009]				
leverage25		-0.195			
		[0.289]			
Growth x Leverage25		0.314			
		[0.119]			
Leverage2550			0.0495		
			[0.726]		
Growth X Leverage 2550			0.00697		
			[0.962]		
Leverage5075				-0.122	
				[0.357]	
Growth X Leverage 5075				0.155	
				[0.238]	
Leverage75					0.125
					[0.279]
Growth X Leverage75					-0.316***
					[0.002]
Industry effects	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes
Industry-time effects	Yes	Yes	Yes	Yes	Yes
_cons	-0.0265	0.292	0.283	0.347	0.221
	[0.925]	[0.126]	[0.146]	[0.076]	[0.281]
R^2 _ *adjusted*	0.132	0.122	0.113	0.116	0.131
N	2701	2701	2701	2701	2701

Notes: as per Table 3.

Table 6
Size effect and executive payment effects on R&D intensity

	1	2	3	4	5	6
Growth opportunity	0.196***	0.205***	0.173**	0.173**	0.210***	0.173**
	[0.005]	[0.005]	[0.012]	[0.012]	[0.004]	[0.013]
Firm size	0.147***	0.141***	0.190***	0.191***	0.158***	0.189***
	[0.003]	[0.005]	[0.000]	[0.000]	[0.002]	[0.000]
ln(board payment)	0.174***	0.168***	0.176***	0.177***	0.180***	0.176***
	[0.002]	[0.003]	[0.002]	[0.002]	[0.002]	[0.002]
Leverage	-0.63***	-0.65***	-0.474**	-0.473**	-0.66***	-0.476**
	[0.007]	[0.006]	[0.050]	[0.049]	[0.005]	[0.049]
CSH	-0.720**	-0.725**	-0.420	-0.416	-0.776**	-0.419
	[0.026]	[0.025]	[0.162]	[0.164]	[0.016]	[0.163]
Industry effects	No	Yes	Yes	Yes	Yes	Yes
Time effects	No	Yes	Yes	Yes	Yes	Yes
Industry-time effects	No	No	No	Yes	Yes	Yes
_cons	-0.43	-0.313	-1.990**	-2.034**	-0.362	-2.027**
	[0.648]	[0.743]	[0.038]	[0.034]	[0.703]	[0.036]
R^2 _ *adjusted*	0.0547	0.0542	0.132	0.132	0.0625	0.131
N	2701	2701	2701	2701	2701	2701

Notes: as per Table 3

Table 7
Estimation of the size of the business group effect on R&D intensity

	Sub-sample for number of subsidiary ≥ its mean value			Sub-sample for number of subsidiary < its mean value		
	1	2	3	4	5	6
Growth opportunity	0.156**	0.193**	0.155*	0.151**	0.186**	0.151**
	[0.043]	[0.027]	[0.055]	[0.042]	[0.014]	[0.042]
Firm size	0.193***	0.156**	0.193***	0.100	0.0717	0.101
	[0.003]	[0.016]	[0.003]	[0.142]	[0.279]	[0.143]
ln(board payment)	0.207***	0.210***	0.207***	0.136*	0.174**	0.137*
	[0.005]	[0.006]	[0.006]	[0.052]	[0.032]	[0.053]
CSH	-0.512	-0.958**	-0.515	-0.0358	-0.215	-0.0396
	[0.214]	[0.026]	[0.213]	[0.913]	[0.532]	[0.904]
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-time effects	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-1.728	-0.0148	-1.793	-0.786	1.092	-0.827
	[0.192]	[0.991]	[0.18]	[0.535]	[0.322]	[0.52]
$R^2_adjusted$	0.131	0.0563	0.13	0.111	0.0396	0.108
N	1639	1639	1639	1062	1062	1062
χ^2	48.76	46.52	57.09	48.76	46.52	57.09
$(p-value)$	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Paired with model 4	Paired with model 5	Paired with model 6	Paired with model 1	Paired with model 2	Paired with model 3

Notes: as per Table 3

Table 8
Chaebol affiliates vs. Non-chaebol firms

	Chaebol affiliate		Non-chaebol firm	
	1	2	3	4
Growth opportunity	0.214**	0.221**	0.188**	0.188**
	[0.041]	[0.040]	[0.028]	[0.029]
Firm size	0.262**	0.257**	0.229***	0.227***
	[0.038]	[0.044]	[0.000]	[0.000]
ln(board payment)	0.0415	0.0354	0.233***	0.232***
	[0.650]	[0.702]	[0.002]	[0.002]
Leverage	-1.160*	-1.187*	-0.362	-0.365
	[0.068]	[0.064]	[0.167]	[0.165]
CSH	0.0613	0.0602	-0.440	-0.442
	[0.902]	[0.904]	[0.210]	[0.208]
Industry effects	Yes	Yes	Yes	Yes
Time effects	No	Yes	No	Yes
Industry-time effects	Yes	Yes	Yes	Yes
_cons	-6.693**	-6.520**	-2.226*	-2.228*
	[0.020]	[0.023]	[0.073]	[0.075]
$R^2_adjusted$	0.358	0.354	0.116	0.115
N	464	464	2237	2237
χ^2	142.04	120.22	142.04	120.22
$(p-value)$	(0.00)	(0.00)	(0.00)	(0.00)
	Paired with model 4	Paired with model 5	Paired with model 2	Paired with model 3

Notes: as per Table 3

Table 9. 2SLS Estimates of the Impact of R&D intensity on stock returns

	Unrestricted sample				Chaebol	Non-chaebol	Chaebol	Non-chaebol
	1	2	3	4	5	6	7	8
R&D intensity	0.0712*	0.135***	0.114**	0.167***	0.166**	0.143***	0.167**	0.146***
	[0.062]	[0.002]	[0.016]	[0.002]	[0.034]	[0.009]	[0.033]	[0.006]
CSH	0.149**	0.163**	0.0656	0.0727	0.132	0.0686	0.131	0.0595
	[0.040]	[0.030]	[0.417]	[0.393]	[0.404]	[0.470]	[0.408]	[0.528]
Foreign ownership		-0.298***					0.0701	-0.879***
		[0.001]					[0.801]	[0.001]
foreign_lead			-0.186*	-0.139	-0.108	-0.145	-0.171	0.677**
			[0.052]	[0.173]	[0.636]	[0.204]	[0.616]	[0.012]
Operating cash flow				-0.0314	-0.0968	-0.0087	-0.105	-0.0179
				[0.818]	[0.683]	[0.995]	[0.661]	[0.907]
Audit committee				-0.100***	-0.0535	-0.103***	-0.0556	-0.104***
				[0.002]	[0.320]	[0.006]	[0.309]	[0.006]
Outside director				0.0157	0.0111	-0.0058	0.0129	-0.011
				[0.840]	[0.936]	[0.946]	[0.926]	[0.898]
Industry effects								
Time effects								
Industry-time effects	-0.184**	-0.168**	0.365***	-0.147*	0.415**	-0.145	0.415**	-0.119
_cons	[0.013]	[0.029]	[0.000]	[0.089]	[0.034]	[0.125]	[0.034]	[0.205]
R^2 _ *adjusted*	0.09	0.03	0.09	0.01	0.27	0.03	0.26	0.03
N	2701	2701	2110	2110	360	1750	360	1750
First-stage estimation								
Growth opportunity	0.202***	0.198***	0.192***	0.189***	0.203***	0.207***	0.202***	0.216***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]
Firm size	0.178***	0.171***	0.190***	0.172***	0.191***	0.214***	0.189***	0.205***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.008]	[0.000]	[0.009]	[0.000]
ln(board payment)	0.168***	0.167***	0.172***	0.171***	0.012	0.226***	0.012	0.227***
	[0.000]	[0.001]	[0.000]	[0.000]	[0.846]	[0.000]	[0.859]	[0.000]
Leverage	-0.428***	-0.404***	-0.476***	-0.492***	-1.21***	-0.373**	-1.212***	-0.367**
	[0.002]	[0.005]	[0.004]	[0.003]	[0.000]	[0.05]	[0.000]	[0.045]
CSH			-0.450**	-0.437**	-0.184	-0.444**	-0.181	-0.414**
			[0.013]	[0.017]	[0.648]	[0.034]	[0.656]	[0.047]
Foreign ownership							-0.241	2.011***
							[0.717]	[0.001]
foreign_lead			-0.049	-0.031	0.052	-0.037	0.261	-1.905***
			[0.841]	[0.901]	[0.925]	[0.895]	[0.744]	[0.002]
Operating cash flow				-0.119	0.549	-0.256	0.570	-0.226
				[0.709]	[0.321]	[0.486]	[0.306]	[0.537]
Audit committee				0.162**	0.211	0.148*	0.219*	0.155*
				[0.032]	[0.112]	[0.092]	[0.100]	[0.076]
Outside director				-0.249	-0.364	-0.142	-0.367	-0.127

				[0.160]	[0.276]	[0.481]	[0.273]	[0.528]
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-1.821***	-0.169***	-2.159***	-1.501**	-4.97***	-1.862**	-4.93***	-1.682**
	[0.000]	[0.001]	[0.000]	[0.024]	[0.001]	[0.029]	[0.001]	[0.049]
R^2 _ *adjusted*	0.132	0.132	0.132	0.133	0.426	0.129	0.379	0.138
F-value(p-value)	17.53(0.00)	16.87(0.00)	14.34(0.00)	12.97(0.00)	9.51(0.00)	9.46(0.00)	9.13(0.00)	9.58(0.00)

Notes: as per Table 3

Figure 1: Summary of hypotheses and implications for the identification strategy

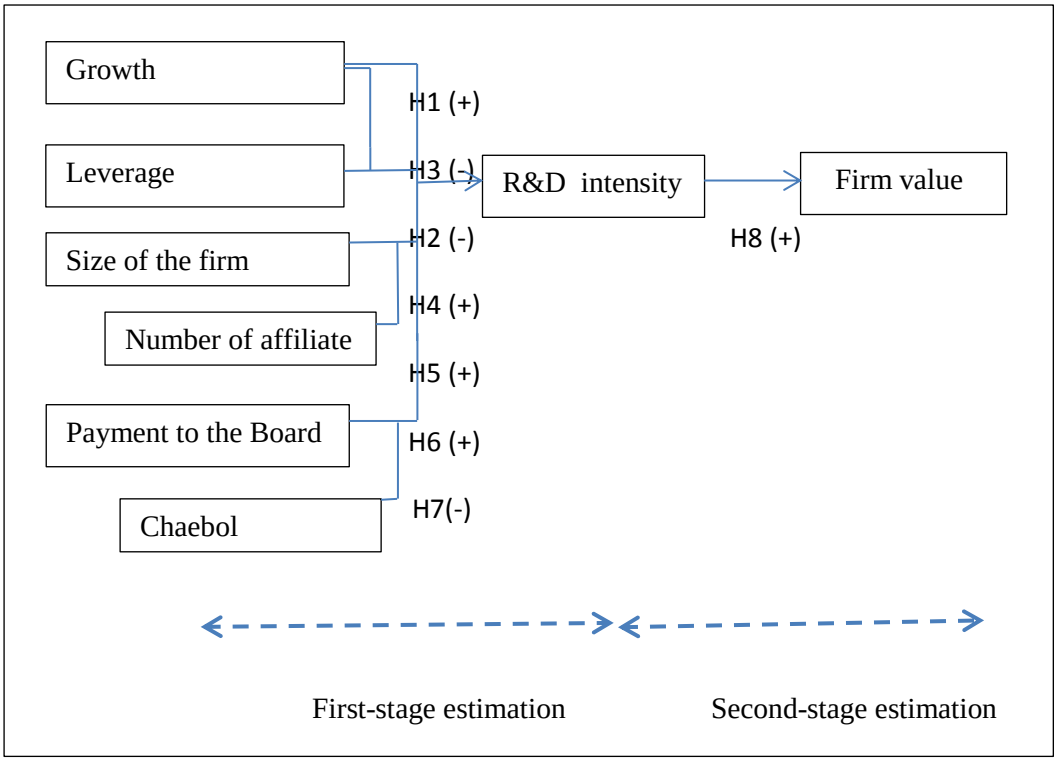
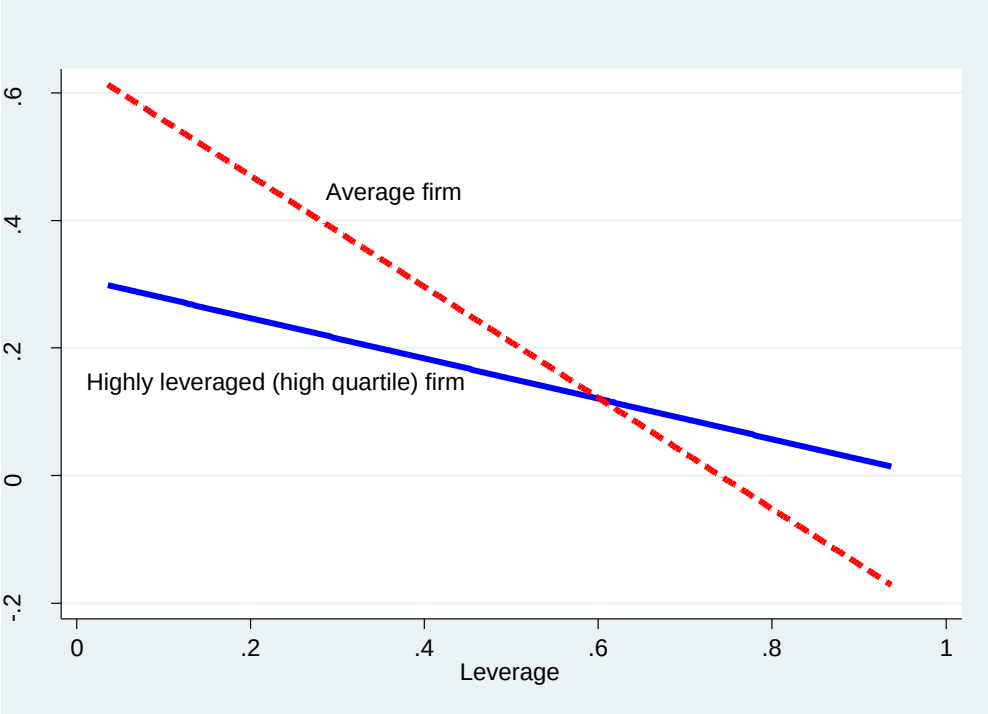
Figure 2: Moderating effect of leverage on the growth opportunity/R&D intensity relationship