

R&D Investment Decisions in Business Groups:
Evidence from a Natural Experiment

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Abstract

This paper examines R&D investment decisions in firms under a pyramidal ownership structure. After the Korea's Monopoly Regulation and Fair Trade Act places limits on group affiliates' equity investments, the controlling owners tend to increase long-term R&D expenditures relatively more in firms that are largely subject to the equity investment regulation. Moreover, this result is more significant for firms where the owners have low cash-flow rights, firms located in lower layers of the pyramid, and firms holding less equity shares over other group affiliates. Overall, these results suggest that controlling owners allocate resources for private benefits within their business group.

JEL Codes: G30, G32, O32

Keywords: Ownership Structure, Investment Decision, Business Group, Private Benefits

1. Introduction

Our study pays special attention to a pyramidal ownership structure of a business group and the relative status of an affiliated firm in the pyramid as factors that drive the firm's investment decisions. This study employs controlling owners' cash-flow rights over the firm, layer of the firm within the business group, and the firm's centrality¹ as key variables that measure each firm's relative status in the group. The setting of pyramidal ownership structures is typical in Korean chaebols, where family owners of the chaebol commonly own and control multiple firms by forming a business group. This study centers on firms' R&D expenditure, which is one of the major long-term investments, and relates the firms' R&D investment decisions to the firms' positions under the pyramidal ownership structures.

This paper identifies the relationship between firms' investment decisions and the firms' relative status within the business group by employing the 2001 regulatory reform on firms' equity investments implemented by the Korea Fair Trade Commission (KFTC) as a shock to firms' investment environments. In April 2001, a regulation that controls equity investments of firms under business groups took effect. This regulation was applied to firms that belong to large business groups with total consolidated assets of 5 trillion KRW and above. Since then, equity holdings held by an affiliated firm within the business groups subject to the regulation were limited to 25 percent of its' net assets. Consequently, this new regulation forced firms to reallocate their resources between different investment alternatives. In this study, we examine the changes made

¹ Centrality measures the average percentage difference in the control rights of the controlling family across all group member firms other than the firm itself, after excluding a specific firm i from the group. Thus, firms with positive value of centrality implies that those firms have shareholding in other group affiliates. See Almeida et al. (2012) for more details on the centrality measure.

to firms' R&D expenditures in the period subsequent to this regulatory shock and highlight the differences in the regulatory effects across firms with different positions under pyramidal ownership structures.

Using a sample of 1,601 member firms owned by the 24 largest Korean chaebol groups² in the period from 1998 to 2009, and employing difference-in-differences (DiD) approach, we provide causal evidence from a quasi-natural experiment that an equity investment regulation positively affects to R&D investment decisions. First, we observe lower long-term R&D expenditures in group member firms under a pyramidal structure when the controlling owners have a higher level of cash-flow rights. For example, one standard deviation increase in the controlling owner's cash-flow rights is associated with a 25.9% lower long-term R&D ratio.³ This result implies that the controlling owners opportunistically bring heterogenous or irrelevant investment policies across member firms in order to pursue their private benefits in a particular way of allocating the short-term investment to firms where they have higher cash-flow rights while assigning the long-term investment to those where they have lower cash-flow rights.

However, the recently passed regulatory reform places limits on group affiliates' equity investments up to a 25% and requires controlling owners to reallocate the excess equity investment. Our results show that after the new regulation, the controlling owners are likely to increase long-term R&D expenditures relatively more in firms where the equity investment ceiling is applied.

² Korean Fair Trade Commission's (KFTC) detailed ownership status information is only available for large Korean business groups whose asset size is greater than 5 trillion KRW. Therefore, we cannot expand our sample to firms in small business groups.

³ Long-term R&D ratio refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. This ratio is used as a proxy value for long-term investment. Korean Generally Accepted Accounting Standard (K-GAAP) allow us to distinguish long-term R&D expenses and short-term R&D. Long-term R&D expenditure are classified as assets on the balance sheet, while short-term R&D expenditure is regarded as expenses.

Consequently, those firms that increase long-term R&D expenditure enhance their performance around the 2001 regulatory reform.

Moreover, we find that this trend of increasing investment is more profound in firms where controlling owners have lower cash-flow rights. However, this trend is less likely in the firms located in the upper layer of the pyramid, where the controlling owners' direct ownership is highly concentrated, and in high centrality firms where short-term equity investment in group affiliates is highly preferred for governance purposes. We confirm that all the results are consistent with alternative samples with consideration of the 2005 and 2007 regulatory relaxation and of exemptions for business groups transformed into holding company structure.

We further conduct placebo tests for verification by studying control rights instead of cash-flow rights. Provided the R&D investment decisions of companies with pyramidal ownership depend on a controlling owner's profit structure, control rights should not be relevant to the R&D investment decisions. We also examine circular ownership chains in lieu of the upper layer of the pyramids given that most firms within any circular ownership chain are indirectly controlled and located in the lower layer of a pyramid. In addition, we investigate equity investment loss on affiliates instead of equity investment on affiliates because equity investment loss should lead to decreased motivation for additional equity investments of central firms. The results of these falsification tests show that voting rights, equity investment loss on affiliates, and indirect ownership through a circular ownership chain are all immune to R&D investment decisions. Finally, we confirm the constant trends in the post-regulatory period by creating a fake regulatory shock after 2005.

We also check that alternative time periods such as a succession period and a Asian financial crisis do not produce similar results. Overall, the results highlight the significance of the regulatory reform that restricted the equity investment by chaebol groups with a pyramidal ownership structure, thereby allowing controlling owners to change R&D investment decisions within their business group.

Our study contributes to the literature in several ways. First, this study is related to the literature that focuses on discretionary R&D investments and agency problems involved with ownership structure. Focusing on Korean chaebol firms that helps us identify various ownership links among affiliates, we conjecture that controlling shareholders' varying degrees of cash-flow rights across affiliated firms results in differing preferences for resource allocations among those firms. We show that the chaebol firm ownership structures allow the controlling family shareholders to divert firm resources among the affiliates for private benefits that do not accrue to other shareholders while leaving the costs of failure to minority shareholders. Specifically, the underinvestment in R&D is severe in the affiliated firms where the controlling shareholders have high cash-flow rights and an overinvestment-related agency problem is more pronounced in the firms where controlling owners have relatively small cash-flow rights.

Second, we employ the regulatory changes on equity investments among chaebol firms during 2001 as a shock on firms' investment decisions, which requested that the large chaebol firms with total assets above 5 trillion KRW meet the 25% limit of their net assets on equity investment. The regulation changes are largely exogenous to the large business groups, and thus provide a desirable natural experimental environment to test how regulatory environment changes affects R&D investment decisions among the group affiliates.

Lastly, the findings of this study can also be added to the literature on chaebol firms. Studying chaebol firms allows us to examine the effects of pyramidal ownership structure, where ownership and control are highly integrated, and to further examine a different degree of the owners' risk aversion and the level of resource endowment. We further consider the newly developed metrics of chaebol ownership structure (e.g., position, centrality, and the critical control threshold) in the study (Almeida, Park, Wolfenzon, 2010). Our results show that underinvestment in R&D is more severe in the firms where the owners have low cash-flow rights, firms located in lower layers of the pyramid, and firms holding less equity shares over other group affiliates.

This paper is organized as follows. Section 2 reviews the relevant literature. Section 3 introduces institutional background and develop testable hypotheses. Section 4 contains a description of the data and sample summary statistics. Section 5 discusses the main results, placebo test, and robustness test. Section 6 provides concluding remarks.

2. Literature Review

2.1. R&D Investment

R&D investment plays a pivotal role as a driving force of gaining future competitive advantage and productivity (Scherer, 1984; Ettlíe, 1998; Guellec and van Pottelsberghe de la Potterie, 2001). R&D investment is distinguished from other investments. For example, R&D investments are considered a risky long-term investment associated with high failure rates and a large amount of sunk and adjustment costs, specifically in low growth environments (Aboody and Lev, 2000; Kor, 2006; Oriani and Sobrero, 2008). Moreover, R&D investments have a significant

level of information asymmetry between managers, and investors and future outcomes of R&D projects are very difficult to evaluate (Hall, 2002; Oriani and Sobrero, 2008). Given these concerns, R&D investment decisions may give rise to agency concerns reflecting a risk-taking propensity as well as resource endowment (Aboody and Lev, 2000; Ho, Tjahjapranata, and Yap, 2006; He and Wang, 2009).

A number of empirical studies show that R&D investment is determined by various factors such as a firm's industry, firm size, debt ratio, institutional ownership, and managerial characteristics (Scherer 1984, Chan et al., 1990; Baysinger et al., 1991, Hansen and Hill, 1991; Cannolly and Hirschey, 2005; Pindado, Queiroz, and Torre, 2010; Lagaras and Tsoutsoura, 2015). Specifically, a manager's risk preferences aligned with various individual traits and their ownership concentrations are considered critical determinants of corporate R&D investment policies. However, these issues have not been fully explored from the perspective of the family firm with a pyramidal ownership structure. Although evidence shows that family ownership is a primary source of corporate investments and economic development (Zahra, 2005; Belenzon and Berkovitz, 2010; Anderson et al., 2012; Choi et al., 2015), the net effect of ownership structure on R&D investment is less clear than the trade-off between costs and benefits of largely concentrated ownerships in family firms. We aim to fill the gap in the literature by closely investigating the influences of pyramidal ownership structures on firms' R&D investment.

2.2. Ownership structure in chaebol firms and R&D investment

Ownership structure is a key factor in determining firm valuation (Demsetz and Lehn, 1985). Jensen and Meckling (1976) suggest that increases in ownership stakes (cash-flow rights) incentivize managers to take risky projects to raise a firm's profit, which would reduce the agency problem of concern that arises from the separation of ownership and control. Family firms create somewhat different types of agency problems that stem from the principal-principal conflicts (Schulze et al., 2001). Claessens et al. (2000) show that the pyramidal business structure allows controlling shareholders to control affiliated firms in complex ownership structures with a varying degree of cash-flow rights and control rights. Controlling shareholders easily and fully control all member firms even with a relatively small portion of cash-flow rights. It has been also shown that controlling shareholders in family firms often take managerial positions instead of appointing outside professional managers (Baek et al., 2006; Sirmon and Hitt, 2003).

The principal-principal conflicts are more problematic in Korean chaebol firms that are also classified as family firms. While there may be positive perspectives of chaebol firms, considerable evidence shows that the business group affiliations lead to severe agency problems involved with biased decision making, inefficient resource allocation, and weak commitments to long-term investments (Stein, 1988; Seru, 2014). Controlling shareholders—insider owners who use equity ownership by affiliated firms as a means of controlling other member firms—gain access to critical firm-specific information and exert substantial influence over resource allocation among affiliates (Chang et al., 2006). Several recent studies show that controlling shareholders tend to abuse inside information for controlling advantages to pursue private benefits at the expenses of minority shareholders. La Porta et al. (2000) find that such expropriation is even more

severe in emerging economies where protection of outside investors is relatively weak. Tunneling is one mechanism family shareholders use for their private gain and for extracting benefits from minority shareholders. For example, Bertrand et al. (2002), Bae et al. (2002), and Baek et al. (2006) show that controlling shareholders of business groups tunnel profits out of member firms where they have low cash-flow rights to affiliated firms where they have high cash-flow rights.

Pyramidal ownership structure allows controlling shareholders to exercise full control over member firms belonging to the same business group, withholding a relatively small portion of its cash-flow rights. Friedman, Johnson, and Mitton (2003) show that the controlling owners have incentives to transfer funds from one firm to other affiliated firms within a business group to preserve their options to expropriate the profits of the firm. We argue that the divergence of controlling shareholders' interests corresponding to their cash-flow rights among affiliates may lead to various degrees of investment decisions as an investment's monetary payoff differs throughout the affiliated firms. Controlling shareholders receive a high dividend rate through direct ownership of affiliated firms where they have a large portion of equity ownership stakes. With this promised dividend from substantial cash-flow rights, they would prefer short-term wealth gains rather than investing in long-term projects in firms where they can quickly cash out firm resources.

Conversely, this divergence of controlling shareholders' interests may lead to the allocation of long-term commitment projects to affiliated firms in which controlling owners have small cash-flow rights (Almeida and Wolfenzon, 2006). This is possible since outside shareholders have incomplete information about the payoff from the investment and controlling shareholders would not be concerned about employment risks at the affiliated firm where they have only a small portion of equity. Given the divergent cash-flow rights and interests of controlling shareholders

among the affiliated firms, those controlling owners may be tempted to extract high short-term earnings by shifting risky projects such as long-term R&D investment to firms with low cash-flow rights while leaving the costs of failed R&D projects to minority shareholders. For the in-depth tests of the effect of complex ownership structure in chaebol firms, we use new metrics of group ownership structure used in the recent study (Almeida et al., 2011).

3. Institutional Background and Hypothesis Development

3.1. Institutional Background

Korea first introduced the so-called equity investment regulations in 1987 as part of the first amendment of the Monopoly Regulation and Fair Trade Act (MRFTA). The regulations were formed to promote transparency, fairness, and competition for affiliated firms and to strengthen the rights of minority shareholders. Specifically, the total equity investments in other member companies within the same business group by any subsidiary of a chaebol were not to exceed the ceiling set by the MRFTA.

In 1993, the ceiling was set to 25% of a firm's total net assets in other affiliates. However, the overall drive for tougher regulations on equity investment by chaebols weakened in the wake of the 1997-1998 Asian financial crisis. Amidst the growing concern over counter-discrimination against domestic companies facing the mounting threat of hostile M&As by foreign investors, the equity investments ceiling was abolished altogether. However, unlike the original intention, the elimination of the regulation allowed large business groups to expand through equity investments

among member firm, which caused the large concerns of Korean Chaebols' concentration of economic power.⁴

When the Korean government announced that the country successfully overcame the crisis, it immediately re-introduced the ceiling measure as of April 2001, and implemented it for the large business groups with total assets of over 5 trillion KRW from the beginning of January 2002. With this, the firms subject to the new ceiling were not allowed to invest in equity shares of other group affiliates in excess of 25% of their net assets.⁵ The equity investments ceiling was eliminated entirely in 2009 as part of the country's efforts to promote local companies' global competitiveness, and corporate disclosure obligation was reinforced instead.

[Table 1 around here]

As indicated in Table 1, with the recently implemented regulatory reform and stronger regulations, the restriction on equity investment was immediately enacted in the cease of the Asian financial crisis. Accordingly, in our sample, the pre-regulatory reform period is from 1998 to 2001 and the post-regulatory reform period is from 2002 to 2009. Overall, these regulatory changes, and the equity investments limit in particular, was unexpected, and the effect of regulatory reform was significant.⁶ Figure 1 shows that the increasing trend of total equity investment ratio suddenly drops around the equity investment regulatory reform in 2001.

⁴ The amount of total equity investments and inside equity ownership among the top 30 business groups had sharply risen to 30 trillion from 18 trillion KRW in 1999, and the elimination of investment ceiling amount allowed controlling shareholders to control large number of affiliated only with a small stake.

⁵ Financial institutions, insurance companies, and holding companies were exempted from equity investment limitation.

⁶ KTTC's research service report "Performance Analysis and Evaluation of Equity Investment Regulation" (Oct. 2006) shows that the average equity investment on group affiliates for 11 largest chaebols significantly decreased during the post-regulatory reform period as follows: 27.87% (1998), 33.13% (1999), 33.30% (2000), 38.08% (2001), 32.12% (2002), 31.89% (2003), and 28.62% (2002).

However, the scope of business groups that the equity investment regulation is applied is relaxed to business groups whose total asset is more than 6 trillion KRW in 2005, and after 2007 the regulation was more relaxed to large business groups with over 10 trillion KRW in total assets with a ceiling 40% of their net assets. During regulatory relaxation periods, Korean government also encouraged large chaebols to transit into holding company form as a condition to be exempt from the equity investment regulation. For these reasons, we conduct robustness test for alternative samples and sample periods to resolve the limitation of regulatory shock.

3.2. Hypothesis Development

In this section, we develop hypotheses for the effect of the new equity investment regulation on R&D expenditures of the firms under pyramidal ownership structures in South Korea.

The regulatory reform on equity investments should affect a firm's resource allocation and investment decision if the firm is subject to the new regulation. In other words, if a firm's total investment on its group affiliates' equity shares is above 25 percent of the firm's net asset values, the firm's additional investment on group affiliates' equity shares should be strictly restricted by the new regulation. Under this change of the business environment, firms must reallocate existing resources to other investment projects, one of which may include long-term R&D expenditures. Consequently, the firm that holds group affiliates' equity shares above 25 percent of the firm's net assets are more likely to increase long-term R&D investments in subsequent periods after the regulatory reform relative to the firm that holds group affiliates' equity shares less than 25 percent of the firm's net asset.

Next, we expect that the effect of the regulatory reform differs across firms depending on the firms' positions within the business group although the new investment regulation is applied to all those firms (i.e. holding group affiliates equity shares higher than 25 percent of the firms' net assets). In this study, we focus on three types of variables that measure each firm's relative position in the business group under the pyramidal ownership structure. Those are the owner's cash flow rights on the firm, layer of the firm under the pyramid, and centrality of the firm in the group. All these variables are highly related to the controlling owners' private benefits. First, an owner's cashflow rights measure how much proportion of the firms' total dividends will be paid out to controlling owners. The higher this value, the more proportions of dividends will be allocated to the owners. Second, the layer of the firm in the group measures how directly the firm is controlled by the owner. If the firm is placed in a higher layer, the firm is more directly governed by the owner, and thus profits of the firm can be more efficiently transferred to the owner. Finally, a firm's centrality measures a relative importance of the firm in terms of securing the owner's controlling power over the entire business group. As a firm's centrality is higher, the degree of the firm's control power over the business group is larger, which ultimately intensifies the owner's controlling right over all group affiliates. In this paper, we investigate the differential effects of the regulatory reform that limits firms' equity investments on the firms' R&D expenditures depending on the owner's cash flow right on the firms, layer of the firms under the pyramid, and the firms' centrality in the group.

First, we expect that the effect of the regulatory reform on an R&D expenditure of the regulated firm (holding group affiliates' equity shares above 25 percent of its net assets) will be more significant if the owner holds lower cash flow rights over the firm. Long-term investments

like R&D expenditures have potential to create big returns in the future by improving their competitive power in the market place, but such investments are subject to a big risk of zero returns if the investments fail to promote the firms' long-term competitiveness. Because of this reason, controlling shareholders may prefer to share the risks (and returns) from the uncertain long-term R&D investments with other minority shareholders. Instead, the owners can decide to allocate short-term and less risky projects to the firms of which the owner holds higher cash flow rights. Consequently, the effect of the new equity investment regulation on firms' subsequent R&D investments are expected to be more significant for the firms with the owner's relatively lower cash flow rights. In the Appendix B, we discuss more details using some numerical examples.

Second, we hypothesize that the regulated firm located in a lower layer under the pyramid is more likely to expand its R&D expenditure after the regulatory reform. In the pyramidal structure, owners' direct ownerships are usually concentrated in the firms' upper layers. Those firms' resources can be directly transferred to controlling owners through dividends or other compensations for the owners' private benefits. Alternatively, earnings from the firms in lower layers should be transmitted to owners indirectly via multiple layers. This process may increase operational inefficiencies in collecting private benefits from the firms in lower layers, and thus incentivizes the owners to extract short-term earnings from the firms in upper layers where the owners' direct ownerships are concentrated. Ultimately, the controlling owners are more likely to allocate short-term projects to firms in upper layers and long-term risky projects like R&D expenditures to firms in lower layers of the pyramid after the new equity investment regulation.

Lastly, we expect that a firm with low centrality in the group expands its R&D investments more in periods subsequent to the regulatory reform than a firm with high centrality does. Firms

with high centrality are connected to many other group affiliates by holding the affiliates' equity shares. Because the investments of central firms (firms with high centrality) in group affiliates' equity shares are crucial for securing the owner's control rights over entire affiliated firms, the central firms may not be able to make flexible changes to existing within-group equity investments. For these reasons, the effect of the regulatory reform on R&D investments will be more significant for firms with less within-group equity investments (low centrality).

Below we hypothesize how the 2001 law regulating firms' equity investments makes changes to R&D expenditures of the firms under the pyramidal ownership structures.

H1: After the 2001 law regulating firms' equity investments, the firm that holds its group affiliates' equity shares higher than 25 percent of the firm's net assets increase its R&D expenditure relatively more than the firm that holds its group affiliates' equity shares lower than 25 percent of the firm's net assets.

H2: The positive effects of the regulatory reforms on firms' R&D expenditures are more significant for 1) firms where controlling owners have lower cash-flow rights, 2) firms located in the lower layer of the pyramid, and 3) firms with low centrality.

4. Data

Our sample consists of 1,601 family firms from the 24 largest Korean chaebols from 1998 to 2009 as designated by the Korean Fair Trade Commission's (KFTC, South Korea's regulatory

authority for economic competition) classification standards.⁷ We use Korean family business group data where detailed information on the set of founding families' ownership as well as R&D investment information is relatively more available. Immediately following the Asian financial crisis, the KFTC required the large Korean chaebols to disclose the controlling families' detailed ownership status information; public access to such information is limited in most jurisdictions but is available in South Korea. This kind of divisional level of founding families' ownership data helps to identify the Korean chaebol's uniquely deep pyramidal ownership structure. However, KFTC ownership data is only available for large Korean chaebols whose asset size is greater than 5 trillion KRW. Due to limitation of ownership data, we cannot compare firms in groups above this size threshold to firms in groups below it. We find that the average cash-flow rights of large Korean chaebols on their affiliates is less than 20%, while the average voting rights is over 50%, indicating that the chaebol family controls the entire group of firms with disproportionately small but key control stakes in pyramidal structure.

In addition, Korean Generally Accepted Accounting Standard (K-GAAP)⁸ classifies R&D expenditures into two different categories: long-term R&D expenses and short-term R&D expenses. Long-term R&D expenditure only includes long-term R&D investments, which are regarded as assets on the balance sheet, while short-term R&D expenditure is regarded as expenses. As such, we use the long-term R&D ratio—the ratio of a firm's long-term research and development (R&D) investment divided by its total assets—as a proxy value for long-term

⁷ Chaebol refers to the large Korean business conglomerates whose controlling entities are founding families, and the 24 family business groups include Samsung, CJ, Shinsaege, Hansol, Hyundai, Hyundai Motors, Hyundai Heavy Industry, Hyundai Department Store, Hyundai Industry Development, KCC, LG (GS), SK, Hanjin, Lotte, Kumho, Hanhwa, Doosan, Dongbu, Hyosung, Daelim, Kolon, Youngpoong, Dongyang, and Taihan Electric. Our sample excludes firms in financial and insurance industry.

⁸ Korea adopted the International Financial Reporting Standard (IFRS) in 2011.

investment. We collect firm's accounting and financial data from Data Guide Pro, a database managed by the leading Korean financial data provider, FnGuide⁹, and retrieve M&A data from Thomson Reuters SDC Platinum. The total amount of assets controlled by these chaebols represents more than 70% of the nominal GDP of the Korean economy at the end of the sample year (901.9 million USD).

[Table 2 around here]

Table 2 summarizes the financial analysis of the sample firms. The analysis is based on data compiled as of the year-end during the sample period. Cash-flow right refers to the sum of direct and indirect equity ownership held by the founding family on a particular group affiliate after excluding treasury stocks and cross shareholdings. The average cash-flow rights for each firm is 19% and the maximal cash-flow rights is 100%, which suggest that those firms are directly owned by the founding family. The average long-term R&D ratio, which refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets is about 1% during the sample period. The financial characteristics of our sample firms are similar to those reported in the previous studies regarding Korean chaebol firms (Bae, Kang, and Kim, 2002; Almeida et al., 2012). Table 2 reports that the sample mean of firm ROA is 6%, and the leverage ratio and payout ratio of 1,601 firm-year observations in the sample are 2.06 and 12%, respectively.

[Table 3 around here]

⁹ The information in this database is roughly equivalent to the information reported in CRSP and Compustat for U.S. firms.

In Table 3, we summarize ownership variables, such as position¹⁰, centrality¹¹, loop¹², cash-flow rights, voting rights, and discrepancy, to look at the ownership pyramidal structures of Korean chaebols. We observe that the maximal position is 5.31, which suggests the deep pyramidal ownership structure of Korean business groups. The public firms have, on average, a position of 1.92 away from the controlling family, while the average position of private firms is 2.16. These average positions imply that public firms are more likely to be the strategically important firms that are directly owned by the controlling family. The maximal centrality of a group is 45.33%, which suggests that a chaebol family's control across all group firms could decrease by that amount after we exclude one specific firm from the group. The average centrality of public firms (3.75) is 6.7 times higher than that of private firms (0.56), suggesting that highly central firms are the public firms in pyramidal business groups. In addition, more than half of the public firms are included in the circular ownership chains, whereas most of the private firms (14%) are excluded from these chains. The controlling families consolidate their indirect control through circular-shareholding mechanisms. These ownership metrics identify that there is typically a deep pyramidal ownership structure in chaebols (Almeida et al., 2012), where owning a small stake in a few key strategic firms enables the owner of the stakes to be the ultimate controller of the entire business group.

¹⁰ The position measures the distance between the family owner and a firm in the group. If the controlling family's shares are all held directly, the value of the company's position is one. In a simple pyramidal structure with two firms, the firm i in the upper layer (chain 1) has a value of one, while the firm j in the lower layer (chain 2) has a value of two. In this case, the position of firm i can be measured by the weighted average of chain 1 and chain 2. The group firms directly owned by the controlling family have a low position value, while indirectly owned affiliates have a high position value. See Almeida et al. (2012) for more details of ownership metrics.

¹¹ Centrality measures the average percentage difference in the control rights of the controlling family across all group member firms other than the firm itself, after excluding a specific firm i from the group. The key strategic member companies that the controlling family uses to set up and control new firms in a business group have a high value of centrality because those firms are connected to many other member firms in the web of ownership. See Almeida et al. (2012) for more details on ownership metrics.

¹² Loop is an indicator that has a value of one if a firm is in a circular ownership chain and zero otherwise.

Consequently, the discrepancy between cash-flow rights and voting rights is as large as 36.34%, indicating the distorted pyramidal ownership structure in Korean Business Groups.

5. Results

5.1. Pyramidal Ownership Structure and R&D Investment

In Table 4, we test to see how the level of the controlling owner's cash-flow rights affects R&D expenditures. Based on the linear model, we regress each firm's *Long-term R&D ratio* on the controlling family's *Cash-flow Right*. We control for size (log of total assets), financial leverage (debt to equity ratio), payout ratio (dividend to net income), ROA, and listed (public or private), and then cluster the standard errors at the firm level. All estimates include industry (2-digit SIC) and year indicator variables since R&D intensity varies according to a firm's industry sector. The estimated effect of the controlling family's cash-flow rights is both economically and statistically significant. Column 1 shows that for one standard deviation increase in the controlling family's cash-flow rights, the R&D ratio decreases by 25.9% ($0.259 = -1.36121 * 0.19$). In Column 1, the level of cash-flow rights significantly decreases the long-term R&D ratio at the 5% statistical significance level. This result implies that the controlling owners pursue private benefits by allocating the short-term investment to firms where they have a higher cash-flow rights while assigning the long-term investment to those where they have a lower cash-flow rights.

[Table 4 around here]

In Columns 2 and 3, we further test business groups with a pyramidal ownership structure using different corporate characteristics — the layer within the pyramid and equity investment in

group affiliates. In Column 2 of Table 4, we regress each firm's *Long-term R&D ratio* on *Layer of Pyramid*, and we find negative point estimates of -1.28278, significant at the 10% level. The coefficient implies that the controlling owners are more likely to allocate the short-term investment to firms where the controlling owners' direct ownership is highly concentrated, whereas they assign the long-term investment to group affiliates that are indirectly owned in the pyramidal ownership structure. In Column 3 of Panel A, we regress each firm's *Long-term R&D ratio* on *Centrality*, and we find negative point estimates of -5.33637, significant at the 5% level. Firms with a high level of equity investment in other group affiliates are the central firms. The controlling owners prefer short-term equity investment in central firms in the pyramidal ownership structure because they can increase their indirect control over the entire business group. The coefficient (-5.33637) implies that the controlling owners are more likely to make short-term investments in central firms, but less likely to assign long-term investment to the firms.

Overall, the results in Table 4 confirm that the different characteristics of the firms in the pyramidal ownership structure, such as a controlling owner's ultimate ownership, position, or centrality in other group affiliates, are negatively correlated with R&D investment decision.

5.2. How Restrictions on Total Equity Investments Affect R&D Investment Decisions

As a next step, we show the results of testing our **H2** to address how an equity investment regulation affects to long-term R&D investment. To examine this issue, in Table 5, we examine the repercussions of the 2001 regulatory reform that suddenly limited equity investments in group affiliates to a maximum of 25 percentage level. Assuming that this exogenous event strictly

restricted short-term equity investments while forcing some long-term investments to be increased within the business group, we use difference-in-differences (DiD) estimation to show causal impact of regulatory reform on long-term R&D expenditures. In Column 1 of Panel A, *Treat* is an indicator that has value of one if a firm has equity investment on group affiliates over 25% of its net assets in 2001, and zero otherwise. Thus, equity investment limitation is only applying to the firms in the treatment group.¹³

[Table 5 around here]

In Columns 1 of Table 5, based on a linear model, we regress each firm's *Long-term R&D ratio* on an interaction term, $Treat \times Post$, while we control for the standalone terms in the same regression. Other empirical specifications are the same as in the previous regression analyses. The *Treat* indicator captures the difference of long-term R&D investment ratio between the firms to which the equity investment regulation was applied or not during the pre-regulatory reform period. The point estimate of coefficient (-1.94394) is negative and statistically significant at 1% level. This result shows that long-term R&D investment of firms where the equity investment ceiling is applied is on average -1.94% lower than those of firms where the equity investment ceiling is not applied. However, the positive coefficient of interaction term (1.83469), which is statistically significant at 5% level, implies that controlling owners increase long-term R&D expenditures relatively more in firms where the equity investment ceiling is applied during the post-regulatory period. The sum of *Treat* indicator and interaction term, $Treat \times Post$, captures the difference of long-term R&D investment ratio between firms in treatment and control group during the post-regulatory reform period. The sum of the point estimates, 0.10925 (0.01436=1.83469-1.94394)

¹³ Among our 1,601 sample firms, treatment group includes 183 firms and control group includes 1,418 firms.

indicates that the difference between firms in the treatment group and control group sharply reduces during the post-regulatory reform period. The Post indicator captures the difference of long-term R&D investment ratio of firms in control group between post-reform period and pre-reform period. The negative point estimate (-1.21906), statistically significant. Overall, these results support our predictions of **H1**. Figure 2 shows an increasing trend of long-term R&D ratio around the equity investment regulatory reform in 2001.

According to **H2**, the upward trend of long-term R&D expenditures is more likely to be found in for 1) firms where controlling owners have lower cash-flow rights, 2) firms located in the lower layer of the pyramid, and 3) firms with low centrality. In Columns 2 to 4 of Panel A, we conduct the conditional analysis. We extend the baseline model from Column 1 of Panel A to test the different characteristics of ownership in the pyramidal structure. The interaction term, $Treat \times Post$, is now decomposed into two, using the following dummy variables: (1) *High Cash-flow Right* versus *Low Cash-flow Right*, (2) *Upper Layer of Pyramid* versus *Lower Layer of Pyramid*, and (3) *High Centrality* versus *Low Centrality*. Using this additional layer of differences, we run a difference-in-differences and decompose (DiD-D) regression.¹⁴

In Column 2 of Panel A, in line with the prediction, the results show that the increasing long-term R&D investment pattern is less likely to be found in firms where controlling owners have higher cash-flow rights. The magnitude of the point estimate (2.35982) of $Treat \times Post \times Lower\ Layer\ of\ Pyramid$, which is significant at the 5% level, is about twice (1.76=2.35982/1.34190) bigger than the opposite case, $Treat \times Post \times High\ Cash-flow\ Right$

¹⁴ We decompose the difference-in-differences (DiD) regression into two parts to isolate the treatment effect. Appendix Table A.1 provides the result of difference-in-difference-in-differences (DiDiD) estimation.

(1.34190). In Column 3 of Panel A, we confirm that the upward trend in long-term R&D expenditure is less likely to be found in firms located in the upper layer of the pyramid. The magnitude of point estimate (1.49956) of *Treat × Post × Lower Layer of Pyramid*, which is significant at the 5% level, is 1.76 times higher than the opposite case, *Treat × Post × Upper Layer of Pyramid* (0.48003). In Column 4 of Panel A, we further confirm that the upward trend in long-term R&D expenditure is less likely to be found in firms with high equity investment in other group affiliates. The point estimate of *Treat × Post × High Centrality* is 0.73046, which is statistically insignificant. However, the point estimate (1.87214) of *Treat × Post × Low Equity Investment* is significant at the 5% level. This result suggests that in response to the regulatory reform, the major central firms' controlling owners do not easily convert the excess equity investment to R&D expenditure and instead prefer short-term equity investment for governance purposes.

The equity investment regulation is relaxed twice in 2005 and 2007. After 2007, the regulation is only applied to large business groups with over 10 trillion KRW in total assets with a ceiling 40% of their net assets. In Panel B of Table 5, we test alternative time period from 1998 to 2004 to avoid the effect of regulatory relaxation after 2005, and the pre and post-regulatory periods are matched as 3 years. In Panel C of Table 5, we test alternative samples by excluding firms that were exempted from the equity investment regulation during sample years. We only include 11 business groups that equity investment ceiling is finally applied after 2007 regulatory relaxation period.¹⁵ In addition, we exclude the business group-year observations that were exempt

¹⁵ The 11 business groups include Samsung, Hyundai Motors, SK, LG, GS, Lotte, Kumho, Hanjin, Hyundai Heavy Industry, Hanwha, and Doosan.

from the regulation by transforming into holding company structure during our sample period.¹⁶ In all Columns of both Panel B and Panel C, similar significant and positive effects are observed, respectively, for the corresponding samples. These results confirm that the findings resolve the potential limitation, which is the relaxation of 2001 regulatory reform and the effect of exemption from holding company transformation.

Overall, the findings in Table 5, confirm that the 2001 regulatory reform, which exogenously decreased the short-term equity investment while inducing long-term investment, resulted in significant long-term R&D expenditure increases. This effect is likely causal.

5.3. Placebo Test

We further conduct a placebo test for verification by investigating control rights, equity investment loss on affiliates, and the circular ownership chain, which are all immune to R&D investment decisions. In Panel A of Table 7, we replace RHS variables and repeat the same regression with Table 4. In Column 1 of Panel A, we investigate control rights instead of cash-flow rights. Provided that the R&D investment decisions for business groups with pyramidal ownership is attributable to the controlling owner's payoff structure, control rights should be irrelevant to the R&D investment decision. Based on the linear model, we regress each firm's *Long-term R&D ratio* on the controlling family's *Voting Right*. The point estimate (-0.71141) of *Voting Right* is statistically insignificant.

¹⁶ Business groups that transformed into holding company structure include CJ (2007), LG (2005), SK (2007), Hanjin (2009), Kumho (2007), Hanhwa (2009), and Doosan (2009).

[Table 6 around here]

In Column 2 of Panel A, we investigate the circular ownership chain instead of the layer of the pyramid. As the controlling families directly own only the strategically important firms in the circular ownership chain, a handful of those firms are located in the pyramid's upper layer. On the other hand, most of the firms are indirectly controlled within the circular ownership chain, and those firms are located in the pyramid's lower layer. We regress each firm's *Long-term R&D ratio* on *Loop*. The point estimate (0.51998) of *Loop* is positive and statistically significant at the 1% level. In Column 3 of Panel A, we investigate equity investment loss on affiliates instead of equity investment in affiliates. The controlling owners prefer short-term equity investments in central firms for governance purposes. However, equity investment loss leads to decreased motivation for additional equity investments. We regress each firm's *Long-term R&D ratio* on *Equity Investment Loss on Affiliates*. The point estimate (-2.82836) of *Equity Investment Loss on Affiliates* is statistically insignificant.

In Panel B of Table 7, we conduct a falsification test to verify constant trends in the post-regulatory period by creating a fake regulatory shock at the end of 2005. In Panel B, we repeat the analyses from Columns Panel A of Table 5 by replacing *Post* dummy to newly created *Post 2005* dummy. The post-period indicates the years from 2006 to 2009, while the pre-regulatory period indicates the years from 2002 to 2005. In Columns 1 to 4 of Panel B, the point estimates of interaction term $Treat \times Post\ 2005$ are all statistically insignificant. Overall, Table 7 shows that the test results identify the underlying economic factors.

5.4. Robustness Test: Alternative Time Period

5.4.1. Succession Period

In this section, we undertake general robustness checks on our key results that are reported in Table 5. One of the important concerns is the implication of the succession, which leads to a sudden reduction in corporate investments during the post-succession period. Tsoutsoura (2015) shows that the presence of higher succession taxes is responsible for a decline in investments after business successions, a slow sales growth, and a depletion of cash reserves. Ellul et al. (2010) show that when entrepreneurs are legally bound to bequeath a minimal stake to non-controlling heirs, investments in family firms can decrease because it reduces the future income that they can pledge to external financiers. In our empirical setting, a maximum of 80% inheritance tax is imposed on the Korean chaebols, which is composed of 50% in inheritance tax rate and 30% in business premium tax rate. This is one of the highest inheritance tax rates among OECD economies. In addition, the 1991 inheritance law reform in Korea stipulates an equal distribution of the property of a deceased person to all the descendants regardless of their birth order, gender, or marital status.

[Table 7 around here]

To identify the cleaner effects of the 2001 regulatory reform, we exclude seven years of each business group's succession period ($t-3 \sim t+3$) to eliminate succession effects on investment during the transition period to the next generation. Using this alternative sample, we show the robustness of our results. In Panel A of Table 7, we rerun the baseline analysis from Table 5. As shown in Panel A of Table 7, the results are similar to those of the baseline regression. These

results suggest that the findings are robust to the potential confounding factor, which is the implications of the succession of family firms.

5.4.2. Asian Financial Crisis

Another important concern is the effect of the Asian financial crisis. Since market responses by individual firms to this macro-economic shock may vary greatly, one may argue that these confounding factors have contributed to the result together. In Panel B of Table 7, we exclude the period of 1998-1999 to distinguish and separate the impact of recession due to the global financial crisis. After excluding the two-year recession period, the sample consists of 1,441 firm-year observations. In Panel B, we rerun the baseline analysis from Table 5. These results suggest that the findings are robust to the potential confounding factor, which is the effect of a recession during a global financial crisis.

6. Conclusion

This paper shows how controlling owners in firms under pyramidal ownership structure make investment decisions. To investigate controlling owners' investment allocation decisions conditional on the exogenous change in investment opportunities, we exploit the passage of the Monopoly Regulation and Fair Trade Act that prohibits equity investments by large business groups with over 5 trillion KRW in net assets. We find that, in the post-regulation periods, the controlling owners tend to increase long-term R&D expenditures relatively more in firms that are

largely subject to the equity investment regulation. Moreover, this result is more significant for firms where the owners have low cash-flow rights, firms located in lower layers of the pyramid, and firms holding less equity shares over other group affiliates.

Our results imply that controlling owners allocate resources for private benefits within their business group. The negative relation between cash-flow rights and the ratio of R&D expenditure suggests that controlling owners want to pursue relatively certain investments in firms where they have high cash-flow rights, while they want to share high risks with other owners in firms where they have low cash-flow rights. In addition, increase in R&D expenditure during the post-regulation periods suggests that the passage of the regulatory reform leads to investment reallocation. Specifically, results about pyramidal ownership structures suggest that controlling owners who should reallocate the excess equity investment due to regulatory reform try to maximize private benefits by less likely increasing long-term investments in firms where direct ownership is heavily concentrated. Finally, results about centrality suggest that controlling owners tend to be reluctant to increase long-term investment in central firms, which are connected with many other group affiliates by equity investment, due to control rights.

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Figure 1: Time Trend of Total Equity Investment

Figure shows the marginal effects of treatment group on total equity investment ratio with 95% confidence interval during sample years. The middle line represents the average difference of total equity investment between firms in treatment groups and control groups. The upper line and lower line represent the upper and lower limit of confidence interval. This figure shows that the increasing trend of total equity investment ratio suddenly drops around the equity investment regulatory reform in 2001. According to the amendment of equity method securities in 1999, total equity investment information is publicly available from 2000.

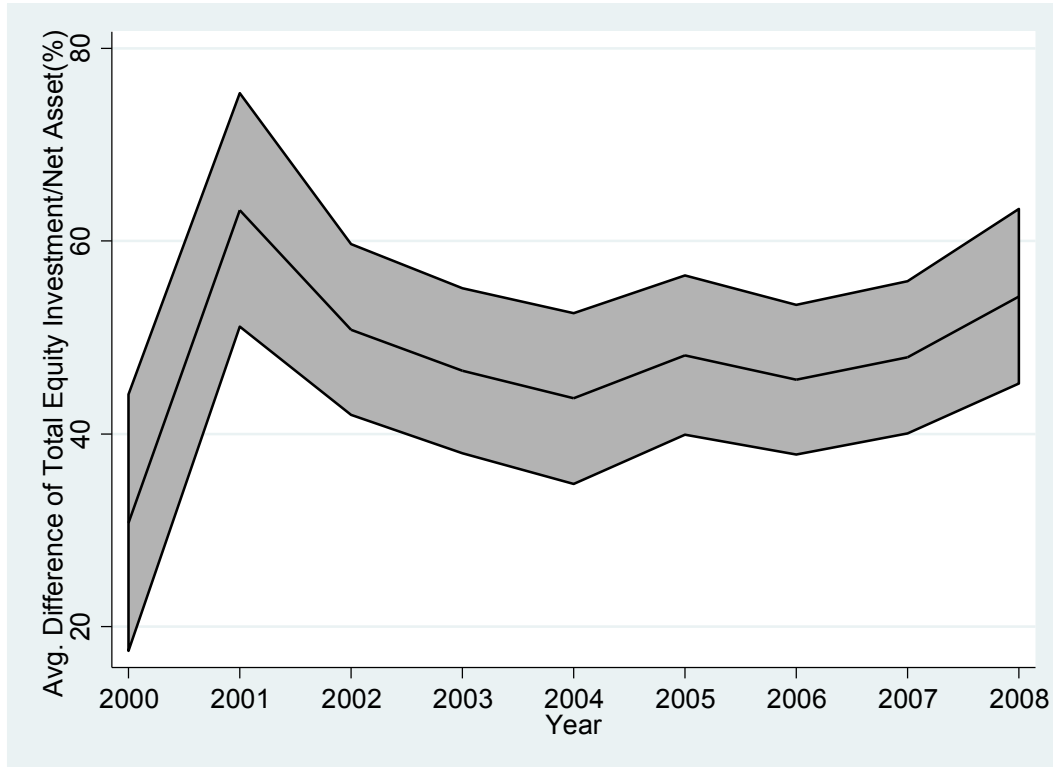


Figure 2: Time Trend of Long-term R&D Investment

Figure shows the marginal effects of treatment group on long-term R&D ratio with 95% confidence interval during sample years. The middle line represents the average difference of long-term R&D ratio between firms in treatment groups and control groups. The upper line and lower line represent the upper and lower limit of confidence interval. This figure shows increasing trend of long-term R&D ratio around the equity investment regulatory reform in 2001.

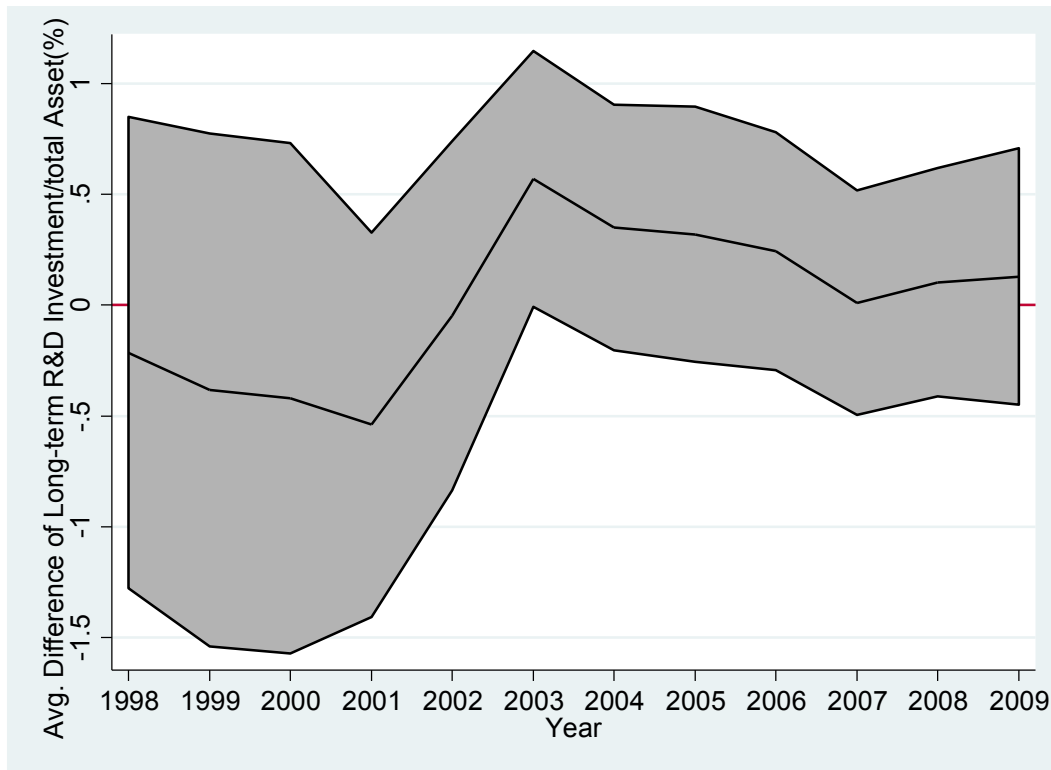


Table 1: Chronicle of Regulation on Total Equity Investment in Korea

Korea first introduced the so-called equity investment regulations in 1987 as part of the first amendment of the Monopoly Regulation and Fair Trade Act (MRFTA). Under the new regulation, the total equity investments in other member companies within the same business group by any subsidiary of a chaebol were not to exceed the ceiling set by the MRFTA, which was 40% of its net assets. The ceiling was revised to 25% of a firm's net asset in 1993. However, the overall drive for tougher regulations on equity investment by chaebols weakened in the wake of the 1997-1998 Asian financial crisis. Amidst the growing concern over counter-discrimination against domestic companies facing the mounting threat of hostile M&As by foreign investors, the equity investments ceiling was abolished altogether. Then in December 2000 when the Korean government announced that the country successfully overcame the crisis, it re-introduced the ceiling measure as of April 2001 that prohibits equity investments by a firm belonging to the 30 largest business groups from exceeding 25% of its net assets. The IMF officially declared the end of its austerity program for Korea in August 2001, and the Korean government relaunched the ceiling on the total equity investments by large business groups with total assets of over 5 trillion Korean Won as of January 2002. With this, the firms subject to this new ceiling were not allowed to invest in equity shares of other domestic firms in excess of 25% of their net assets. After regulation is relaxed in 2005 and 2007, the equity investments ceiling was completely eliminated in 2009 as part of the country's efforts to promote local companies' global competitiveness, and corporate disclosure obligation was reinforced instead.

Enforcement Date	Key Content	Remarks
Apr. 1987	The ceiling on total equity investment was introduced	The total investments should not exceed 40% of net assets
Mar. 1995	The ceiling was revised	The total investments should not exceed 25% of net assets
Feb. 1998	The ceiling system was abolished	
Apr. 2001	The ceiling system was reinstated	Target: Top 30 chaebols; the ceiling: 25%
Jan. 2002	The ceiling system was implemented	Target: Large business groups with over 5 trillion KRW in total assets; the ceiling: 25% of net assets
April 2005	The scope of regulation was relaxed	Target: Large business groups with over 6 trillion KRW in total assets; the ceiling: 25% of net assets
July 2007	The scope and ceiling of regulation was relaxed	Target: Large business groups with over 10 trillion KRW in total assets; the ceiling: 40% of net assets
Mar. 2009	The ceiling system was abolished	
Jul. 2009	Corporate disclosure was reinforced	Tougher mandatory disclosure replaced the ceiling on the total equity investment.

Table 2: Summary Statistics

The sample consists of 1,601 firm-year observations of Korea's 24 largest business groups, as designated by the Korean Fair Trade Commission (KFTC), from 1998 to 2009. Analysis is based on data compiled as of the year end of the corresponding year. Cash-flow right refers to the sum of direct and indirect equity ownership held by the founding family on a particular group affiliate after excluding treasury stocks and cross shareholdings. Long-term R&D ratio refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. Log of total assets refers to the logarithm of total assets of each firm in millions of KRW. Log of sales refers to the logarithm of total sales of each firm in millions of KRW. Leverage refers to the debt ratio, calculated by total debt divided by total equity. ROA refers to the ratio of earnings before interest and tax (EBIT) divided by total assets. Payout ratio refers to the ratio of a firm's net dividends paid divided by its net income. Listed refers to an indicator variable that equals one if a firm is listed on the KOSPI or KOSDAQ exchange, and zero otherwise.

	N	Mean	Std. Dev	Min	Median	Max
Cash-flow Right	1,601	0.19	0.19	0	0.13	1
Long-term R&D/Total Assets	1,601	0.01	0.04	0	0	0.38
Log of Total Assets	1,601	12.99	2.19	7.77	12.87	17.88
Log of Sales	1,572	12.84	2.23	5.11	12.88	17.52
ROA	1,601	0.06	0.08	-0.60	0.06	0.40
Leverage	1,601	2.06	4.06	0	1.48	25.98
Payout Ratio	1,601	0.12	0.38	0	0	1.98
Listed	1,601	0.59	0.49	0	1	1

Table 3: Pyramidal Ownership Structure

The sample consists of 1,601 firm-year observations of Korea's 24 largest business groups, as designated by the Korean Fair Trade Commission (KFTC), from 1998 to 2009. Position refers to the distance between the family and a firm in a business group; a value of one indicates that the firm is directly controlled by the founding family. Centrality refers to the average percentage decrease in control rights across all group firms other than the firm itself, after we exclude a specific firm from the group. Loop refers to an indicator that has a value of one if a firm is in a circular ownership chain, and is zero otherwise. Cash-flow right refers to the sum of direct and indirect equity ownership held by the founding family on a particular group affiliate after excluding treasury stocks and cross shareholdings. Voting right refers to the ratio of the maximum number of stocks that the founding family can use for voting divided by the total number of stocks outstanding. Discrepancy refers to the difference between cash-flow right and voting right.

	N	Mean	Std. Dev	Min	Median	Max
Position						
All Firms	1601	2.02	0.76	1	2.00	5.31
Public	942	1.92	0.79	1	1.98	5.31
Private	659	2.16	0.71	1	2.03	5.00
Centrality (%)						
All Firms	1601	2.44	5.65	0	0.00	45.33
Public	942	3.75	6.84	0	0.70	45.33
Private	659	0.56	2.17	0	0	18.69
Loop						
All Firms	1601	0.36	0.48	0	0	1
Public	942	0.51	0.50	0	1	1
Private	659	0.14	0.35	0	0	1
Cash-flow Right (%)						
All Firms	1601	19.08	19.39	0	13.36	100
Public	942	15.92	17.01	0	11.00	100
Private	659	23.59	21.58	0	18.12	100
Voting Right (%)						
All Firms	1601	55.42	30.14	0	50.00	100
Public	942	41.19	23.30	0	35.31	100
Private	659	75.76	27.00	0	83.34	100
Discrepancy (%)						
All Firms	1601	36.34	27.83	0	30.53	98
Public	942	25.27	20.75	0	20.51	97
Private	659	52.17	29.00	0	54.41	98

Table 4: Pyramidal Ownership Structure and R&D Investment

The sample consists of 1,601 firm-year observations of Korea's 24 largest business groups, as designated by the Korean Fair Trade Commission (KFTC), from 1998 to 2009. Each column reports the coefficients from an OLS regression. Standard errors are clustered at the firm level and reported in parentheses under the coefficient estimates. The dependent variable is long-term R&D ratio that refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. Cash-flow right refers to the sum of direct and indirect equity ownership held by the founding family on a particular group affiliate after excluding treasury stocks and cross shareholdings. Layer of pyramid refers to the inverse value of position. A firm directly owned by the founding family in the top layer of the pyramid has a value of one, and the firms located in the bottom of the pyramid have a value close to zero. Layer of pyramid ranges from (0, 1]. Centrality refers to the average percentage difference in the control rights of the controlling family across all group member firms other than the firm itself, after excluding a specific firm *i* from the group. Controls include the log of total assets (in millions of KRW), the leverage ratio, payout ratio, ROA, and listed. All estimates include industry (SIC-2 digit) and year indicator variables. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variables	Dependent Variable: Long-term R&D Investment/Total Assets (%)		
	(1)	(2)	(3)
Cash-flow Right	-1.36121** [0.553]		
Layer of Pyramid (1/positoin)		-1.28278* [0.770]	
Centrality			-5.33673** [2.268]
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Control	Yes	Yes	Yes
Observations	1,601	1,601	1,601
R-squared	0.111	0.112	0.112

**Table 5: Changes in Monopoly Regulation and Fair Trade Act:
Restrictions on Total Equity Investment to Group Affiliates**

In Panel A, the sample consists of 1,601 firm-year observations of Korea's 24 largest business groups, as designated by the Korean Fair Trade Commission (KFTC), from 1998 to 2009. In Panel B, we test alternative time period from 1999 to 2004 to avoid the effect of regulatory relaxation after 2005 and the pre and post-regulatory periods are matched as 3 years. In Panel C, we test alternative samples by excluding firms that were exempted from the equity investment regulation during sample years. We only include 11 business groups that equity investment ceiling is finally applied after 2007 regulatory relaxation period. In addition, we exclude the business group-year observations that were exempt from the regulation by transforming into holding company structure. Each column reports the coefficients from an OLS regression. Standard errors are clustered at the firm level and reported in parentheses under the coefficient estimates. The dependent variable is long-term R&D ratio that refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. Treat is an indicator that has value of one if a firm has equity investment on group affiliates over 25% its net assets in 2001, and zero otherwise. Post refers to a year dummy that has a value of one after restrictions on total equity investment to group affiliates by 25%, i.e., from 2002 to 2009, and has a value of zero otherwise. High cash-flow right refers to an indicator that has a value of one if controlling owner's cash-flow rights of a firm is greater than the median of all chaebol firms, and zero otherwise. Low cash-flow right refers to an indicator that has a value of one if controlling owner's cash-flow rights of a firm is lower than or equal to the median of all chaebol firms, and zero otherwise. Upper layer of pyramid refers to an indicator that has a value of one if a firm's position is smaller than the median of all chaebol firms, and zero otherwise. Lower layer of pyramid refers to an indicator that has a value of one if a firm's position is greater than or equal to the median of all chaebol firms, and zero otherwise. High centrality refers to an indicator that has a value of one if a firm's centrality is greater than the median of all chaebol firms, and zero otherwise. Lower centrality refers to an indicator that has a value of one if a firm's centrality is smaller than or equal to the median of all chaebol firms, and zero otherwise. Controls include the log of total assets (in millions of KRW), the leverage ratio, payout ratio, ROA, and listed. All estimates include industry (SIC-2 digit) and year indicator variables. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Panel A: Full Sample		Dependent Variable: Long-term R&D Investment/Total Assets (%)			
Variables	(1)	(2)	(3)	(4)	
Treat × Post	1.83469**				
	[0.818]				
Treat × Post × High Cash-flow Right		1.34190**			
		[0.597]			
Treat × Post × Low Cash-flow Right		2.35982*			
		[1.216]			
Treat × Post × Upper Layer of Pyramid			1.49956**		
			[0.701]		
Treat × Post × Lower Layer of Pyramid			2.63359**		
			[1.235]		
Treat × Post × High Centrality				0.73064	
				[0.560]	
Treat × Post × Low Centrality				1.87214**	
				[0.837]	
Treat	-1.94394***	-1.93460***	-1.94437***	-1.94739***	
	[0.584]	[0.582]	[0.584]	[0.584]	
Post	-1.21906	-1.23355*	-1.21410	-1.19981	
	[0.743]	[0.744]	[0.744]	[0.742]	
Industry FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Control	Yes	Yes	Yes	Yes	
Observations	1,601	1,601	1,601	1,601	
R-squared	0.110	0.112	0.112	0.110	

Panel B: Sub Sample (1999~2004)		Dependent Variable: Long-term R&D Investment/Total Assets (%)			
Variables	(1)	(2)	(3)	(4)	
Treat × Post	2.24805**				
	[0.970]				
Treat × Post × High Cash-flow Right		1.74109**			
		[0.786]			
Treat × Post × Low Cash-flow Right		2.75380*			
		[1.409]			
Treat × Post × Upper Layer of Pyramid			1.46065**		
			[0.670]		
Treat × Post × Lower Layer of Pyramid			3.42195**		
			[1.636]		
Treat × Post × High Centrality				0.61428	
				[0.657]	
Treat × Post × Low Centrality				2.12142**	
				[0.918]	
Treat	-2.37895***	-2.36178***	-2.08627***	-2.09097***	
	[0.740]	[0.735]	[0.620]	[0.622]	
Post	-0.92307*	-0.91744*	-1.12051	-1.10089	
	[0.525]	[0.524]	[0.743]	[0.741]	
Industry FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Control	Yes	Yes	Yes	Yes	
Observations	729	729	1,284	1,284	
R-squared	0.125	0.126	0.120	0.116	

Panel C: Sub Sample (11 Groups)		Dependent Variable: Long-term R&D Investment/Total Assets (%)			
Variables	(1)	(2)	(3)	(4)	
Treat × Post	1.56927**				
	[0.741]				
Treat × Post × High Cash-flow Right		1.48259*			
		[0.830]			
Treat × Post × Low Cash-flow Right		1.62669**			
		[0.818]			
Treat × Post × Upper Layer of Pyramid			0.97582		
			[0.621]		
Treat × Post × Lower Layer of Pyramid			2.24564**		
			[0.986]		
Treat × Post × High Centrality				0.78773	
				[0.781]	
Treat × Post × Low Centrality				1.60132**	
				[0.755]	
Treat	-2.08548***	-2.08545***	-2.11295***	-2.08733***	
	[0.723]	[0.724]	[0.730]	[0.724]	
Post	-0.64203	-0.64545	-0.63699	-0.64037	
	[0.845]	[0.845]	[0.847]	[0.846]	
Industry FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Control	Yes	Yes	Yes	Yes	
Observations	981	981	981	981	
R-squared	0.144	0.144	0.147	0.144	

Table 6: Placebo Test

In Panel A, we conduct a placebo test by replacing cash-flow right, layer of pyramid, and equity investment on affiliates to control right, circular ownership chain, and equity investment loss on affiliates, respectively. In Panel B, we conduct a placebo test to verify constant trends in the post-regulatory period. We replace post-regulatory period to years after 2005 while pre-regulatory period indicates years from 2002 to 2005. Each column of Panel A and Panel B report the coefficients from an OLS regression with heteroscedasticity-robust standard errors. Standard errors are clustered at the firm level and reported in parentheses under the coefficient estimates. The dependent variable is long-term R&D ratio that refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. Voting right refers to the ratio of the maximum number of stocks that the founding family can use for voting divided by the total number of stocks outstanding. Loop refers to an indicator that has a value of one if a firm is in a circular ownership chain, and is zero otherwise. Equity invest loss on affiliate refers to the total amount of equity investment in trillion KRW to other affiliates in a business group in a corresponding year. Treat is an indicator that has value of one if a firm has equity investment on group affiliates over 25% of its net assets in 2001, and zero otherwise. Post 2005 refers to a dummy year that has a value of one from 2006 to 2009, and has a value of zero otherwise. Controls include the log of total assets (in millions of KRW), the leverage ratio, payout ratio, ROA, and listed. All estimates include industry (SIC-2 digit) and year indicator variables. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Panel A: Pyramid	Dependent Variable: Long-term R&D Investment/Total Assets (%)		
	(1)	(2)	(3)
Voting Right	-0.71141 [0.609]		
Loop		0.51998 [0.418]	
Equity Investment Loss on Affiliates			-2.82836 [2.078]
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Control	Yes	Yes	Yes
Observations	1,601	1,601	1,601
R-squared	0.109	0.110	0.108

Panel B: Regulatory Reform		Dependent Variable: Long-term R&D Investment/Total Assets (%)			
Variables	(1)	(2)	(3)	(4)	
Treat × Post 2005	-0.71141 [0.609]				
Treat × Post 2005 × High Cash-flow Right		0.51998 [0.418]			
Treat × Post 2005 × Low Cash-flow Right		-2.82836 [2.078]			
Treat × Post 2005 × Upper Layer of Pyramid			-0.21427 [0.265]		
Treat × Post 2005 × Lower Layer of Pyramid			-0.50219 [0.710]		
Treat × Post 2005 × High Centrality				-0.76683 [0.817]	
Treat × Post 2005 × Low Centrality				-0.27838 [0.273]	
Treat	0.19018 [0.678]	0.19353 [0.682]	0.19082 [0.680]	0.18984 [0.678]	
Post 2005	-0.53783** [0.264]	-0.54078** [0.265]	-0.53811** [0.264]	-0.53043** [0.261]	
Industry FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Control	Yes	Yes	Yes	Yes	
Observations	1,194	1,194	1,194	1,194	
R-squared	0.530	0.531	0.530	0.530	

Table 7: Robustness Test: Alternative Time Period

In Panel A, we exclude the succession period of each business group to avoid succession effects on investment during the transition period to the next generation. In Panel B, we exclude the period of 1998-1999 to avoid the effects of the recession during the Asian financial crisis. Each column reports the coefficients from an OLS regression. Standard errors are clustered at the firm level and reported in parentheses under the coefficient estimates. The dependent variable is long-term R&D ratio that refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. Treat is an indicator that has value of one if a firm has equity investment on group affiliates over 25% of its net assets in 2001, and zero otherwise. Post refers to a year dummy that has a value of one after restrictions on total equity investment to group affiliates by 25%, i.e., from 2002 to 2009, and has a value of zero otherwise. High cash-flow right refers to an indicator that has a value of one if controlling owner's cash-flow rights of a firm is greater than the median of all chaebol firms, and zero otherwise. Low cash-flow right refers to an indicator that has a value of one if controlling owner's cash-flow rights of a firm is lower than or equal to the median of all chaebol firms, and zero otherwise. Upper layer of pyramid refers to an indicator that has a value of one if a firm's position is smaller than the median of all chaebol firms, and zero otherwise. Lower layer of pyramid refers to an indicator that has a value of one if a firm's position is greater than or equal to the median of all chaebol firms, and zero otherwise. High centrality refers to an indicator that has a value of one if a firm's centrality is greater than the median of all chaebol firms, and zero otherwise. Lower centrality refers to an indicator that has a value of one if a firm's centrality is smaller than or equal to the median of all chaebol firms, and zero otherwise. Controls include the log of total assets (in millions of KRW), the leverage ratio, payout ratio, ROA, and listed. All estimates include industry (SIC-2 digit) and year indicator variables. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Panel A: Exclude Succession Period		Dependent Variable: Long-term R&D Investment/Total Assets (%)			
Variables	(1)	(2)	(3)	(4)	
Treat × Post	1.01229*				
	[0.556]				
Treat × Post × High Cash-flow Right		0.78967			
		[0.705]			
Treat × Post × Low Cash-flow Right		1.26273*			
		[0.734]			
Treat × Post × Upper Layer of Pyramid			0.35995		
			[0.719]		
Treat × Post × Lower Layer of Pyramid			2.56011**		
			[0.989]		
Treat × Post × High Centrality				1.02528	
				[0.690]	
Treat × Post × Low Centrality				1.01180*	
				[0.559]	
Treat	-1.83131**	-1.79861**	-1.92643**	-1.83146**	
	[0.718]	[0.720]	[0.795]	[0.720]	
Post	-1.29861	-1.29895	-1.24943	-1.29876	
	[0.857]	[0.858]	[0.848]	[0.859]	
Industry FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Control	Yes	Yes	Yes	Yes	
Observations	1,474	1,474	1,474	1,474	
R-squared	0.492	0.492	0.497	0.492	

Panel B: Exclude Asian Financial Crisis Period		Dependent Variable: Long-term R&D Investment/Total Assets (%)			
Variables	(1)	(2)	(3)	(4)	
Treat × Post	1.24862** [0.538]				
Treat × Post × High Cash-flow Right		0.37516 [0.697]			
Treat × Post × Low Cash-flow Right		1.89162** [0.728]			
Treat × Post × Upper Layer of Pyramid			0.58902 [0.625]		
Treat × Post × Lower Layer of Pyramid			2.87360*** [0.949]		
Treat × Post × High Centrality				0.91458 [0.580]	
Treat × Post × Low Centrality				1.26177** [0.547]	
Treat	-1.51342** [0.626]	-1.31601** [0.635]	-1.64717** [0.674]	-1.51226** [0.628]	
Post	-1.41606*** [0.529]	-1.42902*** [0.530]	-1.36997*** [0.521]	-1.41133*** [0.528]	
Industry FE	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	
Control	Yes	Yes	Yes	Yes	
Observations	1,441	1,441	1,441	1,441	
R-squared	0.522	0.525	0.528	0.522	

Appendix A: Variable Definitions

Ownership Structure Variables

Cash-flow right – the sum of direct and indirect equity ownership held by the founding family on a particular group affiliate after excluding treasury stocks and cross shareholdings.

High cash-flow right – an indicator that has a value of one if controlling owner’s cash-flow rights of a firm is greater than the median of all chaebol firms, and zero otherwise.

Low cash-flow right – an indicator that has a value of one if controlling owner’s cash-flow rights of a firm is lower than or equal to the median of all chaebol firms, and zero otherwise.

Position – the distance between the controlling family and a firm in a group. A value of one indicates that the firm is directly controlled by the founding family. In a simple pyramid structure with two firms, the firm *i* in the upper layer (chain 1) has a position value of one, while the firm *j* in the lower layer (chain 2) has a position value of two. In this case, the position of firm *i* can be measured by the weighted average of chain 1 and chain 2, whose importance is weighted by the cash-flow the family receives—the direct cash-flow from firm *i* and the indirect cash-flow from firm *j* through chain 2. The group firms that are directly owned by the controlling family have a low position value, while indirectly owned affiliates have a high position value. See Almeida et al. (2012) for more details on ownership metrics.

Layer of pyramid – the inverse value of position. A firm directly owned by the founding family in the top layer of the pyramid has a value of one, and the firms located in the bottom of the pyramid have a value closer to zero. Layer of pyramid ranges from (0, 1].

Upper layer of pyramid – an indicator that has a value of one if a firm’s position is smaller than the median of all chaebol firms, and zero otherwise.

Lower layer of pyramid – an indicator that has a value of one if a firm’s position is greater than or equal to the median of all chaebol firms, and zero otherwise.

Centrality – the average percentage difference in the control rights of the controlling family across all group member firms other than the firm itself, after excluding a specific firm *i* from the group. The key strategic member companies that the controlling family uses to set up and control new firms in a business group have a high value of centrality because those firms are connected to many other member firms in the web of ownership. See Almeida et al. (2012) for more details on ownership metrics.

High Centrality – an indicator that has a value of one if a firm’s centrality is greater than the median of all chaebol firms, and zero otherwise.

Lower Centrality – an indicator that has a value of one if a firm’s centrality is smaller than or equal to the median of all chaebol firms, and zero otherwise.

Loop – an indicator that has a value of one if a firm is in a circular ownership chain, and zero otherwise.

Voting right – the ratio of the maximum number of stocks that the founding family can use for voting divided by the total number of stocks outstanding. This includes direct and indirect voting shares held by the founding family, subsidiaries, senior managers in special relationships, and non-profit organizations.

Discrepancy – the difference between cash-flow right and voting right.

Firm Characteristics Variables

Treat – an indicator that has value of one if a firm has equity investment on group affiliates over 25% of its net assets in 2001, and zero otherwise. Thus, equity investment ceiling is only applying to treatment group.

Control – an indicator that has value of one if a firm has no equity investment on group affiliates over 25% of their net assets in 2001, and zero otherwise.

Long-term R&D ratio – the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. Long-term R&D expenses only include long-term R&D investments, which are regarded as assets on the balance sheet, and exclude short-term R&D investments, which are regarded as expenses on the balance sheet.

Equity Invest loss on Affiliate – the total amount of equity investment loss in trillion KRW to other affiliates in a business group in a corresponding year.

Log of total assets – the logarithm of total assets of each firm in millions of KRW.

Log of sales – the logarithm of total sales of each firm in millions of KRW.

Leverage – the debt ratio, calculated by total debt divided by total equity.

ROA – the ratio of earnings before interest and tax (EBIT) divided by total assets.

Payout ratio – the ratio of a firm's net dividends paid divided by its net income.

Listed – an indicator variable that equals one if a firm is listed on the KOSPI or KOSDAQ exchange, and zero otherwise.

Appendix B: Ownership structure and investment decision

1. Increasing and linear utility case

We handle the investment allocation problems by employing numerical examples. For simplicity, we start with a linear utility function for a risk-neutral owner and then move on to a concave utility function for a risk-averse owner. We assume that the firm invests \$1 into short-term investment and gets \$M ($M > 1$). The firm invests \$1 to long-term project and gets \$0 or \$W with half probability each ($W > M > 1$) in the future. First, we employ an increasing and linear utility function, i.e., $U(X) = bX$ where X is the cash flow from the project and $b > 0$. We also assume additively time separable utility. Next, there are two firms—one is under the owner's 100 percent cash-flow rights (big-share-firm) and the other one is under the owner's $k \times 100$ percent ($0 < k < 1$) cash-flow rights (small-share-firm). The same amount of investments should be allocated to the two firms because of capacity constraint of each firm. In other words, it is not possible for only one firm to invest in all projects (and the other does nothing). So, short- and long-term projects should be allocated to two firms. If the big-share-firm selects short-term projects and the small-share-firm chooses long-term investment, the owner's expected utility is described as Equation (1) below. On the other hand, if the big-share-firm selects long-term projects and the small-share-firm chooses short-term investment, the owner's expected utility can be calculated as in Equation (2).

$$b \times M + k \times (0.5 \times b \times 0 + 0.5 \times b \times W) = b \times (M + 0.5kW) \quad (1)$$

$$(0.5 \times b \times 0 + 0.5 \times b \times W) + k \times b \times M = b \times (0.5 \times W + k \times M) \quad (2)$$

If Equation (1) is bigger than (2), the owner will allocate the short-term project to the big-share-firm and long-term investment to the small-share-firm. As seen in Equation (3) below, if

$M > 0.5W$, Equation (1) is bigger than (2). In other words, if the expected return of short-term investment is higher than that of long-term investment, the owner allocates all short-term projects to the big-share-firm. Otherwise, the owner will select the other allocation option. In this case, only the relative sizes of M and W (or expected payoffs) matter in investment allocation decisions because we use a linear utility function.

$$\begin{aligned} (M + 0.5kW) - (0.5W + kM) &= (1 - k)M - 0.5(1 - k)W \\ &= (1 - k)(M - 0.5W) > 0 \end{aligned} \quad (3)$$

2. Increasing but concave utility case

As the next step, we move on to an increasing but concave utility function. We assume a risk-averse owner. Compared to the previous case, only the utility function changes. Let's assume V is the utility function. Because it is increasing and concave, we see $V'(X) > 0$ and $V''(X) < 0$. If the big-share-firm selects the short-term project and the small-share-firm chooses the long-term investment, the owner's expected utility will be $V(M) + [0.5 \times V(k \cdot 0) + 0.5 \times V(k \cdot W)]$. If the big-share-firm selects the long-term project and the small-share-firm chooses the short-term investment, the owner's expected utility becomes $[0.5 \times V(0) + 0.5 \times V(W)] + V(k \cdot M)$. To simplify, let's assume $V(0) = 0$. To compare which one is optimal to the owner, we deduct the second one from the first one. Then, we can get the following:

$$\begin{aligned} V(M) + [0.5 \times V(k \cdot 0) + 0.5 \times V(k \cdot W)] - [0.5 \times V(0) + 0.5 \times \\ V(W)] - V(k \cdot M) &= [V(M) - 0.5 \cdot V(W)] - [V(k \cdot M) - 0.5 \cdot V(k \cdot W)]. \end{aligned} \quad (4)$$

The above equation will be positive if M is not very small relative to W (e.g. $M > Z$ where $V(Z) = 0.5 \cdot V(W)$) and V is concave function. In other words, given an adequate rate of return from the short-term investment, it is always optimal for the owner to allocate short-term projects

to the firm under the owner's high cash-flow rights, and long-term projects to the firm with low cash-flow rights if the owner is risk-averse.

3. CARA utility function

Now, we take a specific form of the concave utility function. We employ a CARA power utility function, which is $V(X) = \frac{X^r}{r}$, where $(1 - r)$ means relative risk aversion and $0 < r < 1$. Then, Equation (4) above is transformed like the Equation (5) below:

$$\left[\frac{M^r}{r} - 0.5 \cdot \frac{W^r}{r}\right] - \left[\frac{(k \cdot M)^r}{r} - 0.5 \cdot \frac{(k \cdot W)^r}{r}\right] = \left(\frac{M^r}{r} - 0.5 \cdot \frac{W^r}{r}\right) \cdot (1 - k^r). \quad (5)$$

In this equation, $1 - k^r$ is always positive because $0 < k < 1$. Thus, if M is not very small relative to W to satisfy $\frac{M^r}{r} > 0.5 \cdot \frac{W^r}{r}$, then Equation (5) is always positive. This means it is always optimal for the big-share-firm to select short-term investments and for the small-share-firm to select long-term projects. Also, given M and W , as the relative risk aversion increases (r decreases), Equation (5) is more likely to be positive. Let's set $M = hW$ ($0 < h < 1$), which means M is some proportion of W and both M and W are fixed. Then, $\left(\frac{M^r}{r} - 0.5 \cdot \frac{W^r}{r}\right) \cdot (1 - k^r)$ becomes $(h^r - 0.5) \cdot \frac{W^r}{r} \cdot (1 - k^r)$. Here, $\frac{W^r}{r}$ and $(1 - k^r)$ are always positive, and $(h^r - 0.5)$ increases as r decreases because $0 < h < 1$. So, as the risk aversion increases (r decreases), $(h^r - 0.5) \cdot \frac{W^r}{r} \cdot (1 - k^r)$ becomes more likely to be positive even for smaller h or M . This means that even with a small rate of return from short-term investments (M), it becomes optimal for the big-share-firm to select short-term investments and for the small-share-firm to choose long-term investments when the owner is more risk-averse.

4. Consider intra-firm allocation

Next, we relax our assumptions. Both firms can invest in both projects. In other words, each firm can invest in part of the short- or long-term projects together. The total amount of investment to each of the short- and long-term projects are still \$1. Among \$1 for short-term investment, α is invested by the big-share-firm and the other $(1-\alpha)$ is invested by the small-share-firm. Because total investment of each firm should be identical due to capacity limitation of each firm, the long-term investment allocation should be opposite to those of the short-term investments. So, for \$1 of the long-term projects, $(1-\alpha)$ is invested by the big-share-firm, and the other α is invested by the small-share-firm. Then, the owner's total expected utility will be like Equation (6).

$$V(\alpha M + (1 - \alpha)kM) + 0.5 \times V((1 - \alpha)W + \alpha kW) \quad (6)$$

Now, let's take the derivative of Equation (6) with regard to α . Then, we can obtain the following equation:

$$\begin{aligned} & V'(\alpha M + (1 - \alpha)kM) \cdot (M - kM) + 0.5 \cdot V'((1 - \alpha)W + \alpha kW) \cdot (kW - W) = \\ & [M \cdot V'(\alpha M + (1 - \alpha)kM) - 0.5 \cdot W \cdot V'((1 - \alpha)W + \alpha kW)](1 - k). \end{aligned} \quad (7)$$

If the owner starts with equal allocation between two firms for both projects ($\alpha = 0.5$), the Equation (7) becomes $[M \cdot V'(0.5M + 0.5kM) - 0.5 \cdot W \cdot V'(0.5W + 0.5kW)](1 - k)$. Because $0.5M + 0.5kM$ is smaller than $0.5W + 0.5kW$ ($M < W$) and V is an increasing concave function, $V'(0.5M + 0.5kM) > V'(0.5W + 0.5kW)$. Thus, given adequate payoffs from short-term investments (M) compared to that from half of expected long-term investments ($0.5W$), the owner can increase their expected utility by allocating more short-term investment into the big-share-firm and more long-term investment to the small-share-firm. If the owner's risk-aversion increases, the

utility function will be more concave. This means $V'(0.5M + 0.5kM)$ will be much bigger than $V'(0.5W + 0.5kW)$. That means even if the payoffs from short-term investments (M) is smaller, it will be still optimal for the owner to select the same investment strategy.

5. Other considerations

Time discount: We can apply time discount rates to future cash flows. If we employ the discount rate, the payoffs from long-term investments will be discounted more than those from short-term investments. To simplify, let's assume that no discount rate is applied to short-term payoffs but δ ($0 < \delta < 1$) is applied to long-term payoffs as discount rate. Equation (4) is transformed to

$$[V(M) - \delta \cdot 0.5 \cdot V(W)] - [V(k \cdot M) - \delta \cdot 0.5 \cdot V(k \cdot W)] = [V(M) - V(k \cdot M)] - \delta[0.5 \cdot V(W) - 0.5 \cdot V(k \cdot W)]. \quad (8)$$

As δ decreases from one to zero, Equation (8) will increase even more. Thus, the conclusion regarding the optimal investment decision by the owner will not change and becomes stronger.

Reservation level: There may be a reservation level of the owner's utility in each period. If there is a reservation level, the utility of each period should not be lower than the level. Then, some investment allocations may not be feasible.

Appendix Table A.1: Changes in Monopoly Regulation and Fair Trade Act:

Difference-in-Difference-in-Differences Approach

The sample consists of 1,601 firm-year observations of Korea's 24 largest business groups, as designated by the Korean Fair Trade Commission (KFTC), from 1998 to 2009. Each column reports the coefficients from an OLS regression. Standard errors are clustered at the firm level and reported in parentheses under the coefficient estimates. The dependent variable is long-term R&D ratio that refers to the ratio of a firm's long-term research and development (R&D) investment divided by its total assets. Treat is an indicator that has value of one if a firm has equity investment on group affiliates over 25% its net assets in 2001, and zero otherwise. Post refers to a year dummy that has a value of one after restrictions on total equity investment to group affiliates by 25%, i.e., from 2002 to 2009, and has a value of zero otherwise. Pyramid Variable refers to Low cash-flow right in Column 1, Lower layer of pyramid in Column 2, and Low Centrality in Column 3, respectively. Low cash-flow right refers to an indicator that has a value of one if controlling owner's cash-flow rights of a firm is lower than or equal to the median of all chaebol firms, and zero otherwise. Lower layer of pyramid refers to an indicator that has a value of one if a firm's position is greater than or equal to the median of all chaebol firms, and zero otherwise. Lower centrality refers to an indicator that has a value of one if a firm's centrality is smaller than or equal to the median of all chaebol firms, and zero otherwise. Controls include the log of total assets (in millions of KRW), the leverage ratio, payout ratio, ROA, and listed. All estimates include industry (SIC-2 digit) and year indicator variables. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Variables	Dependent Variable: Long-term R&D Investment/Total Assets (%)		
	(1)	(2)	(3)
	[X] = Low Cash-flow Right	[X] = Lower Layer of Pyramid	[X] = Low Centrality
Treat × Post × Pyramid Variable [X]	2.79328* [1.650]	2.77916** [1.388]	2.47690* [1.439]
Treat × Post	0.19596 [0.566]	0.83270 [0.652]	-0.56913 [1.014]
Post × Pyramid Variable [X]	-1.01672* [0.547]	-1.31682* [0.780]	-1.12709** [0.560]
Treat × Pyramid Variable [X]	-1.96580* [1.047]	-1.28884 [0.936]	-1.97400* [1.166]
Treat	-0.63005 [0.472]	-1.44638** [0.560]	-0.03871 [1.061]
Post	-0.47423 [0.688]	-0.66434 [0.808]	-0.04616 [0.847]
Pyramid Variable [X]	1.23897** [0.550]	0.96400 [0.746]	2.14491*** [0.742]
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Control	Yes	Yes	Yes
Observations	1,601	1,601	1,601
R-squared	0.117	0.117	0.114