Centrality and Corporate Governance Decisions of Korean Chaebols: A Social Network Approach

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ABSTRACT

Almeida et al. (2011) show how Korean chaebols are structured using the critical control threshold centrality. In this paper, we introduce the social network theory to operationalize centrality in the context of the organizational structure of a business group. Specifically, the degree centrality, the Katz centrality, and the Hub/Authority centrality are employed to explain how chaebols make corporate governance decisions—going public, staying private, and being divested—in terms of centrality. We find that firms with high centrality are more likely to go public while firms with low centrality are more likely to stay private or be divested. In addition, firms invested by other group firms tend to stay private and firms without substantial equity stake in other group firms tend to be divested. Firms directly owned by the controlling family are more likely to stay private and less likely to be divested. We calibrate centrality based on the social network theory and explore how Korean chaebol system evolves for survival and prosperity.

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1. Introduction

The distribution of control over assets shapes the quality of economic growth in a country (Morck, Wolfenzon, and Yeung, 2005). Pyramidal ownership in family business group is fairly prevalent outside the United States and the United Kingdom. A pyramid enables a wealthy family to control more than what they own[1] and to access the retained earnings of a firm it already controls to set up another firm (Almeida and Wolfenzon, 2006). Single individuals or families control many firms in numerous countries. Korean business groups, referred to as *chaebols*, have such ownership structure where a single wealthy family at the apex of a pyramid possesses complete control over all firms of the business group through a chain of ownership relations (Bae, Kang, and Kim, 2006). Chaebols also control a large portion of the Korean economy,[2] which can affect economy-wide efficiency, quality of resource allocation, distribution of corporate control, capital market development, and economic growth. The separation of ownership and control exists in pyramidal ownership and it becomes greater as going from the apex to the bottom of the pyramid. At the bottom of the pyramid where the separation is most marked, chaebols control firms with a small ownership stake. Crossholding, super-voting rights, and appointment of family members in executive positions render the separation even more radical (Bebchuk, Kraakman, and Triantis, 2000; and Morck, Wolfenzon, and Yeung, 2005).

Prior literature points to two opposite views regarding the pyramidal structure. A strand of studies portrays a perspective that pyramidal ownership—concentrating control in the hands of a few large shareholders—creates agency problems. This structure is more prevalent in countries with poor investor protection (e.g., Almeida and Wolfenzon, 2006) and enables the owner to have lower ownership for the same control and to divert more from pyramid-controlled firms (Johnson, La Porta, Lopez- de-Silanes, and Shleifer, 2000; Bertrand, Mehta, and Mullainathan, 2002; and Almeida and Wolfenzon, 2006). This relatively low cash flow rights create agency problems because, under the circumstances, it becomes more attractive for the controlling family to pursue private benefits of control than to maximize future cash flows. Jensen and Meckling's (1976) findings suggest that insiders with low cash flow rights have greater incentive to misallocate firm resources, presumably for the private benefits. Almeida and Wolfenzon (2006) show that overinvestment is more likely when the family owns a firm through pyramidal structure because the cost would be shared with other shareholders within the group. The founding family in chaebol is usually the largest shareholder with overwhelming influence and has an incentive to pursue self-interested values other than firm value maximization (Feldman, Amit, and Villalonga, 2016). Such incentive becomes stronger and more attractive for the family as the discrepancy between control rights and cash flow rights grows because the family can pass on more of

[1] Figure 1 of Morck et al. (2005; p. 663) well illustrates in a simplistic manner how a family firm can achieve corporate control greater than commensurate cash flow rights.
[2] According to Bae et al. (2002), chaebols have dominantly controlled the Korean economy during the last few decades. The total assets (gross sales) of the top 30 chaebols comprise 62.5 percent (72.6 percent) of all public firms in Korea.

the costs borne to extract private benefits to other shareholders. Their dominant control stake shields them from short-term pressure in the stock market while extracting private benefits of control in the long run. Stulz (1988) also argues that high control rights provide insiders with more freedom to misallocate—entrenchment.

The other group of work highlight the value-enhancing aspects of the family business group. Ghatak and Kali (2001) argue that firms with financial interlinkage through cross-holding can mitigate the credit rationing issue arising from information asymmetry when these firms possess better information about each other than an outside bank does. Kim (2004) theoretically shows that business group affiliation lowers the likelihood of liquidation of a good-quality firm in emerging markets where banks are not sufficiently competent. Khanna and Palepu (1997, 2000) argue that business group is an efficient form of business organization in emerging markets where capital and labor markets are underdeveloped, facilitating more efficient allocation and financing advantages through leveraging a group's internal capital markets. It can also prop up affiliated firms when they are financially in trouble (Morck and Nakamura, 1999; and Friedman, Johnson, and Mitton, 2003) and mitigate liquidity constraints by pooling resources within the group (Morck et al., 2005). In a similar vein, Lewellen (1971) notes that unrelated diversification in which earnings of the group firms are more likely to be imperfectly correlated reduces the riskiness of the debt and improves financial flexibility.

As depicted above, the organization structure of chaebols bears high importance in and critical implications for the economic growth and functional efficiency of the capital markets in Korea. Almeida et al. (2011) show how Korean chaebols are formed and structured. They calculate the centrality of group firms by employing the critical control threshold centrality (CCC henceforth) method and show that subsidiaries with low pledgeable income are acquired by the central firms and located in the pyramid, while subsidiaries with high pledgeable income are directly acquired by the family and located horizontally. We direct our attention to the effect of centrality on the financial decisions of chaebols after they are formed. Duhaime and Grant (1984) find that the relation of a division with other divisions and its parent firm is a critical factor in divestment decisions. The relative position and centrality of a firm within a group would alter their optimal strategic formulation and allocation of corporate resources, and further systematically moderate not only divestiture but also the firm's other dimensions of financial decision making such as going public and staying private. This paper operationalizes centrality metrics based on the social network theory and explore the firm's corporate governance decisions in light of centrality. We specifically focus on three major firm events that affect corporate governance: going public, staying private, and divestiture[3].

[3] In a broad sense, divesture may include spin-offs, carve-outs and sell-offs, while divestiture in this paper is narrowly defined as only sell-offs.

We first discuss the advantages of the social network measures in estimating the centrality of chaebol subsidiaries over other measures such as the discrepancy between cash flow and control rights, and CCC. We then show that centrality of each subsidiary is significantly related to strategic corporate decisions using 14,923 firm-year ownership observations from 2002 to 2016 to examine our hypothesis.

First, we find that firms with high centrality are more likely to go public. These firms need external financing to expand their business groups or acquire other new subsidiaries into pyramidal control structure. When a central firm goes public, the firm would have more dispersed ownership with numerous atomistic shareholders mostly with passive attitude for voting, which will make it easier for the controlling family to divert corporate resources for private benefits. The cost incurred to garner private benefits can also be shared with public shareholders. Brau and Fawcett (2006) show that one of the strongest motives for IPO (initial public offering) is to promote M&As (mergers and acquisitions) dominantly as an acquirer and hence going public will facilitate future acquisitions by the family firm that has strong incentive to expand the group.

We find that firms invested by other subsidiaries are more likely to stay private. These firms are on average small and placed in lower tiers of the pyramidal group. They usually do not invest actively in other firms, based on the centrality metrics scores that they have. Given that internal capital markets are available in pyramidal structure, a mild financing needs can be relieved through financial support by other group firms. As the wedge between control and ownership stakes is more extreme for these firms, retaining control of them by not going public is critical for the controlling family. In the analysis of directly owned firms by the family, we find that these firms tend to stay private. Almeida et al. (2011) find that family firms directly invest in high income pledgeable firms rather than place them in the pyramid. These firms have high income pledgeability and, therefore, family firms would want to grapple all the benefits instead of sharing them with other shareholders.

Finally, we find that firms without substantial equity stake in other subsidiaries—firms with low out-degree centrality—are more likely to be divested while central firms are less likely to.[4] Almeida et al. (2011) find that firms with low income pledgeability are placed into the pyramid. These non-central firms have higher likelihood of being divested since low performance precedes divestiture and low income pledgeability more likely leads to poor performance. These firms are small in size and more subject to misvaluation, which is one of the motives for divestiture. In view of control rights, divesting a central firm is too costly since it deprives the family firm of the complete control for all the firms under the control umbrella—central and all other controlled firms within the group—while divesting a low tier firm loses control in that firm only. We test these hypotheses using a logit model first, and then a multinomial logit and panel fixed effects model for robust conclusions, which generated the qualitatively same results.

[4] All the centrality metrics for our analysis are discussed in section 2.2.

Our contribution to the literature is twofold. First, what distinguishes our paper from prior literature is that we address corporate governance decisions. Prior literature mostly pays attention to the disparity between control right and ownership stake, agency problem, and wealth effect issues evolving around the organizational structure. More recently, Almeida et al. (2011) direct attention to how the group structure of chaebol is structured in terms of centrality. Going one step further from Almeida et al., we focus on corporate governance decisions arising as the formed structure of chaebol evolves over time: specifically, going public, staying private, and divesting. Second, we newly adopt the social network analysis approach into the organizational structure analysis for chaebols. We calibrate centrality based on the social network theory and explore how Korean chaebol system evolves for survival and prosperity. Our social network metrics are well suited to prior centrality measures used in the prior research. With the information on *directions* of the ownership information, our metrics should be at least equal to or marginally better than the measures in the prior literature information-wise.

The rest of the paper is organized as follows. Section 2 reviews related literature and develops hypotheses and their implications. Section 3 describes data and methodologies. Section 4 provides empirical results. Section 5 summarizes our results.

2. Centrality Metrics and Social Network Approach

2.1 Ownership Structure Measures of Business Groups

Numerous studies have attempted to measure the ownership structure of business groups. The most frequently used measure is the discrepancy between cash flow and control rights that the controlling shareholder holds in each group firm (Joh, 2003; La Porta et al., 1999; Claessens, Djankov, Fan, and Lang, 2002; Bertrand et al., 2002; Lemmon and Lins, 2003; Faccio and Lang, 2002; Kim, Lim and Sung, 2007; and Bena and Ortiz-Molina, 2013, among others). Yet, the definitions of cash flow rights and control rights are subtly different in each study.

Joh (2003) defines cash flow rights as the direct ownership of controlling shareholders of Korean chaebols and the control rights by a simple sum of direct ownership and related firms' ownership. Joh finds that the gap between cash flow and control rights is negatively related to firm probability, suggesting less care for firms in the lower tiers of the pyramid. Lemmon and Lins (2003) and Kim et al. (2007) use ultimate cash flow rights of controlling shareholders by considering the direct ownership plus the indirect ownership through pyramidal structure and cross-shareholdings. Investigating a sample for 800 East Asian firms, Lemmon and Lins show that, during the East Asian financial crisis, firms with the higher gap between cash flow and control rights experience lower stock returns. Kim et al. explain the motive of controlling families of Korean chaebols to directly hold a subsidiary and show that the level of discrepancy is even larger when they consider non-public firms.

La Porta et al. (1999), Faccio and Lang (2002), Claessens et al. (2002), and Bena and Ortiz-Molina (2013) calculate the control rights using the direct ownership by controlling families as well as the indirect ownership through shareholding in other subsidiaries. Studying 27 wealthy economies, La Porta et al. find that controlling shareholders wield power over firms significantly in excess of their cash flow rights using pyramidal structure and management participation. Analyzing 13 Western European countries, Faccio and Lang find that UK and Ireland firms are typically widely held while family-controlled firms are more important in continental Europe. Claessens et al. examine 8 East Asian economies and document that firm value decreases when the control rights of the largest shareholder exceed her cash flow ownership, consistent with an entrenchment effect. Bena and Ortiz-Molina examine private firms newly incorporated to a pyramid in 19 European countries and show that pyramidal structures facilitate financing advantage in setting up new firms when the pledgeability of cash flows is limited.

While the discrepancy between cash flow and control rights is a useful measure to estimate the ownership structure of business group, it is questionable whether it is a sufficient statistic to describe the pyramidal and cross-holding ownership in the business group. As an effort to overcome this skepticism, Almeida et al. (2011) introduce two useful ownership measures for Korean chaebols where both pyramids and cross-shareholdings are common. They calculate the *critical control threshold* centrality of a firm in the group structure, which helps identify whether a certain firm is used by the controlling family to control other subsidiaries. They also introduce a measure, *Position,* to estimate how far down a certain firm is from the controlling firm in the pyramid and to distinguish pyramidal from direct ownership. Almeida et al. find that controlling families use controlling firms to vertically acquire firms with low pledgeable income, while firms with high pledgeable income are directly acquired by controlling families. Their results are consistent with a selection effect rather than tunneling in that the selection of low-income firms into pyramids leads to a discount for the value of a central firm. We supplement our social network centrality metrics with these two measures so that we can check the validity of our metrics.

2.2 Centrality Measures Based on A Social Network Approach

In this section, we introduce centrality metrics widely used in the social network analysis that are relevant to our analysis. The concepts of centrality were first formulated in the social network field. Centrality is about relative importance of nodes (or vertices) and links (or edges). In our context, centrality measures the extent to which a firm interacts with other firms within a business group in terms of ownership. That is, it is a measure for the importance of a firm within the group. The study of networks has developed diverse metrics that convincingly encapsulate the characteristics of networks. This approach has gained popularity from many different disciplines such as physics, computer science, biology, climatology, operations research, and information science. We heavily draw on Newman (2010) and borrow the following metrics of centrality from the social network theory that are deemed to be the most relevant to our context of investigation: i) degree centrality, ii) Katz centrality—In-Katz and Out-Katz, and iii) Hub and Authority.

a) Degree Centrality

Degree centrality is conceptually the simplest measure of centrality defined as the number of links connected to a node, with links counted twice. In social network, an influential person usually establishes many relations to others, which can be measured through the degree. It can be interpreted as the number of opportunities to influence or be influenced directly between the two. In an *undirected* network of *n* nodes, the degree can be defined as following:

$$Deg_S(i) = e^T S_{\cdot i} \tag{1}$$

where *e* is the $n \times 1$ vector (1, 1, 1, …); *S* is the ownership matrix, $S = (s_{ij})$. s_{ij} is the sum of ownership of firm *j* holding the shares of firm *i* and zero if firm *j* does not hold any share of firm *i*. This measure is called simply *degree* or *degree centrality* to accentuate its use as one of the centrality measures.

In a *directed* network such as an ownership network where ties have direction or flow, two separate measures of degree centrality can be defined: *out-degree* and *in-degree centrality*. The number of head ends (tail ends) of a node adjacent to that node is called its *in-degree* (*out-degree*). *Out-degree centrality* (ODC hereafter) is the sum of ownership of a firm holding other firms. *In-degree centrality* (IDC hereafter) is a sum of ownership directed to a firm. The degree in an undirected network is the sum of out-degree and in-degree. In the context of ownership structure, a family or central firm would have high out-degree centrality having many out-going links because it owns the shares of its affiliated firms or invests into those firms.

b) Katz Centrality: Out-Katz and In-Katz Centrality

Degree centrality awards one point to all neighboring nodes and measures the number of the neighbors only. All neighbors, however, may not be equally important. In many cases, nodes having many relations with other nodes can be more important. Instead of assigning one point to each neighbor, *eigenvector centrality* assigns a weighted score proportional to the sum of the scores that its neighboring nodes have. Eigenvector centrality has a nice property that the centrality score can be large either when a node has many neighboring nodes or when it has important nodes, or both. While eigenvector centrality is an index of exposure like degree centrality, this feature allows high-scoring nodes to contribute more to the score of a node, taking relative importance into account. Eigenvector centrality is defined as follows:

$$x_i = \sum_{j \in N} s_{ji} x_j \iff x = S^T \boldsymbol{x} \tag{2}$$

While eigenvector centrality is conceptually appealing, it has a potential problem on directed networks. The centrality score will always be zero unless nodes are with strong connections. Many nodes in reality do not have strong connections, which will lead to zero eigenvector centrality. A way to sidestep this issue is to use Katz centrality (Katz, 1953).

Katz centrality is a variant of the eigenvector centrality that works well only for well-connected networks.[5] In this measure, we tweak eigenvector centrality to some degree by endowing a small amount of centrality to each node so that each node can have a minimum positive centrality score even when they have weak connections. This will ensure that each node has a non-zero score irrespective of their centrality strength of the neighbors. Katz centrality is defined as:

$$x_i = \alpha \sum_{j \in N} s_{ji} x_j + \beta \iff x = \alpha S^T x + \beta e \tag{3}$$

$$Katz_S(i) = e_i^T (I - \alpha S^T)^{-1} e \tag{4}$$

Where e_i is a $n \times 1$ vector where the i^{th} element is one and everything else is zero; I is an $n \times n$ identity matrix. In the analysis of ownership network, it is appropriate for nodes with high in-degree to have high centrality scores although they are not strongly connected. This issue is resolved by adding constants α and β. The value of α should be set so that $(I- \alpha S^T)$ can be invertible. Specifically, we set α at $\left[\frac{1}{(1+\max_i \max\{e^T S_{i.}, S_{i.} e\}}\right]$ in this study. While α cannot be arbitrary, we can assign an arbitrarily large number to β. We use β=1 because we consider only the relative magnitudes of centrality within the business group for our analysis, not absolute values of centrality. We report our results based on Katz centrality using β=1. Similar to in-degree and out-degree earlier, we further take the direction of links into account and construct In-Kats (*IKatz*) and Out-Kats (*OKatz*) centrality.

c) Hub /Authority

For some directed networks, we introduce another two centrality measures with some twists: Hub and Authority. These are also known as *hyperlink-induced topic search* (HITS) put forth by Kleinberg (1999). It was originally developed as a web-page rating algorithm. In some cases, we may want to

[5] Another variant of eigenvector centrality is *Google PageRank*.

assign a high centrality score to a node that *points to* other nodes with high centrality, as opposed to a node that is pointed to by other nodes with high centrality. The former is called *Hub centrality* and the latter *Authority centrality*. Authorities are nodes that have useful information and Hubs are nodes that provide information on where the best authorities are found. A survey paper (seminal paper) is an example of a Hub (an Authority). A survey paper itself does not contain much information on a topic of interest but provides information on where to find by pointing to important papers while a seminal paper contains important information and is pointed to by (or cited by) other papers. In the context of the ownership structure within a business group, authorities are firms that are invested by various important affiliated firms and Hubs are firms that own significant shares in other affiliated firms. Newman (2010) note that Hubs and authorities are not necessarily mutually exclusive. That is, a Hub may be an Authority as well, and vice versa.

Hub and Authority centralities are mutually dependent and, therefore, the calculation of one centrality needs the calculation of the other. Let us denote Authority centrality for firm i as x_i and Hub centrality as y_i. Then, x_i and y_i are defined as follows:

$$x_i = \alpha \sum_{j \in N} s_{ij} y_j \iff x = \alpha S y \quad (5)$$

$$y_i = \beta \sum_{j \in N} s_{ji} x_j \iff y = \beta S^T x \quad (6)$$

where α *and* β are constants. As aforementioned, Authority centrality for node i is defined proportionally to the sum of the Hub centralities of the nodes that point to i. Note that the indices for matrix S switch the order between the two equations (5) and (6). Hub (Authority) centrality becomes greater as a node has many links that point to (are pointed to by) nodes with high Authority (Hub) centrality. The same leading eigenvector for both SS^T and S^TS is required for this approach to work. Let us denote this eigenvector as u. Then we can rewrite Authority and Hub centralities as following:

$$Authority_S(i) = e_i^T u \quad (7)$$

$$Hub_S(i) = e_i^T S^T u \quad (8)$$

We set α *and* β at 1 for our analysis.

d) Critical Control Threshold Centrality (CCC) and Position

We also use the measures developed by Almeida et al. (2011) with which they analyze how chaebols are formed and structured: *critical control threshold centrality* (CCC) and *Position*.[6] The critical control threshold is defined by the authors as the "maximum control threshold for which the firm belongs to the set of firms controlled by the family." This metric relies on the assumption that a family can control a firm when the family owns a certain threshold T ($0 \leq T \leq 1$). For a given level of threshold T, let the set of firms controlled by the family be $C(T)$:

$$C(T) = \left\{ i \in N: f_i + \sum_{k \in C(T) j \neq i} s_{ji} \geq T \right\} \quad (9)$$

where f_i is the direct stake of the family for firm i. It is not easy to calculate $C(T)$ because it is recursively defined. The critical control threshold centrality (CCC) is defined as:

$$CCC = \frac{\sum_{j \neq i} CC_j - \sum_{j \neq i} CC_j^{-i}}{N - 1} \quad (10)$$

where $CC_i = \max\,[T | i \in C(T)]$. CCC is the difference between the average critical control threshold with and without the stakes the firm i holds in other firms. This measures how much decrease in CC occurs when we exclude firm i and represents how central the firm is within the group. CCC is bounded between zero and one, and it is higher as the firm is more central.

Position is the other metric we adopt from Almeida et al. (2011). It is defined as the distance between a family firm and another firm within the business group. In a pyramidal structure, the firm at the apex is in Position 1 and the firm at the floor is in a Position that is greater than and farther from 1. As a firm is closer to the apex, the Position is closer to 1. Almeida et al. formulate Position as follows:

$$Position_i = \frac{f' d_i}{u_i} \cdot 1 + \frac{f' S d_i}{u_i} \cdot 2 + \frac{f' S^2 d_i}{u_i} \cdot 3 + \frac{f' S^3 d_i}{u_i} \cdot 4 + \cdots = \sum_{n=1}^{\infty} \frac{f' S^{n-1} d_i}{u_i} \cdot n \quad (11)$$

where f_i is the direct stake of the family for firm i; d_i is a vector of zeros with one in the i^{th} element. $f'd_i$ is the dividend that the family receives. The family also receives $f'Sd_i$ from firm i through the chains of ownership.

e) Summary

[6] We briefly sketch the CCC and Position to conserve space in this section. For full-fledged descriptions on the metrics formation and estimation, see Almeida et al. (2011).

In this section, we overviewed the centrality metrics to be used for our analysis from social network analysis along with CCC and Position operationalized by Almeida et al. (2011). CCC assumes that a family controls a firm only if it holds more than *T* votes, which is arbitrarily set. It is computed by the average decrease in the critical control threshold across all group firms other than firm *i* after excluding the firm from the group, which may end up with a negative CCC. Our social network metrics are free from this possibility. Our measures also have more information—*directions*—from using indegree and outdegree for Degree Centrality and Katz Centrality along with Hub and Authority.

As the firm is more central, it will have higher ODC, OKatz, and Hub, and Position that is close to one. On the other hand, the non-central firm will have higher IDC, IKatz, and Authority, and Position that is greater than and farther from one. See, for example, Table 1 where actual numbers for these metrics for Samsung subsidiaries are shown.

For more intuitive understanding, we provide a numerical example of the centrality metrics construction with a simplified ownership structure in the Appendix.

2.3. Hypothesis Development: Decisions to Go Public, Stay Private, and Divest

Almeida et al. (2011) examine how chaebols are structured using centrality metrics. In this study, we direct our attention to financial decisions of chaebols on corporate governance after the group structure is formed. Specifically, we scrutinize the decisions of chaebols and their controlled firms to go public, stay private, and divest through the spectrum of social network centrality metrics.

Previous literature has proposed several reasons why firms go public or stay private within the frame of the tradeoff between benefits and costs of going public. On the bright side, an IPO enables a firm to have greater access to capital market, enhanced monitoring by market participants, lower cost of capital, better visibility, and better firm value through liquidity. It also lets group-controlling shareholders infer investor valuations on their firms and cash out. The information gained in the IPO and post-IPO process can be used to promote post-IPO corporate decisions such as capital structure and management's compensation (Subrahmanyam and Titman, 1999; and Maug, 2001). On the other hand, going public will cause controlling families to lose control rights and the private benefits of control. Other downsides include higher administrative costs for filing requirements, potential disclosure of important information to competitors, and emergence of agency problem not only between management and shareholders but also between controlling family and public shareholders.

Masulis et al. (2017) argue that, in developed capital markets, firms use SEOs (seasoned equity offerings) to finance investment opportunities, while firms in emerging markets rely on IPOs (initial public offerings) to fund them. They also note that IPOs of family owned firms lead to the expansion of the family business group. Going public also promotes the dispersion of ownership by selling shares to a large number of investors. Under the presence of dispersed ownership or numerous public shareholders where each has a small stake, it would be easier for them to wield complete control with the least investment in chaebol-controlled firms because individual shareholders are usually a passive voter. In contrast, private firms are typically funded by one large investor such as a venture capitalist or a small number of large angel investors (Chemmanur and Fulghieri, 1999). These large investors would more vigorously voice themselves when they confront interest-conflicted moves by chaebol families. It is highly valuable for chaebols to divert the resources of the family firms for their private benefits without difficulty, such as using retained earnings to set up another firm within the pyramidal structure. Almeida et al. (2011) show that central firms are older and larger, and belong to cross-shareholders' loops. Furthermore, the controlling family uses central firms to hold stakes in firms with lower profitability using a pyramidal ownership structure than firms directly controlled. They need external financing while less central firms can benefit from internal financing by central firms placed high in the pyramid. The controlling family may have less incentive to hold much of the control rights of central firms. Rather, raising outside equity to subsidize affiliated firms under control is more important to central firms. Therefore, the benefits of going public outweigh its costs.

Firms owned by a wealthy family in the pyramidal group have access to the financial support from central firms through the internal capital market (Ghatak and Kali, 2001; Khanna and Palepu, 1997, 2000; and Masulis et al., 2017). The controlling family with less incentive to maintain control in central firms lets these firms go public for external financing while the benefits of going public such as access to external financing is less important for family-controlled firms. Bancel and Mittoo (2009) report that the IPO of a family firm improves bargaining power with creditors and bankers without giving up control. Further, it is less likely that the firm value improves by going public since these firms tend to have low profitability (Almeida et al., 2011). With financing sources available through the internal capital market, going public may not be an ideal strategic move for the controlled firms. Braw and Fawcett (2006) list maintenance of the control over decision making as one of the main reasons to stay private. Monitoring and shareholder voting would be big threats for the controlled firms that have sizable discrepancy between cash flow rights and control rights. Based on the CFO survey, Brau and Fawcett (2006) find that the strongest motive for going public is to create public shares to facilitate acquisitions. Given that these IPO firms are more likely to be an acquirer than a target, it is highly plausible that chaebols go public to be active in acquisitions for the purpose of forming a chain of ownership relations over time. On a different perspective, public firms more likely become a target in an M&A market, compared to private firms. Non-central firms placed in the lower tier of the pyramidal structure are vulnerable while central firms are insured with complex cross-holding against hostile takeovers. For firms directly owned by the family that usually have high income pledgeability according to Almeida et al. (2011), the family would want to maximize private benefits in these firms with complete control, instead of diluting through IPO. All taken together, we put forth our first two hypotheses:

Hypothesis 1. *Firms with high centrality are more likely to go public, while less central firms are less likely to go public.*

Hypothesis 2. *Non-central-non-pyramidal (NCNP) firms, owned directly by a controlling, are more likely to stay private.*

Firms are more (less) central if they have higher (lower) ODC, OKatz, and Hub, and Position that is close to (greater than and farther from) one. See, for example, Table 1 where actual numbers for these metrics for Samsung subsidiaries are shown. A '*non-central-non-pyramidal*' (NCNP) firm is a firm owned directly by a controlling family and not within the pyramidal group structure. Since a NCNP firm neither controls subsidiaries nor is controlled by other subsidiaries, it has a zero ODC (OKatz, or Hub) as well as low IDC (IKatz, or Authority). We formally define the NCNP firm in Section 3.4.

Although divestiture has attracted relatively little attention in the literature, it is a major firm event and an important corporate restructuring activity along with mergers and acquisitions (M&As) that alters the boundaries of the firm. We focus on the differential divesting activities between central and non-central firms within a group while prior literature examines how family and non-family firms differ in terms of divestiture. Family firms will have preference for expansion and diversification in an environment of weak corporate governance (Jensen, 1986), which is an inherent earmark of the Korean chaebols (Bae et al., 2002). Despite this preference, increasing focus and streamlining business through voluntary divestiture has become common in response to market conditions (Kaplan and Weisbach, 1992; and Denis, Denis, and Sarin, 1997). Divestment can be a natural adjustment move to respond to the changing external business environment and to revamp firm performance by addressing organizational and agency issues. It corrects prior misallocation of corporate resources, and reconfigures corporate focus and internal structural arrangements (Weisbach, 1995; and John and Ofek, 1995)

A family owner with substantial discrepancy between control and cash flow rights may make diversification decisions that are aimed at private benefits rather than enhancing firm value for shareholders. Expansion, however, may come with increased bureaucratic costs due to structural complexity, inefficient allocation of corporate resources, and decreasing returns beyond a certain point due to overdiversification, all of which translates into destruction of firm value. Weak governance system—under which private benefits of controls are higher in countries with poor investor protection (Dyck and Zingales, 1984)—is prone to overdiversification with a lopsided power of the family owner (Jensen, 1986), which is later corrected in the form of divestiture. Overdiversification would lead to loss of strategic control and advantage, and performance issues arising from the loss. Divestiture is not likely when the firm experiences better than mediocre performance. Unfavorable performance usually precedes divestiture that is one of structural reforms undertaken to address inefficiency and poor profitability. When the firm at a lower tier of the group structure—that has a substantial wedge between control right and ownership stake—experiences poor performance, the firm may need to raise additional capital. A small ownership stake doubled with increased or expected operating loss and ownership dilution from external financing may make the controlling family feel it less attractive to maintain a controlling shareholder position because both control and financial benefits become smaller. In this case, divestiture may be a rational option to curtail further loss.

Family owners would be highly reluctant to divest central firms to maintain their control they have long built. Given that the control branches from the firm at the apex of the pyramid, divesting the central firm would make it lose most of the control except the portion of the control for the firm in which it directly invested. Divesting a firm in a lower tier of the pyramid loses control as much as the central firm invested. Controlled or non-central firms tend to be smaller and newer (Almeida et al., 2011), which makes them more vulnerable to the changes in market conditions and regulations. Any negative shock will make these lower tier firms a candidate for divestiture earlier than central firms.

Nanda and Narayanan (1999) note that misvaluation is cited as one of the main reasons for divestiture in roughly half of their sample firms. Controlled firms are more likely to be involved in divestiture to correct misvaluation because these firms are smaller and younger, which makes them more prone to negligence and information asymmetry in the market and hence undervaluation, compared to central firms. In line with Nanda and Narayanan, Krishnaswami and Subramaniam (1999) find that undervaluation is mitigated when the parent firm divests its subsidiary. When the central firm is capital constrained, divesting a controlled firm would be an effective alternative to relax such credit constraints. The CEO in a chaebol firm frequently serves as the chairman of the board and wields an absolute control in all group firms. The tenure of the chaebol CEO is highly stable (Moskowitz, 1989). Divesting the central firm is equivalent to giving up all the control the wealthy family enjoys in the firms under the control umbrella—both central and all controlled firms thereunder together—and destroying the underpinning of the exquisite control system built over decades, which is remotely unlikely in any chaebol firm. All these lines of reasoning echo a notion that divestiture is less likely for central firms.

Hypothesis 3. *Firms with high centrality are less likely to be divested, while firms owned by a pyramid are more likely to be divested.*

3. Data, Methodologies, and Summary Statistics

3.1. Data

We extract the ownership data from the Korean Fair Trade Commission (KFTC) which announces the annual list of chaebols and provides the ownership structure as well as shareholdings by subsidiaries on its portal site, www.egroup.go.kr. The KFTC defines chaebols as "a group of companies, more than 30% of whose shares are owned by the same individuals or by companies controlled by those individuals." One advantage of the KFTC database for our study is that chaebols are required by regulation to report complete ownership data along with other critical dimensions of the ownership structure such as the status of affiliate shares, persons with special interest, and financial status of group affiliated firms. As noted in Almeida et al., shareholders are classified into detailed types including family owner and the relatives of the family owner. The ownership information on private group firms is also included in the database, which is rarely found in other countries. This is a desirable feature given that bias is inevitable when public firms only are used to draw conclusions. Kim et al. (2007) report downward bias in the discrepancy measures of the prior literature that do not include private firms. We base this study on all the chaebols announced by the KFTC from 2002 through 2016. Following previous studies on Korean chaebols, we exclude 19 large business groups from our chaebol sample since those groups are not owned by private controlling families but by the government, public institutions, or banks. The resulting dataset consists of 14,923 firm-year observations for analysis. We obtain the financial data from Kis-Value, a database compiled by the NICE (National Information & Credit Evaluation) Information Service.

3.2 Variable Descriptions: Centrality Measures, Position, and Firm Characteristics

[Insert Figure 1 around here]

Figure 1 illustrates an example of the pyramid ownership structure for the Samsung group in 2016. Samsung was founded in 1938 and its controlling ownership has been inherited within the family over generations from founder, Lee Byung-chul, all the way to the current vice chairman of Samsung, Lee Jae-yong. It shows just 21 of 68 subsidiaries for an illustration purpose. As the picture per se suggests, Samsung C&T, Samsung Electronics and Samsung Life Insurance are central firms in the Samsung group. The arrows or directed edges show the ownership relationship and magnitude in percentage. As opposed to central firms, firms placed in the lower tiers of the pyramidal structure may have low centrality. The ownership structure shown is very complicated and it would be more so when all the subsidiaries are included. As noted by La Porta et al. (1999) and Claessens et al. (2002), indirect cross-holdings and a chain of ownership structure are observed between several firms. For example, Samsung Electronics has a stake of 19.6% in Samsung SDI that has 8% in Samsung Everland. In turn, Samsung Everland owns 19.3% of Samsung Life Insurance that has 7.2% in Samsung Electronics. These three firms further have a web of complicated ownership with other firms in Figure 1.

[Insert Table 1 around here]

Table 1 reports centrality measures and Position of each subsidiary of Samsung included in Figure 1. CCC is the critical control threshold centrality suggested by Almeida et al. (2011). As stated in section 2.2, more central firms will have higher ODC, OKatz, and Hub, and Position that is close to 1. On the other hand, non-central firms will have higher IDC, IKatz, and Authority, and Position that is greater than and farther from 1. A quick overview indicates that most central are Samsung Electronics, Samsung C&T, and Samsung Life. For example, Samsung Electronics has 1 for ODC, OKatz, and Hub, which is the highest score possible for each metric. The other metrics also suggest that the firm is highly central, having a high value of CCC (0.606) and low values for IDC, IKatz, and Position—0.032, 0.029, and 1.565, respectively. Consistent with what these metrics suggest, these firms are placed near the apex of the pyramid as shown in Figure 1. Firms at the bottom tier of the pyramidal structure would include firms such as Samsung BioEpia and Samsung Display. These firms' ODC, OKatz, and Authority are zero or close to zero while IDC and IKatz are close to 1 and Position is farther from 1.

3.3. Summary Statistics

[Insert Figure 2 around here]

[Insert Figure 3 around here]

Figure 2 shows that frequencies of the following metrics: ODC, OKatz, and Hub. These metrics are higher for controlling firms at the top of the pyramid. Y-axis is the number of observations and x-axis is the value of these metrics. The number of firms decreases as ODC, OKatz, and Hub increase, representing the pyramidal ownership structure with a small number of controlling firms and a large number of controlled firms. Figure 3 shows the other three centrality metrics: IDC, IKatz, and Authority. These three metrics increase if a firm's shares are owned by more subsidiaries. The graph shows that the number of firms does not monotonically increase or decrease as each metric increases and a substantial portion of our sample firms are owned by other subsidiaries.

[Insert Table 2 around here]

Table 2 tabulates the correlation coefficient matrix between centrality measures. Almeida et al.'s (2011) main centrality metric, CCC, is highly positively correlated with ODC, OKatz and Hub, and negatively with IDC, IKatz, and Authority although the correlation coefficient for Authority may not be sufficiently different from zero. The significant correlations of our social network centrality measures with the established measure—CCC—lend support to the validity and consistency of these newly introduced social network parameters as centrality measures for corporate governance research. ODC is negatively correlated with IDC although their correlations are not perfectly negative. A negative correlation also exists between OKatz and IKatz, and between Hub and Authority. It is possible that firms investing in many other subsidiaries, i.e., firms with high ODC (or OKatz, Hub), are also invested by other subsidiaries. This is somewhat in line with Newman's (2010) statement in his section 7.5 that Hubs and authorities are not necessarily mutually exclusive. He specifically notes "An authority may also be a hub, and vice versa." Position is consistently correlated with our social network centrality metrics, being negatively related with ODC, OKatz, and Hub since firms far down from a controlling family are more likely to be invested by other subsidiaries.

[Insert Table 3 around here]

3.4. Research Design

To test Hypothesis 1, we estimate the following logit regression:

$$Listed\ Dummy_i = 1[\rho_1 Centrality\ Measures\ (or\ Position)_i + \rho 2X + u_i > 0] \quad (1)$$

where *Listed Dummy* is an indicator variable that takes the value of one if the firm is listed and zero otherwise; *Centrality Measures* are our social network metrics for centrality. We include ODC and IDC, OKatz and IKatz, and Hub and Authority in each regression. As shown in Figures 2 and 3, ODC is negatively but not perfectly correlated with its counterpart, IDC. OKatz and Hub show the similar association to their counterparts: IKatz and Authority. ODC is a conceptually opposite metric but, as shown in Table 2, its correlation with IDC is -0.33, suggesting little chance of multicollinearity. The correlations are -0.37 for OKatz and IKatz and -0.07 for Hub and Authority. We further confirm no multicollinearity for these metrics using the VIF (vector inflation factor) statistics. Putting it into perspective, high ODC (OKatz, or Hub) firms that actively invest in other firms within the group may have a high IDC (IKatz, or Authority) when they are concurrently invested by other firms. Position is a measure for how much a subsidiary is distant from the controlling family calculated in Section 2.2.

We also investigate whether a firm directly owned by a controlling family (NCNP firm) is more likely to go public. Almeida et al. (2011) document that firms with high pledgeable income tend to be acquired horizontally through direct ownership by the controlling family. Since those firms are not located in the pyramidal ownership structure, they neither control other subsidiaries nor are controlled by other subsidiaries. Thus, we define a firm directly owned by controlling families as the firm of which ODC (OKatz, or Hub) is zero as well as IDC (IKatz, or Authority) is less than the 10th percentile.[7] *X* in equation (1) represents the set of control variables representing firm characteristics—Firm Age, Firm Size, Leverage, ROE, RD/Assets –and industry/year dummy variables. These variables are defined in the tables that have them.

[7] This type of firm corresponds to a firm that has one for variable "(1)×(2)" in Tables 5, 7, and 8. In unreported results, we also use the 5th or 15th percentile to define the NCNP firms. The results with respect to these different percentiles are qualitatively consistent with the results reported and are available on request.

To test Hypothesis 2, we estimate the following logit regression:

$$\textit{Divested Dummy}_i = 1[\rho_1 \textit{Centrality Measures (or Position)}_i + \rho_2 X + u_i > 0] \qquad (3)$$

where *Divested Dummy* is an indicator variable that takes the value of one if the firm is divested and zero otherwise. In order to examine the differences among the decisions on staying private, going public and being divested, we estimate the following multinomial logit regressions:

$$\mathrm{P}(y_i = k) = \frac{exp^{\beta_k \times Centrality\ Measures\ (or\ Position)_i + \rho_k \times X + u_i}}{\sum_{j=0}^{J} exp^{\beta_j \times Centrality\ Measures\ (or\ Position)_i + \rho_j \times X + u_i}} \qquad (14)$$

where j is equal to zero if a firm stays private, one if a firm went public, and two if a firm was divested.

Finally, we investigate how going public impacts a firm's centrality or Position, by estimating the following fixed effects panel regressions:

$$\textit{Centrality Measures (or Position)}_i = \rho_1 \textit{After IPO Dummy}_i + \rho_2 X + u_i \qquad (15)$$

In this regression, we include listed firms only and use only 2,825 firm-year observations. *After IPO Dummy* is equal to one for firm-years after IPO and zero, otherwise.

4. Empirical Results

4.1. Centrality and Going Public Decisions

As pointed out by Almeida et al. (2011), a controlling family has an incentive to share the ownership of the family firm with outside shareholders because family firms tend to be discounted due to high likelihood of value-destroying investments into their subsidiaries. We hypothesize that high centrality firms are more likely to go public because they have greater external financing needs to expand and grow their group.

[Insert Table 4 around here]

We test Hypothesis 1 using a logit regression with the listing dummy as its dependent variable where the listing dummy takes the value of one for listed firms and zero otherwise. As motivated earlier, we expect going public to be more likely for more central firms—firms with higher ODC, OKatz, and Hub or firms with lower IDC, IKatz, and Authority. The coefficients for all the centrality variables are signed consistently with Hypothesis 1: A positive (negative) sign for ODC, OKatz, and Hub (IDC, IKatz, Authority, and Position). These centrality variables are all significant at the 1% level. Firms with high IDC, IKatz, and Authority may not need any significant financial injection because these metrics capture the degree of investments into them by other group firms. Therefore, these firms are less likely to go public to raise capital. These results are consistent with Brau and Fawcett's (2006) findings that central firms—that have strong incentive to expand their groups through acquisitions—go public to facilitate acquisitions, and with Masulis et al.'s (2017) findings that financing needs of non-central firms are more likely to be relieved by their internal capital markets. The control variables representing firm characteristics suggest that going public is more likely when the firm is older, greater in size, and less levered, and invests intensively in R&D (research and development).

[Insert Table 5 around here]

We test the second hypothesis in Table 5 that shows the results for the same question as in Table 4 with focus centered on directly owned (NCNP) firms. We use the same dependent variable—listing dummy—as in Table 4. We create two indicator variables. *ODC, OKatz, or Hub=0* is an indicator variable that takes the value of one if a centrality measure is zero and zero otherwise. The centrality measure for this variable is ODC for Model (1), OKatz for Model (2), and Hub for Model (3). *IDC, IKatz, or Authority<P10* is an indicator variable that takes the value of one if a centrality measure is within the smallest 10th percentile and zero otherwise. The centrality measure for this variable is IDC for Model (1), IKatz for Model (2), and Authority for Model (3). The interaction variable of these two indicator variables, *(1)×(2)*, represents firms directly owned by the controlling family (NCNP firms in Hypothesis 2).

One of the reasons that the controlling families of chaebols can completely control other group firms with exceptionally low ownership is through interlocking ownership or cross-holdings, which shield the family from outside takeover threats (Joh, 2003). The interaction variable, *(1)×(2)*, to an extent captures the degree of interlocking ownership because social network metrics that we use are *directional*. Therefore, this variable should be very interesting and informative. Other reasons include highly dispersed ownership with almost uniformly atomistic ownership, virtual non-existence of monitoring by institutional investors with high ownership, and the shadow voting rule[8] that limits shareholders from being active on the corporate financial decisions.

The coefficient of *(1)×(2)* is significantly negative, suggesting that firms directly owned by the controlling family are less likely to go public. These firms do not need external financing because they are relatively smaller firms that usually do not invest in other subsidiaries. Also, according to Almeida et al. (2011), these firms have high pledgeable income and were acquired horizontally by the controlling

[8] The shadow voting rule allows the Korean Securities Depository (KSD) to exercise proxy voting in proposition to the pro and con ratio realized at the shareholders' meeting at the request of issuing firms. The objective of this rule is to prohibit the possibility of the shareholders' meeting being failed due to the insufficient number of shareholders present at the meeting. According to the Financial Investment Business and Capital Markets Act in Korea, this rule is no longer in practice from January, 2015.

family, suggesting that the controlling family may not want to share ownership with external shareholders. The control variables are signed qualitatively the same as in Table 4.

4.2. Centrality and Decisions on Divesture

[Insert Table 6 around here]

We test Hypothesis 3 in Table 6 using a logit regression with the divested dummy as its dependent variable where the dummy takes the value of one if a firm is divested and zero otherwise. The table shows that firms with higher ODC, OKatz and Hub are less likely to be divested. Since central firms hold stakes in many other subsidiaries in the pyramidal structure, the controlling family may not want to sell them off in order to retain control rights built over time. The coefficient for Position tells the same story that being divested is less likely when the firm is more central given that Position is close to (greater than and farther from) one when a firm is more (less) central. Firms invested by other subsidiaries—i.e., firms with high IDC and IKatz—are more likely to be divested. The coefficient for Authority is positive but insignificant. Overall, results are consistent with Hypothesis 3. Non-central firms placed in the lower tiers in the pyramidal structure are smaller and subject to misvaluation, with no complexity in terms of control rights, while a divestiture of the central firm means the whole loss of control rights not only of the divested firm but also of all the firms under the control umbrella of the divested firm. Divesting a poorly performing non-central firm would mitigate misvaluation (Nanda and Narayanan, 1999; and Krishnaswami and Subramaniam, 1000) and curtail any further loss.

4.3. Multinomial Logit Analysis: Stay Private, Go Public, or Be Divested

[Insert Table 7 around here]

From this section, we examine the hypotheses in the multinomial logit and panel regression frameworks. First, we run a multinomial logit regression with three outcomes: 1) the firm stays private 1) the firm goes public, and 3) the firm is divested. We use the first outcome (private) as the baseline outcome first in Models (1) and (2), and then use the last outcome (divested) in Model (3) to consider all possible combinations of the outcomes. In Panel A, we use the first set of centrality metrics—ODC and IDC—as the key independent variables. To conserve space, Panel B reports the coefficients of the other centrality metrics only with the same specifications as in Panel A.

In Panel A of Table 7, the coefficients for ODC are positive in Model (1) and negative for Models (2) and (3). Firms with high centrality measured by ODC—firms with a high ODC—are more likely to go public than to stay private or to be divested. There is no significant difference between staying private and being divested. Firms invested by other subsidiaries—firms with a high IDC—are less likely to go public than to stay private or to be divested. As shown in Panel B, we have the qualitatively same results with the same signs and statistical significance when we use Katz centrality or Hub/Authority instead of ODC/IDC. Firms with a high Position, i.e., more distant from the controlling family in the pyramidal structure, are less likely to go public but more likely to be divested compared to going public.

[Insert Table 8 around here]

To direct our attention to the firms directly owned by family firms (NCNP firms), we create two indicator variables and one interaction variable of them. *ODC=0* is an indicator variable that takes the value of one if the ODC score is zero and zero otherwise. *IDC<P10* is an indicator variable that takes the value of one if the IDC score falls in the smallest 10th percentile and zero otherwise. We label these two variables (1) and (2) to create an interaction variable of the two, *(1)×(2).* We identify firms with one for *(1)×(2)* as NCNP firms. These firms are directly owned by the controlling family (IDC<P10) and with no ownership links to other subsidiaries (ODC=0). Panel A reports the results using the ODC- and IDC-based variables while Panel B using the other two sets of centrality metrics with the same construction of the indicator and interaction variables. To conserve space as in the previous table, we report the coefficients of *(1)×(2)* only in Panel B with the same specifications as in Panel A.

In Panel A, the coefficients for *(1)×(2)* are all negative in Models (1) through (3). These results in Models (1) and (2) suggest that the directly owned firms are less likely to go public and to be divested than to staying private. Model (3) result indicates that these firms are also less likely to be divested than to go public. Results in Panel A based on ODC and IDC are consistent with the results based on other centrality counterparts in Panel B.

[Insert Table 9 around here]

One may be interested how centrality evolves around the public sale of the ownership. As an additional quest to our main agenda, we further examine the changes of the centrality metrics after the IPO. We add an additional control variable, KOSPI (Korean Composite Stock Price Index) dummy because going public involves listing in a specific market. It is an indicator variable that takes the value of one if a firm is listed in the KOSPI Market Division and zero otherwise. Korean Exchange (KRX) has three divisions: KOSPI Market Division, KOSDAQ (Korean Securities Dealers Automated Quotations) Market Division, and Derivatives Market Division. The KOSPI Market Division is equivalent to NYSE (New York Stock Exchange); the KOSDAQ Market Division to NASDAQ (National Association of Securities Dealers Automated Quotations) in the U.S. We use clustered robust standard errors in order to control for heteroscedasticity and autocorrelation in the fixed effects regressions.

In Table 9, we run a fixed effects regression to estimate the changes in centrality measures after the IPO. The fixed effects model ensures that our results are driven by the differences in our variables of interest rather than other unobserved firm characteristics that may be correlated with these key variables. The table shows that there is no significant difference in firm centrality between before and after IPO based on ODC, OKatz, Hub, and Position. However, we find significant and negative coefficients for IDC, IKatz, and Authority suggesting that firms are less likely to be invested by other subsidiaries after IPO. One possible explanation is that the IPO enables firms themselves to raise funds in the stock market when they need to. A direct inference based on the CFO survey results by Brau and Fawcett (2006) is that IPO firms are more likely to invest in other firms than to be invested because the main motive for going public is to facilitate acquisition dominantly as an acquirer.

4. Summary and Conclusions

Almeida et al. (2011) show how chaebols are formed and structured using centrality metrics. This paper introduces centrality metrics from the social network theory into the context of the organizational structure of a business group and explores how chaebols make corporate governance decisions—going public, staying private, and being divested—in terms of centrality metrics adopted. We use 14,923 firm-year ownership observations from 2002 to 2016 to examine our hypothesis.

First, we find that firms with high centrality are more likely to go public. As motivated in the hypothesis section, central firms have a stronger incentive to go public in order to raise capital, to facilitate acquisitions, and to share costs borne for expansion and private benefits with other shareholders. Second, firms with low centrality are more likely to stay private or be divested. Specifically, firms invested by other group firms tend to stay private and firms with no substantial equity stake in other group firms tend to be divested. Firms prone to divestiture are small in size and have low income pledgeability and higher likelihood of misvaluation, which makes divestiture a rational choice. Firms directly owned by the control family tend to stay private. This is not surprising given Almeida et al.'s (2001) findings that family firms directly own firms with high income pledgeability. The family would want to capture all the benefits instead of sharing them with other shareholders. In view of control rights, divesting a central firm is too costly since it deprives complete control for all the firms under the control umbrella while divesting a low tier firm loses control in that firm only. As an additional test, we examine whether and how centrality changes after going public. The investment into these IPO firms by other group firms appear to be decreased, based on our metrics. Public firms can tap the stock market when they have financing needs, which consequently leads to less reliance on internal capital markets.

The social network metrics newly adopted in this paper in order to estimate the centrality of chaebol subsidiaries have a strong advantage over other measures such as the discrepancy between cash flow and control rights and CCC. Therefore, we believe that our social network metrics can serve as alternative measures for investigating the complex ownership structure of large business groups. This study calibrates centrality based on the social network theory and shows how Korean chaebol system evolves for survival and prosperity. We believe that our social network metrics can be applied to address a substantial amount of issues to broaden our understanding of general corporate governance and financial decisions of large business groups such as board independence, investment efficiency, dividend policies, among others, which we leave for future studies.

Appendix: Example of Social Network Metrics Construction

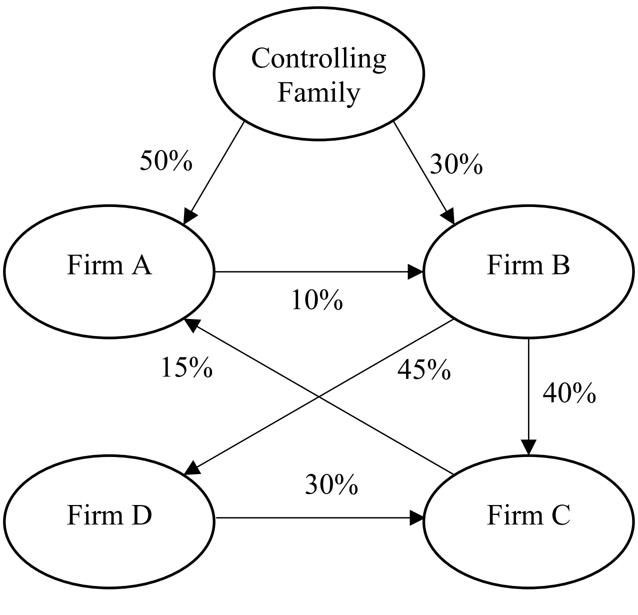
In this Appendix, we describe how we develop each of social network metrics using a simple ownership structure. A simplified example of the ownership structure is illustrated in Table A1:

Table A1. Simple Ownership Structure for Exercise

Order	Shareholder	Issuing Firm	Ownership
1	Founder	Firm A	30%
2	Family	Firm A	20%
3	Firm C	Firm A	15%
4	Founder	Firm B	25%
5	Non-profit Foundation	Firm B	3%
6	Executives	Firm B	2%
7	Firm A	Firm B	10%
8	Firm B	Firm C	40%
9	Firm D	Firm C	30%
10	Firm B	Firm D	45%

The ownership structure in Table 1A can be graphically described as the ownership network. As follows:

Figure A1. Ownership Network



The controlling family includes the founder, family, non-profit foundation and executives. The ownership of the controlling family in Firm A, for example, is 50%; 30% by the founder and 20% by the family. The ownership of the controlling family in Firm B is 30%, which includes 25% by the founder, 3% by the non-profit foundation, and 2% by the executives.

In the network diagram above, we define $s_{i,j}$ as the share ownership of Firm i on Firm j. For instance, s_{CA} represents that Firm C owns 15% of Firm A's shares. Based on the ownership network, we construct the adjacency matrix, $\mathrm{A} = (a_{ij})$, and the network matrix, $\mathrm{S} = (s_{ij})$. For the adjacency matrix, $A = (a_{ij})$, a_{ij} is equal to 1 if $s_{i,j}$ is non-zero, otherwise zero. Using the ownership network in Figure A1, Matrices *A* and *S* are calculated as follows;

$$\mathrm{A} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}, \mathrm{S} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0.5 & 0 & 0 & 0.15 & 0 \\ 0.3 & 0.1 & 0 & 0 & 0 \\ 0 & 0 & 0.4 & 0 & 0.3 \\ 0 & 0 & 0.45 & 0 & 0 \end{bmatrix}$$

Using the adjacency matrix and ownership matrix calculated above, we calculate *degree centrality, Katz centrality* and *Hub/Authority centrality*. To calculate *degree centrality*, we solve Equation (1), while Equations (3) and (4) are employed to calculate *Katz degree*. In Equation (4), we set $\alpha = \frac{1}{1+\max_i \max\{e^T S_{i.}, S_{i.} e\}} = 1.85$, so that the inverse matrix of $(\mathrm{I} - \alpha S^T)$ is always present. For example, *degree centrality* and *Katz centrality* of Firm B are obtained as follows;

$$\mathrm{Deg}_S(B) = e^T S_{\cdot\mathrm{B}} = [1\ 1\ 1\ 1\ 1] \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0.4 \\ 0.45 \end{bmatrix} = 0.85$$

$$\mathrm{Katz}_S(B) = e_B{}^T (\mathrm{I} - \alpha S^T)^{-1} e = [0\ 0\ 1\ 0\ 0] \left[A - (\frac{1}{1.85}) \times S\right]^{-1} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \approx 1.523$$

Equations (7) and (8) are employed to calculate *Hub/Authority centrality*. As in Equation (7), *Authority centrality* is defined as the eigenvector with the highest eigenvalue among the eigenvectors of SS^T. We use *eigs()*—a function provided by MATLAB—to earn the eigenvector, *u*, that includes the highest eigenvalue.

$$u^T = [0.4078\ \ 0.3593\ \ 0.0447\ \ 0.01432\ \ 0]$$

Thus, Hub and Authority centrality of Firm B, $\mathrm{Authority}_S(B)$ and $\mathrm{Hub}_S(B)$, can be calculated as follows;

$\text{Authority}_S(B) = e_B{}^T u = 0.0447$

$\text{Hub}_S(B) = e_B{}^T \text{S}^T u = 0.0053$

Through the procedure discussed above, degree centrality, Katz centrality and Hub/Authority centrality of each firm can be obtained, as reported in Table A2.

Table A2. Calculated Social Network Metrics

Firm	Deg_s	Katz_s	Authority_s	Hub_s
A	0.10	1.0822	0.3593	0.0045
B	0.85	1.5213	0.0447	0.0053
C	0.15	1.0877	0.0132	0.0539
D	0.30	1.1176	0	0.0040

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Figure 1. Pyramid Ownership of the Samsung Group in 2016

The figure graphically shows the ownership structure of Samsung using the 2016 data. For illustration purpose and brevity, we include 21 out of 68 subsidiaries of Samsung in the diagram. The summary of the centrality measures for the firms below is shown in Table 1.

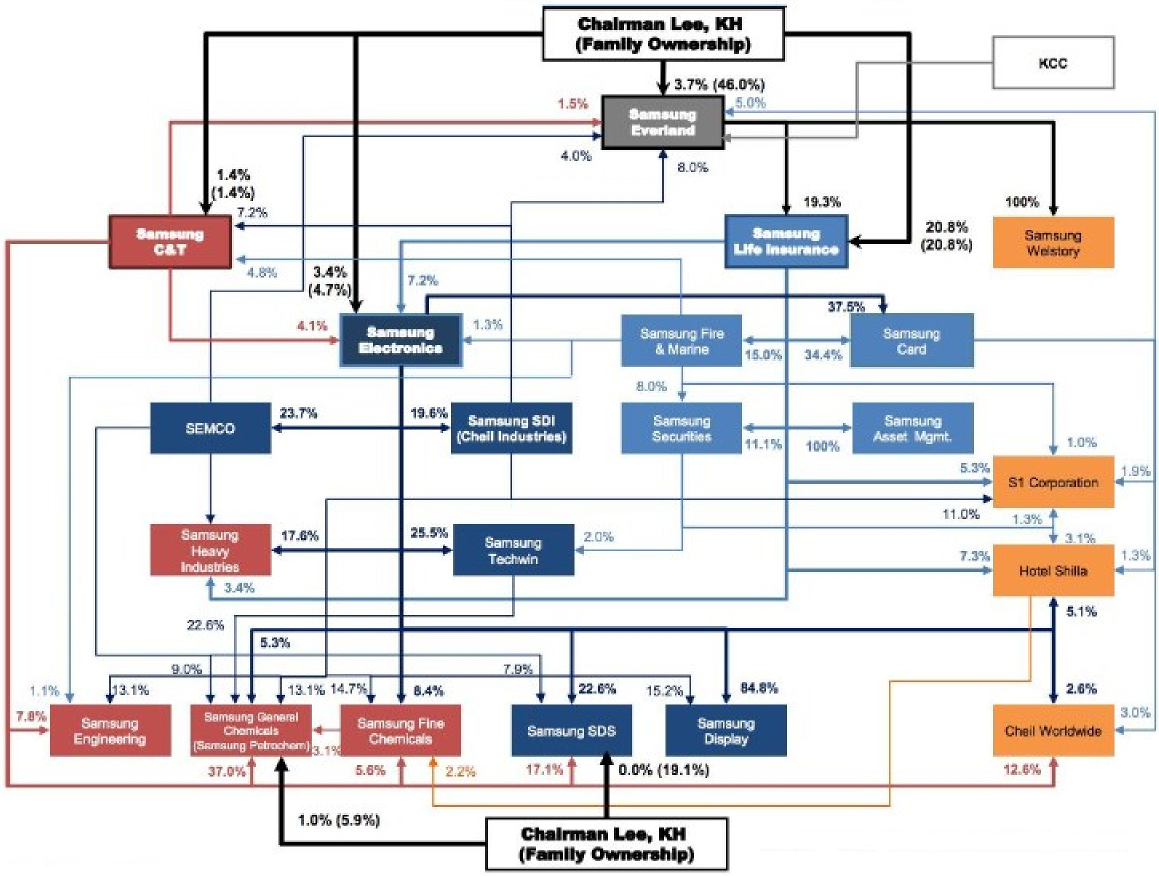

Figure 2. Frequency of ODC, OKatz, and Hub

This figure shows the frequency distributions of three social network centrality measures that predict the same direction as centrality increases. Y-axis is the number of observations and x-axis is the value of these metrics. ODC is out-degree centrality; OKatz is out-degree Katz centrality; These measures are discussed in section 2.2.

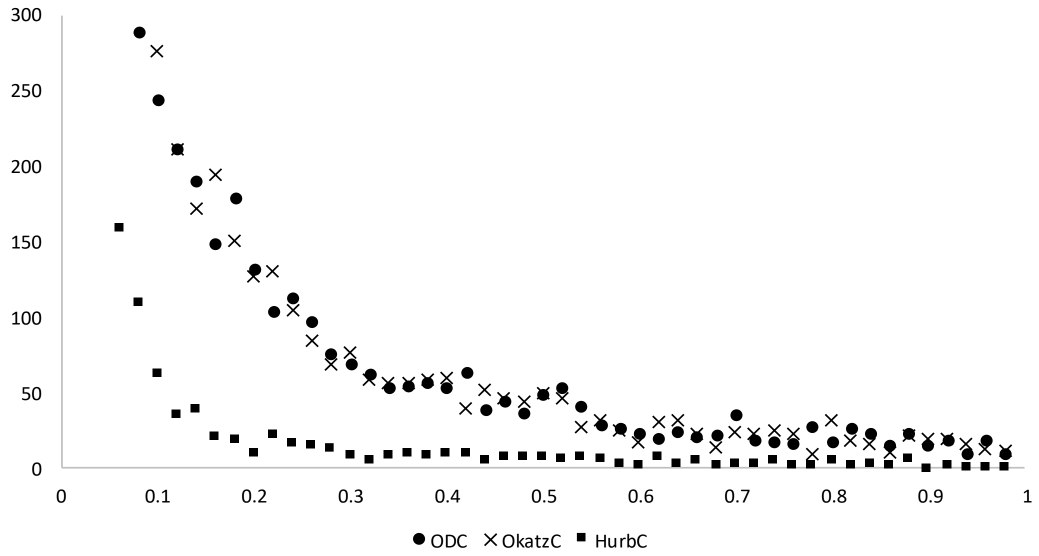

Figure 3. Frequency of IDC, IKatz, and Authority

This figure shows the frequency distributions of three social network centrality measures that predict the same direction as centrality increases. Y-axis is the number of observations and x-axis is the value of these metrics. IDC is in-degree centrality; IKatz is in-degree Katz centrality; These measures are discussed in section 2.2.

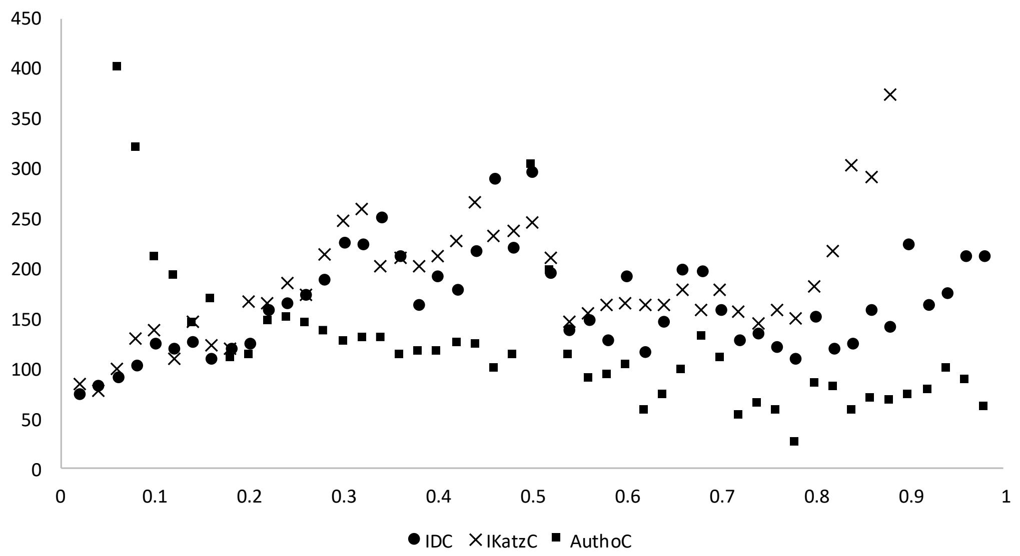

Table 1. Centrality Metrics of Samsung Subsidiaries in Year 2016

The table shows the values of our measures for centrality using the 18 subsidiaries of the Samsung group in year 2016 (See Figure 1). For illustration purpose and brevity, we show only 18 out of 68 subsidiaries of Samsung in this table. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality; CCC is critical control threshold centrality developed by Almeida et al. (2011). All the measures in this table are discussed in section 2.2. All these centrality numbers are calculated using the 2016 data only for illustration purpose.

Company Name	ODC	IDC	OKatz	IKatz	Authority	Hub	CCC	Position
Samsung SDS	0.47	0.47	0.445	0.44	0.273	0.01	0.2	1.406
Samsung Electronics	1	0.03	1	0.03	0.017	1	0.61	1.565
Samsung C&T	0.82	0.34	0.818	0.3	0.007	0.27	0.88	1.018
Samsung Life	0.73	0.42	0.726	0.39	0.061	0.05	1	1.217
SEMCO	0.06	0.08	0.058	0.07	0.243	0.02	0	2.547
Samsung Heavy	0.15	0.12	0.139	0.11	0.202	0.01	0.06	2.423
Samsung Biologics	0.11	0.97	0.107	0.92	0.603	0	0.06	2.13
Samsung Engineering	0	0.03	0	0.03	0.027	0	0	1.751
Samsung F&M	0.26	0.05	0.255	0.05	0.009	0	0.17	1.761
Samsung Securities	0.15	0.05	0.143	0.05	0.006	0.01	0.05	2.245
Cheil Worldwide	0.22	0.18	0.209	0.17	0.181	0	0.06	2.263
Samsung BioEpia	0	0.89	0	0.92	0	0	0	3.13
Samsung Display	0.12	1	0.117	0.93	0.858	0	0.06	2.591
Hotel Shila	0.18	0	0.176	0	0.058	0	0.05	2.399
S1	0.24	0.07	0.228	0.06	0.012	0	0.06	2.514
Samsung Asset Mgt	0	0.99	0	0.96	0.045	0	0	2.217
Samsung SDI	0.42	0.03	0.405	0.03	0.196	0.07	0.16	2.122
Samsung Card	0.17	0.66	0.162	0.64	0.033	0.01	0.08	2.216

Table 2. Correlations between Ownership Measures

This table shows the correlation coefficients among our centrality measures including the most frequently used measure, discrepancy between cash flow rights and control rights. We denote this discrepancy as DCVR. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality; CCC is critical control threshold centrality developed by Almeida et al. (2011). All the measures in this table are discussed in section 2.2. Our sample include a total of 14,923 firm-year observations from 2002 to 2016.

	DCVR	CCC	ODC	IDC	Okatz	IKatz	Hub	Authority	Position
DCVR	1								
CCC	-0.33	1							
ODC	-0.3	0.81	1						
IDC	0.52	-0.27	-0.33	1					
Okatz	-0.31	0.83	1	-0.33	1				
IKatz	0.53	-0.29	-0.35	0.99	-0.35	1			
Hub	-0.25	0.67	0.77	-0.24	0.77	-0.25	1		
Authority	0.08	-0.09	-0.11	0.3	-0.12	0.28	-0.07	1	
Position	0.52	-0.33	-0.27	0.12	-0.27	0.17	-0.22	-0.19	1

Table 3. Distribution of Centrality and Position

This table shows means and medians of our social network centrality metrics for all firm-year observations in Panel A, public vs. private observations in Panel B, and divested vs. non-divested observations in Panel C. Our sample include a total of 14,923 firm-year observations from 2002 to 2016. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality. All the measures in this table are discussed in section 2.2.

Panel A: All Observations							
	Position	ODC	IDC	Okatz	IKatz	Hub	Authority
N	14,923						
Mean	2.346	0.099	0.7	0.099	0.661	0.048	0.284
Median	2.203	0	0.865	0	0.805	0	0.045

Panel B: Public vs. Private							
	Before going public						
N	552						
Mean	2.033	0.17	0.643	0.168	0.608	0.077	0.322
Median	2.022	0	0.712	0	0.665	0	0.231
	After going public						
N	2,331						
Mean	1.879	0.371	0.307	0.373	0.286	0.208	0.154
Median	1.940	0.223	0.284	0.215	0.262	0.002	0.035
	Private						
N	12,040						
Mean	2.452	0.042	0.778	0.042	0.736	0.015	0.307
Median	2.341	0	0.997	0	0.886	0	0.045

Panel C: Divested vs. Non-Divested							
	Divested						
N	1,533						
Mean	2.47	0.052	0.799	0.052	0.650	0.002	0.281
Median	2.40	0	0.993	0	0.775	0	0.039
	Non-Divested						
N	13,390						
Mean	2.332	0.104	0.688	0.104	0.758	0.051	0.285
Median	2.181	0	0.840	0	0.902	0	0.046

Table 4. Going Public Decision and Centrality

The table presents logit regression results with a listing dummy variable as its dependent variable where the listing dummy takes the value of one for listed firms and zero otherwise. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality. These measures are discussed in section 2.2. Firm Age is the natural logarithm of age, difference in years between current and founded year. Firm Size is the natural logarithm of total assets. Leverage is the ratio of total liabilities to total assets. ROE is the return on equity defined as net income divided by shareholders equity. RD/Assets is the ratio of R&D expenditures to total assets. Industry and year dummies are included but their coefficients are not reported to conserve space. The *z* statistics reported in brackets use White (1980) robust standard errors. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Logit Regressions								
	Dependent Variable = 1 if listed or =0, otherwise							
	Model (1)		Model (2)		Model (3)		Model (4)	
ODC	1.241	***						
	[9.00]							
IDC	-3.397	***						
	[-8.20]							
OKatz			1.265	***				
			[9.09]					
IKatz			-3.519	***				
			[-29.16]					
Hub					0.691	***		
					[4.89]			
Authority					-1.256	***		
					[-13.02]			
Position							-0.478	***
							[-11.51]	
Firm Age	0.055	***	0.054	***	0.055	***	0.051	***
	[25.50]		[25.46]		[26.21]		[23.66]	
Firm Size	0.539	***	0.537	***	0.608	***	0.62	***
	[25.32]		[25.28]		[30.14]		[31.75]	
Leverage	-1.158	***	-1.152	***	-1.182	***	-1.131	***
	[-9.30]		[-9.25]		[-9.49]		[-9.20]	
ROE	-0.005		-0.005		-0.005		-0.006	
	[-0.52]		[-0.53]		[-0.59]		[-0.85]	
RD/Assets	4.851	***	4.864	***	4.722	***	4.538	***
	[3.04]		[3.03]		[3.17]		[3.24]	
Constant	278.449	***	277.279	***	275.745	***	266.068	***
	[18.40]		[18.34]		[18.27]		[17.50]	
	Industry and year dummies included							
No of Observations	9,033		9,033		9,033		9,033	
Wald test	2190.21		2185.47		2219.1		2212.29	
Pseudo R^2	0.408		0.408		0.402		0.413	

Table 5. Going Public Decision of Directly Owned Firms

The table presents logit regression results with a listing dummy variable as its dependent variable where the listing dummy takes the value of one for listed firms and zero otherwise. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality. These measures are discussed in section 2.2. *ODC, OKatz, or Hub=0* is an indicator variable that takes the value of one if a centrality measure is zero and zero otherwise. The centrality measure for this variable is ODC for Model (1), OKatz for Model (2), and Hub for Model (3). *IDC, IKatz, or Authority<P10* is an indicator variable that takes the value of one if a centrality measure is within the smallest 10th percentile and zero otherwise. The centrality measure for this variable is IDC for Model (1), IKatz for Model (2), and Authority for Model (3). The interaction variable of these two indicator variables, *(1)*(2)*, represents firms directly owned by the controlling family. Firm Age is the natural logarithm of age, difference in years between current and founded year. Firm Size is the natural logarithm of total assets. Leverage is the ratio of total liabilities to total assets. ROE is the return on equity defined as net income divided by shareholders equity. RD/Assets is the ratio of R&D expenditures to total assets. Industry and year dummies are included but their coefficients are not reported to conserve space. The *z* statistics reported in brackets use White (1980) robust standard errors. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Logit Regressions

Dependent Variable = 1 if listed or =0, otherwise

	Model (1)		Model (2)		Model (3)	
Centrality Measures:	ODC/IDC		OKatz/IKatz		Hub/Authority	
(1)×(2)	-1.229	***	-1.246	***	-0.423	**
	[-7.18]		[-7.17]		[-2.06]	
ODC, OKatz, or Hub =0 (1)	-0.706	***	-0.704	***	-0.677	***
	[-13.11]		[-13.09]		[-12.32]	
IDC, IKatz, or Authority<P10 (2)	1.75	***	1.797	***	0.443	**
	[14.04]		[14.21]		[2.27]	
Firm Age	0.028	***	0.027	***	0.03	***
	[16.89]		[16.70]		[18.83]	
Firm Size	0.18	***	0.18	***	0.25	***
	[12.22]		[12.20]		[17.80]	
Leverage	-0.209	**	-0.211	**	-0.255	**
	[-2.06]		[-2.07]		[-2.43]	
ROE	-0.004		-0.004		-0.004	
	[-0.68]		[-0.67]		[-0.70]	
RD/Assets	2.686	**	2.678	**	2.701	**
	[2.40]		[2.40]		[2.44]	
Constant	-5.258	***	-5.257	***	-6.912	***
	[-13.49]		[-13.45]		[-18.64]	
Industry and year dummies included						
No of Observations	9,033		9,033		9,033	
Wald test	1808.29		1809.44		1770.9	
Pseudo R^2	0.183		0.184		0.158	

Table 6. Decision on Divesture and Centrality

The table presents logit regression results with a divested dummy variable as its dependent variable where the dummy variable takes the value of one when a firm is divested during our sample period and zero otherwise. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality. These measures are discussed in section 2.2. Firm Age is the natural logarithm of age, difference in years between current and founded year. Firm Size is the natural logarithm of total assets. Leverage is the ratio of total liabilities to total assets. ROE is the return on equity defined as net income divided by shareholders equity. RD/Assets is the ratio of R&D expenditures to total assets. Industry and year dummies are included but their coefficients are not reported to conserve space. The *z* statistics reported in brackets use White (1980) robust standard errors. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Logit Regressions Dependent Variable = 1 if divested and 0 otherwise								
	Model (1)		Model (2)		Model (3)		Model (4)	
ODC	-1.224	***						
	[-6.08]							
IDC	[1.30]	***						
	[11.42]							
OKatz			-1.286	***				
			[-6.37]					
IKatz			[1.40]	***				
			[11.58]					
Hub					-1.176	***		
					[-5.03]			
Authority	-0.145	*	-0.148	*	-0.121			
	[-1.74]		[-1.79]		[-1.46]			
Position							0.19	***
							[5.62]	
Firm Age	-0.011	***	-0.011	***	-0.012	***	-0.012	***
	[-4.60]		[-4.53]		[-5.13]		[-4.84]	
Firm Size	-0.131	***	-0.129	***	-0.16	***	-0.172	***
	[-7.03]		[-6.94]		[-9.43]		[-10.45]	
Leverage	-0.032		-0.032		-0.032		-0.028	
	[-0.68]		[-0.67]		[-0.72]		[-0.68]	
ROE	-0.004		-0.004		-0.004		-0.003	
	[-0.38]		[-0.38]		[-0.37]		[-0.33]	
RD/Assets	-0.665		-0.671		-0.608		-0.176	
	[-0.52]		[-0.52]		[-0.48]		[-0.15]	
Constant	125.596	***	126.103	***	126.405	***	133.143	***
	[10.15]		[10.18]		[10.19]		[10.62]	
Industry and year dummies included								
No of Observations	10,449		10,449		10,449		10,449	
Wald test	396.76		397.37		399.95		415.21	
Pseudo R^2	0.047		0.047		0.045		0.046	

Table 7. Multinomial logit Regressions: Private, Public and Divested

This table reports the estimates of multinomial logit regressions that test a firm's financial decisions among three choices: staying private, going public, and being divested. In Panel B, we report the coefficients of other key centrality metrics with the same specifications as in Panel A to conserve space. The coefficients reported in this able show the effects of on the log-odds between each category and reference group. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality. These measures are discussed in section 2.2. Firm Age is the natural logarithm of age, difference in years between current and founded year. Firm Size is the natural logarithm of total assets. Leverage is the ratio of total liabilities to total assets. ROE is the return on equity defined as net income divided by shareholders equity. RD/Assets is the ratio of R&D expenditures to total assets. Industry and year dummies are included but their coefficients are not reported to conserve space. The *z* statistics reported in brackets use White (1980) robust standard errors. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: ODC and IDC

Multinomial Logit Regressions									
Reference Group:	Private						Public		
	Public			Divested			Divested		
	Model (1)			Model (2)			Model (3)		
ODC	1.394	[10.09]	***	-0.121	[-0.56]		-1.515	[-7.33]	***
IDC	-1.161	[-12.27]	***	-0.399	[-4.66]	***	0.762	[6.57]	***
Firm Age	0.054	[25.62]	***	0.006	[2.34]	**	-0.048	[-15.88]	***
Firm Size	0.526	[25.91]	***	-0.036	[-1.81]	*	-0.561	[-21.73]	***
Leverage	-1.064	[-8.99]	***	-0.052	[-0.59]		1.013	[7.45]	***
ROE	-0.003	[-0.55]		-0.005	[-0.45]		-0.001	[-0.12]	
RD/Assets	4.541	[3.51]	***	0.291	[0.20]		-4.250	[-2.80]	***
Constant	275.848	[18.29]	***	184.142	[14.05]	***	-91.706	[-5.25]	***
	Industry and year dummies included								
No of Observations	10,449								
Wald test	2,631.51								
Pseudo R^2	0.25								

Panel B: Coefficients for OKatz, IKatz, Hub, Authority, and Position Only

Reference Group:	Private						Public		
	Public			Divested			Divested		
	Model (1)			Model (2)			Model (3)		
OKatz	1.302	[8.60]	***	-0.060	[-0.28]		-1.362	[-6.12]	***
IKatz	-3.420	[-31.40]	***	0.437	[3.63]	***	3.858	[25.25]	***
Hub	0.792	[5.50]	***	-0.250	[-1.02]		-1.050	[-4.54]	***
Authority	-1.214	[-12.89]	***	-0.397	[-4.65]	***	0.818	[7.07]	***
Position	-0.457	[-11.42]	***	0.103	[3.03]	***	0.560	[11.54]	***

Table 8. Multinomial Logit Regressions: Directly Owned Firms

This table reports the estimates of multinomial logit regressions that test a firm's financial decisions among three choices: staying private, going public, and being divested. In Panel B, we report the coefficients of other key centrality metrics with the same specifications as in Panel A to conserve space. The coefficients reported in this able show the effects of on the log-odds between each category and reference group. ODC is out-degree centrality; IDC is in-degree centrality; OKatz is out-degree Katz centrality; IKatz is in-degree Katz centrality. *ODC=0* is an indicator variable that takes the value of one if ODC is zero and zero otherwise. *IDC<P10* is an indicator variable that takes the value of one if IDC is within the smallest 10th percentile and zero otherwise. The interaction variable of these two indicator variables, *(1)*(2)*, represents firms directly owned by the controlling family. These measures are discussed in section 2.2. Firm Age is the natural logarithm of age, difference in years between current and founded year. Firm Size is the natural logarithm of total assets. Leverage is the ratio of total liabilities to total assets. ROE is the return on equity defined as net income divided by shareholders equity. RD/Assets is the ratio of R&D expenditures to total assets. Industry and year dummies are included but their coefficients are not reported to conserve space. The *z* statistics reported in brackets use White (1980) robust standard errors. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: ODC and IDC

Multinomial Logit Regressions									
Reference Group:	Private						Public		
	Public			Divested			Divested		
	Model (1)			Model (2)			Model (3)		
(1)×(2)	-0.454	[-2.37]	**	-1.385	[-4.52]	***	-0.931	[-2.99]	***
ODC =0 (1)	-0.979	[-12.83]	***	-0.486	[-6.71]	***	0.443	[4.73]	***
IDC<P10 (2)	1.883	[14.15]	***	0.793	[3.98]	***	-1.09	[-6.03]	***
Firm Age	0.044	[21.01]	***	-0.002	[-0.58]		-0.046	[-15.07]	***
Firm Size	0.474	[23.23]	***	-0.114	[-5.93]	***	-0.588	[-23.63]	***
Leverage	-0.821	[-7.25]	***	0.057	[0.85]		0.764	[6.19]	***
ROE	0.003	[0.92]		-0.004	[-0.45]		-0.007	[-0.09]	
RD/Assets	4.756	[3.77]	***	0.522	[0.38]		-4.233	[-3.06]	***
Constant	-13.692	[-24.79]	***	1.745	[3.48]	**	15.437	[23.03]	***
	Industry and year dummies are included								
No. of Observations	10,449								
Wald test	2,383.13								
Pseudo R^2	0.24								

Panel B: OKatz, IKatz, Hub, Authority, and Position: Coefficients of (1) × (2) Only

Reference Group:	Private						Public		
	Public			Divested			Divested		
Coefficients of (1) × (2)	Model (1)			Model (2)			Model (3)		
OKatz / IKatz	-0.46	[-2.37]	**	-1.384	[-4.49]	***	-0.924	[-2.95]	***
Hub / Authority	-0.737	[-3.03]	***	-0.191	[-1.16]		-0.928	[-2.90]	***

Table 9. Changes of Centrality and Position after IPOs

The table shows the estimates of fixed effect model with our centrality metrics as its dependent variable. After IPO is an indicator variable that takes the value of one if the date of an observation is after the IPO and zero otherwise. Firm Age is the natural logarithm of age, difference in years between current and founded year. Firm Size is the natural logarithm of total assets. Leverage is the ratio of total liabilities to total assets. ROE is the return on equity defined as net income divided by shareholders equity. RD/Assets is the ratio of R&D expenditures to total assets. KOSPI (Korean Composite Stock Price Index) dummy is an indicator variable that takes the value of one if a firm is listed in the KOSPI Market Division and zero otherwise. Industry and year dummies are included but their coefficients are not reported to conserve space. The *t* statistics reported in brackets use clustered robust standard errors to control for heteroscedasticity and autocorrelation in the regressions. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Fixed Effects Regression							
Model	(1)	(2)	(3)	(4)	(5)	(6)	(6)
Dependent Variable:	ODC	IDC	OKatz	IKatz	Hub	Authority	Position
After IPO	-0.002	-0.165 ***	-0.004	-0.16 ***	0.016	-0.072 **	-0.032
	[-0.11]	[-5.10]	[-0.21]	[-5.28]	[1.03]	[-2.50]	[-0.68]
Firm Age	0.001	0.001	0.001	0.001	-0.001	-0.001 *	-0.004
	[1.11]	[1.18]	[1.13]	[0.93]	[-1.06]	[-1.74]	[-1.53]
Firm Size	0.047 ***	-0.031 ***	0.046 ***	-0.028 ***	0.02 **	-0.023 ***	0.054 **
	[4.31]	[-3.82]	[4.27]	[-3.77]	[2.37]	[-2.62]	[1.97]
Leverage	0.015	0.041	-0.007	0.056	0.031	0.03	0.042
	[0.32]	[0.87]	[-0.15]	[1.26]	[0.58]	[0.80]	[0.46]
ROE	-0.006 **	-0.004	-0.006 **	-0.004	-0.001	-0.001	0.004
	[-2.17]	[-1.50]	[-2.28]	[-1.41]	[-0.33]	[-0.30]	[0.53]
RD/Assets	-0.097	-0.274 ***	-0.107	-0.26 ***	-0.045	-0.093	0.007
	[-1.16]	[-2.93]	[-1.25]	[-2.80]	[-0.63]	[-0.86]	[0.02]
KOSPI Dummy	0.148 ***	-0.095 **	0.157 ***	-0.095 ***	0.157 ***	0.036	-0.335 ***
	[3.92]	[-2.39]	[4.18]	[-2.60]	[5.17]	[0.80]	[-2.85]
Constant	-1.149 ***	1.39 ***	-1.094 ***	1.28 ***	-0.493 **	0.876 ***	0.867
	[-4.30]	[6.83]	[-4.22]	[6.84]	[-2.45]	[3.83]	[1.31]
Industry and year dummies are included							
No. of Observations	2,825	2,825	2,825	2,825	2,825	2,825	2,824
Wald test	118.66	101.09	123.64	108.15	56.95	22.49	13.17
R^2	0.28	0.3	0.27	0.31	0.06	0.09	0.03