Boardroom Network and Corporate Governance: When Who You Know Contributes to What You Know

by

Inna Abramova
B.A., Lomonosov Moscow State University (2010)
M.A., New Economic School (2013)

Submitted to the MIT Sloan School of Management in partial fulfillment of the requirements for the degree of

Master of Science in Management Research

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2017

Signature of Author: Signature redacted
MIT Sloan School of Management
May 2, 2017

Certified by: Signature redacted
John E. Core
Nanyang Technological University Professor of Accounting
Thesis Supervisor

Certified by: Signature redacted
Rodrigo S. Verdi
Associate Professor of Accounting
Thesis Supervisor

Accepted by: Signature redacted
Catherine Tucker
Sloan Distinguished Professor of Management
Professor of Marketing
Chair, MIT Sloan Ph.D. Program

Boardroom Network and Corporate Governance:
When Who You Know Contributes to What You Know

by

Inna Abramova

Submitted to the MIT Sloan School of Management on May 10, 2017 in partial fulfillment of the requirements for the degree of Master of Science in Management Research

Abstract

In this study, I examine whether boardroom centrality has a causal effect on firm performance. If boardroom ties work as a conduit for information about market, industry, feedback on peers' experience, etc., then I expect central boards' corporate decisions to incorporate richer information and, as a result, become more efficient. Alternatively, if boardroom ties can put a firm at a disadvantage by disseminating proprietary information or conveying incorrect or misleading information, then I expect to find a deterioration in the central firms' performance. To isolate the effect of network centrality on the firm's performance, I use an instrumental variable approach based on director deaths at distant firms within the network. Contrary to the prevailing evidence in the literature, the results suggest that boardroom centrality deteriorates firm performance. To the best of my knowledge, this paper is the first to resolve the disagreement in the literature on the sign of the boardroom centrality effect on performance by using an exogenous setting that can rule out the selection and ability channels from the set of explanations for the results.

Thesis Supervisor: John E. Core
Title: Nanyang Technological University Professor of Accounting

Thesis Supervisor: Rodrigo S. Verdi
Title: Associate Professor of Accounting

Acknowledgements

I would like to thank my advisors John E. Core and Rodrigo S. Verdi for guidance, feedback, and suggestions on this paper. Furthermore, I appreciate helpful suggestions from Egor Abramov, Samuel G. Hanson, Jack Liebersohn, Andrey Malenko, Anton Petukhov, Adi Sunderam, Andrew Sutherland, Joe Weber, and participants of the seminar at MIT Sloan. I thank Adi Sunderam and Baker Library at Harvard for generously sharing the BoardEx data. I thank Hillary Ross for her continuous support as the program manager of the PhD program at the MIT Sloan School of Management.

1. Introduction

In this study, I investigate whether high boardroom centrality of a firm affects its corporate outcomes. In other words, I study whether the board's position in the boardroom network matters its performance. I construct a network in which two firms share a link only if there is a director serving on the boards of both firms and infer exogenous changes in a firm's centrality from deaths of directors that are distant from the firm in the boardroom network. Using these exogenous changes in boardroom network structure, I find that higher board's centrality deteriorates the firm's future performance.

Network ties between firms can work as a conduit for information about various aspects of the economy, including market and industry conditions, details about the experience with managerial and monitoring practices at other firms, professional contacts, as well as regulatory changes. This information exchange among firms likely affects central firms more because their position in the network increases their chances of receiving information that originates anywhere in the network. In other words, their centrality increases the speed of receiving information. Altogether, there are arguments for both positive and negative effects of these information transfers in the network on firm performance. Therefore, depending on whether positive or negative effects prevail, central firms can be at an advantage or a disadvantage respectively as compared to less central firms.

On the whole, there are at least two types of channels through which information flows in the boardroom network can affect the decision-making by board members. In the first type, network information flows in the information set on which a board bases its decisions. In the second type, information diffuses from the firm to the rest of the network and affects the firm's performance: a diffusion of the firm's proprietary information can lead to a loss of the corresponding economic benefit; and a diffusion of the information about the monitoring activities by the directors can influence their incentives through imposing reputational costs that affect the directors' labor market opportunities. As suggested below, both channels can contribute to both positive and negative effects of boardroom network centrality on firms' corporate outcomes.

On the positive side, central firms have richer information about market and industry conditions, experience with managerial and monitoring practices at other firms, professional contacts, regulatory changes, and so forth. The ability to incorporate this information into the boards' decision-making can facilitate better monitoring and, as a result, improve the firms' performance. In addition, directors on the boards of central firms can bear higher reputational risks, since the news about a monitoring failure would spread through the network faster for central firms and thus negatively affect their labor market opportunities. In turn, this can incentivize better monitoring by central boards and boost their performance. On the negative side, network connections can disseminate proprietary information or value-decreasing practices, thus contributing to a loss of economic benefit or inefficient monitoring by central firms. Moreover, the above mentioned reputational risks can turn out to be a double-edged sword, since in the case that CEOs play a crucial role in employment of directors, central directors might have higher incentives to appear as directors that don't cause too much trouble to a CEO.

The key challenge for this analysis is to find a setting with exogenous variation in firms' centralities. This would allow me to examine a causal effect of firms' position in the boardroom network on the quality of their corporate decisions, isolating the causal channel from the endogenous ones like a mere propensity of central directors to choose firms with good performance, or a tendency of highly skilled directors to be more central in the boardroom network. In both of the latter cases, a firm's centrality appears to affect its corporate outcomes, even though this is not the case. In addition, in both of the latter cases, there will be a positive bias in the findings. To the best of my knowledge, while a few papers emphasize the endogeneity concern in their analysis (with regard to performance, see Singh and Schonlau, 2009, Horton et al., 2012, Larcker et al., 2013, and Omer et al., 2013), none uses an exogenous setting that can rule out the described above selection and ability channels from the set of explanations for the changes in firm performance. Furthermore, in addition to the lack of causality in the existing research on this topic, the evidence on the relation between a firm's network centrality and its performance is controversial. Namely, some papers suggest a positive relation between centrality and performance (Singh and Schonlau, 2009, Horton et al., 2012, Larcker et al., 2013), while others find a negative one (Omer et al., 2013, Croci and Grassi, 2014).

To find the causal effect of directors' network centrality on the firm's performance, I use an instrumental variable approach. For my analysis of each firm's performance (subject firm), I look at shocks to its centrality caused by director deaths at firms distant from the subject firm in the boardroom network[1]. Intuitively, each director death exogenously removes the corresponding set of links from the network and thus changes the network structure. In turn, this change in the network structure implies a change in the subject firm's centrality, since

---

[1] I call a firm "distant" from the subject firm in the network if the boardroom distance between these two firms is at least two. In figure 2, I provide an example of a boardroom network and assume Procter & Gamble (P&G) to be the firm under the analysis (subject firm), meaning that I am interested in the effect of P&G's centrality on its performance. I classify the firms into five groups according to the boardroom distance from P&G. P&G is the only firm in group 0, since the boardroom distance from P&G to P&G is zero. Firms that share a director with P&G have a boardroom distance to P&G equal 1 and thus correspond to group 1. Firms that share a director with firms in group 1, but don't have a direct connection to P&G, have a boardroom distance to P&G equal 2 and thus are in group 2. The procedure is similar for firms at greater boardroom distance from P&G.

centrality factors in the whole network structure when characterizing the firm's network position. At the same time, because the death events I consider in the analysis take place at least two boardroom connections away from the subject firm, the corresponding changes in the network structure are plausibly exogenous with respect to the subject firm's performance.

Note that even though deaths are rare events, the instrument I construct provides a powerful identification, since I study the setting in which each director death affects the centralities of a majority of firms in the network.[2] For comparison, consider prior literature that exploits the exogenous nature of director deaths in the analysis. Fracassi and Tate (2012) study external CEO-director ties and look at each director death as a shock to firms at which these directors served. Given the relatively small number of death events, the number of firms affected by the shock is also moderate in Fracassi and Tate (2012). Falato et al. (2014) study busyness of directors serving on multiple boards and look at deaths of directors and CEOs as shocks to directly connected firms. The set of firms directly connected to the firms that experience a death on the board is also relatively small. In contrast, one director death in my setting affects a majority of firms in the network[3], and thus the variation produced by the instrument is strong. The results of the test for weak instruments confirm the strong first stage of the instrumental analysis.

By not factoring in director deaths at the subject firm's board itself, I rule out personal characteristics of the deceased directors as an explanation of changes in the subject firm's performance. Similarly, by excluding director deaths at firms directly connected to the subject

[2] To be more precise, for each year, I analyze firms in the largest connected component of the network (a subset of the network, such that for each two firms there is a sequence of boardroom links that connects the two firms). The focus on the largest connected component stems from some centrality measures being defined only for connected networks. In this setting, each director death on a board of a firm from the largest component changes centralities of every firm in the largest connected component of the network.

[3] Each director death affects every firm in the largest connected component.

firm, I rule out director workload effect studied in the busyness literature (Core et al., 1999, Ferris et al., 2003, Perry and Peyer, 2005, Fich and Shivdasani, 2006, Field et al., 2013, and Falato et al., 2014) from the set of potential explanations of changes in the subject firm's performance. Specifically, after a director death on a board of a firm directly connected to the subject firm, other directors serving on the boards of both firms can become busier as they compensate for the deceased director, which affects the performance of both firms.

I hypothesize that higher boardroom centrality affects the firm's performance, and, using the two-stage least squares analysis that employs exogenous variation in director deaths at distant firms in the network, I find that higher centrality deteriorates the firm's future performance. The results suggest that as a firm's centrality quintile rank increases by 1, its industry-adjusted performance decreases by 22-26% of the performance standard deviation over the two years following the centrality increase, depending on the centrality measure. This effect is not corrected over the next year, so that the three-year cumulative drop in performance has the same size. In other words, my results go against the prevalent evidence in the literature that centrality has a positive effect on performance.

The main contribution of this paper is the resolution of the disagreement in the literature on the sign of the network centrality effect on firm performance. While the prevailing evidence in the literature suggests the relation to be positive, I use the exogenous setting that isolates the causal effect of boardroom centrality on performance and show that centrality deteriorates future performance. Importantly, the instrument I suggest in this paper is useful for any study that employs network structure beyond direct ties, since it allows one to exogenously isolate the effects of changes in network structure on firms' characteristics.

The rest of the paper is organized as follows. Section 2 provides an overview of the related literature. Section 3 develops the hypothesis. Section 4 describes the sample. I outline the research design in section 5, provide results in section 6, and discuss robustness of my results in section 7. I conclude in Section 8.

2. Related Literature

This paper suggests an exogenous research design for the analysis of the effect of board of directors' centrality on corporate governance outcomes. The literature on centrality in the directorate network in relation to the CEO compensation and other corporate indicators is growing rapidly and embraces both the studies finding positive and negative effects of connectedness. The first group of papers emphasizes the informational role of the director network: Directors whose position in the network is central have a higher chances of receiving information generated anywhere in the network, or alternatively, well-connected directors can receive the information faster than poorly-connected ones. In turn, the capability to collect more information contributes to higher monitoring abilities of central directors.

In line with this argument, a number of papers find a positive association between measures of directors' centrality and corporate outcomes. Larcker et al. (2013) show that firms with central boards of directors have higher future return-on-assets growth and earn superior risk-adjusted returns. Moreover, the results in Larcker et al. (2013) are concentrated among firms for which the usefulness of information is the highest – firms with high growth opportunities and firms encountering adverse circumstances. Singh and Schonlau (2009) find that firms with central boards are associated with better performing acquisitions measured with larger post-merger buy-and-hold abnormal returns, stronger improvements in the return-on-assets, and positive annual abnormal returns. Intintoli et al. (2015) investigate how centralities of specific committees are related to corporate indicators and find that firms with well-connected audit committee have a higher quality of financial reporting, firms with well-connected compensation committee are less likely to overpay CEOs, and firms with well-connected boards have lower financing costs, higher payout ratios, and are able to shield themselves from a negative impact of competition shocks. Omer et al. (2016) suggests that firms with well-connected directors are less likely to misstate their annual financial statements, even when connected to another misstating firm. Renneboog and Zhao (2011) study firm-level networks of UK listed firms and find conflicting results for the relation between a firm's connectedness and CEO compensation level and pay-for-performance sensitivity depending on the measure of network centrality. Horton et al. (2012) suggest that better-connected executives and outside directors of UK listed firms are remunerated for their centrality and the aggregate centrality of these individuals provides useful resources to the firm improving the firm's future performance.

Contrary to the above papers finding positive association between board connectedness and firm performance, Omer et al. (2013) suggest that firms with more centrally positioned directors experience lower return-on-assets and Tobin's Q on average. One potential reason for the differences in the findings in Larcker et al. (2013) and Omer et al. (2013) relates to sample composition: the firms studied in Omer et al. (2013) are larger and older firms, which might benefit less from the information exchange facilitated in the network, while Larcker et al. (2013) suggest that the greatest benefits to connectedness are likely to accrue to younger growth firms. Croci and Grassi (2014) find a negative relationship between centrality and firm value, though the results are not robust to different measures of network connectedness. Feyen

(2014) studies firms in Netherlands and suggests that well-connectedness of individual directors and well-connectedness of the board affect returns differently, so boardroom networks simultaneously have distinct positive and negative effects on firm performance. Barnea and Guedj (2009) and Renneboog and Zhao (2011) show that well-connected directors are associated with higher CEO pay. I provide a brief description of the papers addressing the relation between directors' centrality and the firm's corporate outcomes in the following table:

Paper	Outcome Variable	Network Centrality Measure	Results	Sample
Barnea and Guedj *(WP, 2009)*	CEO Pay, Performance Sensitivity, Turnover; Future Directorships	Closeness	-	S&P 1500, 1996 - 2004
Croci and Grassi *(CMOT, 2014)*	M-to-B, ROA	Eigenvector	-	Italy, 2008
Feyen *(WP, 2014)*	Returns, Analyst Forecast Errors	Eigenvector	-/+	Netherlands, 2005 - 2011
Horton et al. *(JBFA, 2012)*	Returns, M-to-B, ROA, Director Compensation	Closeness, Dyadic Constraint	+	UK, 2000 - 2007
Intintoli et al. *(WP, 2015)*	Financial Reporting Quality, CEO Pay, Financing Costs, Response to Competition Shocks	Eigenvector, Closeness, Betweenness, Aggregation	+	US, 2001 - 2010
Larcker et al. *(JAE, 2013)*	Returns, ROA Growth, Analyst Forecast Errors	Eigenvector, Closeness, Betweenness, Aggregation	+	US, 2000 - 2007
Omer et al. *(WP, 2016)*	Probability of Earnings Misstatements, Operating Lease Error Misstatements	Eigenvector, Closeness, Betweenness, Aggregation	+	US, 2004 - 2011
Omer et al. *(WP, 2013)*	ROA, Tobin's Q	Eigenvector, Closeness, Betweenness, Aggregation	- (*)	US, 2000 - 2010
Renneboog & Zhao *(JCF, 2011)*	CEO Pay, Performance Sensitivity	Eigenvector, Closeness	-/+	UK, 1996 - 2007
Singh & Schonlau *(WP, 2009)*	Returns, Post-merger Returns, ROA	Eigenvector, Reach	+	US, 1991 - 2005

JCF, JBFA, CMOT denote J. of Corp. Fin., J. of Business Fin. & Account., Comp. Mathem. Organiz. Theory, respectively. Results are denoted "+" if better corp. governance, "" - if the results aren't fully consistent, and "-/+" - if both positive and negative.*

One drawback of the research on the association between directors' centrality and corporate governance indicators is its inability to provide a reliable evidence of entrality, as opposed to other factors like higher or lower abilities of better-connected directors, causing the changes in the corporate governance outcomes. For example, Intintoli et al. (2015) perform propensity-matching with firm fixed effects estimations, which might help with selection concerns, but don't mitigate the concerns about the abilities of directors as an explanation for their results. In addition, Intintoli et al. (2015) use proportion of audit committee with undergraduate or MBA degree from a top university as an instrument in their analysis. However, holding such a diploma has at least two channels affecting the governance outcomes: increased connectedness and better knowledge of the graduates. Thus, this instrument does not pass the exclusion restriction and cannot rule out the abilities-based explanation for the results. Intintoli et al. (2015) also conduct changes-specification test with deaths of directors on the board. This cannot rule out the abilities-based explanation either, because after the death the board does not have the abilities of the director at its disposal when making decisions, which might result in weaker governance outcomes. That is why in my research design I only factor in deaths at distant firms in the network.

Omer et al. (2013) and Omer et al. (2016) use industry average connectedness as an instrument for the board's connectedness. Since some industries require more talent than others, a higher average industry connectedness might stem from higher-ability directors in this industry. Singh and Schonlau (2009) use a bidder's centrality three years prior to the merger as an instrument for its connectedness in the year prior to the merger. Given that the three-year lag of the bidder's connectedness can still pick up the directors' abilities, it is possible that abilities and not well-connectedness affect the performance of the mergers. Renneboog and Zhao (2011) use board size and CEO's honorary title as an instrument for the board connectedness in estimating the effect of connectedness on the CEO compensation. This instrument does not isolate the effect of network centrality either. Horton et al. (2012) include the lagged firm performance indicators in their specification in order to control for the endogeneity of the firm's selection process, though it does not mitigate concerns regarding the abilities-based explanation for the results. Barnea and Guedj (2009) control for firm and CEO fixed effect, run between-estimations, Fama and Macbeth (1973) regression, use changes-on-changes specification, and proxy for CEO ability. None of these approaches can rule out director abilities as an explanation for the results.

Overall, this paper reconciles the contradicting findings in the literature regarding the effect of boardroom centrality on firm performance and shows that centrality deteriorates firm future performance. The research design in this paper isolates changes in boardroom centrality from the characteristics of the directors on the board. Therefore, this paper contributes to the literature by being the first to perform a causal analysis of the effect of centrality on corporate governance outcomes. While a number of studies look at different types of corporate governance indicators in relation to firm centrality, these papers provide an insight into the range of the effects associated with board centrality rather than shed light on the source of the effect.

3. Hypothesis Development

In this section, I develop my hypothesis regarding the implications of a board's centrality for the firm's performance. In what follows, I argue that there are both positive and negative effects on firm performance caused by boardroom network centrality.

Firms with central boards have higher chances of getting information from anywhere in the network, and are able to receive this information faster than poorly-connected peers. Central boards' rich information environment can incorporate details that are valuable for different aspects of decision-making. For example, general market and industry information can improve the board's forecasting ability and correct the estimates used to evaluate potential projects and perspectives on its business strategy. As a result, the firm's performance can improve.

At the same time, central boards can have an advantage in receiving specific information about network members' projects, investments, and monitoring methodologies, as well as feedback on their effectiveness. This can further increase central firms' profitability by allowing them to begin quickly the projects that are proven to be highly effective. Also, acquisition activity of central firms can be intensified due to a better awareness of acquisition opportunities in the market and lower acquisition information asymmetries (Singh and Schonlau, 2009). Consequently, this can contribute to a higher performance of central firms relative to poorly-connected ones.

Network connections can also provide useful information about professional contacts. The ability of central boards to collect information from the network quickly can broaden the set of professional contacts (consultants, auditors, customers, suppliers, etc.) at a central board's disposal. Together with the feedback from network members on the quality of services by the professional contacts, this can contribute to a better match between the professional contact and the firm's goals and projects. Therefore, the abundance of information can lower the search costs of finding a good match with a service supplier, which ultimately leads to a higher profitability.

Boardroom networks can also facilitate reputational incentives of directors to monitor the firm's activities. When a board does a poor job monitoring the CEO such as overlooking performance-decreasing managerial decisions, high board centrality can make matters worse due to a rapid diffusion of the negative news across the network and subsequent deterioration of the director's labor market opportunities. Therefore, central boards' high motivation to monitor can further strengthen the firm's performance.

Another channel through which information in the boardroom network can affect firm performance is the opportunity to leverage social ties and reduce information asymmetry between the parties when designing a contract. Engelberg et al., (2012) shows that when a firm is connected to a bank via their management's past social ties ("bank-connected" firm), the firm pays significantly lower interest rates and subsequently improves its performance. Other firms in the network could leverage their connections to the "bank-connected" firm, and as a result reduce the information asymmetry between them and the bank. In turn, this decrease in the information asymmetry can lead to a decrease in these firms' interest rates. Taking this one step further, highly-central firms have shorter sequences of boardroom links that lead to "bank-connected" companies, and thus (assuming that it's harder to leverage more distant relations) have higher chances of reducing interest rates and increasing performance.

Furthermore, information flowing via network ties can contribute to central boards' deeper insight into the strategies of related parties (i.e., competitors, customers, and suppliers). In turn, this can give central boards an advantage in terms of the best response strategy and the speed of the strategy adjustment to the actions of related parties in comparison to less-central boards. This knowledge offers opportunities to shield business from unfavorable shocks and use favorable shocks to the full, and thus can facilitate central firms' performance.

Though there are several potential positive effects on firm performance stemming from information diffused in the network, this information diffusion could be detrimental to firm performance. Highly-central firms can suffer from a diffusion of proprietary information across the network. For example, a rapid circulation of information about the firm's production methods, business and marketing plans, salary structure, customer lists, or contracts can provide third parties with a strategic advantage in the form of a timely response to the firm's actions. In turn, the firm might subsequently suffer a loss of economic benefit (e.g., a loss to reputation, image, goodwill, competitive advantage, core technology, or profitability). According to the survey conducted by ASIS International in 2007, financial impact due to proprietary information loss ranges between less than $10,000 to more than $5.5 million, as reported by the respondents.

In addition, the reputational incentives channel, suggested above as a stimulus for better monitoring by directors, can in fact play a negative role and decrease the firm's performance. It might be beneficial for the board members to appear as directors that don't make much trouble for CEOs (Hermalin and Weisbach, 2003). This would improve their labor market opportunities if CEOs influence director employment decisions.

Furthermore, boardroom network connections can facilitate a propagation of corporate practices that are detrimental for firm performance. Bizjak et al. (2009) show that board connections contribute to a spread of employee stock options backdating. Other types of corporate practices that can be diffused in a boardroom network might destroy future firm performance at the cost of improving a short-term performance. When information about value-decreasing tricks is spread across the network, highly-central boards have a higher chance of receiving it faster, and thus can incorporate these tricks sooner.

Overall, there are opposing positive and negative effects of being central in the boardroom network, and the net impact on performance is ambiguous. This leads to my first hypothesis:

H1: Board's centrality affects the firm's performance.

4. Data and Descriptive Statistics

4.1 *Data Sources and Sample Construction*

I construct the boardroom network using BoardEx database.[4] BoardEx covers public and private companies and provides extensive data at an individual level, which allows to identify current and past employers, starting and ending dates of the positions, age, death dates (if applicable) for each person covered in the database, as well as numerous other characteristics. I start the sample selection procedure with all the firms with non-missing CIK values in BoardEx database (14,485 firms). I then exclude observations for which the starting or ending date of a director's position in a company is missing.[5]

Further, I merge the BoardEx data to Compustat using CIK provided in BoardEx and GVKEY provided in Compustat. First, I merge with GVKEY from the annual Compustat file and get 10,104 companies merged. Then I perform a second round of assigning a GVKEY to the BoardEx observations by using GVKEY-CIK link table from WRDS SEC Analytics Suite and get a total of 10,952 companies merged to Compustat.

I keep only board members that serve on a company's board for at least 3 months during a fiscal year[6] in order for them to be able to affect the board decisions. This leaves 10,899 firms

---

[4] I am very grateful to Adi Sunderam and Baker Library at HBS for providing me with access to BoardEx database.

[5] When the day or month of an ending date of board position is missing in BoardEx and the year of a person death matches the ending year of the position, I assume that the ending month is the month of death. In other cases with missing day or month of the starting or ending day of a position, I assume that the person served for the longest possible period (the first day of the month or the first month of the year when the starting date has missing parts; and the last day of the month or the last month of the year when the ending date has missing parts). This positive bias in the length of service by board members works against finding the results, since it includes the set of directors that didn't actually have a chance to affect the boards' decisions into the sample.

[6] I use Compustat fiscal year end variable to determine which fiscal years are covered with a director's service. In rare cases when Compustat doesn't have the end of fiscal year for a firm, I use the dates of fiscal year ends scraped from the SEC server. I assign a fiscal year end to be December 31 of a corresponding year if the fiscal year end cannot be determined by Compustat and SEC filings.

in the sample. The literature shows that the average number of board meetings per year is approximately 7.5 (Brick and Chidambaran, 2010, and Vafeas, 1999), thus, assuming a uniform distribution of board meetings over the fiscal year, a director who serves on a board for at least 3 months can participate in at least 2 meetings during a fiscal year. Therefore, I assume that 2 board meetings are sufficient for a director to incorporate the information diffused in the network into the board's decision-making.

For each year, I exclude observations that are not in the largest component of the boardroom network from the analysis, since some of the centrality measures are defined only for connected networks (networks in which every pair of nodes is connected by a sequence of links). This step reduce the sample to 8,967 firms. Finally, after requiring non-missing values of the control variables and restricting the sample to 2000 – 2015, the sample covers 5,492 firms and 45,835 firm-years. I winsorize firm variables from Compustat at 1% level. Table 1 briefly describes the sample selection procedure and Table 2 shows the descriptive statistics for the boardroom network for each fiscal year.

4.2 *Boardroom Network and Centrality Measures*

For each year, from 2000 to 2015, I construct a boardroom network by connecting two firms only if there is a director who serves on the boards of both companies during the year. As a result, I get an undirected and unweighted network of firms for each year. In order to better capture different aspects of network centrality, I calculate three measures for each year: closeness, betweenness, and eigenvector. I don't use the degree centrality measure in the main set of analyses since the degree measure reflects direct connections of a aboard, while the research design employs shocks to firms that are distant in the network from the subject firm. However, I control for degree centrality in the robustness tests.

Closeness centrality measures how easy it is for a board to reach each of the other boards. If there is a decay of opinion or probability of getting a favor with distance, then closeness centrality captures a board's advantage from being close to other boards. Closeness centrality also measures the influence the board has on the network members by the ease with which it conveys its opinions. For each year t and firm j, this concept is measured by the inverse of the average distance between the board of firm j and any other board:

$$Closeness_j = \frac{n_t - 1}{\sum_{i \neq j} l_t(i,j)}, \quad (1)$$

where $l_t(i,j)$ is the length of the shortest path between boards i and j in year t.

Betweenness centrality measures how crucial a board is in terms of connecting other boards in the network. This centrality measure was first proposed by Freeman (1977) and captures how critical a board is for information transmission in the network. To measure betweenness for a firm j in year t, one needs to factor in all the paths that the board of firm j lies on. First, the number of shortest paths between boards k and i that board j lies on in year t, $P_{j,t}(ki)$, is calculated. Second, the total number of shortest paths between between boards k and i in year t, $P_t(ki)$, is calculated. Third, the number calculated on first step is divided by the number from the second step. Finally, this ratio is averaged across all the pairs of boards in the network:

$$Betweenness_{j,t} = \sum_{k \neq i: j \notin \{k,i\}} \frac{P_{j,t}(ki)/P_t(ki)}{(n_t - 1)(n_t - 2)/2}. \quad (2)$$

Eigenvector centrality determines a board's centrality to be proportional to the sum of its neighbors' centralities. Therefore, eigenvector centrality is self-referential in nature, since centrality of a board depends on how central its neighbors are, which in turn depends on centralities of their neighbors, and so on. This measure is studied in numerous papers and was suggested in Bonacich (1972). For each year t, I calculate eigenvector centrality using the following equation:

$$\lambda \cdot Eigenvector_{j,t} = \sum_{i=1}^{n_t} g_{ji,t} \, Eigenvector_{i,t}, \tag{3}$$

where $g_{ji,t} = 1$ if boards j and i are connected in year t; $Eigenvector_{i,t}$ is the eigenvector centrality of board i in year t, and λ is the proportionality factor.

Altogether, these three centrality measures combine complementary aspects of a board's position in the network. Importantly, larger firms are likely to have larger boards, so the centrality might pick the effects related to size. To mitigate this concern, I follow Larcker et al. (2013) and calculate quintile ranks of centrality measures by first ranking firms in quintiles with regard to their size and then ranking firms within each size quintile into quintiles with respect to centrality values. I do this double-ranking procedure for each centrality measure separately.

Finally, in the robustness section I also use the *Degree* centrality. For each year t and firm j, I calculate *Degree* centrality as the number of links the board of firm j has in year t, divided by the total number of firms in the network excluding the board itself. In order to replicate the results in the existing literature, I also look at the average centrality quintile score, *N_Score*, which is the average of the four quintile ranks: quintile ranks for the three centrality measures defined in (1) – (3) and the quintile rank for the *Degree*.

4.3 *Instrumental Variable*

While extant literature suggests a number of causal effects from boardroom centrality on the firms' performance (e.g. those described in section 3), the existence of an empirical relation between centrality and performance does not guarantee network centrality to drive the results. At least two endogenous explanations come to mind. The first endogenous explanation suggests that central directors can have a wider set of potential employers to choose from due to their greater visibility in the network, and are choosing firms with higher performance. The second endogenous explanation suggests that both network centrality and the firms' performance could result from higher abilities of central directors. Overall, it is difficult to determine what exactly contributes to the relation between centrality and performance.

To isolate the causal effect of boardroom network structure on changes in firm performance, I use an instrumental variable approach. Specifically, I instrument for changes in a firm's network centrality with deaths of directors located at a boardroom distance from the firm of at least two. To address the first requirement for the instrument validity, I argue that a director's death removes corresponding links from the boardroom network, and thus changes the structure of the network. In turn, this necessarily changes the centralities of all the firms in the network. Figure 1 provides a graphical illustration of the intuition for the instrument validity by showing how a removal of a link changes the structure of a network. The network in panel A is an excerpt from the 2015 boardroom network. Two firms are connected only if there is a director that serves on the boards of both firms. The numbers next to the nodes show the values of betweenness centrality for firms in the excerpt. In panel B, the Yahoo-Yelp link disappears and induces a change in betweenness centrality values. If P&G is a subject firm, its increase in betweenness reflects changes in the importance of the firm in terms of connecting other firms in the network. (e.g., the share of paths from Ebay to Yahoo going through P&G increases after the link removal). Therefore, the correlation between director death events and endogenous centrality measures should be strong. I support this claim with the results of the weak instrument test for the first stage.

To address the second requirement for the instrument validity, I suggest that because the death events take place at least two boardroom connections away from the firm, the corresponding changes in network structure are plausibly exogenous with respect to the firm's performance. By not factoring in the deaths at the firm's board itself, I rule out personal characteristics of the directors as an explanation of the results. Similarly, by excluding from the shock events the deaths at a boardroom distance from the firm of 1, I rule out the workload of directors who serve on the boards of both the subject firm and the firm that experienced the death shock as an explanation of the results[7]. After a director death on a board of a firm directly connected to the subject firm, other directors serving on the boards of both firms can become busier as they compensate for the workload of the deceased director, which affects the performance of both firms.

The detailed procedure I use to calculate the instruments is the following. First, for each firm in a given year, I calculate the shortest paths to each of the other firms in the network. I then partition these other firms into four groups according to boardroom distance from the firm and use the three groups corresponding to distances 2, 3, and at least 4 ("≥ 4"), to construct the instruments. Boards that are directly connected to the firm are allocated to the distance group 1. This group is not used as an instrument in this paper, but facilitates the definitions of distance groups that are used in the instrumental analysis. For a given subject firm, I allocate a firm to the distance group 2 (boardroom distance from the firm of two) if it shares a director with some firm in group 1 and does not share a director with the subject firm. Similarly, for the given subject firm, a firm is in the distance group 3, if it shares a director with some firm

[7] The busyness literature studies the workload effects on directors' decision-making. See Falato et al. (2014), Field et al. (2013), Fich and Shivdasani (2006), Perry and Peyer (2005), Ferris et al., (2003), and Core et al. (1999).

in group 2, but does not share a director with the subject firm and does not share a director with any firm in group 1. The last group, group "≥ 4", includes firms at a boardroom distance from the subject firm of s at least four. Figure 2 provides an example of boardroom network and shows how the four distance groups are constructed for Procter & Gamble in 2015. Mathematically, for each year t and group $d \in \{2, 3, "\geq 4"\}$, I construct a square matrix $Distance_t^d$ which has the number of rows and columns equal to the number of firms in the network in year t, and has elements $distance_{ij,t}^d$ equal either 0 or 1, depending on the length of the shortest path between boards i and j in year t:

$$distance_{ij,t}^d = \begin{cases} 1, & if\ the\ shortest\ path\ between\ boards\ i\ and\ j\ in\ year\ t\ is\ d; \\ 0, & otherwise. \end{cases} \tag{4}$$

Second, for each year I identify firms that experienced a director death and construct a vector, $Death_t$, which has the number of rows equal to the number of firms in the network for year t. Each element of this vector, $death_{i,t}$, takes a value of 1 if a director died on the board of firm i in year t and 0 otherwise:

$$death_{i,t} = \begin{cases} 1, & if\ firm\ i\ experienced\ a\ death\ on\ the\ board\ in\ year\ t; \\ 0, & otherwise. \end{cases} \tag{5}$$

On the third and final step, I use the groups corresponding to distance $d \in \{2, 3, "\geq 4"\}$ to construct the vector instruments $N\_Death_t^2$, $N\_Death_t^3$, $N\_Death_t^{\geq 4}$. Intuitively, for a given firm and year, each of these instruments accumulates all the deaths at a boardroom distance from the firm of 2, 3, and at least 4, respectively, and shows the total number of deaths at the corresponding network distance from the firm. Using matrix notation, each year t the vector of values of instruments can be defined as follows:

$$N\_Death_t^d = Distance_t^d \cdot Death_t. \tag{6}$$

Note that each element of the vector $N\_Death^{d}_{j,t}$ provides a value for the instrument corresponding to the distance group d and firm j in year t:

$$N\_Death^{d}_{j,t} = \sum_{i=1}^{n} distance^{d}_{ji,t} \cdot death_{i,t}, \tag{7}$$

where n is the number of firms in the network for year t.

4.4 *Performance Measure and Controls*

I measure performance with firms' operating profitability. Specifically, I look at industry adjusted changes in firms' returns on assets over one-, two-, and three-year future periods: $\Delta ROA_{j,t,t+1}$, $\Delta ROA_{j,t,t+2}$, and $\Delta ROA_{j,t,t+3}$, where for each $k \in \{1,2,3\}$,

$$\Delta ROA_{j,t,t+k} = (ROA_{j,t+k} - ROA_{j,t}) - (ROA^{Median}_{I,t+k} - ROA^{Median}_{I,t}). \tag{8}$$

where $ROA_{j,t}$ is return on assets for firm j in year t measured as contemporaneous net income scaled by lagged assets; and $ROA^{Median}_{I,t}$ is the median return on assets in the j's industry I in year t.

The set of controls in the main specification follows the Larcker et al. (2013) and includes the second lag of the firm's change in return on assets, the firm's market-adjusted returns over the last 12 months, book-to-market, size measured by logarithm of the market capitalization, logarithm of total sales, age measured by logarithm of the number of months since the firm appeared in CRSP, logarithm of total assets, research and development scaled by total sales, leverage measured as long-term debt scaled by total assets, and industry and year fixed effects.

4.5 *Descriptive Statistics*

Table 3 provides descriptive statistics for the final sample I use in the analysis. Panel A shows the distribution of returns on assets and the set of controls defined in section 4.4. Panel B describes centrality measures defined in section 4.2. Panel C summarizes instrumental variables defined in section 4.3. Finally, panel D shows Pearson (above diagonal) and Spearman (below diagonal) correlations between firm characteristics.

5. Research Design

I use an instrumental variable approach to test for the causal effect of boardroom centrality on firm performance. Figure 3 provides a timeline I follow for test specifications. Suppose that a director dies during fiscal year t. This event removes the set of corresponding links from the boardroom network and induces a change in centralities of all the firms in the network over next fiscal year. In other words, a death in year t causes a change in $\Delta Q\_Centrality_{t+1} = Q\_Centrality_{t+1} - Q\_Centrality_t$ for each firm in the network[8]. This change might result from the board, which experienced director death, not finding a substitute director yet or hiring a new director. In the latter case, the new director almost surely has a different set of connections than the deceased director had, so the centralities of firms in the network change. Under the hypothesis studied in this paper, as a firm's centrality changes from year t to year $t + 1$, so does the information diffusion from the firm to the network, as well as from the network to the firm. Consequently, depending on how much time has to elapse before the changes in the information structure of the network manifest in performance, one would expect to see the changes in the firm's performance over one, two, or three years following the change in centrality.

[8] To be more specific, each director death induces changes in centralities of all the firms in the largest connected component of the boardroom network. Smaller connected components are not considered in this analysis.

The main relation of interest comes from the following regression:

$$\Delta ROA_{j,t+\tau} = \alpha + \beta \Delta Q\_Centrality_{j,t+1} + \gamma X_{j,t} + u_{j,t}, \tag{9}$$

where $\Delta ROA_{j,t,t+\tau}$ takes the form defined in equation (8); $\Delta Q\_Centrality_{j,t+1}$ is the one-year ahead change in one of the three centrality measures: closeness betweenness, and eigenvector; $X_{j,t}$ is the vector of controls that follows the analysis in Larcker et al. (2013) and includes the second lag of the firm's change in return on assets, $\Delta ROA_{j,t-1}$; the firm's market-adjusted returns over the last 12 months, $Return_{j,t}$; one plus the firm's book-to-market, $LBM_{j,t}$; logarithm of market capitalization, $SIZE_{j,t}$; logarithm of total sales, $SALES_{j,t}$; logarithm of the number of months since the firm appeared in CRSP, $AGE_{j,t}$; logarithm of total assets, $ASSETS_{j,t}$; research and development scaled by total sales, $R\&D_{j,t}$; long-term debt scaled by total assets, $LVG_{j,t}$; and $u_{j,t}$ includes industry-by-year fixed effects. Section 4.4 provides the definitions of the returns on assets variable and the set of controls.

I suggest the specification that looks at changes in firm performance in relation to changes in centrality to be superior to the one that looks at changes in performance in relation to level of centrality (changes-to-levels). First, levels of centrality measures include an accumulation of past shocks, and these past shocks can be correlated with future firm performance via a channel unrelated to centrality. Second, changes-to-levels specification suggests an unbounded performance growth even when the level of centrality doesn't change over time.

Since the research question addresses the causal effect of boardroom centrality on performance, and equation (9) can be contaminated by endogenous channels relating centrality to firms' performance, I use director deaths at firms distant from the subject firm in the boardroom network (at a boardroom distance from the subject firm of at least two) to instrument for its board's centrality. The first stage of the analysis takes the following form:

$$\Delta Q\_Centrality_{j,t+1} = \tilde{\alpha} + \tilde{\beta} N\_Death_{j,t}^{2,3,\geq 4} + \tilde{\gamma} X_{j,t} + \tilde{u}_{j,t}, \tag{10}$$

where $Death_{j,t}^{2,3,\geq 4}$ corresponds to the three instruments defined in section 4.3.: the number of firms with director deaths at a distance of 2 from the subject firm j in year t, the number of firms with director deaths at a distance of 3 from the subject firm j in year t, and the number of firms with director deaths at a distance of 4 or greater from the subject firm j in year t; $\Delta Q\_Centrality_{j,t+1}$ and $X_{j,t}$ are the same as in equation (9); $\tilde{u}_{j,t}$ includes industry-by-year fixed effects.

Because the instruments do not factor in director deaths at the subject firm's board itself, I rule out personal characteristics of the deceased directors as an explanation of changes in the subject firm's performance. Similarly, by excluding director deaths at firms directly connected to the subject firm from the instruments, I rule out director workload effect studied in the busyness literature (Core et al., 1999, Ferris et al., 2003, Perry and Peyer, 2005, Fich and Shivdasani, 2006, Field et al., 2013, and Falato et al., 2014) from the set of potential explanations of changes in the subject firm's performance. Specifically, after a director death on a board of a firm directly connected to the subject firm, other directors serving on the boards of both firms can become busier as they compensate for the deceased director, which affects the performance of both firms.

It is important to note that even though deaths are rare events, the instrument I construct provides a powerful identification, since a death of one director affects the centralities of all the firms in the network[9]. In order to better explain the difference in the strength of my setting from other settings using exogenous nature of director deaths in their analysis, consider the two papers from prior literature. Fracassi and Tate (2012) study external CEO-director ties and use each director death to shock firms at which these directors served. Given the small number of death events, the number of firms affected by the shock is also small. Falato et al. (2014) study busyness of directors serving on multiple boards and use deaths of directors and CEOs to shock directly connected firms. In contrast, one death in my setting affects the majority of firms in the network (every firm, except the firms that experience deaths on their boards and firms directly connected to these firms), thus the variation produced by my instruments is strong. The results of the weak instrument tests described in the next section support this claim.

The research design in this paper relies on a few assumptions. Namely, I assume that (1) the boardroom network I construct is representative of the actual boardroom connections between firms; (2) the three centrality measures correctly reflect the importance of firms' network position in terms of information diffusion. To the extent that these assumptions are plausible, the results suggested in this paper are informative about the effect of firm centrality on its performance.

6. Results

I start the analysis with an OLS estimation of the relation between the level of firms' boardroom centralities and changes in their future performance. The specification of the tests in this part of the paper parallels the existing literature on the association between centrality

[9] To be more precise, each death in a firm from the largest connected component of the boardroom network (a subset of firms in the network, such that for each two firms there is a sequence of boardroom links that connects the two firms) changes the centralities of all the firms from the largest connected component.

and performance. Specifically, I use the specification close to Larcker et al. (2013), but employ SIC 2-digit industry classification system instead of GICS. I run regressions of future changes in a firm's returns on assets on the level of centrality and the set of controls described in section 4.4. Panel A of Table 4 shows the results of the regressions of one-year changes in returns of assets. Only the average centrality score (column 5) has a marginally significant coefficient, however, as panel B shows, there is a significant positive increase in performance one year ahead, as well as a significant positive two- and three-year cumulative changes in returns on assets following the year of centrality measurement. This might suggest that there is a positive causal effect from boardroom centrality on the future returns on assets, though such confounding effects as (1) selection of highly central directors to the boards of better-performing firms and (2) higher abilities of highly central directors can bias the coefficient estimates upwards.

Further, I proceed to the main analysis of this paper and look at exogenous shocks to changes in firms' centralities, induced by director deaths at firms distant from the subject firm in the network, to test the implications for future performance. I begin by studying whether the first stage is strong. Table 5 shows the results of the regression of changes in centrality quintiles on the three instruments and controls. Statistics reported at the bottom of Table 5 describe the validity of the instruments and the strength of the first stage. The test of overidentifying restrictions does not reject the validity of the instruments. The range of p-values for Hansen's J-statistic is 0.6 – 0.7 (depending on the measure of centrality used in the first stage), which means that the null hypothesis of the instruments being uncorrelated with the error term cannot be rejected. Partial F-statistic is large and confirms that the instruments produce a strong identification. Overall, the instruments are likely to be exogenous and have a strong correlation with the endogenous centrality changes.

The three columns in Table 5 present the results for changes in closeneness, betweenness, and eigenvector centrality measures, respectively. An incremental director death at a boardroom distance of two from a subject firm increases its change in centrality by 0.04 – 0.045, depending on the centrality measure studied. An incremental director death at a boardroom distance of three has a smaller effect on centrality quintile score change and ranges from 0.02 to 0.04. Finally, an incremental director death at a boardroom distance of at least four from a subject firm increases its centrality quintile score by 0.03 – 0.05.

Next, I examine the second stage which shows how the exogenous changes in a firm's centrality manifest in its performance growth. Panel A of Table 6 shows the results for single-period future changes in performance and suggests that it takes around a year for centrality-induced changes in a board's decision-making to get implemented and incorporated into the firm's performance. As the right three columns in Panel A of Table 6 suggest, the negative effect on performance does not spread further in time to the next year. The coefficient of approximately -0.04 means that when a firm's centrality quintile increases from q to $q+1$, its performance drops by approximately 0.04 (16% of one standard deviation in performance). Panel B presents the results for multi-period cumulative changes in future performance. Both one- and two-year ahead cumulative effects from a centrality quintile change on the firm's performance are significant and negative. Depending on the centrality measure and the period, the coefficient on centrality quintile change ranges from -0.05 to -0.07 (approximately, 24% of one standard deviation in performance).

7. Robustness tests

To further corroborate the results in this paper, I perform a few robustness tests. The instrumental variable approach I use in the main set of tests looks at director death events and changes in distant firms' centralities induced by these deaths. One might get interested whether a change in a firm's centrality over a year incorporates its response to the director deaths at distant firms in the network in the previous year. For example, if a firm A experiences a death on its board in year *t* and substitutes the deceased director with a director serving on the board of a distant firm B, then the number of boardroom links for firm B increases from year *t* to year *t+1* as a result of the deaths of director from firm A. This increase in the number of boardroom links for firm B can explain both its changes in *Closeness*, *Betweenness*, and *Eigenvector* centrality measures and the decrease in the firm's performance if the board of firm B becomes busier and has to allocate time among more firms after the death.

First, I run the same tests as in the main results section, but controlling for the changes in the degree (the number of direct connections a firm has). The results for the first stage are shown in Table 7 and suggest that the instruments produce a strong variation in the centrality measures even after controlling for the degree. Table 8 shows that the second stage results are very similar to the results in the main analysis (Table 6).

Second, I narrow the sample down to include only observations when both the list of board members and the boardroom links of a firm don't change from the previous year. This ensures that the changes in centrality during a year following the director deaths at distant firms are not stemming from any changes on the board. The first stage for this subsample is shown in Table 9 and the second stage for one-, two-, and three-year ahead changes in performance are presented in

Table 10. The partial F-statistics in Table 9 suggest that the joint explaining power of the instruments is strong enough to produce a p-value of less than 0.01. The second stage suggests that even for the firms that stay exactly the same both in terms of the board composition and the board links, a positive change in centrality causes future performance to decrease. However, the reader should interpret the results of this test with a caution, since due to a small number of firms that don't change their board composition and links over a year, there is a big drop in the size of the sample, which reduces the power of the test. One might also wonder whether the firms that preserve their board and links over a year are different from a general firm in the sample, thus causing a selection issue.

8. Conclusion

In this study, I examine whether boardroom centrality has a causal effect on firm performance. In other words, I study whether the directors' position in the boardroom network matters for the firm's performance. If boardroom ties work as a conduit for information about market, industry, feedback on peers' experience, etc., then I expect central boards' corporate decisions to incorporate richer information and, as a result, become more efficient. Alternatively, if boardroom ties diffuse proprietary information across the network or spread value-decreasing practices that improve current performance at the cost of the future one, then high centrality can put a firm at a disadvantage and I expect to find a deterioration in the central firms' performance.

The key challenge for this analysis is to find a setting with exogenous variation in firms' centralities. Otherwise, the results will be confounded with endogenous effects stemming from a mere propensity of central directors to choose firms with good performance, or a tendency of highly skilled directors to be more central in the boardroom network. To the best of my knowledge, while the literature emphasizes the endogeneity concern in the analysis of the relation between centrality and corporate outcomes, there are no causal tests of the centrality effect, and the evidence on the relation between a firm's network centrality and its performance is controversial.

To isolate the effect of network centrality on the firm's corporate outcomes, I use an instrumental variable approach based on director deaths at distant firms within the network. The results suggest that boardroom centrality deteriorates firm performance. Intuitively, each director death exogenously removes the corresponding set of links from the network and changes the network structure. In turn, this change in the network structure implies a change in centrality for every firm in the network. At the same time, because the director deaths take place at least two boardroom connections away from the subject firm, the corresponding changes in the network structure are plausibly exogenous with respect to the subject firm's performance.

The main contribution of this paper is the resolution of the disagreement in the literature on the sign of the network centrality effect on firm performance. While the prevailing evidence in the literature suggests the relation to be positive, I use the exogenous setting that isolates the causal effect of boardroom centrality on performance and show that centrality deteriorates future performance. Importantly, the instrument I suggest in this paper is useful for any study that employs network structure beyond direct ties, since it allows one to exogenously isolate the effects of changes in network structure on firms' characteristics.

References

Barnea, A., Guedj, I., 2007. Sympathetic boards: director networks and firm governance. EFA 2007 Ljubljana Meetings Paper, Austin.

Bonacich, P., 1972. Factoring and Weighting Approaches to Status Scores and Clique Identification. Journal of Mathematical Sociology 2, 113–120.

Core, J.E., Holthausen, R.W., Larcker, D.F., 1999. Corporate governance, chief executive officer compensation, and firm performance. Journal of Financial Economics 51, 371–406.

Croci, E., Grassi, R., 2014. The economic effect of interlocking directorates in Italy: New evidence using centrality measures. Computational and Mathematical Organization Theory 20, 89–112.

Engelberg, J., Gao, P., Parsons, C.A., 2012. Friends with money. Journal of Financial Economics 103, 169–188.

Falato, A., Kadyrzhanova, D., Lel, U., 2014. Distracted directors: Does board busyness hurt shareholder value? Journal of Financial Economics 113, 404–426.

Fama, E.F., Macbeth, J.D., 1973. Risk , Return , and Equilibrium : Empirical Tests 81, 607–636.

Ferris, S.P., Jagannathan, M., Pritchard, A.C., 2003. Too Busy to Mind the Business ? Monitoring by Directors with Multiple Board Appointments. The Journal of Finance 58, 1087–1111.

Feyen, E., 2014. Boardroom Networks and the Cross-Section of Stock Returns : Evidence From the Netherlands.

Fich, E.M., Shivdasani, A., 2006. Are Busy Boards Effective Monitors? The Journal of Finance LXI, 689–724.

Field, L., Lowry, M., Mkrtchyan, A., 2013. Are busy boards detrimental? Journal of Financial Economics 109, 63–82.

Fracassi, C., Tate, G., 2012. External Networking and Internal Firm Governance. The Journal of Finance 67, 153–194.

Freeman, L.C., 1977. A Set of Measures of Centrality Based on Betweenness. Sociometry 40, 35–41.

Hermalin, B.E., Weisbach, M.S., 2003. Boards Of Directors as an Endogenously Determined Institution: A Survey of the Economic Literature. Economic Policy Review 9, 7–26.

Horton, J., Millo, Y., Serafeim, G., 2012. Resources or Power? Implications of Social Networks on Compensation and Firm Performance. Journal of Business Finance and Accounting 39, 399–426.

Intintoli, V., Kahle, K.M., Zhao, W., 2015. Board Connectedness and Board Effectiveness, Working Paper.

Larcker, D.F., So, E.C., Wang, C.C.Y., 2013. Boardroom centrality and firm performance. Journal of Accounting and Economics 55, 225–250.

Omer, T.C., Shelley, M.K., Tice, F.M., 2016. Do Director Networks Matter for Financial Reporting Quality? Evidence from Restatements.

Omer, T.C., Shelley, M.K., Tice, F.M., 2013. When Do Well-Connected Directors Affect Firm Performance? Working Paper.

Perry, T., Peyer, U., 2005. Board seat accumulation by executives: A shareholder's perspective. Journal of Finance 60, 2083–2124.

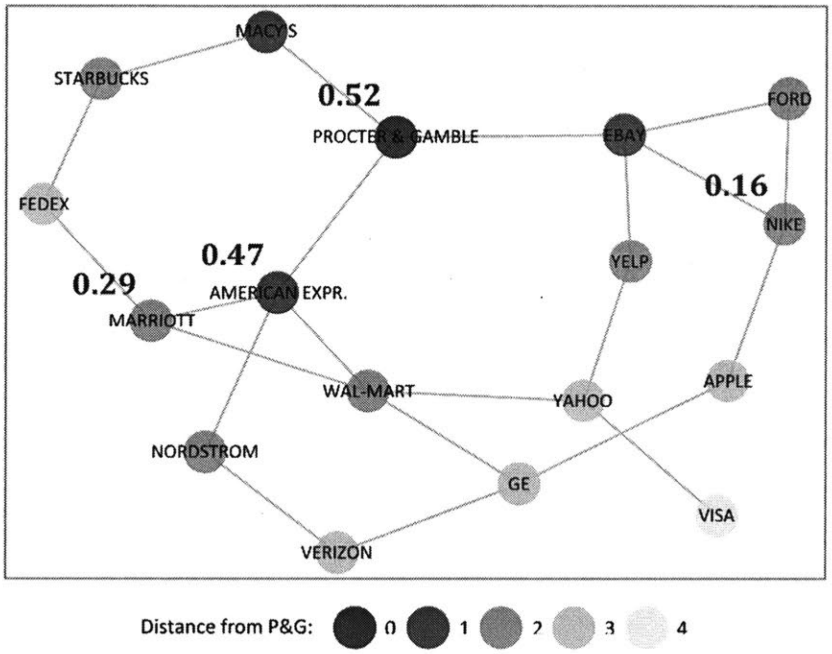
Renneboog, L., Zhao, Y., 2011. Us knows us in the UK: On director networks and CEO compensation. Journal of Corporate Finance 17, 1132–1157.

Singh, P.V., Schonlau, R.J., 2009. Board Networks and Merger Performance. SSRN Electronic Journal.

Vafeas, N., 1999. Board meeting frequency and firm performance. Journal of Financial Economics 53, 113–142.

Figure 1. Excerpt from 2015 boardroom network.
The network in panel A is an excerpt from the 2015 boardroom network. Two firms are connected only if there is a director that serves on the boards of both firms. The numbers show the values of betweenness centrality for firms in the network. In panel B, the Yahoo-Yelp link disappears and betweenness centrality values change. If P&G is a subject firm, its increase in betweenness reflects changes in the importance of the firm in terms of connecting other firms in the network. (e.g., the share of paths from Ebay to Yahoo going through P&G increases after the death).

Panel A: The link between Yahoo and Yelp is present.



Panel B: The link between Yahoo and Yelp is removed.

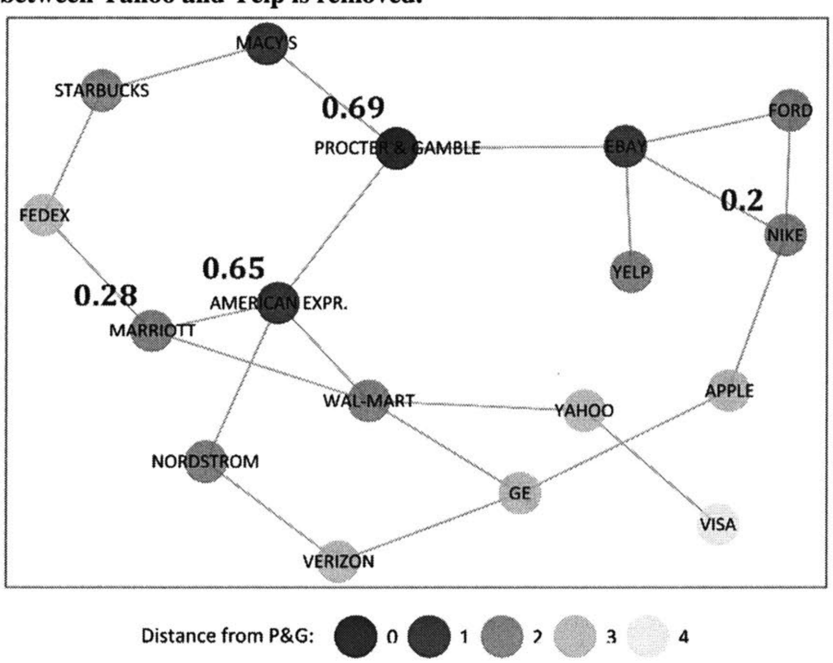


Figure 2. Distribution of distances to P&G in an excerpt from 2015 boardroom network.
This network is an excerpt from 2015 boardroom network. Two firms are connected only if there is a director that serves on the boards of both firms. Taking Procter&Gamble (P&G) as a subject firm, all the rest firms are classified to 4 groups according to their boardroom distance from P&G. The first group includes all the firms that share a director with P&G. Since one director is enough to connect these firms with P&G, the boardroom distance to P&G equals 1 for group 1. The second group includes all the firms that share a director with some firm in group 1 and don't have a director in common with P&G itself. It takes two directors to connect the firms in group 2 with P&G, so the boardroom distance is 2. Similar rationales define groups 3 and 4. Here only one firm, Visa, is allocated to group 4. In the main analysis, I aggregate all the firms at a distance at least 4 from P&G to group "≥4".

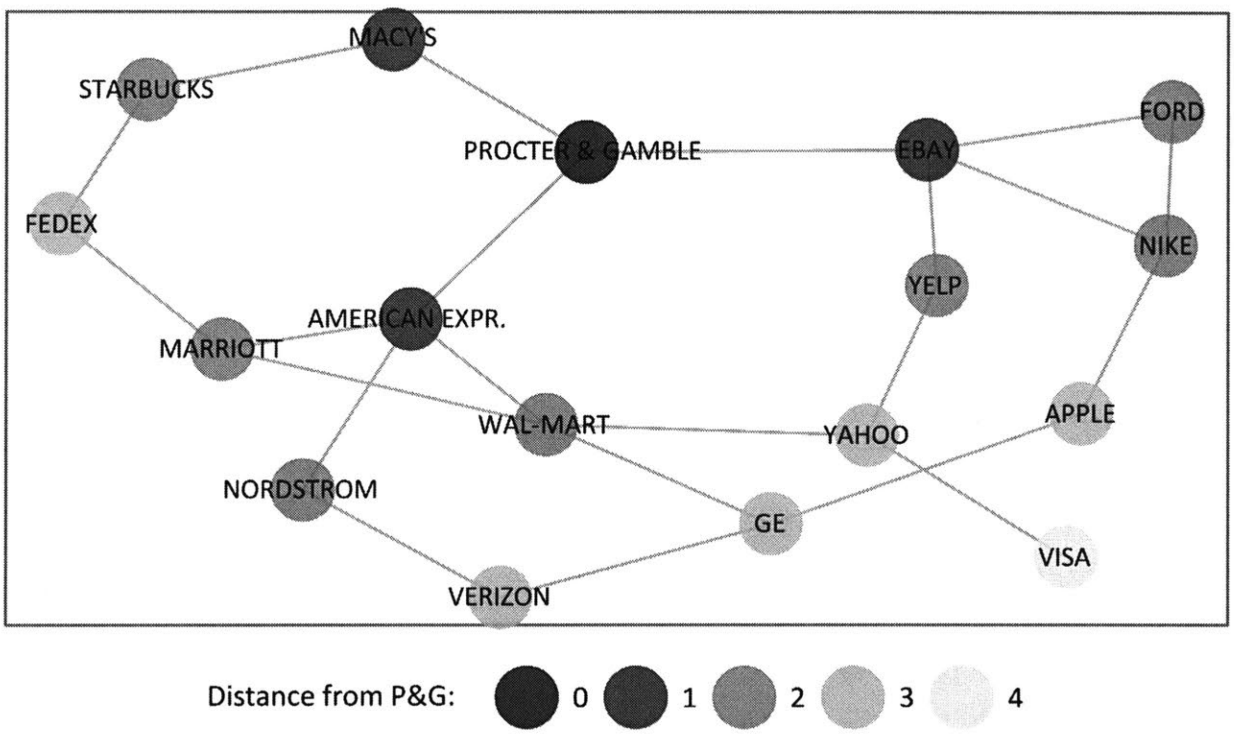


Figure 3. Timeline for one-year-ahead change in performance.

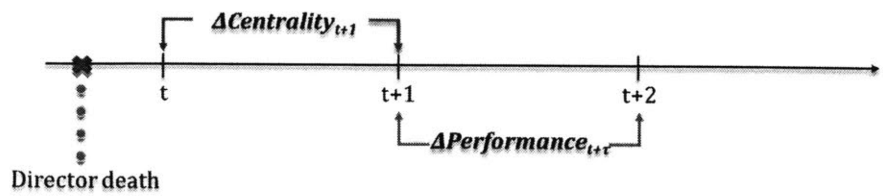


Table 1. Sample selection procedure

Step in the sample selection procedure	*# of Firms*
1. Observations in BoardEx with non-missing CIK:	14,485
2. Observations merged with Compustat:	10,952
3. Observations such that a director serves on a board for at least 3 months:	10,899
4. Observations in the largest connected component:	8,967
5. Observations merged with controls, with stock price above $1, and restricted to 2000 - 2015:	**5,492**

44,428 firm-years over 2000 - 2015

Table 2. Boardroom network summary statistics.

For each of the fiscal years 2000 – 2015, I use BoardEx database to construct a boardroom network on a firm level. Each row describes the network for a corresponding fiscal year. The first three columns describe the number of firms, links and directors in the boardroom network for the corresponding fiscal year. For each fiscal year, the last five columns describe the largest connected component of the boardroom network. This connected component includes the largest subset of the firms in the network, for which any two firms can reach each other via a sequence of boardroom links. *# Deaths* is the number of director deaths that happed in firms from the largest components during the corresponding fiscal year. In the following column, I calculate the number of deaths in the largest component as a percentage of the number of firms in this component for a given fiscal year. *Diameter* is the longest path between two firms in the component, i.e. the longest sequence of links between two firms in the component. *Avg. path length* is the average length of the shortest path connecting two firms in the component, i.e. average smallest number of links connecting two firms in the component.

Fiscal year	*# Firms*	*# Links*	*# Directors*	*# Firms, largest component*	*# Deaths, largest component*	*Deaths, % of # Firms, largest component*	*Diameter, largest component*	*Avg. path length, largest component*
2000	6,654	12,895	35,212	3,918	58	1.48	15	5.44
2001	6,922	14,116	38,156	4,159	65	1.56	17	5.40
2002	7,193	15,022	40,707	4,376	90	2.06	17	5.40
2003	7,448	15,927	43,644	4,637	105	2.26	18	5.40
2004	7,811	17,412	46,310	5,000	130	2.60	15	5.41
2005	8,145	18,073	48,438	5,306	135	2.54	19	5.54
2006	8,416	18,143	50,260	5,470	133	2.43	16	5.62
2007	8,471	18,034	51,490	5,510	153	2.77	18	5.72
2008	8,300	17,126	50,964	5,375	152	2.83	21	5.82
2009	7,925	15,552	48,567	5,020	125	2.49	21	5.87
2010	7,707	15,516	47,398	4,909	111	2.26	20	5.79
2011	7,597	15,316	46,665	4,850	107	2.21	19	5.81
2012	7,447	15,084	45,730	4,774	110	2.30	18	5.69
2013	7,373	14,987	45,374	4,827	130	2.69	20	5.72
2014	7,436	15,607	45,481	4,897	127	2.59	19	5.67
2015	7,427	15,829	45,381	4,932	70	1.42	18	5.61

Table 3. Sample Summary statistics

Panel A shows the summary statistics for the dependent variable and controls. *ROA* is returns on assets calculated as the firm's net income scaled by lagged assets; *ln(1+B/M)* is the log of one plus the firm's book-to-market ratio; *R&D* is the firm's research and development expense scaled by total sales; *Ln(Size)* is the log of market capitalization; *Ln(Assets)* is the log of total assets; *Ln(Sales)* is log of total sales; *Leverage* is the firm's long-term debt scaled by total assets; *Age* is the log of the number of months since the firm appeared in CRSP. Panel B describes the centrality measures *Closeness*, *Betweenness*, and *Eigenvector*, which are defined in section 4.2. *The Mean, P25, Median, and P75 numbers for Eigenvector centrality are pre-multiplied by* 10^3. Panel C summarizes the instrument variables N_Death^2, N_Death^3, and $N\_Death^{\geq 4}$ which measure the number of director deaths at a boardroom distance of 2, 3, and at least 4 from the firm respectively. Panel D presents the Pearson (above diagonal) and Spearman (below diagonal) correlations for firm characteristics.

	Mean	*Std.*	*P25*	*Median*	*P75*
Panel A: dependent variable and controls					
ROA	0.002	0.251	-0.007	0.031	0.076
ln(1+B/M)	0.434	0.337	0.252	0.399	0.575
R&D	0.560	9.671	0.000	0.000	0.055
Ln(Size)	6.727	2.022	5.362	6.738	8.084
Ln(Assets)	6.947	2.115	5.483	6.936	8.353
Ln(Sales)	6.394	2.142	5.050	6.462	7.822
Leverage	0.188	0.208	0.008	0.136	0.297
Age	5.172	0.795	4.605	5.176	5.765
Panel B: Centrality measures					
Degree	6.907	5.507	3	5	9
Closeness	0.189	0.027	0.171	0.190	0.208
Betweenness	0.002	0.003	0.000	0.001	0.003
*Eigenvector*100*	0.149	0.410	0.000	0.000	0.002
Panel C: Instrument variables					
N_Death^2	1.357	2.098	0	1	2
N_Death^3	8.112	8.860	1	5	12
N_Death^4	24.413	16.126	10	23	37
$N\_Death^{\geq 4}$	105.352	28.295	89	109	126

Table 3 *(continued)*

Panel D: Pearson (Spearman) correlations above (below) diagonal

	Ln(Size)	*Ln(Assets)*	*ln(1+B/M)*	*R&D*	*Leverage*	*Ln(Sales)*	*Age*	*Degree*	*Closen.*	*Betw.*	*Eigenv.*	N_Death^2	N_Death^3	$N\_Death^{\geq 4}$
Ln(Size)	1	0.87	-0.26	-0.04	0.13	0.82	0.28	0.49	0.53	0.44	0.02	0.41	0.50	-0.18
Ln(Assets)	0.87	1	0.04	-0.07	0.22	0.87	0.31	0.47	0.48	0.42	0.03	0.40	0.47	-0.18
ln(1+B/M)	-0.30	0.03	1	-0.04	-0.16	-0.02	0.00	-0.12	-0.14	-0.08	0.01	-0.09	-0.12	0.02
R&D	-0.14	-0.34	-0.25	1	0.00	-0.19	-0.03	0.00	0.00	0.00	0.00	-0.01	-0.01	0.01
Leverage	0.25	0.38	-0.04	-0.30	1	0.18	0.04	0.12	0.14	0.08	0.00	0.08	0.11	-0.07
Ln(Sales)	0.83	0.87	-0.05	-0.31	0.33	1	0.34	0.47	0.51	0.42	0.02	0.42	0.50	-0.18
Age	0.27	0.30	0.03	-0.11	0.11	0.34	1	0.23	0.23	0.22	0.03	0.23	0.25	-0.07
Degree	0.49	0.44	-0.16	0.05	0.19	0.49	0.19	1	0.78	0.85	0.24	0.69	0.78	-0.31
Closen.	0.54	0.49	-0.17	-0.01	0.22	0.55	0.21	0.84	1	0.62	0.02	0.64	0.82	-0.40
Betw.	0.46	0.42	-0.13	0.04	0.17	0.46	0.18	0.88	0.74	1	0.12	0.59	0.64	-0.30
Eigenv.	0.52	0.49	-0.15	-0.06	0.20	0.54	0.23	0.71	0.84	0.61	1	0.02	0.02	-0.01
N_Death^2	0.41	0.39	-0.11	-0.03	0.16	0.43	0.19	0.63	0.69	0.55	0.59	1	0.75	-0.27
N_Death^3	0.50	0.47	-0.15	-0.03	0.20	0.52	0.20	0.78	0.92	0.68	0.78	0.69	1	-0.29
$N\_Death^{\geq 4}$	-0.20	-0.19	0.03	0.02	-0.12	-0.21	-0.07	-0.29	-0.42	-0.28	-0.26	-0.24	-0.29	1

Table 4. Endogenous relation between centrality and future changes in returns on assets.
Panel A contains the results for regression of firm-specific one-year-ahead changes in ROA adjusted for contemporaneous change in industry median ROA on quintile ranks of centrality measures and controls. The quintile ranks of the four centrality measures (*Closeness*, *Betweenness*, *Eigenvector*, and *Degree*) are calculated by first sorting firms into size quintiles each fiscal year, and then sorting the firms within each size quintile into centrality quintiles (highest centrality values correspond to rank 5). *N_Score* is the average of the four centrality measures for a given fiscal year. *ROA* is returns on assets calculated as the firm's net income scaled by lagged assets; *ln(1+B/M)* is the log of one plus the firm's book-to-market ratio; *R&D* is the firm's research and development expense scaled by total sales; *Ln(Size)* is the log of market capitalization; *Ln(Assets)* is the log of total assets; *Ln(Sales)* is log of total sales; *Leverage* is the firm's long-term debt scaled by total assets; *Age* is the log of the number of months since the firm appeared in CRSP. Centrality measures *Closeness*, *Betweenness*, *Eigenvector*, and *Degree*, are defined in section 4.2. Panel B combines the results for two-year-ahead, three-year-ahead, cumulative two-year, and cumulative three-year change in returns on assets. Industry and year fixed effects are included in every regression. The *t*-statistics clustered by firm are shown in parentheses. *, **, and *** indicated 10%, 5%, and1% levels of significance, respectively.

Panel A: $\Delta ROA_{t+1} = ROA_{t+1} - ROA_t$

	(1)	(2)	(3)	(4)	(5)
Q_Degree_t	0.001				
	(1.489)				
$Q\_Closeness_t$		0.002			
		(1.492)			
$Q\_Betweenness_t$			0.001		
			(1.264)		
$Q\_Eigenvector_t$				0.001	
				(1.637)	
N_Score_t					0.002*
					(1.779)
ΔROA_{t-1}	-0.010	-0.010	-0.010	-0.010	-0.010
	(-0.001)	(-0.001)	(-0.001)	(-0.002)	(-0.002)
$Return_t$	0.006	0.007	0.006	0.006	0.007
	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)
$(1 + B/M)_t$	-0.001	-0.001	-0.001	-0.001	-0.001
	(-0.000)	(-0.000)	(-0.000)	(-0.000)	(-0.000)
$Size_t$	-0.004	-0.004	-0.004	-0.004	-0.004
	(-0.001)	(-0.002)	(-0.002)	(-0.001)	(-0.001)
$R\&D_t$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.000)	(-0.000)	(-0.000)	(-0.000)	(-0.000)
$Leverage_t$	0.027	0.027	0.027	0.027	0.027
	(0.005)	(0.003)	(0.004)	(0.003)	(0.002)
$Assets_t$	0.014	0.014	0.014	0.014	0.014
	(0.005)	(0.002)	(0.002)	(0.002)	(0.004)
$Sales_t$	-0.012	-0.011	-0.012	-0.011	-0.012
	(-0.003)	(-0.004)	(-0.005)	(-0.004)	(-0.002)
Age_t	-0.000	0.000	0.000	0.000	-0.000
	(-0.000)	(0.000)	(0.000)	(0.000)	(-0.000)
Observations	44,428	44,428	44,428	44,428	44,428
R^2	0.004	0.004	0.004	0.004	0.004

Table 4. *(continued)*

Panel B: regression of future changes in ROA	ΔROA_{t+2}	ΔROA_{t+3}	$\Delta ROA_{t,t+2}$	$\Delta ROA_{t,t+3}$
N_Score_t	0.002***	-0.001	0.005***	0.004**
	(3.089)	(-1.079)	(4.351)	(2.756)
ΔROA_{t-1}	0.000	-0.001	-0.010	-0.012
	(0.058)	(-0.094)	(-0.472)	(-0.518)
$Return_t$	-0.010***	-0.006***	-0.003	-0.008
	(-5.511)	(-3.507)	(-0.596)	(-1.426)
$(1 + B/M)_t$	0.000	0.000	-0.000	-0.000
	(1.499)	(0.886)	(-1.140)	(-0.950)
$Size_t$	0.001	0.000	-0.003	-0.004
	(0.696)	(0.117)	(-0.658)	(-0.834)
$R\&D_t$	0.000	0.000	0.000	0.000
	(1.237)	(0.845)	(0.660)	(0.663)
$Leverage_t$	0.003	0.053**	0.030*	0.078**
	(0.215)	(2.683)	(1.894)	(2.953)
$Assets_t$	0.000	0.002	0.015*	0.016**
	(0.122)	(0.484)	(2.140)	(2.198)
$Sales_t$	-0.005*	-0.003	-0.018***	-0.018**
	(-1.999)	(-0.761)	(-3.007)	(-2.596)
Age_t	0.000	-0.001	0.001	-0.001
	(0.152)	(-1.010)	(0.233)	(-0.396)
$Observations$	40,066	35,774	40,066	35,774
R^2	0.006	0.006	0.009	0.013

Table 5. The 2SLS first stage for the effect of centrality on future changes in ROA.
This table shows the results for the first stage of the 2SLS regression of firm-specific future changes in ROA on changes in quintile ranks of centrality measures and controls, where changes in centrality quintiles are instrumented with number of director deaths at a boardroom distance of 2, 3, and at least 4 (instruments N_Death^2, N_Death^3, and $N\_Death^{\geq 4}$ are defined in section 4.3). The quintile ranks of the three centrality measures (*Closeness*, *Betweenness*, and *Eigenvector*), are calculated by first sorting firms into size quintiles each fiscal year, and then sorting the firms within each size quintile into centrality quintiles (highest centrality values correspond to rank 5). *ROA* is returns on assets calculated as the firm's net income scaled by lagged assets; *ln(1+B/M)* is the log of one plus the firm's book-to-market ratio; *R&D* is the firm's research and development expense scaled by total sales; *Ln(Size)* is the log of market capitalization; *Ln(Assets)* is the log of total assets; *Ln(Sales)* is log of total sales; *Leverage* is the firm's long-term debt scaled by total assets; *Age* is the log of the number of months since the firm appeared in CRSP. Centrality measures *Closeness*, *Betweenness*, *Eigenvector*, and *Degree*, are defined in section 4.2. Industry-by-year fixed effects are included in every regression. The *t*-statistics clustered by 2-digit industry SIC codes are shown in parentheses. *, **, and *** indicated 10%, 5%, and1% levels of significance, respectively.

	ΔQ $Closen._{t+1}$	ΔQ $Between._{t+1}$	ΔQ $Eigenv._{t+1}$
$N\_Death_t^2$	0.036***	0.047***	0.038***
	(5.951)	(4.393)	(3.920)
$N\_Death_t^3$	0.019***	0.042***	0.019*
	(4.018)	(4.834)	(1.804)
$N\_Death_t^{\geq 4}$	0.033***	0.051***	0.031***
	(6.895)	(5.765)	(3.112)
ΔROA_{t-1}	0.016*	0.027**	0.015
	(1.846)	(2.468)	(1.555)
$Return_t$	-0.003	-0.002	0.005
	(-0.673)	(-0.316)	(1.013)
$(1+B/M)_t$	-0.000	-0.001	0.001
	(-0.260)	(-1.030)	(1.223)
$Size_t$	0.056***	0.039***	0.047***
	(14.646)	(8.443)	(9.274)
$R\&D_t$	0.000	0.001***	-0.000**
	(0.856)	(4.553)	(-2.192)
$Leverage_t$	-0.006	-0.044**	-0.006
	(-0.378)	(-2.100)	(-0.331)
$Assets_t$	0.001	-0.003	0.009
	(0.295)	(-0.457)	(1.453)
$Sales_t$	-0.008**	0.002	-0.014***
	(-2.194)	(0.342)	(-3.199)
Age_t	-0.001	-0.004	-0.006*
	(-0.365)	(-1.199)	(-1.669)
Observations	44,428	44,428	44,428
Partial R-squared	0.015	0.006	0.007
Partial F-statistic	135.4	155	107.1
(F p-val.)	<0.001	<0.001	<0.001
Overidentification, Hansen J	0.764	0.892	0.844
(J p-val.)	0.682	0.640	0.656

Table 6. The 2SLS second stage for the effect of centrality on future changes in ROA.

Changes in centrality quintiles are instrumented with number of director deaths at a boardroom distance of 2, 3, and at least 4 (N_Death^2, N_Death^3, and $N\_Death^{\geq 4}$ are defined in section 4.3). The quintile ranks of *Closeness*, *Betweenness*, and *Eigenvector* centralities are calculated by first sorting firms into size quintiles each fiscal year, and then sorting the firms within each size quintile into centrality quintiles (highest centrality values correspond to rank 5). *ROA* is calculated as the firm's net income scaled by lagged assets; *ln(1+B/M)* is the log of one plus the firm's book-to-market ratio; *R&D* is the firm's research and development expense scaled by total sales; *Ln(Size)* is the log of market capitalization; *Ln(Assets)* is the log of total assets; *Ln(Sales)* is log of total sales; *Leverage* is the firm's long-term debt scaled by total assets; *Age* is the log of the number of months since the firm appeared in CRSP. Centrality measures *Closeness*, *Betweenness*, *Eigenvector*, and *Degree*, are defined in section 4.2. Industry-by-year fixed effects are included in every regression. The *t*-statistics clustered by 2-digit industry SIC codes are shown in parentheses. *, **, and *** indicated 10%, 5%, and1% levels of significance, respectively.

Panel A: single-period changes

	$\Delta ROA_{t+1} = ROA_{t+1} - ROA_t$			$\Delta ROA_{t+2} = \Delta ROA_{t+2} - \Delta ROA_{t+1}$			$\Delta ROA_{t+3} = \Delta ROA_{t+3} - \Delta ROA_{t+2}$		
$\Delta Q\_Closeness_t$	-0.011			-0.035***			0.001		
	(-0.824)			(-3.987)			(0.071)		
$\Delta Q\_Betweenness_t$		-0.013			-0.043***			-0.002	
		(-0.819)			(-3.731)			(-0.162)	
$\Delta Q\_Eigenvector_t$			-0.012			-0.043***			0.001
			(-0.795)			(-4.337)			(0.081)
ΔROA_{t-1}	-0.009	-0.009	-0.009	0.001	0.001	0.001	-0.001	-0.001	-0.001
	(-0.567)	(-0.554)	(-0.568)	(0.157)	(0.256)	(0.182)	(-0.166)	(-0.156)	(-0.167)
$Return_t$	0.008	0.008	0.008	-0.011***	-0.011***	-0.010***	-0.006***	-0.006***	-0.006***
	(1.397)	(1.391)	(1.426)	(-4.885)	(-4.861)	(-4.737)	(-7.141)	(-7.099)	(-6.761)
$(1 + B/M)_t$	-0.001	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
	(-1.098)	(-1.102)	(-1.084)	(0.707)	(0.645)	(0.834)	(0.952)	(0.925)	(0.982)
$Size_t$	-0.004	-0.004	-0.004	0.002	0.002	0.002	0.000	0.001	0.000
	(-1.065)	(-1.088)	(-1.079)	(0.539)	(0.468)	(0.564)	(0.214)	(0.256)	(0.211)
$R\&D_t$	-0.000	-0.000	-0.000	0.000***	0.000***	0.000***	0.000	0.000	0.000
	(-0.106)	(-0.081)	(-0.120)	(3.851)	(4.115)	(3.747)	(1.475)	(1.550)	(1.383)
$Leverage_t$	0.028***	0.028***	0.028***	0.002	0.000	0.002	0.054*	0.054*	0.054*
	(7.223)	(6.559)	(7.205)	(0.174)	(0.019)	(0.181)	(1.823)	(1.794)	(1.827)
$Assets_t$	0.014	0.014	0.014	0.001	0.001	0.001	0.001	0.001	0.001
	(1.535)	(1.526)	(1.562)	(0.131)	(0.130)	(0.169)	(0.422)	(0.409)	(0.415)
$Sales_t$	-0.011	-0.011	-0.011	-0.006*	-0.005*	-0.006*	-0.003**	-0.003**	-0.003**
	(-1.592)	(-1.566)	(-1.625)	(-1.796)	(-1.777)	(-1.899)	(-1.982)	(-1.994)	(-1.980)
Age_t	0.000	0.000	0.000	0.000	0.000	0.000	-0.002	-0.002	-0.002
	(0.196)	(0.153)	(0.143)	(0.119)	(0.081)	(0.075)	(-1.450)	(-1.486)	(-1.442)
Observations	44,428	44,428	44,428	40,066	40,066	40,066	35,774	35,774	35,774

Table 6 *(continued)*

Panel B: multi-period changes

	$\Delta ROA_{t,t+2} = ROA_{t+2} - ROA_t$			$\Delta ROA_{t,t+3} = \Delta ROA_{t+3} - \Delta ROA_t$		
$\Delta Q\_Closeness_t$	-0.054***			-0.056***		
	(-6.693)			(-2.962)		
$\Delta Q\_Betweenness_t$		-0.065***			-0.070***	
		(-6.383)			(-2.847)	
$\Delta Q\_Eigenvector_t$			-0.067***			-0.068***
			(-6.625)			(-2.896)
ΔROA_{t-1}	-0.010	-0.009	-0.010	-0.012	-0.010	-0.012
	(-0.524)	(-0.471)	(-0.528)	(-0.568)	(-0.488)	(-0.575)
$Return_t$	-0.002	-0.002	-0.002	-0.008	-0.008	-0.007
	(-0.510)	(-0.479)	(-0.400)	(-1.474)	(-1.429)	(-1.372)
$(1 + B/M)_t$	-0.000	-0.001	-0.000	-0.000	-0.000	-0.000
	(-1.323)	(-1.295)	(-1.161)	(-0.922)	(-0.962)	(-0.695)
$Size_t$	-0.001	-0.002	-0.001	-0.002	-0.003	-0.002
	(-0.318)	(-0.454)	(-0.255)	(-0.461)	(-0.539)	(-0.437)
$R\&D_t$	0.000	0.000	0.000	0.000	0.000	0.000
	(0.990)	(1.021)	(0.963)	(0.916)	(0.972)	(0.849)
$Leverage_t$	0.030***	0.028***	0.030***	0.078***	0.076***	0.079***
	(2.985)	(2.799)	(3.062)	(3.288)	(3.068)	(3.283)
$Assets_t$	0.015**	0.015**	0.015**	0.016***	0.016***	0.016***
	(2.425)	(2.472)	(2.473)	(3.408)	(3.476)	(3.578)
$Sales_t$	-0.018**	-0.018**	-0.019**	-0.019***	-0.018***	-0.019***
	(-2.174)	(-2.156)	(-2.267)	(-2.729)	(-2.712)	(-2.986)
Age_t	0.001	0.001	0.001	-0.001	-0.002	-0.002
	(0.382)	(0.340)	(0.314)	(-0.642)	(-0.675)	(-0.705)
Observations	40,066	40,066	40,066	35,774	35,774	35,774

Table 7. The 2SLS first stage that controls for degree change.

This table shows the results for the first stage of the 2SLS regression of firm-specific future changes in ROA on changes in quintile ranks of centrality measures and controls, where changes in centrality quintiles are instrumented with number of director deaths at a boardroom distance of 2, 3, and at least 4 (instruments N_Death^2, N_Death^3, and $N\_Death^{\geq 4}$ are defined in section 4.3). The quintile ranks of the three centrality measures (*Closeness*, *Betweenness*, and *Eigenvector*), are calculated by first sorting firms into size quintiles each fiscal year, and then sorting the firms within each size quintile into centrality quintiles (highest centrality values correspond to rank 5). *ROA* is returns on assets calculated as the firm's net income scaled by lagged assets; *ln(1+B/M)* is the log of one plus the firm's book-to-market ratio; *R&D* is the firm's research and development expense scaled by total sales; *Ln(Size)* is the log of market capitalization; *Ln(Assets)* is the log of total assets; *Ln(Sales)* is log of total sales; *Leverage* is the firm's long-term debt scaled by total assets; *Age* is the log of the number of months since the firm appeared in CRSP. Centrality measures *Closeness*, *Betweenness*, *Eigenvector*, and *Degree*, are defined in section 4.2. Industry-by-year fixed effects are included in every regression. The *t*-statistics clustered by 2-digit industry SIC codes are shown in parentheses. *, **, and *** indicated 10%, 5%, and1% levels of significance, respectively.

	ΔQ $Closen._{t+1}$	ΔQ $Between._{t+1}$	ΔQ $Eigenv._{t+1}$
$N\_Death_t^2$	0.038***	0.047***	0.036***
	(3.923)	(4.412)	(6.002)
$N\_Death_t^3$	0.019*	0.042***	0.018***
	(1.774)	(4.784)	(3.987)
$N\_Death_t^{\geq 4}$	0.031***	0.051***	0.033***
	(3.090)	(5.738)	(6.910)
$\Delta Q\ Degree_{t+1}$	0.013***	0.012***	0.011***
	(5.269)	(4.356)	(4.281)
ΔROA_{t-1}	0.015	0.027**	0.016*
	(1.574)	(2.492)	(1.865)
$Return_t$	0.004	-0.002	-0.003
	(0.958)	(-0.369)	(-0.735)
$(1 + B/M)_t$	0.001	-0.001	-0.000
	(1.232)	(-0.996)	(-0.207)
$Size_t$	0.047***	0.039***	0.057***
	(9.264)	(8.529)	(14.496)
$R\&D_t$	-0.000**	0.001***	0.000
	(-2.140)	(4.724)	(0.928)
$Leverage_t$	-0.006	-0.044**	-0.006
	(-0.344)	(-2.103)	(-0.389)
$Assets_t$	0.009	-0.003	0.002
	(1.548)	(-0.404)	(0.382)
$Sales_t$	-0.014***	0.002	-0.008**
	(-3.266)	(0.374)	(-2.148)
Age_t	-0.005	-0.003	-0.000
	(-1.378)	(-0.916)	(-0.090)
Observations	44,428	44,428	44,428
Partial R-squared	0.007	0.006	0.015
Partial F-statistic	108.7	156.2	136.7
(F p-val.)	<0.001	<0.001	<0.001
Hansen J	0.832	0.897	0.754
(J p-val.)	0.660	0.639	0.686

Table 8. The 2SLS second stage that controls for degree change.

Changes in centrality quintiles are instrumented with number of director deaths at a boardroom distance of $i = 2,3$, and at least 4 (N_Death^i). Centrality quintiles are double-sorted each fiscal year: first by size, then by centrality within each size quintile. *ROA* is calculated as the firm's net income scaled by lagged assets; *ln(1+B/M)* is the log of one plus the firm's book-to-market ratio; *R&D* is the firm's research and development expense scaled by total sales; *Ln(Size)* is the log of market capitalization; *Ln(Assets)* is the log of total assets; *Ln(Sales)* is log of total sales; *Leverage* is the firm's long-term debt scaled by total assets; *Age* is the log of the number of months since the firm appeared in CRSP. Centrality measures are defined in section 4.2. Industry-by-year fixed effects are included in every regression. The *t*-statistics are clustered by 2-digit industry SIC.

Panel A: single-period changes

	$\Delta ROA_{t+1} = ROA_{t+1} - ROA_t$			$\Delta ROA_{t,t+2} = ROA_{t+2} - ROA_t$			$\Delta ROA_{t,t+3} = ROA_{t+3} - ROA_t$		
$\Delta Q\_Closeness_t$	-0.012			-0.067***			-0.068***		
	(-0.803)			(-6.510)			(-2.902)		
$\Delta Q\_Betweenness_t$		-0.013			-0.066***			-0.070***	
		(-0.826)			(-6.355)			(-2.858)	
$\Delta Q\_Eigenvector_t$			-0.011			-0.054***			-0.056***
			(-0.831)			(-6.585)			(-2.969)
$\Delta Q\ Degree_{t+1}$	-0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000
	(-0.334)	(-0.328)	(-0.386)	(0.120)	(0.049)	(-0.233)	(0.055)	(0.053)	(-0.289)
ΔROA_{t-1}	-0.009	-0.009	-0.009	-0.010	-0.009	-0.010	-0.012	-0.010	-0.012
	(-0.568)	(-0.554)	(-0.567)	(-0.528)	(-0.471)	(-0.524)	(-0.575)	(-0.487)	(-0.568)
$Return_t$	0.008	0.008	0.008	-0.002	-0.002	-0.002	-0.007	-0.008	-0.008
	(1.427)	(1.392)	(1.398)	(-0.400)	(-0.479)	(-0.509)	(-1.372)	(-1.429)	(-1.473)
$(1 + B/M)_t$	-0.001	-0.001	-0.001	-0.000	-0.001	-0.000	-0.000	-0.000	-0.000
	(-1.084)	(-1.102)	(-1.098)	(-1.160)	(-1.295)	(-1.324)	(-0.694)	(-0.961)	(-0.922)
$Size_t$	-0.004	-0.004	-0.004	-0.001	-0.002	-0.001	-0.002	-0.003	-0.002
	(-1.078)	(-1.086)	(-1.065)	(-0.254)	(-0.452)	(-0.319)	(-0.437)	(-0.537)	(-0.461)
$R\&D_t$	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(-0.121)	(-0.082)	(-0.106)	(0.962)	(1.021)	(0.989)	(0.848)	(0.971)	(0.915)
$Leverage_t$	0.028***	0.028***	0.028***	0.030***	0.027***	0.030***	0.079***	0.076***	0.078***
	(7.213)	(6.556)	(7.234)	(3.062)	(2.798)	(2.985)	(3.284)	(3.067)	(3.288)
$Assets_t$	0.014	0.014	0.014	0.015**	0.015**	0.015**	0.016***	0.016***	0.016***
	(1.562)	(1.526)	(1.534)	(2.477)	(2.475)	(2.427)	(3.588)	(3.485)	(3.417)
$Sales_t$	-0.011	-0.011	-0.011	-0.019**	-0.018**	-0.018**	-0.019***	-0.018***	-0.019***
	(-1.627)	(-1.568)	(-1.594)	(-2.266)	(-2.156)	(-2.175)	(-2.984)	(-2.712)	(-2.730)
Age_t	0.000	0.000	0.000	0.001	0.001	0.001	-0.002	-0.002	-0.001
	(0.116)	(0.127)	(0.164)	(0.316)	(0.338)	(0.371)	(-0.697)	(-0.670)	(-0.644)
Observations	44,428	44,428	44,428	40,066	40,066	40,066	35,774	35,774	35,774

Table 9. The 2SLS first stage for firms that don't change their board composition and links.

Changes in centrality quintiles are instrumented with number of director deaths at a boardroom distance $i = 2,3$, and at least 4 (N_Death^i). Centrality quintiles are calculated by first sorting firms into size quintiles each fiscal year, and then sorting the firms within each size quintile into centrality quintiles (highest centrality values correspond to rank 5). Control variables are defined in section 4.4. Industry-by-year fixed effects are included in every regression. The *t*-statistics are clustered by 2-digit industry SIC codes. *, **, and *** indicated 10%, 5%, and1% levels of significance, respectively.

	$\Delta ROA_{t+1} = ROA_{t+1} - ROA_t$			$\Delta ROA_{t,t+2} = ROA_{t+2} - ROA_t$			$\Delta ROA_{t,t+3} = ROA_{t+3} - ROA_t$		
	$\Delta Q\ Clos._{t+1}$	$\Delta Q\ Betw._{t+1}$	$\Delta Q\ Eig._{t+1}$	$\Delta Q\ Clos._{t+1}$	$\Delta Q\ Betw._{t+1}$	$\Delta Q\ Eig._{t+1}$	$\Delta Q\ Clos._{t+1}$	$\Delta Q\ Betw._{t+1}$	$\Delta Q\ Eig._{t+1}$
$N\_Death_t^2$	0.038	-0.001	0.048	0.053*	-0.004	0.064	0.063*	0.012	0.047
	(1.575)	(-0.039)	(1.077)	(1.903)	(-0.133)	(1.338)	(1.874)	(0.352)	(0.872)
$N\_Death_t^3$	0.017	0.008	0.022	0.036	0.015	0.038	0.042	0.031	0.020
	(0.752)	(0.284)	(0.564)	(1.326)	(0.516)	(0.921)	(1.354)	(0.902)	(0.466)
$N\_Death_t^{\geq 4}$	0.029	0.015	0.031	0.046*	0.021	0.046	0.053*	0.037	0.028
	(1.266)	(0.564)	(0.771)	(1.754)	(0.732)	(1.080)	(1.733)	(1.095)	(0.627)
ΔROA_{t-1}	-0.020	-0.101***	-0.021	-0.028	-0.116***	-0.031	-0.049	-0.121***	-0.041
	(-0.276)	(-3.088)	(-0.429)	(-0.418)	(-3.886)	(-0.789)	(-0.822)	(-3.736)	(-1.092)
$Return_t$	-0.007	0.015	0.051**	-0.008	0.015	0.058***	-0.011	0.013	0.053**
	(-0.284)	(1.143)	(2.519)	(-0.346)	(1.120)	(2.605)	(-0.466)	(0.972)	(2.389)
$(1 + B/M)_t$	-0.021	-0.043	-0.003	-0.011	-0.038	0.002	-0.016	-0.028	-0.006
	(-0.586)	(-0.959)	(-0.076)	(-0.303)	(-0.745)	(0.055)	(-0.458)	(-0.545)	(-0.149)
$Size_t$	0.067***	0.022	0.018	0.087***	0.025	0.029	0.089***	0.024	0.023
	(2.867)	(0.858)	(0.592)	(3.576)	(0.858)	(0.918)	(3.669)	(0.689)	(0.711)
$R\&D_t$	-0.017***	-0.009***	-0.016***	-0.016***	-0.009***	-0.015***	-0.015***	-0.008***	-0.015***
	(-6.776)	(-4.375)	(-7.600)	(-7.381)	(-3.625)	(-7.553)	(-5.641)	(-2.725)	(-7.541)
$Leverage_t$	0.048	0.011	0.047	0.049	-0.001	0.058	0.016	-0.034	0.004
	(0.780)	(0.136)	(0.416)	(0.864)	(-0.015)	(0.627)	(0.255)	(-0.358)	(0.043)
$Assets_t$	-0.033	-0.047*	0.005	-0.046	-0.039	-0.004	-0.049	-0.030	-0.003
	(-0.846)	(-1.685)	(0.090)	(-1.189)	(-1.377)	(-0.079)	(-1.323)	(-0.935)	(-0.069)
$Sales_t$	-0.019	0.026	-0.026	-0.022	0.017	-0.025	-0.018	0.015	-0.022
	(-0.777)	(1.242)	(-0.741)	(-0.939)	(0.671)	(-0.708)	(-0.730)	(0.531)	(-0.646)
Age_t	0.026	0.027*	-0.009	0.030	0.035*	-0.009	0.022	0.030	-0.017
	(1.320)	(1.763)	(-0.312)	(1.399)	(1.947)	(-0.329)	(0.998)	(1.632)	(-0.582)
Observations	4,526	4,526	4,526	4,109	4,109	4,109	3,724	3,724	3,724
Partial R-squared	0.010	0.008	0.003	0.011	0.009	0.003	0.011	0.010	0.002
Partial F-statistic	14.86	7.480	6.734	16.67	6.885	3.896	15.03	7.654	3.707
(F p-val.)	<0.001	<0.001	<0.001	<0.001	<0.001	0.012	<0.001	<0.001	0.016
Hansen J	0.504	0.529	1.261	1.806	1.900	1.596	0.904	1.444	0.464
(J p-val.)	0.777	0.768	0.532	0.405	0.387	0.450	0.636	0.486	0.793

Table 10. The 2SLS second stage for firms that don't change their board composition and links.

Changes in centrality quintiles are instrumented with number of director deaths at a boardroom distance of 2, 3, and at least 4 (N_Death^2, N_Death^3, and $N\_Death^{\geq 4}$ are defined in section 4.3). Centrality quintiles are calculated by first sorting firms into size quintiles each fiscal year, and then sorting the firms within each size quintile into centrality quintiles (highest centrality values correspond to rank 5). *ROA* is calculated as the firm's net income scaled by lagged assets; *ln(1+B/M)* is the log of one plus the firm's book-to-market ratio; *R&D* is the firm's research and development expense scaled by total sales; *Ln(Size)* is the log of market capitalization; *Ln(Assets)* is the log of total assets; *Ln(Sales)* is log of total sales; *Leverage* is the firm's long-term debt scaled by total assets; *Age* is the log of the number of months since the firm appeared in CRSP. Centrality measures *Closeness*, *Betweenness*, and *Eigenvector* are defined in section 4.2. Industry-by-year fixed effects are included in every regression. The *t*-statistics clustered by 2-digit industry SIC codes are in parentheses. *, **, and *** indicated 10%, 5%, and1% levels of significance, respectively.

Panel A: single-period changes

	$\Delta ROA_{t+1} = ROA_{t+1} - ROA_t$			$\Delta ROA_{t,t+2} = ROA_{t+2} - ROA_t$			$\Delta ROA_{t,t+3} = ROA_{t+3} - ROA_t$		
$\Delta Q\_Closeness_t$	-0.091**			-0.103***			-0.081**		
	(-2.558)			(-2.972)			(-2.106)		
$\Delta Q\_Betweenness_t$		-0.092**			-0.082*			-0.065	
		(-2.421)			(-1.710)			(-1.365)	
$\Delta Q\_Eigenvector_t$			-0.116**			-0.157**			-0.133**
			(-2.365)			(-2.302)			(-2.059)
ΔROA_{t-1}	0.031	0.024	0.031*	0.006	-0.001	0.004	0.018	0.015	0.017
	(1.613)	(1.099)	(1.648)	(0.228)	(-0.038)	(0.161)	(0.463)	(0.377)	(0.452)
$Return_t$	0.052*	0.054*	0.058*	0.047	0.049	0.057*	0.049	0.051	0.057*
	(1.830)	(1.762)	(1.926)	(1.476)	(1.431)	(1.756)	(1.470)	(1.442)	(1.650)
$(1 + B/M)_t$	-0.004	-0.006	-0.003	-0.004	-0.006	-0.003	-0.004	-0.004	-0.003
	(-0.586)	(-0.762)	(-0.350)	(-0.456)	(-0.582)	(-0.253)	(-0.415)	(-0.457)	(-0.314)
$Size_t$	-0.006	-0.011	-0.010	-0.010	-0.016	-0.014	-0.022	-0.027	-0.026
	(-1.191)	(-1.396)	(-1.473)	(-0.991)	(-1.375)	(-1.135)	(-1.352)	(-1.587)	(-1.590)
$R\&D_t$	-0.005***	-0.005***	-0.006***	-0.001	0.000	-0.001	0.015***	0.016***	0.014***
	(-4.810)	(-5.894)	(-4.257)	(-0.521)	(0.564)	(-0.732)	(10.467)	(11.553)	(8.820)
$Leverage_t$	-0.005	-0.009	-0.004	-0.016	-0.021	-0.011	-0.022	-0.025	-0.022
	(-0.373)	(-0.590)	(-0.258)	(-0.750)	(-0.980)	(-0.563)	(-0.940)	(-1.147)	(-0.963)
$Assets_t$	0.014	0.013	0.018	0.021	0.023	0.026	0.029	0.031	0.032
	(1.321)	(1.065)	(1.338)	(1.254)	(1.279)	(1.229)	(1.320)	(1.339)	(1.323)
$Sales_t$	-0.011	-0.007	-0.012	-0.016*	-0.012	-0.017	-0.005	-0.003	-0.007
	(-1.300)	(-0.899)	(-1.281)	(-1.699)	(-1.365)	(-1.537)	(-0.420)	(-0.226)	(-0.457)
Age_t	-0.001	-0.001	-0.004	0.000	0.000	-0.004	-0.002	-0.002	-0.006
	(-0.322)	(-0.281)	(-1.229)	(0.064)	(0.024)	(-0.782)	(-0.652)	(-0.572)	(-1.154)
Observations	4,526	4,526	4,526	4,109	4,109	4,109	3,724	3,724	3,724