Director Networks and Firm Value*

Tor-Erik Bakke[1], Jeffrey R. Black[2], Hamed Mahmudi, and Scott C. Linn[3]

December 6, 2017

Abstract

Are the professional networks of corporate directors valuable? More connected directors may have better information and more influence, which can increase firm value. However, directors with larger networks may also be busy or spread value-decreasing management practices. To identify the effect of director networks on firm value, we use the unexpected deaths of well-connected directors as a shock to the director networks of interlocked directors. By looking at the announcement returns and using a difference-in-differences methodology, we find that this negative shock to director networks reduces firm value. This evidence suggests that director networks are valuable.

JEL Classification: G3, G32, D85, L14

Keywords: Board of directors, network centrality, quasi-natural experiment, firm value

* We are grateful to Bill Megginson, Mauricio Larrain, Borja Larrain and Peter Mackay and seminar participants at the University of Oklahoma and Pontificia Universidad Catolica de Chile for helpful comments.

[1] College of Business Administration, The University of Illinois at Chicago, Phone: (312) 996-2980; E-mail: tbakke@uic.edu
[2] Fogelman College of Business, University of Memphis, Phone: (901) 678-3632; E-mail: jrblack@memphis.edu
[3] Price College of Business, University of Oklahoma, Phone: (405) 325-3444; E-mail: slinn@ou.edu

Director Networks and Firm Value

Abstract

Are the professional networks of corporate directors valuable? More connected directors may have better information and more influence, which can increase firm value. However, directors with larger networks may also be busy or spread value-decreasing management practices. To identify the effect of director networks on firm value, we use the unexpected deaths of well-connected directors as a shock to the director networks of interlocked directors. By looking at the announcement returns and using a difference-in-differences methodology, we find that this negative shock to director networks reduces firm value. This evidence suggests that director networks are valuable.

1. Introduction

The board of directors of a corporation is responsible for making decisions on major corporate issues and establishing policies related to management such as setting CEO compensation and firing and hiring the CEO. The director network, defined as the connections, both current and former, between a firm's board of directors and board members at other firms, may allow well-connected boards to perform these crucial tasks more effectively. Connected directors may not only have better access to information about value-increasing management practices (Mizruchi, 1990; Mol, 2001), but also have more influence over fellow directors and management to ensure these practices are implemented (DeMarzo, Vayanos, and Zwiebel, 2003). Moreover, better connected directors may have better access to suppliers, customers or politicians through their network which can lead to strategic economic benefits for the firm. Conversely, a well-connected board could also have negative effects on firm value. For instance, more connected directors could be more distracted (Fich and White, 2003; Loderer and Peyer, 2002; Fich and Shivdasani, 2006) or they may spread value-destroying management practices or misleading information (Bizjak, Lemon, and Whitby, 2009; Snyder, Priem, and Levitas, 2009; Armstrong and Larcker, 2009).

To determine whether the benefits of connected boards on average outweigh the costs, we use an exogenous shock which reduces board connectedness to examine if director networks are valuable. Specifically, we use the unexpected deaths of well-connected directors as a negative shock to the networks of directors who sit on the same board as the deceased director (interlocked directors). The death of the well-connected director severs the network tie between the interlocked director and the deceased director's network. This represents a negative shock to the director network of other firms on whose board the interlocked director also sits (director-interlocked firms). By looking at the announcement returns of the director-interlocked firms and using a difference-in-differences methodology, we find that this negative shock to director networks reduces firm value suggesting that director networks are value-enhancing.

Existing work finds evidence of a positive association between director networks and firm value (Larcker, So, and Wang, 2013). However, due to the pervasive endogeneity of director choice and firm value, convincingly establishing causality has eluded researchers. For instance, better connected directors may choose to sit on the boards of better performing firms, or an omitted variable such as investment opportunities may be correlated with both director connectedness and firm value. Moreover, well-connected directors are usually more experienced and talented which further complicates identifying the effect of directors' connectedness on firm value.

Our experimental setup (illustrated in Figure 1) helps overcome this endogeneity problem. First, the unexpected death of interlocked directors is unlikely to be correlated with value-relevant omitted variables which could contaminate inference. Second, the randomness of the unexpected death results in estimates that are not subject to the bias caused by the endogenous matching between directors and firms. Finally, as we study how the unexpected death of well-connected directors affects the value of interlocked firms (and not the deceased director's firm itself), we are able to separate out the effect of board connectedness on firm value from the effect of other value-relevant director attributes.

We focus on professional networks in which directors are connected if they currently or previously served on the same board. The advantage of focusing on professional connections is that they are observable, objective and not subject to sample selection concerns. For instance, unlike many educational ties where directors may have simply co-existed in the same environment, directors that served on the same board have had repeated face-to-face interactions and a working relationship. The disadvantage is that we miss other types of social connections that could also facilitate the flow of information and affect the centrality of a director in the network.

Well-connected directors can be thought of as directors who are central to the network's flow of information and resources (i.e., directors who have high centrality measures in the board network). To find the deaths of the most connected directors, we first compute commonly used centrality measures for all directors in our sample. Our sample consists of the unexpected deaths of seven well-connected directors which results in 128 directors at 159 interlocked firms that experienced negative shocks to their director networks. These director-interlocked firms lose access to the deceased director's network and are therefore considered the treatment group.[1]

[1] We measure connections in our network at the finer director level before aggregating it at a firm level. This estimation allows us to accurately account for loss of multiple connections by multiple directors of the interlocked firms due to the sudden death of each well-connected director.

For our identification strategy to be effective the exogenous shock to director networks, induced by unexpected deaths of well-connected interlocked directors, needs to be sufficiently large to create an economically meaningful drop in the board centrality measures of treated firms. To this end we focus on publically traded Canadian firms in the period 2000 to 2012. We use Canadian firms because network shocks, such as the one we utilize, are more likely to be economically large in smaller and denser networks such as Canadian board networks.[2] Intuitively, this is because the loss of one well-connected director is more likely to lead to the interlocked firm being cut off from other firms in the network (i.e., becoming less central in the network). In contrast, in a larger and more disperse network like in the US the loss of a well-connected interlocked director is likely to have a smaller impact on the interlocked firm as firms are connected through multiple links which means the importance of losing a connection (even a relatively important one) is reduced.[3]

The shock to the connectedness of director-interlocked firms is economically and statistically significant. We find that the centrality of treated firms falls by about 1% relative to control firms.[4] Moreover, it is likely that the change in the centrality measure understates the magnitude of the shock as it implicitly assumes that readjusting the network is frictionless. In reality adjusting one's network, to compensate for the loss of the well-connected directors network, entails significant frictions in the form of search costs. In further support of the argument that these shocks are significant, Falato, Kadyrzhanova, and Lel (2014) find that replacing a lost director is both time consuming and costly.

[2] With the exception of the density (the average number of director links between two firms) of director networks in US and Canada, other institutional features of publicly traded firms (e.g.., board characteristics etc.) in the two countries are similar. This homogeneity reinforces the external validity of our findings. Moreover, most countries tend to have director networks that is more similar to Canada rather than the US, which also suggests that our results are applicable outside of Canada.

[3] For example, in our sample of publicly traded Canadian firms in 2012, on average every director has 11.69 connections with other directors in the network. In contrast, in the equivalent sample of publicly traded firms in the US in 2012, a director, on average, has 83.30 connections with other directors in the network. This suggests a loss of a connection and in particular a connection with a well-connected director in Canada may result in a relatively larger loss in network centrality measures compared to the loss of a director connection among US firms.

[4] Changes in eigenvector centrality best capture the effect of the loss of a well-connected director on an interlocked director's network which is the focus of our identification strategy.

To test whether the elimination of network ties affects firm value, we conduct an event study around the unexpected deaths of the well-connected directors. We compare the announcement returns of treated firms to a matched sample of control firms, from the same industry that are of similar size and director centrality prior to the event, which were unaffected by the director network. shock We show that the shock to director networks, caused by an unexpected death of a director, results in negative cumulative abnormal returns (CARs) for director-interlocked firms relative to the control sample. Specifically, in univariate results, we find that relative to control firms, treated firms have around 0.6 percent lower abnormal returns in response to the unexpected death of well-connected interlocked directors on the day the death is announced. When controlling for other various factors in a multivariate seemingly unrelated regression (SUR) framework, this difference is about 0.3 percent but remains highly statistically significant. This indicates that the loss of network connections led to a statistically and economically significant decline in firm value of director-interlocked firms.

We investigate whether our results are driven by an increase in the busyness of interlocked directors. This is important as our results could be confounded by the fact that the unexpected death of the well-connected director has two effects on interlocked directors: (i) a negative shock to the director's network and (ii) an increase in the director's busyness (Falato, Kadyrzhanova, and Lel, 2014). To separate these two effects, we redefine treated firms to only include firms who lost a past connection due to the unexpected death of one of the well-connected directors. These firms have at least one director who previously served on the same board as the deceased director (a past connection), but do not currently share a director with the deceased director's firm(s). As the loss of a past connection does not increase the busyness of the interlocked director, but does affect the connectedness of the director, this strategy (see Figure 2) enables us to better isolate the first effect (i). We find that our results continue to hold using only past connections suggesting that our results are not simply an artifact of an increase in director busyness but are at least in part due to a reduction in the connectedness of the firm's directors.

Next, we explore if our results are driven by the loss of a connection to financial firms, and therefore access to financing. To test this we omit network shocks which involve the passing of a bank director. We find that our result, that adverse network shocks reduce firm value, persists despite no change in interlocked firms' direct connections to bank directors. This suggests that the value of director networks is not solely due to connections to banks and better access to finance.

We contribute to several strands of literature. First, we contribute to the broad literature on the value of connections. Faccio and Parsley (2009) show that political connections are valuable; Hochberg, Ljungqvist and Lu (2007) find that more connected venture capital firms perform better; Cohen, Frazzini, and Malloy (2008) and Cohen, Frazzini, and Malloy (2010) show that connections based on shared educational backgrounds are valuable to mutual fund managers and equity research analysts respectively; Engelberg, Gao, and Parsons (2013) provide evidence that CEOs are paid more when their network connections are more valuable while Faleye, Kovacs, and Venkateswaran (2012) show that better-connected CEOs innovate more. We add to this literature by showing that firms benefit from having better-connected boards.

Second, our paper extends the literature that studies the influence of director networks generally. This literature uncovers positive as well as negative implications to having a well-connected board. Barnea and Guedj (2009) and Renneboog and Zhao (2011) show that firms with better connected directors pay their CEOs more, but these firms also grant pay packages with lower pay-performance sensitivity. In addition, Barnea and Guedj (2009) show that well connected directors are more likely to be recruited to more directorships but provide softer monitoring of management.

On the positive side, Horton, Millo, and Serafeim (2012) show that the positive link between connectedness and director compensation is not due to the connected directors using their power to extract economic rents. Instead, they find evidence that firms compensate directors for their network connections. Moreover, Fogel, Ma, and Morck (2014) show that powerful independent directors are associated with fewer value-destroying M&A bids, more high-powered CEO compensation, more accountability for poor performance, and less earnings management. Helmers, Patnan, and Rau (2015) find that better-connected boards spend more on R&D and obtain more patents. Shelley, and Tice (2015) demonstrate that firms with well-connected boards are less likely to both misstate their annual financial statements and adopt practices that reduce financial reporting quality. Although we do not investigate the effect of director networks on corporate policy, we show within the context of a carefully controlled empirical design, that overall well-connected boards are value-enhancing.

Third, we add to the literature that studies the link between board connectedness and firm value. Several studies have found positive associations between the connectedness of a firm's board of directors and its operating performance (Hochberg, Ljungqvist, and Lu, 2007; Horton, Millo, and Serafeim, 2012; Crespí-Caldera and Pascual-Fuster, 2015). Larcker, So, and Wang (2013) show that firms with more connected boards have significantly higher risk-adjusted returns than firms with less connected boards. Stern (2015) demonstrates, using a learning model, that better connected board chairmen (but not directors in general) are associated with more value creation for their firms. In contrast to these papers, we provide causal evidence that having better connected directors increases firm value.

Fogel, Ma, and Morck (2014) provide evidence that the unexpected death of powerful directors negatively affects the value of the powerful director's firm. However, unlike in our paper, they are unable to distinguish whether the decline in value was due to the loss of the deceased director's talent or due to the loss of the deceased director's connections. As connected directors are likely to be talented, this may confound inference. We get around this challenge by examining the effect of the unexpected death on director-interlocked firms only. Thus we are able to isolate the direct effect of director networks on firm value.

2. Director Networks and Firm Value

In this section we discuss the link between the connectedness of a firm's board of directors and firm value. We start by discussing the benefits of director networks, and then switch to the potential costs. The potential benefits of having well-connected directors come in three forms. First, directors can use their boardroom networks to gain access to valuable information from other directors. This information could be related to industry trends, market conditions, and regulatory changes or could be information on value-enhancing business practices (e.g., technological innovations, effective corporate governance mechanisms etc.). Thus, well-connected directors are able to make better decisions as they have access to a larger pool of information. (Mizruchi, 1990; Mol, 2001).

Second, well-connected directors may have better access to strategic economic benefits through their networks. For instance, closely connected firms could benefit from collusion and other anti-competitive behavior (Pennings, 1980).[5] Another potential strategic benefit is that connected firms may enjoy political favors or superior supplier or customer relationships which could not be possible without access to a large professional network of directors.

Finally, better connected directors may be more influential and therefore better able to prevail in discussions with the rest of the board and management. As demonstrated in a theory paper by DeMarzo, Vayanos and Zwiebel (2003), an individual's influence on group opinions depends not only on accuracy, but also on how well-connected the individual is. Thus, a director who is well-connected within the network of directors is more likely to have the power to sway other directors in the board room towards his views. Both the well-connected director's access to superior information and increased power to persuade the board should lead to better firm decisions and enhanced shareholder value.

There are also potential costs to having a well-connected board. Bizjak, Lemon, and Whitby (2009), Snyder, Priem, and Levitas (2009) and Armstrong and Larcker (2009) find that director connections facilitate the propagation of value-destroying governance practices. Moreover, well-connected directors with multiple directorships may be busy and therefore unable to allocate sufficient time and attention to monitoring and advising on all the boards on which they serve. This in turn could negatively affect firm value (Core et al., 1999; Fich and White, 2003; Loderer and Peyer, 2002; Fich and Shivdasani, 2006).

Several papers provide evidence suggesting that the benefits of director networks exceed the costs and that director networks overall increase firm value. Larcker, So, and Wang (2013) demonstrate that firms with large director networks are associated with superior risk-adjusted returns and greater increases in future profitability than firms with less connected boards. However, endogeneity remains a significant concern. This must be properly addressed before advising firms to go out and hire more connected directors.

In this setting endogeneity concerns are numerous and multi-faceted. One concern is reverse causality. For instance, more connected directors may choose to work for better firms (Masulis and Mobbs, 2012). Moreover, connected directors may also use their

[5] It is important to note that, although collusion can have a positive effect on firm value, if it leads to the violation business law, the regulatory, litigation, and reputation costs can negatively affect firm value.

networks to correctly anticipate which firms are likely to perform well. Thus, causality may flow from firm value to more connected boards, and not vice versa. Another concern is omitted variables. Any unobservable variable that affects firm value and is correlated with board connectedness can contaminate inference. For example, connected directors may choose to work for firms with better governance or good investment opportunities, both of which are likely to affect firm value. Although, it is possible to find proxies for both governance and investment opportunities, these proxies are imperfect and any measurement error could significantly bias the estimated coefficients.

Another important latent variable is director ability. Fogel, Ma, and Morck (2014) provide evidence that the sudden death of powerful directors negatively affects the value of the powerful director's firm. However, powerful directors are also likely to be talented. By omitting director talent, Fogel, Ma, and Morck (2014) are not able to determine whether it is the loss of the deceased director's connections or talent that causes the decline in firm value. In the identification section (section 4) we discuss how we tackle these endogeneity concerns and provide persuasive causal evidence that more connected boards increase firm value, but first we present our data and how we measure director connectedness.

3. Data and Network Centrality Measures

3.1 Data

Our sample consists of Canadian public firms in the Clarkson Centre for Business Ethics and Board Effectiveness dataset from 2000 to 2012. We use annual firm-level accounting data from Worldscope and return data from Datastream. We drop all observations with missing or negative total assets. We calculate Tobin's Q as the sum of market capitalization and the book value of debt, scaled by total assets. Leverage is calculated as total debt over total assets (and is treated as missing if less than zero), and ROA is calculated as net income over total assets. Finally, cash and capital expenditures are scaled by total assets. Firm size is log(total assets). All continuous variables are winsorized at the 1^{st} and 99^{th} percentiles.

3.2. Director network centrality measures

We construct director networks measures for each firm-year in our sample using data from the Clarkson Centre for Business Ethics and Board Effectiveness. Two directors are linked if they (i) currently or previously sit on the same board or (ii) only previously sat on the same board.[6] The network is undirected and unweighted. Undirected networks assume that influence and information flow both ways between connected directors. In unweighted networks each link between directors has equal importance (i.e., the intensity of each link is the same).

As is common in the literature (Renneboog and Zhao, 2011; Larker, So, and Wang, 2013; Berkman, Koch, and Westerholm, 2015; Crespi-Cladera and Pascual-Fuster, 2015) we restrict attention to the director's professional network (i.e., shared directorates). The advantage of focusing on professional connections is that we can observe the entire network. Moreover, no judgement is involved in determining the ties. Finally, directors that served on the same board have had repeated face-to-face interactions and a working relationship. In contrast, educational ties (considered by Fogel, Ma, and Morck (2014)) could range from situations in which directors worked closely together to situations in which directors may have simply co-existed in the same environment. A downside of focusing only on professional connections is that that we miss other types of social connections (i.e., friends, acquaintances, family etc.) that could also facilitate the flow of information and affect the centrality of a director in the network. Unfortunately, data on social ties is not widely available.

Using the start and end dates for each director's position, we construct a separate adjacency matrix for each year from 2000 through 2012. Intuitively, the adjacency matrix represents the network structure in each sample year. More specifically, the adjacency matrix $\boldsymbol{A}$ is a symmetric matrix in which each row and corresponding column refer to an individual director. Director i is then defined as connected to director j ($\boldsymbol{A}[i, j] = \boldsymbol{A}[j, i] = 1$) if the two directors sit on the same firm's board in the same year, or *have ever* sat on the same board in the same year at some point in the past. If a director leaves the sample completely, and does not return, then all of her connections are severed. This could happen for various reasons from retirement to illness to a career change, as well as death.

[6] In regard to past connections, we use director start dates, and end dates for each position that each director holds to establish if directors previously sat on the same board. This approach allows the network to extend back beyond 2000. One shortcoming is that we miss past connections if at least one of the directors ended a position before 2000.

Using the adjacency matrices constructed based on our network of directors and UCINET software (see Borgatti, Everett, and Freeman (2002)), we calculate the four network centrality measures for each director each year: degree, eigenvector, closeness, and betweenness. Degree centrality measure is the number of connections a given director has within the network. Mathematically, the degree centrality for director *i* is simply the sum of column *i* (or row *i*) in the adjacency matrix.

Eigenvector centrality is closely related to degree centrality. Intuitively, eigenvector centrality weights each connection by how important it is. Specifically, eigenvector centrality is an iteratively calculated weighted average of the importance of a director's direct contacts, with weights determined by the importance of their direct connections, and so on. Assuming E_i is the eigenvector centrality measure for director *i*, and $\boldsymbol{E}$ is a vector containing $[E_1, E_2,\ldots, E_i,\ldots,E_N]$, then the aforementioned iterative calculations will converge to the condition $\boldsymbol{AE} = \lambda\boldsymbol{E}$, where λ is the eigenvalue associated with $\boldsymbol{E}$.[7] The resulting E_i values are then normalized using a Euclidian normalization in order for the sum of the squares of the resulting centrality measures to equal 1 for any given network. This allows for comparison of eigenvector centrality measures between different networks.

A director's closeness centrality captures how close the director is to every other director in the network. Closeness centrality is calculated as the reciprocal of the sum of the shortest distances between the director and every other director in the network. One complication is that in large and complex network, such as the one we study, some directors in isolated subnetworks may have undefined distances to others (i.e., there are some parts of the network they cannot access). To account for this, we follow Fogel, Ma, and Morck (2014), and define director i's closeness, C_i as

$$C_i = \frac{n_i - 1}{\sum_{i \neq j \in N} g_{ij}} \times \frac{n_i}{N}, \tag{1}$$

where n_i is the size of the subnetwork which contains director *i*, g_{ij} is the geodesic distance from director *i* to director *j*, and *N* is the size of the entire network. This correction calculates the closeness of a director within a sub-network, and then weights that closeness measure by the relative size of the sub-network, which will correct for a director being highly

[7] Since the adjacency matrix $\boldsymbol{A}$ may have multiple eigenvalues, we apply the Perron-Frobenius theorem to ensure that all $E_i \geq 0$, and use the eigenvector $\boldsymbol{E}$ with the largest λ.

connected within a very small sub-network (i.e., one firm with a board that has no connections to any other directors at other firms).

A director's betweenness centrality is the number of the shortest-paths between all directors in the network that go through the director. To better understand this measure, consider a spoke-and-hub network. The center hub will lie on every shortest path between the other directors (high betweenness), but a spoke will not lie on any of the shortest paths (low betweenness).

Directors who score highly on any of these four network centrality measures are likely to have more power and influence as well as better access to information. That being said, different centrality measures are important for different reasons. For example, the number of immediate connections a director has – degree centrality – as well as the importance of those connections – eigenvector centrality – may increase the director's power and influence in the board room (Renneboog and Zhao, 2011) and enable directors to better convince or persuade other directors or management. Closeness and betweenness centrality may be more apt to capture a director's ease of accessing valuable information. For example, if a director has a high betweenness centrality, then she is more likely to broker conversations with other directors, gaining insight to potentially valuable information. Similarly, if a director has a high closeness centrality, then his position to access information is advantageous relative to other directors in the network. It can also be argued that betweenness centrality better captures the power of the director as high betweenness implies that the director is on more of the shortest paths within the network and therefore more influential (Lee, Cotte, and Noseworthy (2010)). Given the subtle differences between the measures, we report and use all four measures in our analysis.

4. Identification Strategy

4.1 Quasi-natural experiment

In this section we describe how we identify the effect of director networks on firm value (also see Figure 1 for an illustration of our identification strategy). We focus on the negative shocks to director network stemming from the unexpected deaths of well-connected directors. To find the unexpected deaths of well-connected directors we first identify all directors who left the sample between 2000 and 2012. Second, we prioritize the directors with the highest network centrality measures. Specifically, we search for unexpected death among the 200 most connected directors for each year in our sample. Third, to ascertain which of the well-connected directors left the sample due to an unexpected death, we hand collect information about the passing of numerous directors from Factiva, obituaries, news media, and press releases. We eliminate all directors who left the sample for a reason other than death (i.e. career change, retirement, etc.). To ensure that the death is unanticipated and exogenous, we also exclude director deaths in which the director retired prior to his passing, or had a prolonged illness which caused them to leave a firm in the year of their death.

Ultimately, we classify seven deaths as unexpected. Specifically we identify unexpected deaths of well-connected directors in 2001, 2002, 2003, 2005, 2006, and two in 2011. To illustrate what we consider an unexpected death, consider two examples. One director, Donald Fullerton, died May 29, 2011. His obituary claimed it to be a “sudden but peaceful passing.” Another director, John Beddome, died on May 10, 2005 “after a brief and courageous struggle with cancer.” We deem each of the seven director deaths (see section 3.3) to be sufficiently unexpected so that any the impact of their deaths is not already impounded in market prices. Even if deaths were partially anticipated it is likely that much uncertainty is still resolved on and around the announcement date. Moreover, the suddenness of the deaths implies that the firm did not have a readily available replacement. Consistent with this conjecture, Falato, and Kadyrzhanova, and Lel (2014) provide evidence that about half of firms, that lost a director due to death, do not fill the director vacancy one or two year after the death. They show that firms fill director vacancies even slower after an unexpected death.

To identify the impact of the board connectedness on firm value, we conduct an event study around each unexpected death. Treated firms are defined as any firm that had a director interlock with the deceased director’s firm. These firms lost access to the well-connected director’s network and are therefore subject to a network shock. Given that the deaths were unexpected, announcement returns should capture the value implications of the network shock on the firm value of director interlocked firms. Moreover, the unexpected nature of the shock also ensures that we have exogenous variation in director networks allowing the identification of a causal effect. We compare the abnormal returns of treated firms to a baseline of similar control firms, that were unaffected by the network shock (i.e., do not have an interlock with the deceased director's firm). To the extent that the market anticipated how firms would react to loss of network connections, this difference-in-differences test can be interpreted as the causal effect of director connectedness on firm value.

It is important to recognize that we exclude the deceased director's firm from our analysis (i.e., these firms are not part of our treatment group). The deceased director firms could see drops in value for two reasons, due to (i) the loss of the deceased director's network connections and (ii) the loss of the deceased director's talents, experience and knowledge. By focusing our analysis only on director-interlocked firms we are able to, unlike Fogel, Ma, and Morck (2014), to isolate the effect of the shock to board connectedness on firm value.

Overall, our identification strategy has three main advantages relative to the existing literature. First, the unexpected death of interlocked directors is unlikely to be correlated with value-relevant omitted variables which could lead to biased inference. Second, the randomness of the unexpected death results in implies our results are not an artifact of the endogenous matching between directors and firms. Finally, by studying interlocked firms we are able to separate out the effect of board connectedness on firm value from the effect of other value-relevant director attributes.

4.2 Unexpected director deaths as shocks to director networks

For each year in which we identify sudden director death, we create "shocked" adjacency matrices for each year. These shocked matrices are identical to the pre-shock matrices, except for the column and row corresponding to the deceased director, in which we change each element to zero.[8] In other words, the post-shock network structure is identical to the pre-shock network structure except that the well-connected director is removed from the network. To assess the magnitude of the shock to director networks induced by well-connected director deaths, we aggregate the estimated centrality measures at the firm level

[8] In 2011, there are two chronological shocks. The first shocked adjacency matrix is treated the same as the other shocked matrices, but for the second shocked matrix, we use the first shocked matrix as the pre-shock matrix, and eliminate connections of the second deceased director.

by averaging the network centrality measures of firms' current directors each year. This is done for both the pre-shock and shocked director networks. Next, we find the percentage change in firm-level average director centrality by dividing the difference in the shocked and pre-shocked centrality by the pre-shock centrality value. This provides us with a relative measure of how much a given death affects the network centrality of each firm's board of directors.

How large are our network shocks? To determine this we compare how the shock affected firms with direct connections to the deceased directors firms (treated firms) to firms without this direct connection (control firms). We find that the shock to director networks is economically and statistically significant. Eigenvector centrality is significantly shocked, dropping 0.91% more for treated firms relative to control firms. The other network centrality measures also experience statistically significant drops, but the magnitudes are smaller (degree, closeness, and betweenness centrality are differentially shocked by -0.26%, -0.02%, and -0.15%, respectively). This is not unexpected as eigenvector centrality is the centrality measure that is best suited to capture the loss of an important individual connection (as is the case in our setting).

We also regress the percentage changes in average firm network centrality on a treatment dummy. The regression coefficient on the treatment dummy captures the DID estimate of the effect of the network shocks on the network centrality measures. We also include a number of control variables as well as industry fixed effects in the regressions. The controls include board size (number of firm directors), size, market-to-book, and profitability. The standard errors are panel-corrected standard errors (PCSE). The results of these regressions are in Table 3 Panel A. The most notable result is that all four of the centrality measures were negatively shocked by the deaths of these directors (all except one is also statistically significant).

It is important to keep in mind that the estimated shocks to the network centrality measures likely understate the true impact of the network shock. This is because the calculation of the post-shock adjacency matrix assumes that directors can adjust their networks immediately and without any costs (e.g., search costs). For instance, to compute betweeness and closeness centrality for the post-shock network all the shortest paths are recalculated. In reality this readjustment of the network (i.e., the recalculation of all the shortest paths) is unlikely to be frictionless, but is likely to be both time-consuming and costly. Taken together, this evidence suggests that the deaths of the seven well-connected directors likely had an important negative impact on the network centrality of connected firms.

4.3 Parallel Trends Assumption and Matching

The key identifying assumption underlying the DID estimation technique is that the parallel trends assumption is satisfied, that is, in the absence of treatment both treated and control firms should experience parallel trends in the outcome variable. In our setting, this implies that in the absence of the negative shocks to director networks (induced by unexpected director deaths) treated and control should have experienced similar changes in firm value around the event windows. Although the parallel trends assumption cannot be directly tested, we test if observable firm characteristics of treated and control firm are similar in the pre-shock period. Descriptive statistics of the pre-shock firm characteristics are displayed in Table 1 Panel A. We see that, compared to the rest of the sample, on average treated firms are much larger, have more board members, and are much better connected in the director network. The samples also differ in terms of cash holdings, Tobin's Q, and profitability (ROA).

Given the significant differences in pre-shock characteristics of the treated and untreated firms, we employ a matching procedure to obtain more similar treatment and control samples. Specifically, from the subsample of untreated firms in the same 1-digit SIC code, we limit the possible matches for each treated firm to its 7 nearest neighbors in pre-shock average director degree centrality, and then match each treated firm with the 3 nearest neighbors in pre-shock firm size. Matching is done with replacement. This results in a control sample of 477 firm-years, or 3 matched firms for each of the 159 treated firm-years. Descriptive statistics for the treated and matched control sample are displayed in Table 2. We use three different methods to test for differences in the distribution of the two samples. The difference in means is tested using both a pooled difference-in-means t-test and a paired difference t-test, while the difference in medians is tested using a two-sided (rank-sum) Wilcoxon Z-test.

Because we are using Canadian firms, we are unable to utilize the full Fama and French (1993) 3-factor model to calculate abnormal returns, but only a market model, therefore a treatment and control sample matched on both size and book-to-market is important to alleviate concerns about systematic bias in our measurement of abnormal returns. Therefore, it is comforting that, as can be seen from Table 2 Panel A, the pre-shock samples are similar in both firm size and Tobin's Q. We also see that the treatment and control firms are similar on most other dimensions, including board size, cash holdings, leverage, capital expenditures and return on assets. We do find statistically significant differences in both the means and medians in network centrality; however, the economic significance of the difference is fairly small. For example, while the mean control firm has directors with an average of 29.14 connections, the mean treated firm has director with an average of 31.92 connections, a relatively small difference. Overall, the matched samples are similar on observables which makes it less likely that a differential trend during the event windows is biasing our results.

4.4 Director Networks

We define the director network at a director level instead of at a firm-level (e.g., see Larcker, So and Wang (2013)). That is, connections are determined at the director level and aggregated to the firm rather than being defined at the firm level where a connection between two firms is based on having at least one interlocked director. There are three main reasons for this. First, we are interested in the effect of director networks on firm value rather than linkages between firms per se. Thus, our identification strategy exploits exogenous variation in director centrality by looking at the death of well-connected directors in the director network. Defined this way the loss of connections to well-connected directors leads to meaningful interruptions in information flow for interlocked firms.

Second, defining the network at the firm-level may to lead to inaccurate estimates of the size of network shocks induced by the unexpected death of well-connected directors. This can be understood as follows. Networks that are constructed at a firm level do not differentiate between cases where more than one of the treated firm's directors sit on the same board as the deceased director and cases where only one of the firm's directors is on the same board as the deceased director. In both cases the interlocked firm loses its connection with the deceased director's network (i.e., the drop in firm-level centrality would be the same) despite the fact that in the former the information flow for the interlocked firm could be interrupted more dramatically than the latter as the firm loses two or more connections rather than one. Thus, director-level centrality aggregated to the firm-level would correctly record the differential impact on the firm's centrality while a firm-level approach would not.

Moreover, when connections are measured at a firm level, the centrality measures of the interlocked firms that have connections with at least two directors of the shocked firm, and one of the two who is well-connected passes away, remain unchanged. This is because these two firms are still connected by the other director, despite the fact that the information flow for the interlocked firm is interrupted following the death of the well-connected director. Therefore, when connections are defined at a firm level, for a death of a director to have a meaningful effect on the centrality measures of the interlocked firms it has to be the case that the interlocked firm is connected with the other firm only through the connection with the deceased director.

4.5 Why Canada?

Our identification methodology relies on exogenous variations in board centrality measures induced by unexpected deaths of well-connected interlocked directors. For this technique to be effective it is important that the network shocks are sufficiently large to create an economically meaningful drop in the treated firms' board centrality measures. In the US director networks are large and relatively crowded (i.e., firms often have multiple paths to other firms or subnetworks). This implies that the loss of a connection – even an important connection – is likely to have a relatively small effect on a firm's centrality in the network as the firms is likely to have other directors who are linked to the lost part of the network (i.e., there are more interlocks between firms). Unlike in the US, in Canada the importance of a loss of one connected director to the interlocked firms is likely to be larger as on average firms are connected with fewer interlocked directors (in some cases only one). Thus, the severing of an important connection in Canada is less likely to have a large impact on the board's centrality as it is hard to find new paths to replace the network access provided by the deceased director (i.e., there are fewer interlocks to adequately replace the lost interlock).[9]

In our Canadian sample, a director has an average of 11.69 connections with other directors in the network. In contrast, in the equivalent sample of publicly traded firms in the US in 2012, a director, on average, has 83.30 connections with other directors in the network. This suggests a loss of a connection, and in particular a connection with a well-connected director, in Canada may result in a relatively larger loss in network centrality measures compared to the loss of a director connection among US firms.

Even though our identification strategy (for the reasons mentioned above) may not be effective in the US, our results are unlikely to be unique to the Canadian setting. First, institutional features of publicly traded firms, especially board structures, in the two countries are comparable. This homogeneity allows better external validity for our findings and suggests the estimated value effect of professional director network connections can be extended to directors in other countries such as US. Second, many other countries have director networks that share similar characteristics to the Canadian director network (i.e., they have smaller economies and fewer firms). Thus, our results should be readily applicable to these countries. To sum up, the Canadian setting enables our empirical strategy to be effective and therefore allows the identification of the effect of director network centrality on firm value while still providing decent external validity.

5. Empirical Results

5.1. Market reaction to the unexpected death of well-connected interlocked directors

We start our presentation of the empirical results, by examining the cumulative abnormal returns (CARs) around the announcement of the unexpected director deaths. To implement our tests we first calculate abnormal returns for all firms in our sample using the market model. We use returns on the S&P/TSX Composite Index, including dividends, obtained from Datastream as the market return in the model. Betas are estimated using data

---

[9] An analogy may help. Consider a city that is linked to other cities by roads. If there are a many road connecting cities together (i.e., a crowded network) then closing one road, even an important road, is unlikely to have a large impact of the city's centrality in the network as it is easy to find a detour. However, if there are fewer roads (i.e., the network is less dense), then closing an important road is likely to have a larger impact on the city's centrality. The US is more less the former example, while Canada is more similar to the latter.

from 230 trading days prior to the death of each well-connected director, as we exclude the 30 days prior to the event date from the estimation window to mitigate contamination. We focus on event windows (0), (0,+1), (-1,+1) as well as (-2,+2) to allow for potential leakage of information prior to the announcement. Day zero is the announcement date of director deaths. Leakage is a possibility in the cases in which the director is admitted to a hospital and passes away relatively quickly, however, leakage is unlikely if the director's death is due a stroke, heart attack or accident.

Next, we calculate cumulative abnormal returns (CARs) for each event window for the treated and control firms separately. As can be seen in Table 3, treated firms have abnormal returns that are negative in three of the four event windows, however because the CARs are clustered over seven different event periods, cross-correlation may bias standard errors in a standard t-test downward and lead to over rejection of the null hypothesis (Kothari and Werner, 2006). Therefore, we compare the differences of the CARs of the treated and control firms in the event windows. This controls for market-wide variation in the seven event periods, which eliminates concern over cross-correlation biasing standard errors. We find that treated firms have event-day abnormal returns of -0.36%, compared to 0.23% for control firms, resulting in a difference-in-differences (DID) estimate of -0.59%. This effect is statistically significant at the 1% level. When we expand the event window, we find the DID estimate is -0.44% in the (0, +1) event window, and -0.45% in the (-1, +1) event window, both of which are statistically significant using a paired-difference t-test. These results suggest with the negative shock to director connectedness results in a decrease in firm value.

Although, the treatment and the matched control group are similar (see section 4), it is possible that omitted variables could be driving our univariate findings. Thus, we further test the how our network shocks effect firm value in a multivariate setting. This allows the inclusion of control variables and industry fixed effects. We use a seemingly unrelated regression (SUR) framework which simultaneously estimates a system of equations, one regression equation for each shock, while allowing residuals to be correlated within each shock, but uncorrelated between different shocks, and then recursively estimating the regression coefficients in a generalized least squares framework. We choose this methodology as SUR parameter estimates are always at least as efficient as those of ordinary least squares, provided that sample size is sufficiently large, and cross-sectional correlations are significant.[10] In the regressions we control for board size (number of firm directors), size, market-to-book, and profitability. Another potential concern is that the residuals are correlated within each of the shocks leading to biased estimates of standard errors. To adjust for this standard errors are panel-corrected standard errors (PCSE).

Table 4 Panel A reports the cross-sectional regressions with CARs on the left-hand side and an indicator variable that equals one if the firm is a member of our treated group on the right hand side. The results for the announcement day suggest that the treated firms experience abnormal returns that are smaller than those for the control firms by 0.3% which is statistically significant at the 5% level. In the other windows, the results are economically similar, but statistically insignificant. If the markets efficiently process the implications of the deaths for director networks, then this result is perhaps not surprising. At the mean, a -0.30% decrease in firm value is approximately equivalent to a $19.7 million loss in market capitalization per treated firm.[11]

We also find that these results are qualitatively robust to instead using a paired difference specification in which each pair is a treated firm and a matched control firm. To this end, we regress the difference between treatment and control firm abnormal returns on the differences between treatment and control firm characteristics. The paired difference regression has the advantage that statistical power is improved in matched-pair regressions due to the additional information (i.e., the treated firm is matched to its matched control firm) that is disregarded in pooled regressions. Since the control variables in this specification must take the form of matched-differences, this eliminates the possibility of industry fixed effects, however because control firms are matched to industry peers, this is not a concern.

The results using the paired difference specifications are in Table 4 Panel B. We again find that treated firms, those with direct connections to the deceased director, have event-day announcement returns that are lower than control firms (0.23%). Expanding the event window to include the day following the death (i.e., (0,+1)), we see that treated firms' stocks

[10] Karafiath (1994) shows that in a sufficiently large sample (>75) cross-correlation in residuals is not an important concern in cross-sectional regressions with CARs as the dependent variable.

[11] This is calculated as -0.30% × $6,564,604,348 where the latter number is the average market capitalization of treated firms.

had returns that were 0.31% lower compared to their control firms. Collectively these results are consistent with the negative shocks to director centrality reducing firms value differentially in our treated firms relative to our control firms.

5.2 Busyness

The value effect evident in the previous regressions is possibly due to two economic mechanisms. Firm value either dropped due to the exogenous severing of director network connections, or because board members from treated firms must now work more for the firm of the deceased, and thus neglect their other firms. This is the busyness effect hypothesized by Falato, Kadyrzhanova, and Lel (2014). They find, using the sudden death of interlocked directors, a negative abnormal market reaction for interlocked firms which they attribute to the increased busyness of the interlocked directors.[12] This confounding effect of busyness is a threat to the internal validity of our results as the firm value of the director-interlocked firms (treated firms) could decrease either due to a negative shock to director networks or because its board is more distracted.

We tackle this challenge by showing that our results continue to hold in a sample where director busyness is unaffected. To avoid the contamination of the increased busyness effect, we focus on a subsample of firms which do not share an interlocked director with the firm of the deceased, but which do have a past professional connection to the deceased director. In other words, we analyze the returns of firms which have directors that previously sat on boards with the deceased, but did not at the time of his death. This allows us to isolate the effect of a change in network centrality without any confounding changes in busyness. This is because the director with only a past connection to the deceased will experience a loss of connectedness, but will not be incurring an increased workload due to the death.[13] Thus, in this subsample the shock only affects the director's network and not his busyness allowing

[12] Falato, Kadyrzhanova, and Lel (2014) define interlock as when two directors not only sit at on the same board but also on the same committee.

[13] It is possible for a firm to have both a current and past connection to the deceased director. This would occur if one of a firm's directors is currently interlocked with the deceased director's firm and another director previously sat on a board with the deceased director. However, we verify that this does not occur for any of the treated firms in this study. Thus, treated firms have either a current or past connections to the deceased director, but not both.

us to better identify the effect of the negative network shock on firm value (see Figure 2 for an illustration of this identification strategy).

Panel B of Table 2 displays the subsample of treated firms that only have past connection with the deceased directors, and thus no busyness-effect contamination, and their matched control firms. We can see that treated and control groups have comparable means and medians for most observable pre-shock firm characteristics. Pre-shock network centrality measures are statistically different between treated and control firms, but are mostly economically similar. This is comforting as it suggests that the parallel trends assumption is likely to hold in this setting.

Table 3 Panel B reports the univariate results. First, treated firms exhibit economically and statistically significant drops in firm value during the event windows. On the announcement date firm value drops 0.55%. If we expand the window to also include the day after the announcement we find an even larger 0.91% drop in firm value. This result is highly robust to different definitions of the event window. Second, we also find that treated firms experience significantly larger deceases in value relative to control firms. We find a -0.69% event-day DID estimate indicating a significant decrease in firm value. When we expand the event window, we find DID CAR estimates of -1.09%, -1.07%, and -0.90% for the (0, +1), (-1, +1), and (-2, +2) event windows, respectively, all statistically significant at the 1% level.

These results continue to hold in a multivariate setting. We use the same specifications as in Table 4, but only retain treated firms (and their matched control firms) that have a past connection with the deceased directors. In Panel A of Table 5 we regress abnormal returns on a treatment dummy, controls variables and industry fixed effects using the SUR methodology. The coefficient on the treatment dummy is negative and statistically significant in all event windows (except having a p-value of 0.103 in the (-2,+2) window). This indicates that firms that experience a negative network shock see decreases in firm value relative to control firms, despite having no shock to busyness. For the announcement date this differential decline in value is 0.41%. This effect becomes more pronounced in the (0, +1) event window, decreasing by 0.69%. Both of these effects are significant at the 5% significance level. The (-1, +1) event window shows a 0.63% differential in abnormal returns, with a p-value of 0.057.

We also repeat the paired difference regressions from Table 4 Panel B (i.e., each pair is a treated firm and its matched control firms) in this setting. The results are in Panel B of Table 5. Here the intercept (the DID estimate) remains fairly similar to the pooled specification above, however the statistical significance increases. We find a -0.37% differential change in firm value on the event-day, a -0.68% change in the (0, +1) event window, a -0.64% change in the (-1, +1) event window, and a -0.61% change in the (-2, +2) event window – all statistically significant at either the 5 or 1% level. Using the average market capitalization of this treated subsample, the economic magnitude of these abnormal returns ranges from $25 to 46 million per firm – value which is being lost due to the negative network shock. It is also important to note that we also see a highly significant change in degree centrality for this subsample.[14] This suggests that the network shock had a material adverse effect on board connectedness, and further suggest that the observed decline in firm value is indeed due to the change in director centrality.

In sum, the above results suggest that network shocks lead to reductions in firm value independently of any busyness effect. This is not to suggest that busyness is not important or that busyness does not have adverse effects on firm value as found in Falato, Kadyrzhanova, and Lel (2014). Even though we show that network shocks reduce firm value, it is likely that both factors matter in practice.

We perform some additional tests to further separate the busyness and network channels. Following Falato, Kadyrzhanova, and Lel (2014), we postulate that if the deceased directors sat on smaller committees, then the unexpected deaths should have a greater impact the busyness of the interlocked directors. In contrast, if the deceased director sat on a larger committee the shock to busyness of the interlocked director is smaller. Thus, if busyness is driving our results we expect to find that our results are stronger when the deceased director sat on a smaller committee. To accomplish this we use a triple difference methodology where the third difference is whether the deceased directors sat on small or large committees.

[14] Using only the subsample of treated firms which only have past connections to the deceased director, we repeat the tests of the internal validity of the shock (as in Table 3 Panel A) and report the results in Table 3 Panel B. We find similar results to those reported in Table 3 Panel A.

To implement these tests, we first find that the median committee size of the seven deceased directors is 7 directors. We then create a dummy variable (*Big Committee)* that equals 1 if the observation is related to the death of a director whose average committee size was greater than the median of 7, and 0 otherwise. Next, we use the paired-difference specification for the regression so that the dummy variable can directly be interpreted as the differential impact of the busyness effect. In contrast with the previous test, we also limit the sample to firms that were currently interlocked. This is done because past connections are unaffected by busyness.

If the busyness effect is prevalent in our sample, the *Big Committee* dummy variable will be significantly positive in these regressions with CARs as the dependent variable. A positive coefficient implies that the effect of the network shocks on firm value is attenuated when the deceased director sits on larger committees. In Table 6 we run these triple difference tests using SUR regressions, and the same control variables as previously, but adding industry fixed-effects.

Interestingly, we do not find that the *Big Committee* dummy variable is significantly positive. In fact, the dummy variable is negative in all specifications, and significant at the 5% level when looking at cumulative abnormal returns in the (-2, +2) event window. This is inconsistent with the busyness channel. In Panel B of Table 6 we run similar triple difference regressions except that we have the matched-difference in changes in centrality measures on the left hand side. We find that in terms of degree, closeness, and betweenness centrality, the unexpected deaths of the directors on big-committees shocked the treated firms significantly more than the deaths of the directors on small committees. This is consistent with larger shocks to director networks leading to larger value-effects for *Big Committee* firms. Eigenvector centrality, however was shocked differentially more, suggesting that while the deceased directors on big committees were more connected and central, they may not have been as important. In sum, the results of the SUR regressions in Table 6 provide additional evidence that the value effect which we observe is not simply an artifact of interlocked director busyness, but are instead due to the severing of ties in director networks.

5.3 Robustness Tests

Firms not only benefit from director networks in the form of information flow, but they can also benefit in the form of preferential access to finance from interlocked financial institutions (Stearns and Mizruchi, 1993; Uzzi, 1999; Huang, Jiang, and Lie, 2017). Therefore, it is possible that at least part of the loss in firm value we observe could be due to the loss of a board interlock to banks, and thus a loss of a source of capital. To help separate the effect of access to finance from the information effect, we replicate our analysis, omitting the deaths of two directors, Montegu Black and Donald Fullerton, who sat on the boards of The Toronto-Dominion Bank and Canadian Imperial Bank of Commerce, respectively. These two deaths severed the ties of several firms' directors to a financial institution. So by studying only the deaths of the remaining five directors, none of whom sat on the board of a financial institution, we should be able to argue that our main results are not merely an access-to-finance effect. The results of this analysis can be found in Table 7.

The five remaining network shocks leave us with a sample of 459 – 114 treated firms and 342 matched-control firms. Again, we find that average degree, closeness, and betweenness centrality all decreased more for treated firms than control firms following the death of the five directors (significant at the 1% level), confirming that the loss of these connections was indeed a differentially negative shock to the network centrality of the treated firms. With respect to firm value, we again find evidence that the loss of these network connections is detrimental to treated firms relative to control firms. In Panel A, we find that treated firms have 1-day abnormal returns 0.41% less than control firms, which is significant at the 5% level. This effect grows to -0.64% and -0.61% in the (0,+1) and (-1,+1) event windows, both statistically significant. In the paired-difference model in Panel B, we find that treated firms have 1-day abnormal returns 0.38% less than control firms, 2-day differential abnormal returns of -0.66%, and 3-day differential abnormal returns of -0.65%, all significant beyond the 1% level. These results confirm that the loss of a direct connection to financial institutions cannot explain our main results. Note that this result does not imply that the value of director networks is not, at least partially, due to more connected directors facilitating access to finance. In fact, it is possible that the negative effects of director deaths on value are at least partially driven by the loss of connections with directors who have connections to financial institutions which could enable their firms to have easier access to finance.

As suggested by Roberts and Whited (2012), because the parallel trends assumption is untestable, we perform a falsification test to further test the internal validity of our experimental setting and to assuage concerns that our results are found purely by chance. The proposed falsification test also allows us to refute that our results are due to some fundamental differences between the treated and control firms. Specifically, we draw a stratified random sample of 7 placebo dates (one random business day from 2001, 2002, 2003, 2005, 2006 and two days from 2011 – the years of the actual network shocks), and use the 1-day abnormal returns of the actual treated and matched-control firms from those 7 days to run the difference-in-differences regression model in Panel A of Table 4 with AR(0) as the dependent variable. We keep the regression coefficient on the Treated Dummy variable and re-run the simulation 10,000 times. A histogram of the resulting regression coefficients is displayed in Figure 3.

The distribution of the bootstrapped DID coefficients has a mean of 0.094% with a standard deviation of 0.231%. The actual observed DID coefficient of -0.297% is therefore 1.69 standard deviations below the mean (a p-value of 0.0451). Also of note, only 279 of the 10,000 simulated coefficients are below the actual coefficient (an empirical p-value of 0.0279). Both of these statistics suggests that, at the 5% significance level, the differential loss in firm value we observe is not due to random chance, nor due to any fundamental difference between the treated and control firms, and is instead caused by the negative shock to the director networks caused by the seven unexpected director deaths.

6. Concluding Remarks

We use exogenous variation provided by the unexpected death of well-connected directors to isolate the impact of board connectedness on firm value. To this end we study the abnormal returns of interlocked firms, whose interlocked director suffers a negative shock to his network of board connections, relative to control firms who are unaffected by the shock. We find that the negative network shock leads to about a 0.6% decrease in firm value.

Our approach sidesteps many of the identification challenges faced by other papers. Given that the director deaths we study are unexpected, the variation in director networks we study is unlikely to be correlated with important omitted variables that affect firm value. Moreover, the unexpected deaths break up the endogenous matching in the director labor market, whereby highly connected directors choose better performing firms, making reverse causality less of a concern in our setting. By focusing our analysis on the interlocked firms (and not the deceased director's firm), we are able to isolate the impact of director networks from potential confounding variables such as director talent and experience. Also, by studying past connections, we find that our results are not an artifact of the increase in busyness of interlocked directors following the unexpected deaths. Finally, by omitting unexpected deaths of directors of banks, we are able to dismiss the explanation that our results are entirely due to the loss of access to finance.

Our findings are important as it is difficult to draw causal inference between board characteristics, such as director networks, and shareholder value. Moreover, the recent regulatory interest in this area makes our findings topical and highly relevant as it suggests firm performance can be improved by having a better connected board. We acknowledge that our test does not allow us to disentangle the specific channel through which director networks affect value. For instance, the loss of connection could lead to a loss of access to information. Or it could be due to a decline in the power and influence of the director. Thus, in future research it would be interesting to ascertain why director networks are valuable.

References

Armstrong, C., Larcker, D., 2009. Discussion of "The impact of the options backdating scandal on shareholders" and "Taxes and the backdating of stock option exercise dates". Journal of Accounting and Economics 47, 50-58.

Barnea, A., Guedj, I., 2009. Director networks. Working Paper.

Bizjak, J., Lemmon, M., Whitby, R., 2009. Option backdating and board interlocks. Review of Financial Studies 22, 4821-4847.

Borgatti, S., Everett, M., Freeman, L., 2002. UCINET 5 for Windows: Software for social network analysis. Analytic Technologies, Harvard, MA.

Cohen, L., Frazzini, A., Malloy, C., 2008. The small world of investing: The use of social networks in bank decision-making. Journal of Political Economy 116, 951-979.

Cohen, L., Frazzini, A., Malloy, C., 2010. Sell-side school ties. The Journal of Finance 65, 1409-1437.

Core, J., Holthausen, R., Larcker, D., 1999. Corporate governance, chief executive officer compensation, and firm performance. Journal of financial economics 51, 371-406.

Crespí-Cladera, R., Pascual-Fuster, B., 2015. Optimal board independence with non-strictly independent directors, Working Paper.

DeMarzo, P., Vayanos, D., Zwiebel, J., 2003. Persuasion bias, social influence, and uni-dimensional opinions. The Quarterly Journal of Economics 118, 909-968.

Engelberg, J., Gao, P., Parsons, C., 2013. The price of a CEO's rolodex. Review of Financial Studies 26, 79-114.

Faccio, M., Parsley, D., 2009. Sudden deaths: Taking stock of geographic ties. Journal of Financial and Quantitative Analysis 44, 683-718.

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

Faleye, O., Kovacs, T., Venkateswaran, A., 2014. Do better-connected CEOs innovate more? Journal of Financial and Quantitative Analysis 49, 1201-1225.

Fama, E., French, K., 1993. Common risk factors in the returns on stocks and bonds. Journal of Financial Economics 33, 3-56.

Fich, E., Shivdasani, A., 2006. Are busy boards effective monitors? The Journal of Finance 61, 689-724.

Fich, E., White, L., 2003. CEO compensation and turnover: The effects of mutually interlocked boards. Wake Forest L. Rev. 38, 935.

Fogel, K., Ma, L., Morck, R., 2014. Powerful independent directors. Working Paper.

Huang, Q., Jiang, F., and Lie, E., 2017. The Value of Social Networks during Periods of Distress. Working Paper.

Helmers, C., Patnam, M., Rau, P., 2015. Do board interlocks increase innovation? Evidence from a corporate governance reform in India? Evidence from a Corporate Governance Reform in India (April 19, 2015).

Hochberg, Y., Ljungqvist, A, Lu, Y., 2007. Whom you know matters: Venture capital networks and investment performance. The Journal of Finance 62, 251-301.

Horton, J., Millo, Y., Serafeim, G., 2012. Resources or power? Implications of social networks on compensation and firm performance. Journal of Business Finance & Accounting 39, 399-426.

Kothari, S., Warner J., 2006. Econometrics of event studies. Handbook of Corporate Finance: Empirical Corporate Finance, Volume A, Ch. 1.

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

Lee, S.H.M., Cotte, J., Noseworthy. T.J., 2010. The role of network centrality in the flow of consumer influence. Journal of Consumer Psychology 20, 66-77.

Loderer, C., Peyer, U., 2002. Board overlap, seat accumulation and share prices. European Financial Management 8, 165-192.

Masulis, R.W., Mobbs, S., 2014. Independent director incentives: Where do talented directors spend their limited time and energy?. Journal of Financial Economics, 111, 406-429.

Mizruchi, M., 1990. Cohesion, structural equivalence, and similarity of behavior: An approach to the study of corporate political power. Sociological Theory 8, 16-32.

Mol, M., 2001. Creating wealth through working with others: Inter-organizational relationships. The Academy of Management Executive 15, 150-152.

Omer, T., Shelley, M., Tice, F., 2014. Do well-connected directors affect firm value? Journal of Applied Finance 24, 17-32.

Pennings, J., 1980. Interlocking directorates. Jossey-Bass Inc Pub.

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

Roberts, M.R., Whited, T.M., 2012. Endogeneity in Empirical Corporate Finance. Handbook of the Economics of Finance 2, 493-572.

Snyder, P., Priem, R., Levitas, E., 2009, August. The diffusion of illegal innovations among management elites. In Academy of Management Proceedings 1, 1-6.

Stearns, L. B., Mizruchi, M. S., 1993. Board composition and corporate financing: The impact of financial institution representation on borrowing. Academy of management Journal, 36, 603-618.

Stern, L., 2015. A learning-based approach to evaluating boards of directors. Working Paper.

Uzzi, B., 1999. Embeddedness in the making of financial capital: how social relations and networks benefit firms seeking financing. American Sociological Review 64, 481-505.

Table 1
Descriptive Statistics

Panel A presents the pre-shock descriptive statistics for all of the untreated firms in the Canadian sample. Data for board and network variables are collected from the Clarkson Centre. Other firm-level data are collected from Worldscope. Panel B presents descriptive statistics for the treated firms. A firm is considered treated if one of its current directors had a network connection, past or present, with the deceased director. Firms in which the deceased director currently sitting on the board are excluded from both the untreated and treated samples.

Panel A: Untreated

	Obs.	Mean	St. Dev.	Min	Median	Max
Board Size	3,537	7.941	3.809	1	7	25
Degree Centrality	3,537	15.429	10.200	1	12.875	47.583
Eigenvector Centrality	3,537	0.007	0.011	0	0.001	0.056
Closeness Centrality	3,468	0.165	0.090	0	0.197	0.276
Betweenness Centrality	3,537	7,201	7,980	0	4,679	38,003
Ln(Assets)	2,363	13.410	2.359	7.533	13.494	20.357
CapEx/Assets	2,354	0.087	0.098	0	0.055	0.475
Cash/Assets	2,359	0.136	0.183	0	0.061	0.823
Leverage	1,985	0.265	0.203	0.001	0.234	0.963
Tobin's Q	2,299	1.696	1.606	0.109	1.204	10.229
ROA	2,361	-0.033	0.237	-1.557	0.024	0.269

Panel B: Treated

	Obs.	Mean	St. Dev.	Min	Median	Max
Board Size	247	11.798	3.956	3	11	23
Degree Centrality	247	30.160	10.428	7.333	30.538	47.583
Eigenvector Centrality	247	0.021	0.015	0	0.019	0.056
Closeness Centrality	247	0.238	0.025	0.166	0.238	0.276
Betweenness Centrality	247	15,242	8,970	1,361	13,827	38,003
Ln(Assets)	181	15.608	2.065	10.396	15.560	20.357
CapEx/Assets	181	0.061	0.064	0	0.043	0.402
Cash/Assets	181	0.079	0.130	0	0.028	0.823
Leverage	167	0.255	0.176	0.001	0.240	0.816
Tobin's Q	179	1.102	0.771	0.109	1.045	5.018
ROA	181	0.025	0.120	-0.937	0.031	0.252

Table 2
Matched Sample Pre-shock Firm Characteristics

This table contains comparisons of the means and medians of the treated and matched-control pre-shock samples. Firms are dropped from the sample if they are missing data on assets, industry (SIC code), or abnormal returns. Each treated firm is then matched with three untreated firms, with replacement, based on industry, pre-shock firm size, and pre-shock degree centrality. Panel A contains all treated and control firms. Panel B contains only treated firms with no current director interlock and their matched control firms. In the Treated Mean column, the means of the treated and control samples are tested using a pooled sample t-test. In the Treated Median column, the distributions of the treated and control samples are tested using a non-parametric rank-sum test. In the Paired Difference column, the control firm is subtracted from the paired treated firm and the means are tested against zero using a standard t-test. ***, **, and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A: All treated and matched-control firms

	Matched Control			Treated			Paired	
Variable	**N**	**Mean**	**Median**	**N**	**Mean**	**Median**	**N**	**Difference**
Board Size	477	13.195	13.000	159	13.189	13.000	477	-0.006
Degree	477	29.140	29.500	159	31.915***	32.333***	477	2.775***
Eigenvector	477	0.021	0.020	159	0.023*	0.020**	477	0.003***
Closeness	477	0.232	0.236	159	0.239**	0.239**	477	0.007***
Betweenness	477	12,313	10,845	159	14,818***	13,171***	477	2,505***
Ln(Assets)	477	15.887	15.656	159	15.930	15.830	477	0.043
CapEx/Assets	477	0.066	0.044	159	0.061	0.041	477	-0.005
Cash/Assets	477	0.064	0.023	159	0.068	0.026	477	0.004
Leverage	460	0.265	0.243	149	0.254	0.240	435	-0.012
Tobin's Q	477	1.095	0.946	158	1.046	0.994	474	-0.046
ROA	477	0.033	0.029	159	0.042	0.032	477	0.008**

Panel B: Firms with no current interlock

	Matched Control			Treated			Paired	
Variable	**N**	**Mean**	**Median**	**N**	**Mean**	**Median**	**N**	**Difference**
Board Size	201	12.746	12.000	67	12.642	13.000	201	-0.104
Degree	201	29.463	30.333	67	32.399**	32.333**	201	2.936***
Eigenvector	201	0.020	0.021	67	0.024*	0.020	201	0.003***
Closeness	201	0.242	0.248	67	0.247	0.246	201	0.005***
Betweenness	201	12,574	11,453	67	15,646***	13,171**	201	3,072***
Ln(Assets)	201	16.004	15.872	67	15.947	16.056	201	-0.057
CapEx/Assets	201	0.061	0.041	67	0.056	0.032	201	-0.005
Cash/Assets	201	0.075	0.024	67	0.078	0.026	201	0.003
Leverage	194	0.234	0.215	63	0.250	0.240	184	0.008
Tobin's Q	201	1.173	1.022	67	1.053	0.973	201	-0.121*
ROA	201	0.042	0.033	67	0.048	0.033	201	0.006

Table 3
Matched Sample Post-Shock Changes

This table contains comparisons of the means and medians of the treated and matched-control abnormal returns and changes in network centrality. Firms are dropped from the sample if they are missing data on assets, industry (SIC code), or abnormal returns. Each treated firm is then matched with three untreated firms, with replacement, based on industry, pre-shock firm size, and pre-shock degree centrality. Panel A contains all treated and control firms. Panel B contains only treated firms with no current director interlock and their matched control firms. In the Treated Mean column, the means of the treated and control samples are tested using a pooled sample t-test. In the Treated Median column, the distributions of the treated and control samples are tested using a non-parametric rank-sum test. In the Paired Difference column, the control firm is subtracted from the paired treated firm and the means are tested against zero using a standard t-test. ***, **, and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A: All treated and matched-control firms

	Matched Control			Treated			Paired	
Variable	**N**	**Mean**	**Median**	**N**	**Mean**	**Median**	**N**	**Difference**
AR (0)	477	0.23%	0.12%	159	-0.36%***	-0.20%***	477	-0.59%***
CAR (-2, +2)	477	0.39%	0.44%	159	0.35%	0.35%	477	-0.04%
CAR (-1, +1)	477	0.40%	0.18%	159	-0.05%	0.09%	477	-0.45%*
CAR (0, +1)	477	0.19%	0.07%	159	-0.26%	-0.18%*	477	-0.44%**
%ΔDegree	477	-0.03%	0.00%	159	-0.29%***	-0.19%***	477	-0.26%***
%ΔEigenvector	477	5.38%	-0.29%	159	5.37%	-1.13%	477	-0.01%
%ΔCloseness	477	-0.04%	-0.01%	159	-0.04%	-0.03%***	477	0.00%
%ΔBetweenness	477	0.03%	-0.01%	159	-0.01%	-0.06%***	477	-0.05%

Panel B: Firms with no current interlock

	Matched Control			Treated			Paired	
Variable	**N**	**Mean**	**Median**	**N**	**Mean**	**Median**	**N**	**Difference**
AR (0)	201	0.14%	0.11%	67	-0.55%***	-0.08%**	201	-0.69%***
CAR (-2, +2)	201	0.06%	0.21%	67	-0.84%**	0.26%	201	-0.90%***
CAR (-1, +1)	201	0.22%	0.14%	67	-0.85%***	-0.29%**	201	-1.07%***
CAR (0, +1)	201	0.18%	0.21%	67	-0.91%***	-0.38%***	201	-1.09%***
%ΔDegree	201	-0.06%	0.00%	67	-0.16%**	0.00%***	201	-0.10%***
%ΔCloseness	201	-0.06%	-0.01%	67	-0.05%	-0.02%	201	0.02%
%ΔEigenvector	201	7.47%	0.99%	67	12.69%	0.86%	201	5.22%**
%ΔBetweenness	201	0.14%	0.08%	67	0.01%	0.08%	201	-0.13%

Table 4
Multivariate Analysis of Shock – Full Matched Sample

This table displays results for the multivariate difference-on-differences analysis on the effect of a shock to the director network. The pooled sample in Panel A contains all of the treated firms and their matched-control firms as separate observations. The dependent variables are percentage changes in the four network centrality measures following the shock to the director network and the cumulative abnormal returns in the event-windows surrounding the directors' deaths. The dependent variables are regressed on a dummy variable equaling 1 for treated firms, as well as control variables and industry fixed effects (using 1 digit SIC codes). The intercept term is subsumed by the fixed-effects. Panel B contains a sample of paired differences of treated and control firms. The control firm is subtracted from the treated firm for the dependent and control variables. No fixed effects are used in Panel B, allowing the intercept to be inferred as the difference-in-differences coefficient. All regressions use unbalanced panel, seemingly unrelated regression methodology, allowing the residuals on the seven event-days (director deaths) to be correlated. The variance-covariance matrix is adjusted using panel-corrected standard errors. Two-tailed p-values are in parenthesis below their corresponding coefficient. ***, **, and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A: Pooled Specifications

Dependent variable	%Δ Degree	%Δ Eigenvector	%Δ Closeness	%Δ Betweenness	AR (0)	CAR (-2,+2)	CAR (-1,+1)	CAR (0,+1)
Treated Dummy	**-0.282*** **	**-0.367**	**-0.016*** **	**-0.151*** **	**-0.297** **	**-0.103**	**-0.108**	**-0.254**
	(0.000)	**(0.329)**	**(0.000)**	**(0.000)**	**(0.032)**	**(0.738)**	**(0.664)**	**(0.215)**
Ln(Assets)	0.011**	0.466***	-0.001	0.015**	-0.096*	-0.366***	-0.294***	-0.197**
	(0.041)	(0.009)	(0.254)	(0.011)	(0.079)	(0.002)	(0.003)	(0.015)
Tobin's Q	0.016*	0.170	0.000	0.008	0.042	-0.230	-0.223	-0.135
	(0.079)	(0.518)	(0.939)	(0.418)	(0.666)	(0.289)	(0.196)	(0.336)
ROA	-0.113	0.174	-0.025**	-0.046	-1.917	-6.971***	-2.458	-2.151
	(0.274)	(0.945)	(0.013)	(0.654)	(0.114)	(0.008)	(0.243)	(0.210)
Board Size	0.008***	-0.038	0.001***	0.001	-0.004	-0.024	0.020	0.019
	(0.000)	(0.529)	(0.000)	(0.651)	(0.853)	(0.604)	(0.602)	(0.551)
R^2	0.432	0.022	0.092	0.092	0.043	0.051	0.032	0.038
Obs.	635	635	635	635	635	635	635	635
Fixed Effects	Industry	Industry	Industry	Industry	Industry	Industry	Industry	Industry

Panel B: Paired-Difference Specifications

Dependent variable	%Δ Degree *difference*	%Δ Eigenvector *difference*	%Δ Closeness *difference*	%Δ Betweenness *difference*	AR (0) *difference*	CAR (-2,+2) *difference*	CAR (-1,+1) *difference*	CAR (0,+1) *difference*
Intercept	**-0.259*** **	**-0.913*** **	**-0.015** **	**-0.149*** **	**-0.232** **	**-0.148**	**-0.168**	**-0.311** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.012)**	**(0.492)**	**(0.332)**	**(0.041)**
Ln(Assets)	0.008	0.408	0.000	0.010	-0.098	-0.032	-0.136	-0.338*
difference	(0.623)	(0.159)	(0.656)	(0.375)	(0.355)	(0.898)	(0.499)	(0.059)
Tobin's Q	0.014	0.108	0.000	0.000	0.066	-0.114	-0.746***	-0.609***
difference	(0.357)	(0.664)	(0.545)	(0.991)	(0.581)	(0.687)	(0.001)	(0.002)
ROA	-0.222	-0.039	-0.011	-0.097	-1.525	-9.835***	0.652	-0.895
difference	(0.172)	(0.987)	(0.117)	(0.251)	(0.297)	(0.003)	(0.803)	(0.697)
Board Size	0.013***	0.006	0.000***	0.003*	-0.030	-0.001	0.041	0.029
difference	(0.000)	(0.899)	(0.001)	(0.074)	(0.210)	(0.983)	(0.371)	(0.472)
R^2	0.052	0.004	0.013	0.008	0.009	0.026	0.027	0.033
Obs.	474	474	474	474	474	474	474	474
Fixed Effects	None	None	None	None	None	None	None	None

Table 5
Multivariate Analysis of Shock – No Current Interlock Subsample

This table displays results for the multivariate difference-on-differences analysis on the effect of a shock to the director network. The pooled sample in Panel A contains the treated firms with no current interlock to the deceased director and their matched-control firms as separate observations. The dependent variables are the cumulative abnormal returns in the event-windows surrounding the directors' deaths. The dependent variables are regressed on a dummy variable equaling 1 for treated firms, as well as control variables and industry fixed effects (using 1 digit SIC codes). The intercept term is subsumed by the fixed-effects. Panel B contains a sample of paired differences of treated and control firms. The control firm is subtracted from the treated firm for the dependent and control variables. No fixed effects are used in Panel B, allowing the intercept to be inferred as the difference-in-differences coefficient. All regressions use unbalanced panel, seemingly unrelated regression methodology, allowing the residuals on the seven event-days (director deaths) to be correlated. The variance-covariance matrix is adjusted using panel-corrected standard errors. Two-tailed p-values are in parenthesis below their corresponding coefficient. ***, **, and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A: Pooled Specifications

Dependent variable	AR(0)	CAR(-2,+2)	CAR(-1,+1)	CAR(0,+1)
Treated Dummy	**-0.409****	**-0.647**	**-0.631***	**-0.694****
	(0.034)	**(0.103)**	**(0.057)**	**(0.013)**
Ln(Assets)	-0.083	-0.294**	-0.261**	-0.129
	(0.263)	(0.050)	(0.036)	(0.236)
Tobin's Q	-0.093	-0.211	-0.331	-0.232
	(0.481)	(0.430)	(0.132)	(0.213)
ROA	1.476	3.471	3.458	0.693
	(0.361)	(0.275)	(0.173)	(0.753)
Board Size	0.010	-0.017	0.028	0.018
	(0.749)	(0.789)	(0.601)	(0.685)
R^2	0.059	0.105	0.088	0.062
Obs.	268	268	268	268
Fixed Effects	Industry	Industry	Industry	Industry

Panel B: Paired-Difference Specifications

Dependent variable	AR(0) *difference*	CAR(-2,+2) *difference*	CAR(-1,+1) *difference*	CAR(0,+1) *difference*
Intercept	**-0.366****	**-0.614****	**-0.637*****	**-0.681*****
	(0.011)	**(0.039)**	**(0.010)**	**(0.001)**
Ln(Assets)	-0.371**	-0.111	-0.375	-0.591**
difference	(0.017)	(0.728)	(0.146)	(0.014)
Tobin's Q	-0.074	-0.347	-0.983***	-0.799***
difference	(0.661)	(0.318)	(0.001)	(0.001)
ROA	2.103	5.416	9.187***	1.477
difference	(0.354)	(0.218)	(0.010)	(0.631)
Board Size	-0.014	0.013	0.028	0.014
difference	(0.732)	(0.883)	(0.694)	(0.812)
R^2	0.037	0.010	0.075	0.069
Obs.	201	201	201	201
Fixed Effects	None	None	None	None

Table 6
Triple Difference Analysis of Shock – Paired Current Interlock Subsample

This table displays results for the multivariate difference-in-difference-on-differences analysis on the effect of a shock to the director network for the deaths of directors on big committees vis-á-vis directors on small committees. Panel A contains a sample of paired differences of the treated firms with a current (not past) interlock to a firm of the deceased director and their matched-control firms as separate observations. The dependent variables are the cumulative abnormal returns in the event-windows surrounding the directors' deaths. The dependent variables are regressed on a dummy variable equaling 1 for observations stemming from the death of a director who had an average committee size greater than 7 (the median), as well as control variables and industry fixed effects (using 1 digit SIC codes). Panel B contains the same sample and specification, but with the percentage changes in network centrality measures as the dependent variables. All regressions use unbalanced panel, seemingly unrelated regression methodology, allowing the residuals on the seven event-days (director deaths) to be correlated. The intercept term is subsumed by the fixed-effects in both panels. The variance-covariance matrix is adjusted using panel-corrected standard errors. Two-tailed p-values are in parenthesis below their corresponding coefficient. ***, **, and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A: Abnormal Returns

Dependent variable	AR(0) *difference*	CAR(-2,+2) *difference*	CAR(-1,+1) *difference*	CAR(0,+1) *difference*
Big Committee Dummy	**-0.035**	**-1.594****	**-0.438**	**-0.310**
	(0.911)	**(0.013)**	**(0.434)**	**(0.533)**
Ln(Assets)	-0.036	-1.000**	-0.339	-0.430
difference	(0.808)	(0.011)	(0.268)	(0.112)
Tobin's Q	0.108	-1.010**	-1.146***	-0.919***
difference	(0.549)	(0.034)	(0.001)	(0.003)
ROA	-3.356*	-21.028***	-6.161*	-1.943
difference	(0.077)	(0.000)	(0.070)	(0.532)
Board Size	-0.065**	-0.066	-0.064	-0.060
difference	(0.022)	(0.358)	(0.264)	(0.229)
R^2	0.163	0.290	0.243	0.222
Obs.	273	273	273	273
Fixed Effects	Industry	Industry	Industry	Industry

Panel B: Network Centrality Measures

Dependent variable	%Δ Degree *difference*	%Δ Eigenvector *difference*	%Δ Closeness *difference*	%Δ Betweenness *difference*
Big Committee Dummy	**-0.209*****	**2.324*****	**-0.002***	**-0.152*****
	(0.000)	**(0.001)**	**(0.076)**	**(0.006)**
Ln(Assets)	0.008	0.321	-0.001	0.007
difference	(0.592)	(0.490)	(0.531)	(0.690)
Tobin's Q	-0.001	0.723*	0.000	-0.023
difference	(0.931)	(0.098)	(0.935)	(0.123)
ROA	-0.238	8.513**	-0.012*	-0.203
difference	(0.140)	(0.028)	(0.091)	(0.172)
Board Size	0.010***	0.082	0.000	0.003
difference	(0.001)	(0.305)	(0.206)	(0.337)
R^2	0.204	0.134	0.071	0.044
Obs.	273	273	273	273
Fixed Effects	Industry	Industry	Industry	Industry

Table 7
Robustness Test – No Bank Connection Subsample

This table displays results for the multivariate difference-in-differences analysis on the effect of a shock to the director network when a non-bank affiliated director passes. This isolates the effect networks from the effect of access to finance. The pooled sample in Panel A contains all of the treated firms from the 5 remaining shocks and their matched-control firms as separate observations. The dependent variables are percentage changes in the four network centrality measures following the shock to the director network and the cumulative abnormal returns in the event-windows surrounding the directors' deaths. The dependent variables are regressed on a dummy variable equaling 1 for treated firms, as well as control variables and industry fixed effects (using 1 digit SIC codes). The intercept term is subsumed by the fixed-effects. Panel B contains a sample of paired differences of treated and control firms in Panel A. The control firm is subtracted from the treated firm for the dependent and control variables. No fixed effects are used in Panel B, allowing the intercept to be inferred as the difference-in-differences coefficient. All regressions use unbalanced panel, seemingly unrelated regression methodology, allowing the residuals on the seven event-days (director deaths) to be correlated. The variance-covariance matrix is adjusted using panel-corrected standard errors. Two-tailed p-values are in parenthesis below their corresponding coefficient. ***, **, and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

Panel A: Pooled Specifications

Dependent variable	%Δ Degree	%Δ Eigenvector	%Δ Closeness	%Δ Betweenness	AR (0)	CAR (-2,+2)	CAR (-1,+1)	CAR (0,+1)
Treated Dummy	**-0.197*** **	**0.023**	**-0.008*** **	**-0.112*** **	**-0.407** **	**-0.439**	**-0.609***	**-0.643** **
	(0.000)	**(0.976)**	**(0.002)**	**(0.000)**	**(0.023)**	**(0.236)**	**(0.052)**	**(0.017)**
Ln(Assets)	0.000	0.360**	-0.002***	0.001	-0.040	0.082	0.014	0.043
	(0.982)	(0.022)	(0.000)	(0.909)	(0.439)	(0.393)	(0.873)	(0.561)
Tobin's Q	0.018	-0.061	0.000	-0.001	0.124	0.265	0.284	0.140
	(0.237)	(0.880)	(0.848)	(0.954)	(0.282)	(0.256)	(0.138)	(0.380)
ROA	-0.372*	2.779	-0.041**	-0.328	-2.302	-6.184**	-2.295	-2.781
	(0.062)	(0.500)	(0.011)	(0.342)	(0.123)	(0.037)	(0.351)	(0.166)
Board Size	0.010***	-0.121	0.001***	0.003	-0.031	-0.079	-0.058	-0.074*
	(0.001)	(0.257)	(0.000)	(0.442)	(0.249)	(0.149)	(0.223)	(0.068)
R^2	0.205	0.017	0.041	0.029	0.074	0.080	0.066	0.066
Obs.	459	459	459	459	459	459	459	459
Fixed Effects	Industry	Industry	Industry	Industry	Industry	Industry	Industry	Industry

Panel B: Paired-Difference Specifications

Dependent variable	%Δ Degree *difference*	%Δ Eigenvector *difference*	%Δ Closeness *difference*	%Δ Betweenness *difference*	AR (0) *difference*	CAR (-2,+2) *difference*	CAR (-1,+1) *difference*	CAR (0,+1) *difference*
Intercept	**-0.147*** **	**-0.543**	**-0.010*** **	**-0.102*** **	**-0.382*** **	**-0.510***	**-0.652*** **	**-0.662*** **
	(0.000)	**(0.208)**	**(0.000)**	**(0.000)**	**(0.002)**	**(0.055)**	**(0.003)**	**(0.001)**
Ln(Assets)	0.002	0.226	-0.002	0.011	-0.145	0.079	-0.009	-0.219
difference	(0.923)	(0.624)	(0.193)	(0.537)	(0.251)	(0.783)	(0.970)	(0.321)
Tobin's Q	0.036	0.237	0.001	0.015	0.201	-0.142	-0.478	-0.332
difference	(0.146)	(0.624)	(0.544)	(0.672)	(0.249)	(0.688)	(0.103)	(0.215)
ROA	-0.933***	-3.008	-0.043**	-0.805*	0.322	-3.980	5.241*	1.803
difference	(0.001)	(0.479)	(0.013)	(0.063)	(0.868)	(0.278)	(0.093)	(0.518)
Board Size	0.019***	0.108	0.001***	0.008*	-0.042	-0.030	-0.048	-0.066
difference	(0.000)	(0.228)	(0.000)	(0.098)	(0.167)	(0.640)	(0.387)	(0.194)
R^2	0.079	0.008	0.019	0.018	0.019	0.007	0.014	0.016
Obs.	342	342	342	342	342	342	342	342
Fixed Effects	None	None	None	None	None	None	None	None

Figure 1 – Experimental Setup

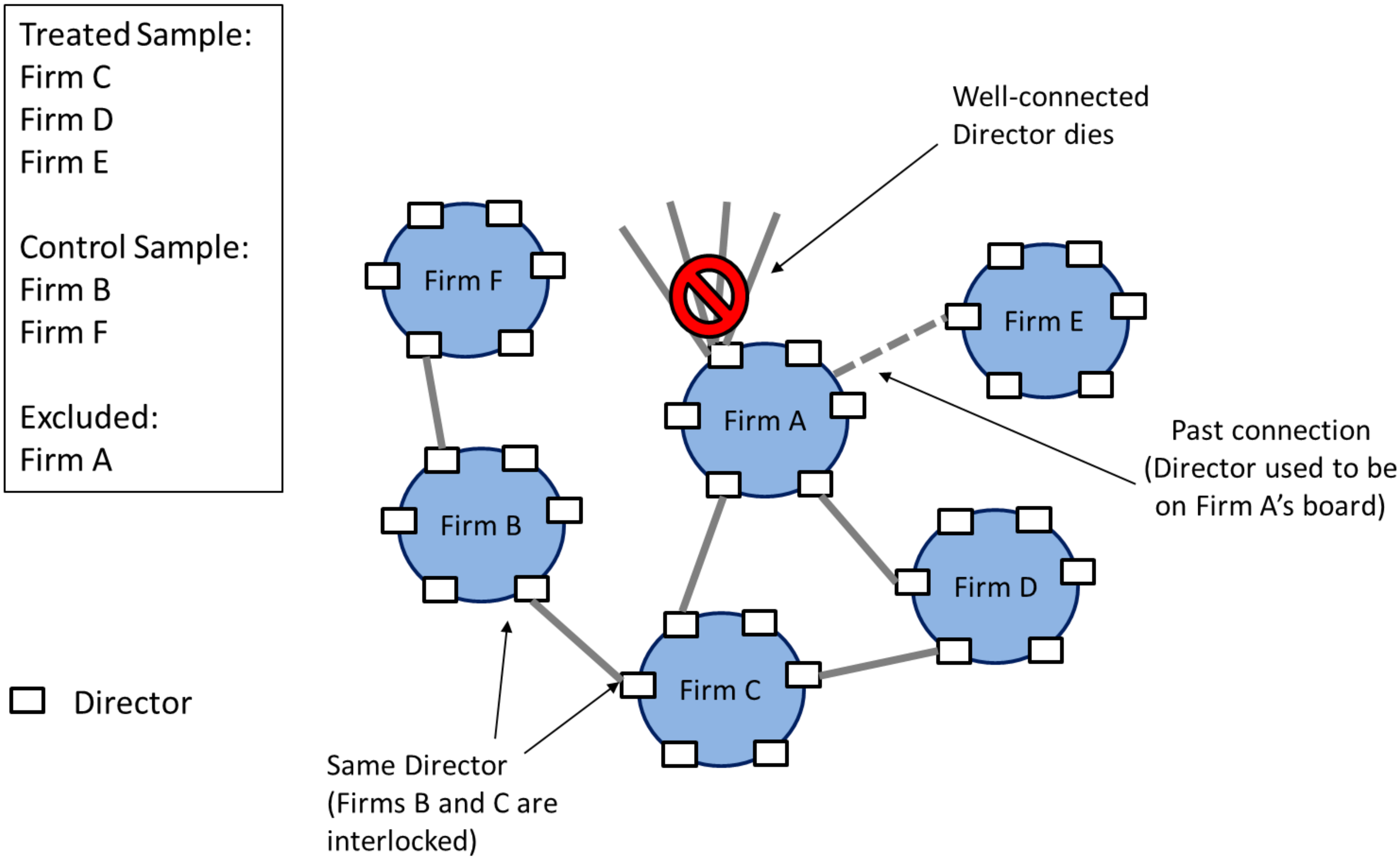

Figure 2 – Busyness

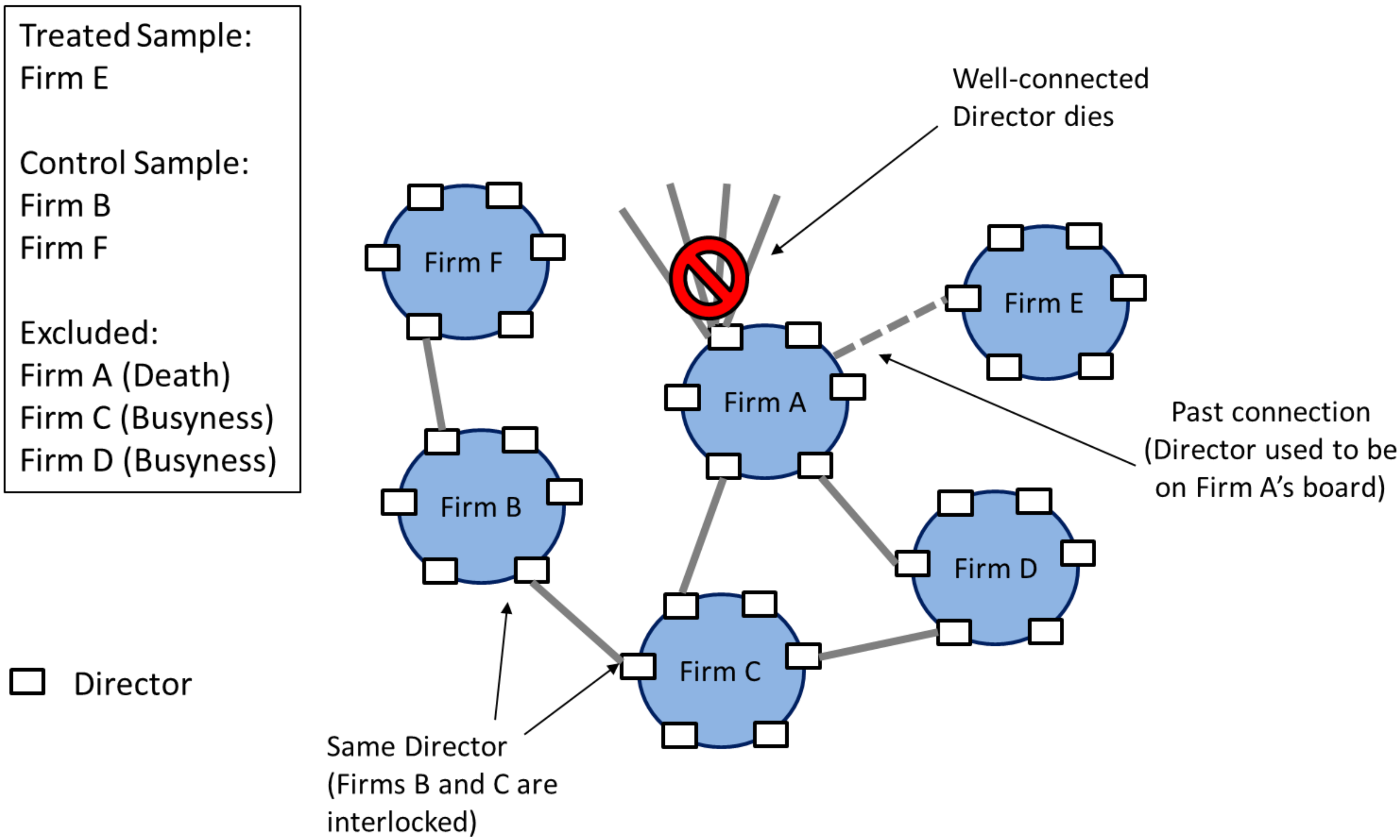

Figure 3: Bootstrap Falsification Test

This figure shows a histogram of the *Treated Dummy* regression coefficients from 10,000 bootstrap simulations of the regression in Panel A of Table 4 with *AR(0)* as the dependent variable. For each simulation, we draw a stratified random sample of 7 days (one random business day from 2001, 2002, 2003, 2005, 2006 and two days from 2011 – the years of the actual network shocks), and use the 1-day abnormal returns of the actual treated and matched-control firms from those 7 days to run the difference-in-differences regression model. We keep the regression coefficient on the *Treated Dummy* variable and re-run the simulation.

The actual regression coefficient of -0.297% is also plotted for reference. It lies 1.69 standard deviations below the mean of the simulation (a p-value of 0.0451). 279 of the 10,000 simulated coefficients are below the actual coefficient (an empirical p-value of 0.0279).