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The Value of Firm Networks: A Natural Experiment on Board Connections

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Non-Technical Summary

Directors of corporations often sit on several boards, a practice labeled "interlocking directorates". Policymakers and practitioners see this phenomenon ambivalent. Connections across the boardroom network may just manifest a "crony capitalism", providing powerful insiders an opportunity for rent-seeking but reducing firm value as a result. At the same time, they may facilitate the flow of information, providing top decision-makers of the firm with timely information regarding suppliers, customers, competitors, or lenders. In this case, having well-connected board members may be beneficial for the firm value.

Unfortunately, assessing the causal effect of board connections on firm value is not straightforward. Supposing that well-connected board members tend to sort into successful firms, this would result in a positive correlation between firm value and the presence of connected directors. However, it tells little about the effect of interlocking directorates on firm value.

In this paper, we exploit a "ban" on interlocking directorates, passed in December 2011 in Italy, which prohibits all firms in the insurance and finance industries to share board members. Given the importance of these industries, and especially banks, among Italian firms, this kind of regulation had a widespread effect on the network of Italian listed corporations. Moreover, the announcement of the law was unexpected. It provides an excellent opportunity for an event study analysis and allows us to examine the stock market response of firms affected by this regulation.

We construct a simple measure of network centrality which captures the extent to which the directors of a firm are connected. Firms will score high according to our proxy, for example, if it is connected to many firms, or if it is connected to a firm that is connected to many firms.

We find that firms expected to lose centrality because of the reform, experience a significant drop in valuation following the announcement of the ban on interlocking directorships. Hence, board connections are perceived as valuable by market participants. We also show that the information channel plays a significant role: the effect we find is much stronger in firms with low analyst coverage or characterized by more uncertainty regarding their valuations. Precisely these firms need alternative channels of information transmission, such as those based on network connections. We also explore how interlocking directorates are related to other types of firm networks, i.e. the input-output and the ownership network. Finally, we find that board members who lose centrality following the implementation of the law experience a drop in compensation: thus, board connections are important determinants of directors' pay.

Overall, our results suggest that interlocking directorates are beneficial for the firm value. However, it is important to point out that they may not always translate into a gain for consumers: for example, board connections may favor collusive behavior, lowering competition and overall welfare. Hence, policymakers should response flexible enough to accommodate appropriate reactions in cases that may have different implications for consumers' welfare.

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Abstract

This paper presents causal evidence of the effects of boardroom networks on firm value. We exploit exogenous variation in network centrality arising from a ban on interlocking directorates of Italian financial and insurance companies. We leverage this shock to show that firms that become more central in the network as a result of the shock experience positive abnormal returns around the announcement date. We find that information dissemination plays a central role: results are driven by firms that have higher idiosyncratic volatility, low analyst coverage, and more uncertainty surrounding their earnings forecasts. We also find that firms benefit more from boardroom centrality when they are more central in the input-output network, as this reinforces information complementarities, or when they are less central in the cross-ownership network, as well as when they suffer from low profitability and low growth opportunities. Network centrality also results in higher compensation for board directors.

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1. Introduction

Boards of directors play a crucial role in advising and monitoring corporate decisions. Hence, a large amount of empirical work has been devoted to understanding differences across boards and their implications for firm outcomes. Establishing a causal link between board characteristics and firm value is, however, difficult because the board composition is an equilibrium outcome of a mechanism design problem (see Adams et al., 2010, for an overview).

In this paper, we consider the role of inter-firm networks arising from shared (interlocking) directorships. By analyzing their causal effects on firm value we take a step forward in this research agenda. Networks, and in particular the centrality of firms in the boardroom network, are important since personal relationships are a salient feature of many economic exchanges: They shape the information flow between firms, facilitate resource exchange, and promote interpersonal and inter-organizational linkages.

Our main contribution is the use of exogenous variation in firms' network centrality arising from a regulatory shock to the board composition of Italian listed companies. This event, a ban of interlocking directorships directed at financial and insurance companies, allows us to address endogeneity concerns that are pervasive in this literature. We provide causal evidence on the interaction between boardroom networks and economic outcomes, and find that firms' stock market valuations benefit from having directors who are more connected, or *central*, in the firm network. Hence, we resolve existing uncertainty regarding the true effect of networks from the previous literature[1] that is likely stemming from the inability to address the endogeneity of governance and board structures. We also show that board connections are rewarded: directors experience an increase in compensation when their firm becomes more central as a result of this shock.

The ban of interlocking directorships that we study was enacted in December 2011. This shock has implications for the network structure of firms at large, given the central role of banks and insurance companies, the targets of the policy, in the Italian corporate network. We hand-collect data on the composition of corporate boards of listed firms, as well as

1 See Fracassi and Tate (2012). Alternatively, Cohen et al. (2008) use social networks to identify information transfers.

the compensation of each member, from the firms' mandatory filings for the years 2009–2014. We then match this dataset with firm stock returns and accounting data. From the board data we construct annual board networks, from which we derive standard firm-level measures of network centrality (degree, Katz centrality, betweenness, and closeness), and then construct a synthetic proxy as the first principal component of the four, which we simply label "centrality".[2] We exploit the regulatory change on interlocking directorships to simulate the effect of the reform on firms' locations in the network of shared board members.

While some firms will lose centrality after the reform, some, due to the non-linear nature of our network measures, will gain centrality in the firm network. We identify the component of the change in firm centrality that is resulting uniquely from the policy and, hence, is forecastable by investors. We find that it has strong predictive power for the post-reform evolution of the actual network centrality of the firms. This suggests that the effects of the reform on the network structure are long-lasting and, hence, are likely to be priced by investors.

In our baseline tests, we regress the three-day announcement return, centered around the policy announcement, on the predicted change in network centrality induced by the reform. We find that a standard deviation increase in predicted centrality determines a 90 basis point rise in stock returns. This result is robust to a number of additional tests. We find that, if anything, the coefficient rises in magnitude if we extend our window to five or seven days around the announcement day. We also find that our results do not depend on any component of our centrality measure in particular: three out of four proxies are at least marginally significant. Moreover, results are relatively unaffected by the exclusion of control variables, or by the inclusion of a more exhaustive set of controls in our main specification.

To identify and substantiate the economic channels behind our evidence, we re-estimate the baseline specification in different sub-samples by sorting according to various firms' characteristics. We conjecture that some firms might find boardroom connections more valuable than others. We start with proxies that allow us to identify a network information channel. Firms with high valuation uncertainty, as proxied by idiosyncratic volatility, low analyst coverage, and high volatility of earnings forecasts, may find the flow of information

2 See for example Hochberg et al. (2007), Larcker et al. (2013), El-Khatib et al. (2015) or Fracassi (2017).

channelled through the boardroom network more valuable. We find that this is indeed the case. Our evidence for a value enhancing role of information transmission within a network confirms the theory of incentive-compatible information sharing among competitors, such as Stein (2008). He shows that information complementarities together with repeated interactions can provide incentives for valuable information sharing within a network. Next, we sort firms according to profitability and growth prospects. We expect firms with lower performance to benefit more from the boardroom connections. We find this to be the case too. The firms driving the result are those characterized by lower profitability, as measured by return-on-assets, and lower growth opportunities, as measured by sales growth and Tobin's Q.

Given the growing interest in the role of firms' connections in propagating shocks to the economy, we next examine the existence of complementarities between the boardroom network and other types of networks. We focus our attention on input-output and cross-ownership networks. We find that firms that operate in industries that are more central in the input-output network benefit more from having a central board. This result has further reaching implications, as it shows that the shock amplification uncovered in the literature on the micro origins of aggregate fluctuations[3] can be even larger than previously thought if considered in combination with other firms' connections. In contrast, we find that connections due to cross-ownerships can serve as a substitute for the ties formed through interlocking boards. This result too has more general implications: common ownership is presumed to affect market power with hidden social costs (see Azar et al., 2018). Our results show that the same is potentially also true for interlocking boards.

Finally, we explore the impact of network centrality on directors' compensation, a topic which has attracted increasing attention (see literature review) due to the extraordinary rise in executive compensation. Unlike previous work, we focus on board networks, which could raise executives' compensation by increasing their outside options. To test this channel we hand-collect data on directors' pay, including top executives, and find a positive and significant relationship between network centrality and compensation. Perhaps surprisingly, we find that all the board members, and not only the top executives, benefit from network

3 See among others Gabaix (2011), Acemoglu et al. (2012), and Carvalho and Gabaix (2013).

centrality.

This paper is organized as follows. Section 2 relates our paper to existing research. Section 3 discusses the institutional setting and regulatory framework we exploit and describes the construction of our boardroom-network measures and instrumental variable strategy. Section 4 presents results on the validity of our instruments and on the stock market reaction following the reform announcement. Section 5 presents results on director compensation.

2. Related Literature

Our work is related to the literature that tries to establish the effects of board characteristics, and more specifically of board network centrality, on firm outcomes. A commonly used empirical strategy is based on the idea of constructing networks from social, educational or professional connections predating the current relationship (Cohen et al., 2008, 2010; Kuhnen, 2009; Engelberg et al., 2012, 2013; Kramarz and Thesmar, 2013) so as to avoid confounding networks with current firm performance. Other authors have exploited changes in network centrality arising from the appointment of existing board members to other boards (Larcker et al., 2013; Hann et al., 2019; Burt et al., 2019). In contrast to this literature, we focus on a previously unexplored exogenous regulatory shock in Italy specifically aimed at the boardroom network structure, rather than the general board composition. For the purpose of identification, a strength of our approach is that we can validate it by showing that both stock market valuations and board centrality do not appear to exhibit any pre-trends prior to the announcement of the policy. Besides, most other papers examine the role of bilateral connections between individuals (see, e.g., Fracassi and Tate, 2012; Fracassi, 2017; Shue, 2013), whereas causal evidence on the effects of boardroom connections through interlocking board members is sparse.

More central firms have been shown to benefit from increased information flows in the context of venture capital (Hochberg et al., 2007), mutual fund investments (Cohen et al., 2008), analyst recommendations (Cohen et al., 2010), borrowing (Engelberg et al., 2012), corporate investment (Fracassi and Tate, 2012) and R&D expenditures (Faleye et al., 2014).

Evidence in the context of M&A is more mixed (El-Khatib et al., 2015; Chikh and Filbien, 2011; Stuart and Yim, 2010). Board connections may also have a detrimental role due to a reduction in monitoring intensity (Fracassi and Tate, 2012), distortions in director selection (Kuhnen, 2009), voting behavior of mutual funds (Butler and Gurun, 2012), corporate investment (Güner et al., 2008), and option backdating (Bizjak et al., 2009). Hence, the impact of boardroom connections, and network centrality in particular, on firm value is ex ante unclear, but we are able to tackle this question by exploiting a natural experiment. In addition, we contribute to the growing literature on the importance of directors as advisers rather than just monitors (see, e.g., Dass et al., 2013).

Some of our results have also broader implications and provide insights for related fields and other strands of the literature, for example on firms' networks and CEO compensation. We show that there is some degree of complementarity between boardroom and input-output networks, a result which speaks more broadly to the literature on intersectoral input–output linkages as multipliers of firms' idiosyncratic shocks (see Gabaix, 2011; Acemoglu et al., 2012; Carvalho and Gabaix, 2013, among others). On the other hand, our evidence of a the substitutability between the boardroom network and co-ownership has important implications for the industrial organization literature and the social costs of hidden market power (see Azar et al., 2018). Like co-ownership, interlocking boards can also mask firms' dominant market positions.

Finally, our paper sheds new light on the role of a firm's network position on the compensation of its directors and executives (see also Engelberg et al., 2013; Brick et al., 2006; Hwang and Kim, 2009; Balsam et al., 2017). Directors' compensation, and especially that of CEOs, has received vast attention also given its exponential growth in recent years. A large amount of literature has attempted to examine the origins of this growth, varying from luck (Bertrand and Mullainathan, 2001) and assortative matching (Gabaix and Landier, 2008) to rent sharing in a knowledge economy (Garicano and Rossi-Hansberg, 2008). We contribute to this literature by showing that boardroom connections have a substantial effect on compensation, both for top executives and for directors.

3. Institutional Setting

3.1. Institutional Setting

In December 2011, the Italian government presented a piece of legislation commonly known as the "Save Italy" decree. Very broad in scope, it was a response to investors' concerns about the sustainability of the Italian debt level at the peak of the sovereign debt crisis. Given the emergency of the economic situation, the decree was sudden and unexpected. Beyond its main goal, the decree contained a ban on interlocking directorships for all competing firms in the finance and insurance sector.

Most listed Italian companies adopt a two-tier governance structure, with the two bodies being the board of directors (*Consiglio d'Amministrazione*) and the audit committee (*Collegio Sindacale*). The ban on interlocking boards applies to members of both bodies.[4] As a result of this law, many directors had to leave some of their posts. Initially the decree did not specify an exact time frame for the decision on which post to leave or to maintain. This was clarified at a later stage, when April 27, 2012 was established as a deadline. After this date a non-compliant director would have to step down from all her seats.

A number of features make this policy particularly well-suited as a natural experiment. We argue that its prescription had a significant impact and that its implementation was unexpected.

Although the scope of the reform was limited only to the finance and insurance sectors, it proved to be quite effective in dispersing the boardroom network between listed firms for two reasons. First, the finance industry historically has had a central role in the network of firms, with directors often being in both banks' and firms' boardrooms. Second, the definition of competing companies was strict and unambiguous, as it established that all banks or insurance companies were subject to the ban as long as they had a single branch in the same province. Given the nationwide presence of the banks and insurance companies in our sample of large, listed firms, the law had a de facto impact on all firms in these industries, as long as they shared at least one director. This guaranteed full and broad compliance with the

4 We will, for brevity, refer to members of the audit committee as directors as well.

law. This stands in contrast to similar legislative acts, such as the Clayton Act in the U.S., which has been rarely enforced also due to a lack of a well-defined classification of competing firms.[5] In contrast, the Italian law induced full compliance.

Figure 1 illustrates the effects of the ban on interlocking directorships on the network of Italian companies at large. It plots the graph density, i.e., the number of observed links over the number of all possible links, of the boardroom network at an annual frequency over the sample period 2009-2014 and shows that network density has experienced a sharp decrease following the reform in 2011. In Section 3.4 we provide a quantification of the impact of this law on the distance between the actual and the predicted network.

The content of the decree, and the provision on interlocking directorates, became known to investors only when the decree was presented to the parliament, becoming immediately effective, on December 6. The provision was, arguably, unexpected by investors. This is confirmed by the fact that press coverage of this law was completely absent before December 6. We searched the web archive of *Sole 24 Ore*, the main daily financial newspaper, using the tag "interlocking directorates." The first article examining the implications of the provision appeared on December 7,[6] whereas no article on the topic appeared in the year leading up to the decree.

3.2. Measures of Network Centrality

We derive our information on director networks from board data on Italian listed companies available at the website of the *Italian Companies and Exchange Commission* (CONSOB). The reporting frequency on board composition is biannual. We collect name and position of each board member and manually match firm names to Compustat Global to obtain financial data. Using these data, we construct an undirected and unweighted firm network. We define two firms as being connected if they share at least one board member.

Other interpersonal and non-professional connections formed in more informal contexts (education, club membership, etc.) might extend beyond the network of shared directorates.

5 For example, Apple and Google shared two directors, including Google's CEO Eric Schmidt, for three years, before the Federal Trade Commission forced them to break the tie (See "Google and Apple Eliminate Another Link Tie", New York Times, October 12, 2009).

6 See "Le regole di Monti sui pluri-banchieri", Sole 24 Ore, December 7, 2011

However, as noted in Hwang and Kim (2009) and Larcker et al. (2013), there is most likely some degree of strategic complementarity between the social and the boardroom network. Moreover, unlike members in common clubs, shared directors are guaranteed to interact on economically relevant topics during mandatory meetings.

In our empirical analysis, we construct several network centrality metrics. The advantage over the use of simpler measures (e.g., a raw count of the number of firm connections) is that we can capture both direct and indirect links among firms. Network centrality is a multi-dimensional object that encompass several forms of interactions, including the one we will be mainly focusing on, namely the information transmission (Hochberg et al., 2007; Fracassi, 2017). We follow previous work (e.g. Hochberg et al., 2007; Larcker et al., 2013) and measure the firms' relative position in the network using four simple statistics.[7]

Degree centrality is the simplest measure of a firm's network position and counts the number of direct ties of a firm to other firms, i.e., whether they share at least one director. The more connections a firm possesses, the more channels it has to access information and leverage its connections in economic exchanges.

The same motive is also captured by *Katz centrality*.[8] Unlike degree centrality, which accounts only for first-degree connections, this measure takes into account the centrality or *importance* of firms with which the firm shares a director. Being connected to others that are themselves central increases the centrality of the firm itself. The relative centrality of firms that are only indirectly connected to most central firms is dampened by an attenuation factor.[9] As such, Katz centrality better captures a firm's power or prestige (Fracassi, 2017) and especially does so in its vicinity. This measure is particularly well suited in quantifying the quality and the amount of the information flows, since it focuses on firms which are both more central and more indirectly connected.

7 See Appendix A for a more formal definition of each measure.

8 We propose using Katz centrality instead of the more commonly used eigenvector centrality (Hochberg et al., 2007) in order to consistently measure the centrality of firms located in unconnected components (i.e. a smaller set of firms not connected to the rest of the corporate network). For these unconnected components eigenvector centrality is 0 and small changes in board composition over time could lead to the instability of eigenvector centrality over time.

9 When the attenuation factor α converges to 0 Katz centrality is constant for all firms; when α converges to an upper bound Katz centrality coincides with eigenvector centrality. We make a very conservative choice and set $\alpha = 0.05$.

The extent of indirect information transmission is well captured by *closeness centrality*. It is constructed from the inverse average distance between a given firm and any other firm in the network. Intuitively, it is large when only a few shared directors are needed for the information flow to reach a firm.

The last metric we consider is *betweenness centrality*. It measures how much control a given firm has over the information flow between any other two firms. More technically, it measures how often a given firm lies on the shortest path of information flow between two other firms in the network. Intuitively, the directors of firms with high betweenness centrality can pass information from otherwise unconnected parts of the network.

Since these centrality measures are strongly correlated and, ultimately, we only seek to capture how central a firm is in the network along all these dimensions, our main results are based on their first principal component, henceforth simply labeled *centrality*.[10]

3.3. Illustrative Example

To fix ideas, in Figure 2 we describe the potential impact that a policy like the one considered here can have on a stylized network with two banks and six firms. Circles represent the firms (nodes), lines between nodes (edges) are created if two firms share a director and the size of the nodes is proportional to the value of our centrality measure. In Panel (a), both Bank A and Bank B are very central in the network. They have a high degree and Katz centrality (see Table 1). Katz centrality exhibits more variation and differs across companies with the same degree centrality; i.e. Company A and B have two direct connections, but Company A has higher Katz centrality since it is connected to Bank A, which is, in turn, very central.

Enforcement of the regulatory shock results in a ban of the link between Bank A and Bank B. In addition, we assume that the shared director between both banks is also on the board of Company A, and that she decides to leave the board of Bank A. Hence, the latter loses ties to both Bank B and Company A. This has significant implications for the overall network structure, visible from the changes of the four centrality measures and in the overall network density. In addition, although firms rank fairly similarly across all measures prior to

10 See also El-Khatib et al. (2015) or Larcker et al. (2013) for similar techniques to reduce dimensionality in the context of corporate networks

the shock, the effect of the shock is heterogeneous across firms and measures.

Bank A was initially the most central according to all measures. After the shock, it instead has the same centrality as Bank B (according to degree and Katz centrality). In terms of information transmission, Company C and D play a more important role after the shock, well captured by the change in betweenness. Intuitively, both companies become ex post pivotal for information transmission from the nodes connected to Bank B (i.e. Company A and B) to the nodes connected to Bank A (i.e. Company E and F). If it were not for the connections of Company C and D information transmission would be inhibited. A significant change is also seen for closeness centrality. This is especially the case for companies in the periphery (A,B,E,F), as well as for both banks. The reason is that the severed tie between Bank A and Bank B inhibits the information flow by increasing the distance to the periphery.

3.4. Predicting Network Centrality

Our empirical strategy exploits the exogenous change in firm network centrality induced by the reform to identify its causal effects on firm value. Importantly, we only use information available to investors at the time of the announcement of the policy, and identify the component of the change in firm centrality that was forecastable by investors.

We use the boardroom network in June 2011 (before the reform) to simulate the change in the network structure due to breaks in the ties between the firms affected by the reform. To this end, we first select all directors that create an interlock between banks or insurance companies. Next, we choose a simple criterion to predict which boards each of the selected directors are more likely to leave. We assume that high-ranking executives, i.e. CEO, president, vice-president, and general director,[11] are more likely to remain in the firm where they hold this position. We further assume that the position of ordinary board member is more highly valued than the ones in an auditing committee. We solve remaining tie-breaks by assuming that directors remain at the firm where they earned more in 2010.

Comparing predicted resignations to actual resignations from the press releases (all mentioning the regulation as the reason) we correctly predict 68% of the resignations. This

11 *Direttore generale* is a role present only in few firms. This is effectively equivalent to a Chief Operating Officer.

suggests that our criterion for selecting boards is reasonable. Based on the above, the predicted change in centrality Δ is defined as the difference between predicted and actual centrality:

$$\Delta = \overline{Centrality}_{i,06/2011} - Centrality_{i,06/2011}, \tag{1}$$

where $\overline{Centrality}$ is the simulated and $Centrality$ the actual network centrality of a given firm i.

4. Network Centrality and Firm Value

We build on our hand-collected data of board members by hand-matching firm names to corresponding Compustat Global identifiers. For any inconsistencies, we cross-referenced the hand-collected data on board composition and financial data from Compustat with data from annual reports to ensure proper matching. We get data on daily stock prices, as well as firm-level financial and balance sheet variables, for all companies listed on the Milan Stock Exchange from Compustat Global. We further match firms with Datastream to obtain data on market capitalization. Analyst coverage and earnings forecasts are obtained from IBES. Description of the procedure for collecting information on directors' compensation, which will be used in the next section, is described in Section 5.2 and, more detailed, in Appendix B.[12]

4.1. Effects on Network Centrality

At the time of the policy announcement, investors can anticipate how the firm network is going to evolve as a result of the reform only to some extent. As a preliminary test, we are interested in knowing whether (i) the reform has a significant effect on the configuration of the board network, and (ii) whether the effect is persistent. Both conditions need to be satisfied to have a significant stock market reaction.

12 Definitions of all other variables used can be found in Table A10

We use data on board composition at the annual level, and estimate:

$$y_{i,t} = \beta \times \Delta_i \times Post_t + \eta_i + \delta_t + \varepsilon_{i,t} \quad (2)$$

where y is a network centrality measure, *Post* is a dummy equal to 1 after December 2011, and zero otherwise.

Δ is the predicted change in firm i's network centrality, constructed by simulating the network after breaking the ties among firms connected prior to the reform (see Section 3.4 for details). We estimate the model over the 12/2009–12/2014 period including all firms that have at least one observation before and one after the reform.

Table 3 reports results estimates of the coefficient β. As expected, in column 1, where the dependent variable is our measure of network centrality, the coefficient is large and significant, with a t-statistic of 6.10. In columns 2 through 5, we test whether any of the four components of our network centrality measure are driving this positive association. We find that coefficients are indeed all positive and, except for closeness (t-statistics= 1.48), large and significant: the coefficients on degree, Katz, and betweenness (columns 2 through 4) have t-statistics equal to 5.06, 10.91, and 2, respectively.

We also perform an event study analysis by replacing $\Delta \times Post$ with a vector of interactions between Δ and time dummies, omitting the coefficient corresponding to the last pre-reform year, 2011. In Figure 2, the coefficients are small and insignificant for the years 2009 and 2010, while they increase significantly in the post-reform years 2012 through 2014. Hence, there is no evidence of a pre-trend in changes in network composition. Moreover, there is no apparent reversion after the reform. This suggests that firms, whose ties with other firms were broken by the reform, were unable to recover their centrality in the firm network.

4.2. Baseline Results

We now turn to the main point of our analysis, namely the impact of the reform on firms' market values through changes in the network. In Table 3, we estimate the following equation:

$$CAR_i = \beta \times \Delta_i + \gamma X_i + \varepsilon_i \tag{3}$$

CAR_i is the cumulative abnormal return over a three-day window surrounding the announcement date. Daily abnormal returns are either raw, net of the risk-free rate, or risk-adjusted using either the market model or the Fama French three-factor model.

Δ is our main coefficient of interest. It captures the impact of the predicted change in the principal component of the four centrality measures. We standardize it to facilitate interpretation. The vector X includes our control variables, namely size, defined as Log(total assets), and ROA, defined as income divided by lagged total assets. We choose those since they are consistently observed for the entire sample. We nevertheless check that results are unaffected if we include additional controls or no controls at all (see Table 4). X also includes industry dummies, defined using the Fama-French 17 industries classification.[13]

In Column 1 of Table 3 we use the raw stock return as dependent variable and find that a one-standard deviation change in predicted centrality is associated with a 90 basis points increase in stock returns. The coefficient on Δ is statistically significant at the 5% level (t-statistic= 2.23). This result does not depend on the particular benchmark used to adjust for risk. In column 2 we use the market return as benchmark, and in column 3 we use the three Fama-French factors. The coefficients and the statistical significance are virtually identical.

As a first robustness test, we run our baseline regression separately for the daily return on day $t-5$ and the buy-and-hold return between day $t-5$ to $t-4$, $t-5$ to $t-3$, and so on, until $t+5$. The purpose of this exercise is to test whether there is any "pre-trend" in the change of valuation preceding the announcement of the interlocking ban, and whether we find any evidence of reversion to the mean. We can confirm that this is not the case. Figure 3 plots the estimated β_j's coefficients for these regressions along with 95% confidence

13 We have used the 12, 30, 38, and 49 industries classification, finding similar results.

intervals. The coefficients are close to 0 for the days before the reform and increase around and after its announcement, indicating that the timing of the change in market valuation coincides with the announcement of the policy.

4.3. Robustness Tests

In this section we verify the robustness of our results across different specifications. In Table 4 we present several variations of the baseline specifications of Table 3. For brevity, in all the tests that follow we use the market model to adjust stock returns, but results are similar with different benchmarks. Columns 1 through 3 examine whether the effect of network centrality on stock market valuations vanishes over time. In addition to our baseline -1,+1 window, results are shown for a five-day (column 2) or seven-day (column 3) window around the announcement date. Point estimates and standard errors are similar. With a -2,+2 window the coefficient on Δ is 1.02, and it rises to 1.19 with a -3,+3 window. In both cases coefficients are significant at the 5% level.

In columns 4 through 7, we regress the three-day cumulative abnormal return on the four different components of our main centrality measure, standardized as usual. There is no evidence that our results are driven by a specific proxy. All the coefficients are positive and economically large, with the only exception of betweenness centrality. Results are the strongest for the Katz and closeness centrality measures, whereby estimated coefficients are 1.20 and 0.79, respectively, both significant at the 1% level. The coefficient on degree centrality is 0.74 and significant at the 10% level. Only the coefficient on betweenness centrality appears small and more noisily estimated.

In columns 8 and 9 we test whether any of the control variables are driving our results. In column 8 we exclude all controls except the industry dummies. In this case the coefficient rises to 1.24 and is significant at the 1% level. In column 9 we include standard predictors of stock returns, beyond ROA, size, the logarithm of market capitalization and Tobin's Q. The coefficient and the statistical significance are, again, similar to those found in our benchmark estimates. We conclude that results are robust.

In the three sections that follow, we put under the microscope the economic channels behind our results. We start with the role of information acquisition, and move to examine complementarities with other firms' connections, namely input-output and cross-holdings. We then analyze the importance of firm profitability and growth opportunities.

4.4. The Role of Information

The literature on boardroom networks so far mostly highlights the importance of information flows between connected firms. We examine their role to obtain more definite results on this prominent channel within the setting of our natural experiment. Recent empirical work has highlighted the downside of boardroom connections, showing that they tend to disseminate bad managerial practices, such as option backdating (Bizjak et al., 2009), earnings management (Chiu et al., 2013) or insider trading (Akbas et al., 2016). On the contrary, we find that the information transmitted through boardroom networks can increase firm value. A more connected boardroom promotes information transmission to outside investors and improves the quality and availability of information for directors and advisers.

Our strategy consists of identifying the firms that may benefit the most from information transmission and test whether the impact of the change in network centrality is stronger for them. Our hypothesis is that network centrality and other sources of information are likely to be substitutes. Hence, firms, that lack access to providers of external information are likely to be more sensitive, in terms of market valuations, to changes in network centrality. For this purpose, we construct three proxies that capture the ease with which board members can access information regarding the market environment: idiosyncratic volatility (IVOL), analyst coverage, and the dispersion of analyst earnings forecasts.

We follow Hirshleifer et al. (2013) and estimate IVOL by regressing, for each firm, the daily excess stock return on the equity premium over the 12 months that precede the announcement (i.e. from December 2010 to November 2011 included) and compute the standard deviation of the residuals. Analyst coverage captures, instead, access to external reporting (Hong et al., 2000). Because analyst coverage is strongly correlated with firm size, a potential confounding factor, we regress the logarithm of one plus the number of analysts covering the firm in the previous calendar year on the logarithm of total market capitalization and its squared value. We then sort firms according to the estimated error from this regression. Finally, we use the dispersion of analyst earnings forecasts as a measure of disagreement about firms' market valuation. This captures well the degree of heterogeneity in investors' beliefs (Johnson, 2004). Disagreement is constructed as the standard deviation of net income forecasts for 2010 (available from IBES) standardized by the book value of assets. Since about half of the firms have no coverage, estimates are based on a smaller sample of 124 observations.

In Table 5 we estimate Equation (3) for two different subsamples. More specifically, we sort firms according to whether they are below or above the sample median of each proxy discussed above. As hypothesized, results are much stronger in firms with higher idiosyncratic volatility, lower residual analyst coverage and higher dispersion of analyst forecasts. In these sub-samples, the coefficients of interest are 1.49, 1.24, and 2.16, respectively. All are significant at the 5% level. In the other subsamples, the effect of changes in network centrality is positive but insignificant at conventional levels. Hence, firms whose market values are less uncertain or for which there is ample and more clear external reporting appear to benefit less from boardroom connections.

4.5. Input-Output and Ownership Networks

Boardroom networks are one way, among many others, in which firms are connected. An interesting aspect to examine is whether connections along various dimensions are complementary to each other or neutralize each other. We consider two such alternative networks based on input-output and cross-ownership connections.

We start with value-chain connections, that have recently attracted a considerable amount of attention also in the firms' dynamics and macro literature (see, among others, Acemoglu et al., 2012; Carvalho and Gabaix, 2013). While their focus is more on whether idiosyncratic shocks multiply through the input-output network, we examine a parallel aspect. We ask whether the beneficial effects of information transmitted through the boardroom network are amplified in the presence of value chain connections (Barrot and Sauvagnat, 2016; Gabaix, 2011). Firms that are more central in the input-output network are more susceptible to shocks regardless of whether these are upstream technology shocks or downstream demand shocks. As such, we expect these firms to benefit more from the flow of information provided by a more central position in the boardroom network. This test is motivated also by the evidence in Dass et al. (2013), who show that companies are better isolated from industry shocks and have a shorter cash conversion cycle when they share directors with firms in related upward or downstream industries.

Input-output data for the year 2010, aggregated to 62 NACE industries,[14] are provided by the *Istituto Nazionale di Statistica* (ISTAT). We match sample firms to (potentially multiple) NACE codes using official crosswalks to the Compustat's NAICS code.[15] We then compute industry-level network centrality for both a directed, weighted and unweighted input-output network, where the weights in the former are the input flow from sector i to j relative to total input demand of sector j. For the unweighted network we define two industries i and j to be connected if i's output exceeds 1 percent (Carvalho, 2014) of j's total input purchases. Based on this network, we then compute Katz centrality[16] and estimate Equation (3) for two subsamples according to whether a firm operates in an industry that is below or above the sample median of centrality in the input-output network.

Results of this exercise are displayed in Table 6. As hypothesized, results are much stronger for firms that operate in more central, downstream industries. In this case the coefficients are equal to 1.66 and 1.77, depending on whether we use the weighted or unweighted network measure. On the other hand, the coefficients drop to 0.12 and 1.04 in industries that are less central. Even though the coefficient is statistically significant for the weighted network, it is still much lower in magnitude. Hence markets perceive that a central position in the boardroom network is better able to isolate a firm from shocks originated in upstream industries.

Next, we examine the complementarity with cross-ownership networks as a source of information. This case is also insightful since it is relatively unexplored. Data on cross-

14 We exclude home production.

15 We match based on 6-digit NAICS codes and impute any shorter NAICS codes as long as they map uniquely into a NACE category. Wherever this is not possible, we used NACE classifications provided by AMADEUS. If a 6-digit NAICS code maps into more than one of the NACE codes, we compute the firms' network centrality as the average of the corresponding NACE industry centrality.

16 See also Carvalho (2014) for a structural interpretation of Katz centrality in the context of input-output networks.

ownership of Italian firms is collected from mandatory filings of the CONSOB and manually matched to our board data. Our sample includes all listed Italian companies as well as unlisted Italian and foreign (listed or unlisted) companies reported as owners. We exclude all institutional owners. While most of the literature on ownership networks has considered directed networks in the context of corporate control (Glattfelder and Battiston, 2009), in our case the direction of the edges is less relevant. We therefore compute Katz centrality for the undirected, weighted cross-ownership network using the ownership stakes as weights. Alternatively we also compute centrality for the undirected, unweighted ownership network, where two firms are connected if the ownership stake exceeds either 1% or 2%. We re-estimate our baseline specification for two sub-samples depending on whether firms' centrality in the ownership network is below or above the sample median. Results in Table 7 indicate that firms profit more from a central position in the boardroom network when they are less central in the ownership network. For the weighted network (column 1 and 2), the coefficient on Δ is a significant 1.43 for firms characterized by low centrality, and 0.55 (insignificant) for firms with high centrality in the ownership network. Results are very similar when using unweighted networks regardless of whether we choose 1% (column 3 and 4) or 2% (column 5 and 6) as a cutoff. Hence, interlocking and ownership networks reinforce each other. In other words, firms that are less central in the ownership network benefit more from boardroom centrality.

4.6. Profitability and Growth Opportunities

Further insights into the effects and the economic channels behind the reform might be gained by examining its heterogenous impact across firms with different characteristics. More specifically, we ask whether firms with different degrees of profitability or different growth prospects benefit differently from the change in their centrality. Ex ante the answer is unclear. Firms with ample growth opportunities may be less in need of a central boardroom to obtain information about investment opportunities. On the other hand, the information channeled through boardroom connections might benefit more innovative, and hence more profitable, firms simply for the fact that these firms have access to more lucrative investment projects.

We proxy past profitability using ROA and growth opportunities using Tobin's Q and Sales Growth, all measured with one-year lag. We then again estimate Equation (3) in two sub-samples, defined according to whether a firm is below or above the sample median. Table 8 shows that firms characterized by low ROA, sales growth and Tobin's Q benefit the most from increased network centrality. The coefficients on Δ range between 1.37 and 1.90 for this group of firms, and are significant at the 1% or 5% level. Coefficients on firms with better ex ante performance or growth opportunities are smaller in magnitude and, if anything, negative, albeit being estimated with less precision. We conclude that boardroom connections are especially valuable for firms facing downturns or in need of finding profitable investment opportunities.

5. Director Compensation

5.1. Isolating the Effect on Compensation

A firms' surplus is jointly determined and jointly split between firms' owners and firms' directors. The importance of directors' compensation, and in particular of a CEO's pay, has received wide attention in recent years because of its exponential growth. While many determinants of the cross-sectional or time-series variation of compensation have been examined previously (see Edmans and Gabaix, 2016, for an extensive review), none so far have examined the role of boardroom centrality on directors' compensation. The question is meaningful as network centrality might affect compensation through several channels. A first obvious and prominent reason can be rent sharing. As centrality raises firms' surplus, so too does directors' compensation. Besides this, a central position might improve directors' outside option and their bargaining position within the firm by facilitating access to potential employers (see, e.g., Liu, 2014).

In this test our unit of observation is now the director, not the firm, and the dependent variable is the logarithm of her annual compensation. Contrary to past literature (for example, Engelberg et al., 2013), our strategy allows us to tackle the endogeneity of the network connections between directors by adopting an IV strategy. Our measure of centrality considers only links between firms originating from interlocking directorates, and not past professional and non-professional connections. However, in other respects; our measure is broader since we do not simply count connections between directors, but rather consider the entire, multidimensional boardroom network structure by taking direct and indirect links into account. Another difference with most previous work is that we focus on all board members, not just CEOs.

More formally, we estimate the following model:

$$Log(Compensation_{i,j,t}) = Centrality_{i,t} + \eta_{ij} + \delta_t + \varepsilon_{i,j,t} \tag{4}$$

where the dependent variable is the logarithm of director j, employed at firm i in year t, and Centrality is our usual proxy for network centrality. Importantly, we instrument Centrality using the expected change in network centrality induced by the reform, Δ, interacted with a "Post reform" dummy, as in Equation (2). We double-cluster standard errors at the director and firm level to account for two potential layers of autocorrelation.

5.2. Results

Table 9 shows the causal effect of network centrality on directors' compensation. We use a sample of 13,066 directors whose compensation is hand-collected from mandatory governance filings, so-called *Relazioni sulla Remunerazione*, that are annually filed with the Italian stock exchange (*Borsa Italiana*). Since these only became mandatory in 2011, we hand-collect compensation data from annual reports for the years 2009-2010.[17] Similarly to the DEF14A filings in the US, reports contain data on fixed compensation (*compensi fissi*), bonus payments (*bonus*), non-monetary benefits (*benefici non monetari*) and other compensation (*altri compensi*). Reporting in these categories is not always consistent, but we harmonize it across firms so that differently reported compensation components were assigned to one of the broader categories above.

Stock and option grants are reported separately. In order to ensure consistent valuation,

17 While coverage is almost universal for all listed companies starting in 2011, there are some companies where we are unable to recover annual reports or compensation information for 2009 or 2010.

we follow the standard methodology used by the "Execucomp" database and again re-value all grants using our hand-collected data on the number of stocks/options, grant-date share price, grant date, and, specifically for option grants, strike price and expiration date.[18]

Column 1 of Table 9 shows that a one-standard deviation increase in centrality induces a large and statistically significant increase in compensation, corresponding to a 12% pay raise. The first stage F-statistic is 47.16, suggesting that our instrument is very strong. In columns 2 and 3 we distinguish between high-rank directors (CEO, chairman, and vice-chairman) and low-rank directors (all the others). The point estimate of the coefficient is larger for top executives than for the other directors, being equal to 0.18 and 0.11, respectively. However, results are statistically significant only for non-top directors. This is likely due to the higher statistical power of the latter test, given that in this case the sample size is about three times larger (9,287 versus 3,175 observations).

In columns 4 through 6 we replicate our tests but now collapse all observations at the firm-year level. Hence, an observation is the average Log(Compensation) at the firm-year level. The advantage of this specification is that every firm gets the same weight, independent of its number of directors. Moreover, attrition of individual executives or directors becomes less problematic. The inclusion of firm-director fixed effects implies that an executive who is part of a firm board only before or only after the appointment will not enter the sample because of collinearity. On the contrary, the estimates at the firm-year level are robust to directors' turnover.

In columns 4 through 6, we indeed find larger and more precise coefficients on the centrality variable. The coefficient is equal to 0.33 when all directors are included. When we split directors according to their rank, we find coefficients equal to 0.32 and 0.41 for high- and low-rank directors, respectively. All these estimates are statistically significant at the 5% or 1% level.

18 Details on specific assumptions are in Appendix B

6. Conclusion

This paper presents causal evidence on the effects of firms' centrality in the network of shared boardrooms on firm value and pay setting. To this end, we leverage a change in Italian corporate governance legislation that rules out interlocking directorships between banks and insurance companies. The reform was fully unexpected and out of the firms' span of control, hence it well qualifies as a natural experiment.

Upon verifying that the reform has a meaningful impact on network connections, we document that firms that end up being more central in the network as a result of the policy experience positive abnormal returns around the announcement date. They also pay significantly higher compensations to their directors. This effect is robust when using alternative return risk adjustments, when controlling for different firm-level observables and industry fixed effects, or when using several measures of network centrality.

We find that the value-enhancing effects of increases in network centrality are due to information spillovers. Abnormal returns are especially high for firms with higher idiosyncratic risk, lower analyst coverage, and higher disagreement among analysts. Hence, firms with more uncertain market valuations or with lower external coverage benefit more from the boardroom centrality. At last, we uncover a complementarity between boardroom networks and input-output networks on one side and cross-ownership on the other. Our results have broader validity and implications for the salience of firm network on market valuations.

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7. Figures

Figure 1
Graph Density around the Event

Figure 1 displays the the annual “graph density” of the firm network. Density is the number of observed links normalized by the total number of all possible links in a given year. The horizontal dashed line corresponds to the reform year.

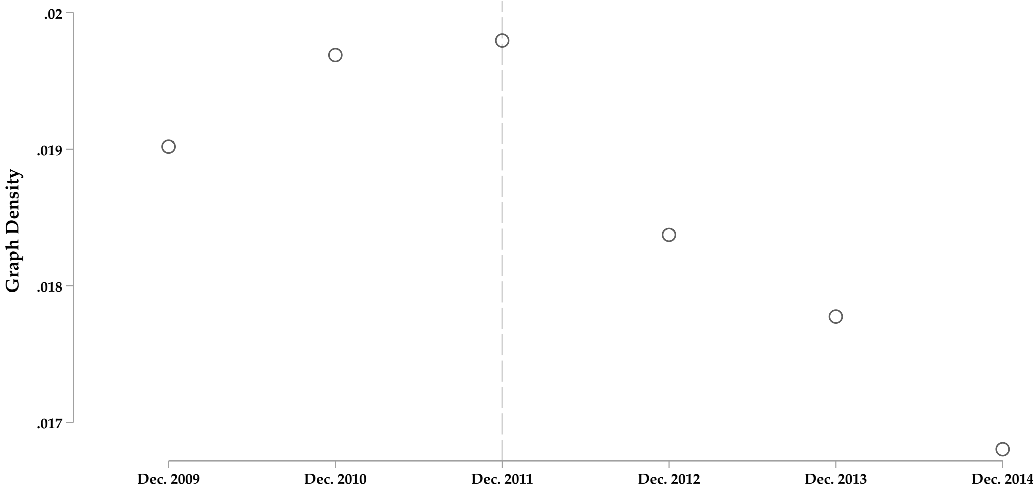
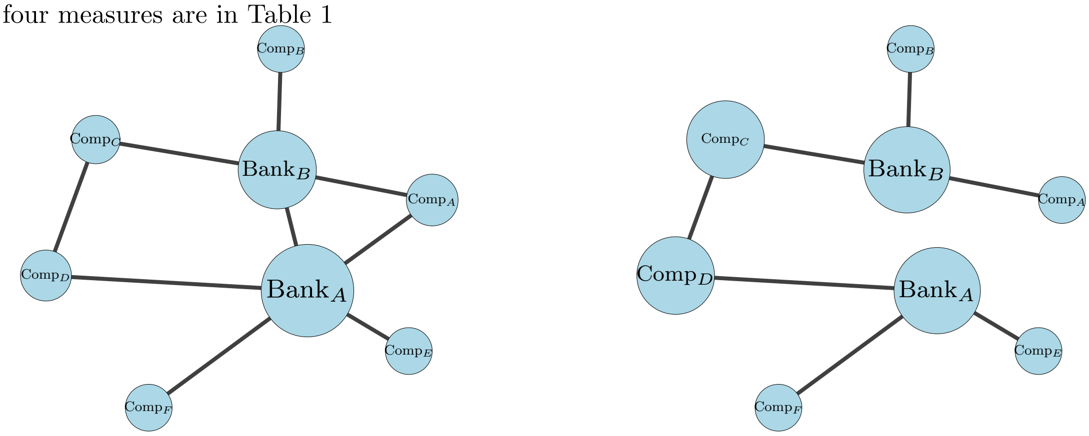


Figure 2
Fictional Corporate Network and Potential Effect of Regulation

Figure 2 shows an illustrative example of a potential boardroom network structure before and after simulating the effects of enacting the reform. We assume a director to be on the board of Bank A, Bank B, and Company A, and that the director steps down from his position at Bank A, hence also severing the tie between Company A and Bank A. The size of the nodes scales with the principal component of the four network measures (Degree, Katz, Closeness, Betweeness) as used in our main analysis. Actual values for each of the four measures are in Table 1



(a) Before **(b) After**

Figure 2
Event Study: Network Centrality

Figure 2 shows coefficients from regressing Centrality (PCA) on firm and year fixed-effects, and year dummies multiplied by the predicted change in Centrality Δ. The coefficients β_t associated to the year dummies interacted with Δ are plotted together with the 95% confidence intervals. Standard errors are clustered at the firm level. $t = 0$ corresponds to the reform year 2011, and β_0 is normalized to zero.

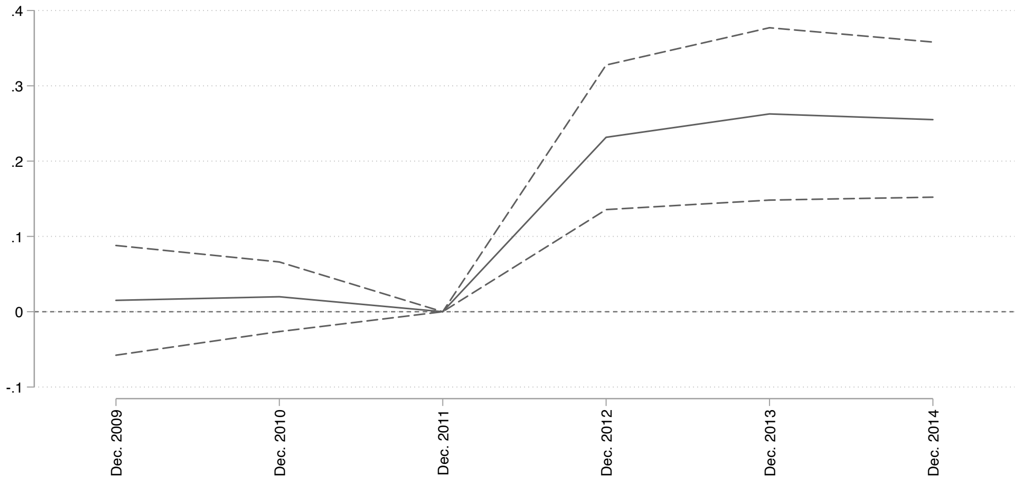
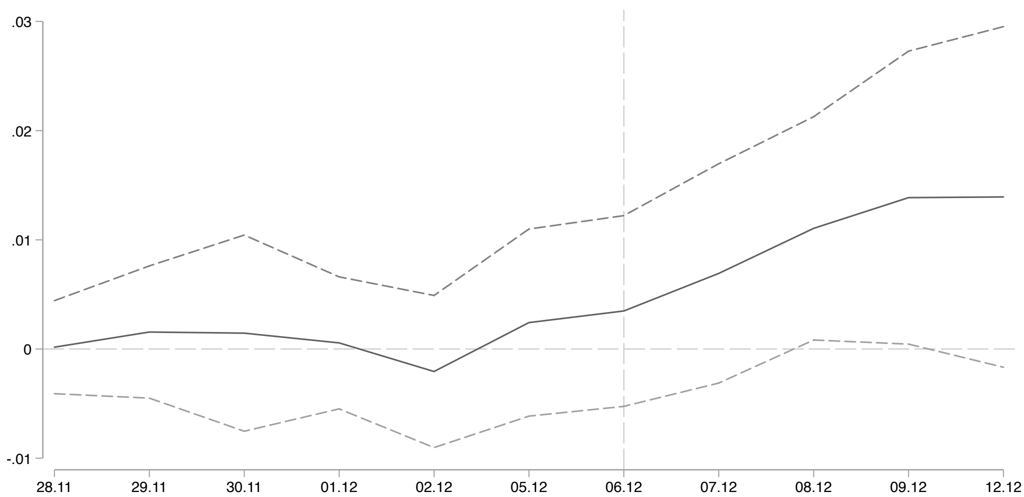


Figure 3
Event Study: Buy-and-Hold Abnormal Returns

Figure 3 shows coefficients from regressing compounded abnormal returns using the market model for risk adjustment on the predicted change in Centrality Δ. The coefficients β_j associated with the cross-sectional regression of returns compounded from $t-5$ to $t = j$ on Δ are plotted together with 95% confidence intervals.



8. Tables

Table 1
Fictional Corporate Network and Potential Effect of Regulation

Table 1 shows values for the four different network measures used in the main analysis before and after the simulated effect of the reform based on the fictional network example illustrated in Figure 2. We use degree centrality, Katz centrality, closeness, and betweenness as defined in Section 3.2. Density is the number of observed links normalized by the total number of all possible links in a given year.

	Before				After			
	Degree	Katz	Betweeness	Closeness	Degree	Katz	Betweeness	Closeness
Bank A	5.00	1.65	13.00	0.86	3.00	1.35	11.00	0.62
Bank B	4.00	1.54	8.50	0.79	3.00	1.35	11.00	0.62
Comp A	2.00	1.32	0.00	0.64	1.00	1.14	0.00	0.43
Comp B	1.00	1.15	0.00	0.50	1.00	1.14	0.00	0.43
Comp C	2.00	1.29	1.50	0.62	2.00	1.26	12.00	0.60
Comp D	2.00	1.28	1.00	0.60	2.00	1.26	12.00	0.60
Comp F	1.00	1.16	0.00	0.52	1.00	1.14	0.00	0.43
Comp G	1.00	1.16	0.00	0.52	1.00	1.14	0.00	0.43
Density	0.31				0.25			

Table 2
Predicted and Actual Changes in Network Centrality

Table 2 shows results from testing the predictive power of Δ, the predicted change in the board network induced by the reform. Coefficients are estimated by regressing the instrument (Δ multiplied by a post-reform dummy) on each of the different network measures. Each regression includes firm and year fixed-effects. Standard errors, clustered at the firm level, are displayed in parentheses. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

	Centrality	Degree	Katz	Betweenness	Closeness
	(1)	(2)	(3)	(4)	(5)
$\Delta \times \mathbb{1}(t > \text{Dec. } 2011)$	0.238^{***}	0.241^{***}	0.535^{***}	0.134^{**}	0.034
	(0.039)	(0.043)	(0.049)	(0.067)	(0.023)
Observations	1,514	1,514	1,514	1,514	1,514
R^2	0.875	0.885	0.903	0.751	0.798
Firm FE	X	X	X	X	X
Time FE	X	X	X	X	X

Table 3
Baseline

Table 3 shows estimated coefficients from a regression of cumulative abnormal returns on the predicted change in network centrality. Cumulative abnormal returns are calculated over a one-day window surrounding the announcement date. Daily abnormal returns are either raw (obtained by subtracting the risk-free rate) or risk-adjusted, using either the market model (column 2) or the Fama French three-factor model (column 3). The vector of control variables includes size, defined as log(total assets), and ROA, defined as net income divided by lagged total assets. Each regression includes industry-fixed effects, following the Fama-French 17-industry classification. Standard errors, clustered at the firm level, are displayed in parentheses. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

Risk Adjustment:	Raw	Market Model	Fama-French
	(1)	(2)	(3)
ΔCentrality	0.899**	0.903**	0.911**
	(0.404)	(0.408)	(0.415)
Observations	260	260	260
R^2	0.144	0.144	0.141
Industry FE	X	X	X
Controls	X	X	X

Table 4
Robustness

Table 4 shows coefficients from a regression of cumulative abnormal returns on the predicted change in network centrality. Cumulative abnormal returns are calculated over a three-day window surrounding the announcement date, except in columns 2 and 3, where we use a 5- and 7-day window, respectively. Abnormal returns are risk-adjusted using the market model. The vector of control variables includes size, defined as log(total assets), and ROA, defined as net income divided by lagged total assets. Column 8 is estimated without any controls, while column 9 additionally includes log of market capitalization and Tobin's Q. Column 4 - 7 shows results of regressing cumulative abnormal returns on predicted changes in four centrality measures: Katz centrality (column 4), Betweenness Centrality (column 5), Degree Centrality (column 6), Closeness Centrality (column 7). Each regression includes industry-fixed effects, following the Fama-French 17-industry classification. Standard errors, clustered at the firm level, are displayed in parentheses. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔCentrality	0.903**	1.018**	1.193**					1.237***	0.898**
	(0.408)	(0.473)	(0.547)					(0.420)	(0.443)
ΔKatz				1.139***					
				(0.385)					
ΔBetweenness					0.173				
					(0.413)				
ΔDegree						0.739*			
						(0.428)			
ΔCloseness							0.798***		
							(0.293)		
Observations	260	260	260	260	260	260	260	260	254
R^2	0.144	0.147	0.147	0.150	0.134	0.141	0.144	0.118	0.167
Industry FE	X	X	X	X	X	X	X	X	X
Window	-1,+1	-2,+2	-3,+3	-1,+1	-1,+1	-1,+1	-1,+1	-1,+1	-1,+1
Controls	X	X	X	X	X	X	X	None	All

Table 5
Information Transmission

Table 5 shows coefficients from a regression of cumulative abnormal returns on the predicted change in network centrality. Cumulative abnormal returns are calculated over a three-day window surrounding the announcement date and are risk-adjusted using the market model. Firms are sorted according to three variables: IVOL (columns 1 and 2), residual analysts' coverage (columns 3 and 4), and standard deviation of earnings forecasts (columns 5 and 6). Firms belong to the "Low" or "High" subsample if each measure is below or above the sample median. Idiosyncratic volatility (IVOL) is estimated by regressing, for each firm, daily excess stock return on the daily equity premium over the 12 months that predate the announcement and computing the standard deviation of the residuals. Residual analysts' coverage is the residual of a regression of the logarithm of 1 plus the number of analysts covering the firm in the previous calendar year on log market capitalization and its squared value. Standard deviation of forecasts is the standard deviation of analysts' net income forecasts in the previous calender year normalized by total assets. The vector of control variables includes size, defined as log(total assets), and ROA, defined as net income divided by lagged total assets. Each regression includes industry-fixed effects, following the Fama-French 17-industry classification. Standard errors, clustered at the firm level, are displayed in parentheses. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

Sorting by:	IVOL		Residual Analysts' Coverage		St. Dev. Forecast	
	Low	High	Low	High	Low	High
ΔCentrality	0.682*	1.494**	1.236**	0.732	0.846	2.161**
	(0.387)	(0.638)	(0.567)	(0.603)	(0.598)	(0.912)
Observations	129	131	127	127	62	62
R^2	0.252	0.230	0.127	0.198	0.287	0.356
Industry FE	X	X	X	X	X	X
Controls	X	X	X	X	X	X

Table 6
Network Complementarities — Input-Ouput Network

Table 6 shows coefficients from a regression of cumulative abnormal returns on the predicted change in network centrality. Cumulative abnormal returns are calculated over a three-day window surrounding the announcement date and are risk-adjusted using the market model. Firms are sorted according to their centrality in the unweighted input-output network (columns 1 and 2) or weighted input-output network (columns 3 and 4). Firms belong to the "Low" or "High" subsample if each measure is below or above the sample median. The vector of control variables includes size, defined as log(total assets), and ROA, defined as net income divided by lagged total assets. Each regression includes industry-fixed effects, following the Fama-French 17-industry classification. Standard errors, clustered at the firm level, are displayed in parentheses. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

Sorting by:	Unweighted IO Network		Weighted IO Network	
	Low	High	Low	High
ΔCentrality	0.122	1.660***	1.041**	1.772**
	(0.529)	(0.508)	(0.466)	(0.884)
Observations	154	106	130	130
R^2	0.103	0.265	0.396	0.270
Industry FE	X	X	X	X
Controls	X	X	X	X

Table 7
Network Complementarities — Ownership Network

Table 5 shows coefficients from a regression of cumulative abnormal returns on the predicted change in network centrality. Cumulative abnormal returns are calculated over a three-day window surrounding the announcement date and are risk-adjusted using the market model. Firms are sorted according to their centrality in the weighted (column 1 and 2) or unweighted cross-ownership network, where two firms are connected if the ownership exceed 1% (column 3 and 4) or 2% (column 5 and 6). Firms belong to the "Low" or "High" subsample if each measure is below or above the sample median. The vector of control variables includes size, defined as log(total assets), and ROA, defined as net income divided by lagged total assets. Each regression includes industry-fixed effects, following the Fama-French 17-industry classification. Standard errors, clustered at the firm level, are displayed in parentheses. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

Sorting by:	Weighted Own. Network		Unweighted Own. Network (1%)		Unweighted Own. Network (2%)	
	Low	High	Low	High	Low	High
ΔCentrality	1.432**	0.553	1.443***	0.753	1.749***	0.580
	(0.561)	(0.466)	(0.509)	(0.457)	(0.426)	(0.409)
Observations	130	130	130	130	130	130
R^2	0.314	0.072	0.174	0.172	0.192	0.162
Industry FE	X	X	X	X	X	X
Controls	X	X	X	X	X	X

Table 8
Profitability and Growth Opportunities

Table 8 shows coefficients from a regression of cumulative abnormal returns on the predicted change in network centrality. Cumulative abnormal returns are calculated over a three-day window surrounding the announcement date and are risk-adjusted using the market model. Firms are sorted according to three variables: ROA (columns 1 and 2), sales growth (columns 3 and 4), and Tobin's Q (columns 5 and 6). Firms belong to the "Low" or "High" sample sample if each measure is below or above the median. ROA is defined as net income divided by lagged total assets. Sales growth is defined as the growth rate of firm revenues. Tobin's Q is defined as total assets plus market value of equity minus common value of equity all divided by total assets. The vector of control variables includes size, defined as log(total assets), and ROA, defined as return divided by lagged total assets. Each regression includes industry-fixed effects, following the Fama-French 17-industry classification. Standard errors, clustered at the firm level, are displayed in parentheses. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

Sorting by:	ROA		Sales Growth		Tobin's Q	
	Low	High	Low	High	Low	High
ΔCentrality	1.396***	-0.136	1.902**	-1.660	1.365**	-0.013
	(0.511)	(0.393)	(0.824)	(1.650)	(0.587)	(0.422)
Observations	130	130	102	102	127	127
R^2	0.212	0.107	0.178	0.222	0.259	0.103
Industry FE	X	X	X	X	X	X
Controls	X	X	X	X	X	X

Table 9
Directors' Compensation

Table 9 shows regressions testing the effect of centrality on total compensation. Coefficients are estimated from a regression of log(total compensation) on centrality, where centrality is instrumented by the predicted change in the network multiplied by the post-reform dummy. Data on compensation is hand-collected from mandatory filings and annual financial reports. In columns 1 through 3 the unit of observation is a director-year, whereas network centrality is derived from the firm-level network. Column 1 uses data on all board members, column 2 includes only high-ranked directors (CEO, President and Vice-President), and column 3 includes the remaining directors. Standard errors are twoway-clustered at the firm and director level and displayed in parentheses. Column 4-6 repeats the analysis at the firm-level, where the dependent variable is the average of log(total compensation) and standard errors are clustered at the firm level. ***, **, and * indicate statistically different from zero at the 1%, 5%, and 10% level of significance, respectively.

Unit of Observation:	Director			Firm		
Directors:	All	High Rank	Low Rank	All	High Rank	Low Rank
Centrality	0.120**	0.176	0.109**	0.333**	0.321**	0.408***
	(0.049)	(0.133)	(0.046)	(0.148)	(0.159)	(0.156)
Observations	12,622	3,175	9,287	1,323	1,312	1,320
R^2	0.000	-0.009	0.004	-0.118	-0.012	-0.140
F-Stat	47.160	31.899	46.195	25.336	25.615	25.344
Director-Firm FE	X	X	X			
Firm FE				X	X	X
Year FE	X	X	X	X	X	X

A. Definition of Centrality Measures

The board data represents a bi-partite (firm - director) graph $\mathcal{G}$ with corresponding adjacency matrix B. We obtain the firm network $\mathcal{F}$ and director network $\mathcal{D}$ as the unweighted graphs from the respective one-mode projections of B ($B'B$ and BB').

Degree centrality is formally defined as:

$$d_i = \sum_{j \neq i} a_{ij} \tag{5}$$

Katz Centrality is defined as:

$$k_i = \alpha \sum_{j} a_{ij} k_j + \beta \tag{6}$$

The first term is exactly the definition of "Eigenvector centrality" while the second term is the constant centrality assigned to any vertex. The parameter α governs the contribution of each term to the overall centrality; i.e. for $\alpha = 0$ each firm would have the same centrality β. Throughout our analysis we chose $\alpha = 0.05$, but results are similar for different α. Technically, there is an upper limit on α for K to converge. With respect to this bound we choose a fairly conservative value that ensure consistency and convergence across time.

Closeness centrality is defined, following Newman (2018), as the harmonic mean distance between firms:

$$c_i = \frac{1}{n-1} \sum_{j \neq i} \frac{1}{d_{ij}}, \tag{7}$$

where d_{ij} This definition has two convenient properties: firstly, for unconnected firms $d_{ij} = \infty$ and hence the corresponding term in the sum is zero and simply drops out. Secondly, firms that are close to firm i are naturally given more weight reflecting that once a firm is far away in the network it matters less how far away it is exactly.

Betweenness centrality is defined as:

$$b_i = \sum_{s,t} n^i_{s,t}. \tag{8}$$

B. Data Collection

Data on board members and compensation are hand-collected from mandatory annual filings with the Italian Companies and Exchange Commission (CONSOB), the Italian stock exchange (Borsa Italiana) and firms' annual reports. Data on board members (names and role) and firm names are reported bi-annually and are available from CONSOB. Reports were first cleaned and name spelling harmonized across reporting years. Company names have been hand-matched to Compustat and Datastream firm-identifiers to obtain data on daily stock returns and annual firm-level data. For any inconsistencies we cross-referenced the hand-collected board composition and financial data from Compustat with data from annual reports to ensure proper matching.

Data on compensation of all board members (executives and directors) was hand-collected from mandatory annual *Relazioni sulla Remunerazione* filed with the Italian stock exchange. These filings are only available starting in 2011. For the remaining years we hand-collected compensation data from annual reports. While coverage starting in 2011 is universal for all listed companies, there are a few companies where we were unable to recover annual reports or compensation information for 2009 or 2010.

The contents of the reports are similar to DEF 14A filings of US companies. They contain data on fixed compensation (*compensi fissi*), bonus payments (*bonus*), non-monetary benefits (*benefici non-monetari*) and other compensation (*altri compensi*). Reporting is not consistent across firms and differences in categorization were harmonized so that differently reported compensation components were assigned to one of the broader categories above.

Stock and option grants are recorded separately. We collected (if available) the number of stocks or options, grant date, grant date share price, and, specifically for option grants, the strike price and expiration date. We calculate the value of the option grants using the

Black-Scholes formula, following the methodology and conventions used by Execucomp in order to estimate option values. Unless otherwise reported we assume the strike price to equal the grant date stock price. As a risk-free rate we use the interest rates paid on a 7-year German government bond.

We estimates the stock variance using 60-month return data. If the price series are shorter than 12 months, we use the sample average standard error. We obtain estimates for the dividend yield by averaging dividend yields over a three-year period. Both variance and dividend yield are winsorized at the 5% level.

To calculate the time to expiration, we assume the options are granted on 1st July if the grant date is not reported. We follow Execucomp's convention and use 70% of the option term calculated from grant-date and term data given that executives rarely wait until the expiration date to exercise their options. For the companies who do not provide any information on neither grant and expiration dates we assume the time to expiration to be 7 years.

C. Variable Definition

Table A10
Variable Definition

Variable	Definition	Source
Total Assets	Total Assets (*at*)	Compustat Global
ROA	Income Before Extraordinary Items (*ib*) divided by lagged total Assets (*at*); all 2010	Compustat Global
Market Value of Equity	Stock price multiplied by Common Shares Outstanding both at end-of-fiscal-year month; all 2010	Compustat Global & Datastream
Tobin's Q	Total Assets (*at*) plus Market Value of Equity minus Common Value of Equity (*ceq*) all divided by Total Assets; all 2010	Compustat Global & Datastream
Sales Growth	Log growth rate of Sales (*sale*); all 2010	Compustat Global
IVOL	Residual standard deviation of regression of daily excess stock return on the equity premium over the from December 2010 to November 2011	Compustat Global
Residual Analyst's Coverage	Residual of regression of logarithm of 1 plus the number of analysts covering the firm in 2010 on the logarithm of total market capitalization and its squared value	IBES
Standard Deviation of Earnings Forecasts	Standard deviation of last analysts' consensus net income forecast preceding the end of the firm fiscal year 2010 divided by total assets	IBES
Total Compensation	Fixed compensation (*compensi fissi*) + bonus payments (*bonus*) + non-monetary benefits (*benefici non-monetari*) + other compensation (*altri compensi*) + value of stock and option grants	Borsa Italiana

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