Boardroom Centrality and Firm Performance: Evidence from Private Firms

Mansoor Afzali and Jukka Kettunen

Abstract

We study the link between boardroom centrality and operating performance in private firms. We argue that the centrality-performance relationship is stronger for private firms whose increased connectedness is likely to provide certification benefits, decrease transaction costs by reducing information asymmetry, and improve access to critical resources. Using a sample of Finnish and Swedish private firms, we find that private firms with more central boards have better performance, growth, and efficiency than private firms with less central boards. Moreover, in a sample of private and public firms, we find that private firms with greater eigenvector centrality outperform size-matched public firms. Subsample analyses further show that networks are crucial for young firms. This is consistent with the view that better-connected directors provide firms with informational resources when they need them the most. Overall, our findings show that boardroom interlocks are positively associated with immediate economic benefits to private firms.

Keywords:

Boardroom centrality, social networks, firm performance, firm growth, firm efficiency, private firms, public firms

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1. Introduction

Boardroom centrality is the establishment of networks through directorship interlocks, and it plays a crucial role in the exchange of information and resources (Javakhadze, Ferris, and French, 2016). Despite this role, the studies on firm performance do not examine the role of boardroom centrality in private firms. The closest ones focus on entrepreneur's social and collaborator networks (for a review, see Stam, Arzlanian, and Elfring, 2014). However, such studies primarily rely on cross-sectional surveys and small samples and do not provide a unanimous prediction on whether the association of boardroom centrality and performance among private firms should be positive or negative. Therefore, this study aims to test the performance implications of boardroom centrality in private firms.

Besides its novelty, two other reasons make this question particularly interesting to study in the private-firm setting. First, results on the association of boardroom centrality and firm performance are mixed even among public firms (e.g., Ferris, Jagannathan, and Pritchard, 2003; Fich and Shivdasani, 2006; Cashman, Gillan, and Jun, 2012; Horton, Millo, and Serafeim, 2012; Larcker, So, and Wang, 2013; Hauser, 2018). Moreover, the literature has shown that private firms differ from public firms in various ways including their investment policies (Caballero, Engel, and Haltiwanger, 1995; R. W. Cooper and Haltiwanger, 2006; Asker, Farre-Mensa, and Ljungqvist, 2011), financial constraints (Beck, Demirgüç-Kunt, and Maksimovic, 2005; Hope, Thomas, and Vyas, 2011), capital structure decisions (Brav, 2009), types of dividend smoothing (Michaely and Roberts, 2012), use of corporate jets (Edgerton, 2012), CEO compensation-performance sensitivity (Gao and Li, 2015), and the responses to economic uncertainty (Afzali, Colak, and Fu, 2021). Furthermore, Gao and He (2019) show that private and public firms differ in their board composition. Such differences can be particularly relevant to the association between boardroom centrality and firm performance.

The extant literature provides many explanations as to why private and public firms may differ in their board composition. Board composition can be seen as a rational response to the needs, uncertainty, and changing conditions of the operating environment (Harris and Raviv, 2008; Linck, Netter, and Yang, 2008). For instance, compared to public firms, access to finance can constitute a such need and a critical growth constraint for private firms (Beck and Demirguc-Kunt, 2006). According to the resource dependence theory (Pfeffer and Salancik, 1978), managers cope with uncertainty and inter-organizational dependence by attempting to reduce others' power over them and if possible, gain power over the other. One option to achieve this is to engage in inter-firm collaboration e.g., through board interlocks especially if the inter-organizational dependence is high (Pfeffer and Salancik, 1978; Finkelstein, 1997).

However, the performance implications of boardroom centrality appear ambiguous in prior literature. For example, Cashman et al. (2012) argue that it can have either a positive or negative effect on performance, depending on the context and the sample. In particular, the research that focuses on the centrality-performance relationship in public firms finds both negative and positive implications. On the one hand, directors with multiple directorships can be seen as too "busy" and therefore negatively affect firm performance (Fich and Shivdasani, 2006; Hauser, 2018). On the other hand, such directors can provide firms with critical channels of information and resource exchange that positively influences firm performance (Horton, Millo, and Serafeim, 2012; Larcker, So, and Wang, 2013).

In private firms, additions to boards are likely to be related to attaining critical resources and coping with growth constraints, which can facilitate different collaborations and partnerships that positively affect performance (BarNir and Smith, 2002; Wynarczyk and Watson,

2005). For example, Javakhadze et al. (2016) find that such collaborations not only contribute to stricter contract enforcement and more efficient decision-making but also to improving access to capital that thereby reduces transaction costs. Hence, we argue that greater boardroom centrality in private firms is likely to have substantial benefits with respect to organizational legitimacy, transaction costs, and sustainable value creation. For instance, since private firms are more opaque (Ball and Shivakumar, 2005; Burgstahler, Hail, and Leuz, 2006) and have more stringent loan contract terms compared to public firms (Ackert, Huang, and Ramírez, 2007), appointing well-connected directors to their boards can increase their credibility. Moreover, if boardroom centrality is seen as a valuable and rare resource, it can help improve access to critical resources, build sustainable competitive advantage, and support long-term value creation (Barney, 1991). Therefore, we hypothesize that boardroom centrality is likely to be positively associated with the performance of private firms. Consistent with the resource-dependence view, we further argue that since private firms have greater information needs, boardroom centrality can be more important to them than to public firms.

To empirically test these hypotheses, we construct a boardroom network using directorship interlocks in small- and medium-sized private enterprises that operate in Finland and Sweden.[1] The foundation for choosing this sample rests on the comprehensive mandatory public disclosures in the Nordic region. Nordic countries require private firms to file financial statements and information on board members and executives in the national trade registers that are publicly accessible. Such data are difficult to obtain from the US, where private firms are not subject to public disclosure. In Finland and Sweden, the relatively high taxation, tax-driven financial reporting of private firms, low threshold for statutory audits, and low ratio of the gray economy to GDP mitigate the concerns that central boards would systematically and materially inflate or deflate their reported performance. Overall, our sample provides an extensive mapping of information routes through board interlocks and high-quality disclosures of firm performance. This information enables us to reduce data inaccuracies and helps us in correctly estimating the centrality-performance relation in private firms.

We use the Bureau van Dijk's Orbis database to get director-level as well as accounting information for our sample. Orbis provides data on boards with unique identification numbers for each director, appointment, resignation, and validity date as well as an indicator of whether the director is current or previous. We use this information to construct a boardroom network comprised of 107,022 unique directors belonging to 34,019 unique Finnish and Swedish firms. For network construction, we include both public and private firms. Following studies on the network theory of social capital (Lin 1999), we use four distinct but related measures of boardroom centrality. We calculate the degree, closeness, and eigenvector centrality in boardrooms as well as their aggregate dyadic constraint that Horton et al. (2012) refer to as the "brokerage position".

Using these measures, we find that well-connected firms have significantly higher future performance than less-connected ones. Specifically, well-connected firms have higher one-year-ahead changes in their returns on assets and returns on equity as well as growth in sales

[1] Granular and high-quality Nordic data is previously used to study firm performance and board structure (Eisenberg, Sundgren, and Wells, 1998), dividend-based earnings management (Kasanen, Kinnunen, and Niskanen, 1996), and determinants of foreign currency denominated debt (Keloharju and Niskanen, 2001). The replication of such studies in different institutional settings suggests that results obtained from using Nordic data are largely generalizable. For instance, the negative association between board size and firm performance documented by Eisenberg et al. (1998) is also reported in the U.S. by Yermack (1996). Similarly, Daniel, Denis, and Naveen (2008) report similar patterns of dividend-based earnings management in the U.S. as documented by Kasanen et al. (1996).

and assets. These associations hold after controlling for the influence of industry, year, size, age, sales growth, tangibility, financial slack, and capital expenditure. To assess the effect of networks on performance efficiency, we use two tests. In the first test, we look at the one-year-ahead financial slack (ratio of cash and cash equivalents scaled by total assets). We find that better networking boards hoard less cash as compared to worse networking firms. Our second test uses the one-year-ahead changes in sales per employee as a measure of productivity. We find that firms with well-connected boards have better employee productivity than firms with less-connected boards. Consistent with our prediction, we also find some evidence that private firms with greater eigenvector centrality have better one-year-ahead returns on assets and sales growth than size-matched public firms.

A potential limitation of our study is the assumption that formal networks such as directorship interlocks are the primary channels of information and resource exchange. In practice, managers can also have connections that are informal and not related to their profession. Although our network measures might not capture the total breadth of a director's network, there are several factors that mitigate these concerns. Specifically, the informal and formal networks are positively correlated (Hwang and Kim, 2009) as informal connections to other organizations complement formal ones because they can be used strategically to manage resource dependence (Westphal, Boivie, and Chng, 2006). Furthermore, the directors holding the most formal connections (i.e., board seats) can be too busy to efficiently manage a firm, which might result in weaker profitability (Fich and Shivdasani, 2006; Hauser, 2018). Therefore, our network measures are most likely to under, not overestimate the boardroom centrality-performance relationship.

Our findings can also have several alternative causal explanations. For instance, research has shown that directors are attracted to and are more likely to accept positions on better-connected boards (Masulis and Mobbs, 2014). Similarly, directors can prefer sitting on boards that are performing well. In these cases, our findings may simply reflect a match between quality directors and, as Larcker et al. (2013) refer to them, "prestigious firms". To mitigate these endogeneity concerns, we perform three tests.

First, we test the positive centrality-performance relationship in a subsample of firms that have the same degree of centrality in the current and the previous year. Since there are no changes in their direct networks, any increase in informational networks can potentially be exogenous to these firms. We continue to find a positive centrality-performance relationship. This finding suggests that increases in future performance can be attributed to the level of connectedness of the current board and mitigates concerns that the firm's prestige can lead to better connections. Second, we look at determinants of boardroom networks and find no evidence of past performance inducing a change in our network measures. In our third specification, we study a unique sample of firms that initiate a directorship interlock and compare them to a set of firms that remain isolated for the entire sample period. We find that newly-interlocked firms outperform those that never form an interlock during the sample period. This further implies that firms benefit from having an extended boardroom network and illustrates that the positive centrality-performance relationship is not likely to be due to endogenous matching.

Our study makes two distinct contributions. First, we study the relationship between boardroom centrality and the performance and efficiency of private firms – a research setting never studied before. The other studies in this line of literature primarily focus on the centrality-performance relationship in public firms. For instance, Horton et al. (2012) examine listed firms in the UK and find that boardroom centrality is positively associated with stock

returns and accounting performance. Larcker et al. (2013) replicate these findings in the US and further show that better-connected firms receive more positive analyst forecast errors than worse-connected firms. Our study adds to this line of research by showing that private firms with well-connected boards outperform those with less-connected boards. We also find that well-connected private firms hoard less cash. Javakhadze and Rajkovic (2019) find similar evidence for public firms from 39 countries.

Second, we compare the dynamics of boardroom networks in private and public firms and find some evidence that private firms benefit more from network centrality than public firms. Other studies have found several differences between private and public firms. For instance, Brav (2009) studies the lending behaviors of private and public firms and finds that private firms almost exclusively rely on private debt financing and avoid external financing. Gao and Li (2015) compare the compensation packages of CEOs in private and public firms. Their results show that compared to similar private firms, CEOs in public firms are paid 30 percent more. Furthermore, the CEO compensation-performance sensitivity is greater in public firms than in private firms. More recently, Afzali et al. (2021) study the behavior of private and public firms during economic uncertainty. They find that while private firms engage in cheating on taxes, public firms pay more bribes to mitigate economic uncertainty. Our findings extend the literature on public and private firm differences by indicating that the boardroom centrality-performance link is more important to private firms than to public firms.

The remainder of the paper is organized as follows: Section 2 presents a literature review. In Section 3, we describe the data and give sample statistics on boardroom networks. We discuss our results and robustness tests in Section 4. Section 5 provides alternative explanations and additional analyses. Section 6 concludes.

2. Related literature and hypotheses development

Recent studies that have explored the role of social networks constitute a relatively new research avenue in corporate finance and financial accounting literature. Information is disseminated in the network of directors and executives, and it produces power and economic rents to those who can access and exploit it. The classical agency theory (Jensen and Meckling, 1976) provides hypotheses for studying whether principals or agents benefit from the information disseminated in the network. Accordingly, earlier applications of social networks to corporate financing focus on managerial entrenchment and the monitoring of executives (Horton, Millo, and Serafeim, 2012; El-Khatib, Fogel, and Jandik, 2015).

A larger and more recent strand of literature examines how board interlocks can bring shareholders various economic benefits, such as lowering the tax burden (Brown, 2011; Brown and Drake, 2014), increasing innovation (Su, Xiao, and Yu, 2019), increasing access to financing and investment (Intintoli, Kahle, and Zhao, 2018), and improving credit ratings (Benson, Iyer, Kemper, and Zhao, 2018). Most of these studies use data on public firms from North America. Fewer studies have combined social networks with performance which according to Drucker (1954) is the ultimate test of the validity of business models.[2]

[2] A related stream of literature also focuses on individual networks and their significance for cost of capital (Engelberg, Gao, and Parsons, 2012), access to finance (Javakhadze, Ferris, and French, 2016), corporate risk-taking (Ferris, Javakhadze, and Rajkovic, 2017), and insider trading (Afzali and Martikainen, 2021).

2.1 Boardroom centrality and firm performance

Boardroom centrality can have either a positive or negative effect on performance depending on the context and sample (Cashman, Gillan, and Jun, 2012). Well-connected, but busy boards are negatively associated with performance according to studies focusing on large firms (Fich and Shivdasani, 2006; Hauser, 2018). However, for boards to be classified as "busy" at least half of their independent directors should serve on three or more boards. According to Ferris et al. (2003) busy boards are mostly associated with large listed firms which is supported by approximately half of the multiple directorships being observed in Forbes 500 firms. They find that for firms in Compustat with total assets in excess of $100 million, only 6 percent of the directors that are "busy" hold three or more board seats. In the S&P 500 firms, the negative association between board busyness and performance has been attributed to inefficient monitoring (Fich and Shivdasani, 2006).

By contrast, the association of boardroom centrality and firm performance is positive in a broader sample that also includes non-S&P 500 firms. For instance, Horton et al. (2012) study a panel of over 4,000 UK firms and find that on average, connected boards have better future stock returns and returns on assets. Similarly, studying a sample of publicly traded firms in the US, Larcker et al. (2013) find a positive relation between boardroom centrality and firm performance that is represented by characteristic-adjusted returns, growth in returns on assets, and positive analyst forecast errors. These findings on the relationship between boardroom centrality and firm performance are both polarized and sample-dependent. The combination of the lack of research on boardroom centrality in private firms, contradictory findings related to network centrality, and the significant differences in board structures between small private and large listed firms (Linck, Netter, and Yang, 2008) constitute the main reasons for revisiting the relationship between boardroom centrality and performance in the private firm setting.

2.2 Board structure in private and public firms and hypothesis development

The board structures of private and public firms are substantially different (Gao and He, 2019). Generally, the board structure is determined by balancing between the costs and benefits of monitoring and advising: monitoring limits entrenchment; while advising assists with the development, strategy, and growth of the firm (Linck, Netter, and Yang, 2008). The demand for monitoring as a determinant of board structure is typically studied with the agency theory (Li, 1994; Bathala and Rao, 1995; Boone, Casares Field, Karpoff, and Raheja, 2007). Private firms have greater external governance needs (i.e., higher agency costs) and therefore have a higher proportion of outside directors on the board than public firms (Gao and He, 2019).

The importance of board networks is illustrated by the multitude of examples that demonstrate their potential in improving private firms' access to critical resources. Such examples typically include access to financing (Beck and Demirguc-Kunt, 2006), credibility (Certo, 2003), and means of collaboration (Barney, 1991). To improve access to critical resources, firms can enter into formal or informal interfirm collaborations; the likelihood of which increases the higher the interdependence of the firms. According to the resource dependence theory, managers cope with such interorganizational dependence and environmental uncertainty by attempting to gain a competitive advantage over their peers (Pfeffer and Salancik, 1978; Finkelstein, 1997). Hence, the board structure can be seen as a rational response to the changing conditions of the external environment (Linck, Netter, and Yang, 2008).

Director appointments are not exogenous of firm operations but are reflections of shocks that change the optimal number of directors (Harris and Raviv, 2008). Consequently, the board's size and composition are systematically related to the needs of the firms' environment and those that do not adjust to such needs have suboptimal performance (Pfeffer and Salancik, 1978). In comparison to pub-

lic firms, private firms face more serious growth constraints related to critical resources such as financing, management expertise, and qualified personnel. For instance, their access to external financing is more limited (Beck and Demirguc-Kunt, 2006) as illustrated by creditors requiring more collateral and covenants while charging higher prices on debt for private firms (Ackert, Huang, and Ramírez, 2007). Additions to the board can improve access to financing. For instance, in startup firms, increasing boardroom centrality by appointing independent directors can serve as an important mechanism to balance power between the entrepreneur and investors thereby improving access to financing (Broughman, 2013). Similarly, in a country with bank-dominated financial markets, a bank officer may be one of the early additions to the board for a growing private firm (Eisenberg, Sundgren, and Wells, 1998).

Prestigious well-connected boards can increase the credibility and organizational legitimacy of small, opaque firms. Building on the signaling theory, Certo (2003) finds that prestigious boards can improve IPO performance. To increase credibility, firms can seek to appoint outside CEOs to their boards (i.e., certification hypothesis) typically from firms that are geographically close and have similar financial and investment policies, and comparable governance (Fahlenbrach, Low, and Stulz, 2010). According to the certification hypothesis, the successful recruitment of such a CEO to the board demonstrates to external parties that a business leader who is considerate of their reputation thinks highly enough of the firm to join its board. Moreover, the certification effect might exist even though the director may be too busy to actively contribute to the board: the appointment might still serve as a quality stamp for the firm that thus, secures its current value (Fahlenbrach, Low, and Stulz, 2010).

Collectively these studies indicate that boardroom centrality is likely to be beneficial to firms, especially during the early life cycle of a growth-oriented firm. Specifically, it can improve access to critical resources such as advisory, certification, legitimacy, strategic partnerships, and financing that can positively contribute to firm performance. Consistent with these arguments, we formulate the following hypothesis with respect to boardroom centrality:

H1a: Boardroom centrality is positively associated with the performance and growth of private firms.

Boardroom centrality assists firms in operating more efficiently with fewer financial buffers and slack resources. Specifically, boardroom centrality relaxes the critical growth constraint of private firms, that is, the access to external financing that in turn reduces the sensitivity of investment to internal financing (Javakhadze, Ferris, and French, 2016). Similarly, Chuluun et al. (2017) find that for well-connected firms, innovation activities are associated with lower uncertainty and spreads for bond yields. Trust from the financiers allows firms to operate with a lower cash buffer and less slack resources. Slack represents potentially usable resources that can be directed to the achievement of organizational goals (George, 2005). Organizations use both financial and social slack to improve performance (F. Daniel, Lohrke, Fornaciari, and Turner, 2004). Financial slack is a predictor of risk-taking (Wiseman and Bromiley, 1996). For example, the dot-com bubble (1999-2002) and the financial crisis of 2008 decreased risk-taking as represented by investment in growth options and innovation. Subsequently, these crises were accompanied by the accumulation of cash which demonstrates that especially cash and cash equivalents are used to finance growth options and R&D (Jalilvand and Kim, 2013). Collectively, these studies indicate that better access to external financing allows firms to seize growth opportunities and operate more efficiently with less of a financial buffer and less slack resources.

Boardroom centrality can also positively influence employee productivity. This influence can happen for example through advising, facilitating IT-investments, and improving access to higher quality workers. Specifically, skilled labor is one of the most important resources in building a competitive advantage (Barney, 1991) and hence a potential growth constraint for private firms. According to the

upper echelon theory (Hambrick and Mason, 1984), organizational outcomes are to a large extent influenced by the characteristics of the top management. This influence means that success in attracting high-quality directors can have a positive effect on the efficiency of the whole organization. Building on the upper echelon theory, Chuang et al. (2009) find that top managers' age and education are associated with the extent of IT adoption. This association supports the idea of nominating directors that can identify the IT investments needed to maintain market position and to improve efficiency. Among private firms, those growing and becoming international may be able to offer more attractive jobs and hence attract more skilled labor (Gomez–Mejia, 1988).

Collectively, boardroom centrality improves access to financing that lowers the need to hoard more cash, and enhances access to high-quality workers that potentially result in higher employee productivity. Consequently, we formulate the following hypothesis:

H1b: Boardroom centrality is positively associated with lower financial slack (greater efficiency) and higher employee productivity in private firms.

The literature shows that private firms differ from public firms with respect to their board composition (Gao and He, 2019). For example, private firms hire more outside directors than public firms. Hiring well-connected directors can assist both private and public firms in reducing information asymmetries and giving the firm a competitive advantage over its competitors. Public firms, however, have several channels of information and resource exchange such as publicly available performance metrics and analyst forecasts on competitors as well as access to a wealth of resources through institutional shareholders. In contrast, private firms are more opaque (Ball and Shivakumar, 2005; Burgstahler, Hail, and Leuz, 2006) and potentially have fewer channels of information and resource exchange. Therefore, we argue that the positive centrality-performance relationship can be more relevant to private than to public firms. We formulate our second hypothesis as follows:

H2: In comparison to similar public firms, boardroom centrality is associated with higher performance and growth in private firms.

3. Research design

3.1 Construction and description of boardroom network

We obtain our sample from the Bureau van Dijk's Orbis database which is a data resource for private and public firm firms. Orbis contains financial and corporate structure information for over 300 million firms worldwide.[3] It provides data on boards with unique identification numbers for each director, appointment, resignation, and validity dates, as well as an indicator of whether the director is current or previous.[4] We use this information to construct a network comprised of 107,022 unique directors belonging to 34,019 unique Finnish and Swedish private and public firms.[5] Our final sample for network construction, which includes both public and private firms,

[3] Studies have used Orbis to assess the relationship between ownership and bank versus public debt (Lin et al. 2013), public tax return disclosure (Hoopes, Robinson, and Slemrod, 2018), firm listing status (Bartholdy and Olson, 2017), and measurement of the value of intangibles (Clausen and Hirth, 2016), among others.

[4] Orbis has a higher frequency of updating data than the databases used in other studies. The updating frequency for Finland is twice a month and weekly for Sweden. Orbis also follows all registered firms in Finland without restrictions on sector or area as well as directly verifying the accuracy of information provided from the firm itself every year provided that it has more than nine employees.

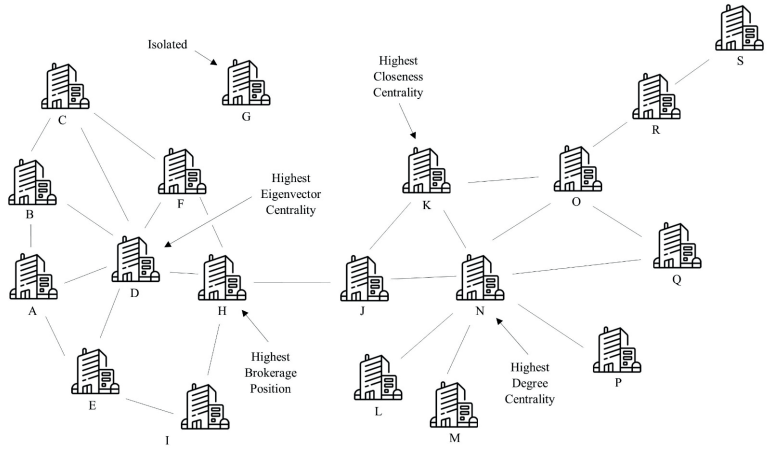
[5] We initially start with a sample of Nordic firms but drop Danish firms due to unavailable financial data, Norwegian firms due to unavailable board-level data, and Icelandic firms due to fewer observations.

is comprised of 515,927 director-year observations for the period from 2012 to 2017.[6] Using this data, we construct an undirected and unweighted network for each board based on their shared directorates.

3.2 Network measures

We use four measures of social networks based on the literature.[7] Following Horton et al. (2012) and Larcker et al. (2013), we use closeness centrality, brokerage position, degree centrality, and eigenvector centrality to measure board connectedness for each year. These measures are defined as follows and illustrated in Figure 1.

Figure 1
Measures of boardroom centrality.
This figure presents a sample network of firms established through director interlocks. Firm G is isolated since it does not have any direct connections to other firms in the network. Firm N has the highest degree centrality since it has a direct connection to seven other firms. Firm K has the highest closeness centrality since the distance between it and all other firms in the network is the shortest. Firm H has the highest brokerage position because it connects two unconnected subnetworks within the entire network. Firm D has the highest eigenvector centrality since it not only has multiple direct connections to other firms but the firms that it is connected to are also relatively well-connected. Further descriptions of Closeness Centrality, Brokerage Position, Degree Centrality, and Eigenvector Centrality are detailed in subsection 3.2.



Degree Centrality measures a firm's total number of direct connections. Presumably, a firm is more central if it possesses relatively more channels of information exchange. Degree centrality illustrates the number of first-degree linkages to outside boards. Mathematically, it can be expressed by Eq. (1).

$$Degree\ Centrality_i = \sum_{k \neq i} u(i,k) \tag{1}$$

where $u(i,k)$ represents a direct link between firm i and k. In Figure 1, firm *N* has the highest degree of centrality since it has a direct link with seven other firms.

[6] Excluding public firms from the sample would make our network incomplete and therefore affect the performance-centrality relationship.

[7] The main reasoning behind using four different measures is not only to reduce measurement error but to also provide robust results across different measures that capture different aspects of network centrality. While the four measures are similar, their effect on the outcome variable may be different. For instance, Goergen, Renneboog, and Zhao (2019) show that a director's degree and eigenvector centrality have statistically significant effects on insider trading but closeness centrality is statistically insignificant.

Closeness Centrality measures the centrality of a firm by capturing how close it is to all other firms in the network. Since closeness centrality captures the centrality of a firm within the entire network, it considers both direct and indirect ties with other firms. A higher measure of closeness indicates that a firm is better networked and more central. Firms with a higher closeness measure can access information quickly and more accurately than firms with a lower closeness measure. Mathematically, the measure can be expressed by Eq. (2).

$$Closeness\ Centrality_i = \frac{N-1}{\sum_{k \neq i} v(i,k)} \tag{2}$$

where $v(i,k)$ represents the distance between firms i and k. Hence, *Closeness Centrality* is the inverse of the mean distance between firm i and any other firm reachable from it in a network of N firms. In Figure 1, firm *K* has the highest closeness centrality since it is more central to several subnetworks within the entire network.

Brokerage Position, on the other hand, captures the degree of relative informational advantage a firm has over other firms in the network. It measures the extent to which a firm can serve as a broker of information. It is based on the concept of structural holes (Burt, 1995, 2005). It gives firms the informational advantage to serve as a link between disconnected or loosely connected networks, thus giving them wider and faster access to information and more control over its diffusion. Mathematically, it can be expressed by Eq. (3) and (4).

$$Brokerage\ Position_i = 1 - \text{AGGREGATE DC}_i \tag{3}$$

$$\text{DC} = \left(P_{ik} + \sum_q P_{iq} P_{qk} \right)^2, \qquad \text{for } p \neq i,k \tag{4}$$

where the aggregate dyadic constant (Eq. (4)) measures the redundancy of a firm's ties. The proportion of firm i's relations invested in firm k is denoted by p_{ik}; the sum of products in the parenthesis is the extent of firm i's relations invested in firm q's relations that in turn are invested in firm k. The total sum of the terms in the parenthesis is the proportion of firm i's relations that are directly or indirectly invested in its connections with firm k. In Figure 1, firm H connects two large subnetworks within the entire network and therefore has the highest brokerage position.

These measures primarily capture the strength of direct connections or the centrality of the nodes in a network. However, another important measure of centrality is eigenvector centrality that not only considers the direct connections but also the strength of indirect connections (See Goergen et al. (2019) for a more detailed description of eigenvector centrality). A firm with connections to other firms which are in turn more connected has potentially more channels of

$$Eigenvector\ Centrality_i = \frac{1}{\lambda} \sum_{k=1}^{1} A_{ik}\, C_E(i) \tag{5}$$

communication. Mathematically, eigenvector centrality is described by Eq. (5).

where λ is a constant, A_{ik} represents the adjacent vertices between firm *i* and its *k* neighbors, and $C_E(i)$ measures the sum of all adjacent vertices' eigenvector centrality scores. In Figure 1, firm *D* has the highest eigenvector centrality since it is connected to several other firms that are

in turn relatively well connected.

To calculate degree centrality, closeness centrality, and brokerage position, we use Pajek – a software program that uses methods in social network analysis – and techniques illustrated in Nooy, Mrvar, and Batagelj (2018). To calculate eigenvector centrality, we use Gephi which is an open-source software used for the calculation and visualization of networks. Similar to Larcker et al. (2013), we create quintile ranks for each of these four network measures every year to mitigate the effects of outliers and make regression results easier to interpret. Larcker et al. (2013) also argue that the first principal component obtained from a principal component analysis of the four network measures that they use captures nearly 70 percent of the variation in the four measures. Since the loadings are similar for all four measures, they create an equal-weighted average quintile rank for each of the four centrality measures. We conduct a similar principal component analysis using our four centrality measures and find that the first principal component explains 78.2 percent of the variation. We also find that the loadings on the four measures are similar across all four measures of centrality. We, therefore, create a fifth measure, *Network Centrality*, that is based on the quintile rank of the first principal component score of the four network measures. For brevity, we use *Network Centrality* in our robustness checks and cross-sectional tests only.

3.3 Firm performance measures

The literature has used several different measures of firm performance. However, data limitations related to private firms present some challenges to using all these measures. For instance, while a market-based measure of performance such as Tobin's Q can be used for public firms, private firms do not have publicly available market values to calculate this measure. Our analysis is therefore limited to the operating performance of the firm. We follow Horton et al. (2012) and Larcker et al. (2013) and use the one-year-ahead changes in the return on assets (denoted as *Return on Assets*) and the return on equity (denoted as *Return on Equity*) as our main proxies for firm performance. Additionally, we follow Campello (2006) and Cooper et al. (2008) and use growth in sales and growth in assets as alternative measures of the performance and growth of firms.

3.4 Financial slack and employee productivity measures

To assess the relationship between boardroom centrality and firm efficiency, we use two distinct measures. First, we argue that hoarding large amounts of cash presents an agency problem since such cash could be used for investments. It can also signal that a firm has fewer growth opportunities and is therefore accumulating cash and cash equivalents. Moreover, George (2005) shows that discretionary financial slack (measured through cash and cash equivalents) has important implications for the performance of private firms. We, therefore, measure financial slack as the ratio of cash and cash equivalents to total assets. To measure employee productivity, we follow Cronqvist et al. (2009) and use a variation of sales per employee.

3.5 Baseline empirical model

To assess the centrality-performance relationship (*H1a*), we estimate the model in Eq. (6):

$$
\begin{aligned}
Performance_{t+1} &= \alpha + \beta_1 Q(Centrality)_t + \beta_2 Firm\ Size_t + \beta_3 Firm\ Age_t + \beta_4 Sales\ Growth_t \\
&+ \beta_5 Leverage_t + \beta_6 Cash\ Ratio_t + \beta_7 Tangibility\ Ratio_t + \beta_8 Capital\ Expenditure_t \\
&+ \beta_x Industry\ FE + \beta_y Country\ FE + \beta_z Year\ FE + \varepsilon
\end{aligned} \tag{6}
$$

where *Performance* is the one-year-ahead changes in *Return on Assets* and *Return on Equity*, and the one-year-ahead growth in sales and assets. For *H1b*, we use *Cash Ratio* and *ΔEmployee Productivity* as our dependent variables. *Q(Centrality)* is the individual quintile rank for *Degree Centrality*, *Closeness Centrality*, *Brokerage Position*, and *Eigenvector Centrality*, respectively. Based on prior research, we add a number of control variables to isolate their effect on firm performance. Specifically, we follow Larcker et al. (2013) and Horton et al. (2012) and add *Firm Size*, *Firm Age*, *Sales Growth*, *Leverage, Cash Ratio*, *Tangibility Ratio*, and *Capital Expenditure*.[8] All variables are defined in the Appendix in Table A1. We also add industry, county, and year fixed effects. We define industries based on the Fama and French (1997) 48-industry group by using four-digit standard industry classification codes. Unlike Larcker et al. (2013), we do not add contemporaneous performance metrics to control for momentum in performance. Specifically, there are two potential concerns in adding these metrics to our model. First, as pointed out by Larcker et al. (2013, footnote 21), adding them can introduce survivorship bias to the analyses. In our sample, requiring the presence of these metrics results in sample attrition of 3,423 firm-years. Second, as pointed out by Horton et al. (2012), adding them may result in endogeneity. Therefore, we remove the variable from our model; but our inferences are not affected if we include it. We cluster the standard errors at the firm level and report robust *t*-statistics for all our results.

To test our second hypothesis (*H2*), we estimate the model in Eq. (7):

$$
\begin{aligned}
Performance_{t+1} &= \alpha + \beta_1 Private_t + \beta_2 Centrality_t + \beta_3 Private_t \times Centrality_t + \beta_n Controls_t \\
&+ \beta_x Industry\ FE + \beta_y Country\ FE + \beta_z Year\ FE + \varepsilon
\end{aligned} \tag{7}
$$

where *Performance* is either the one-year-ahead changes in *Return on Assets* or the one-year-ahead growth in sales. *Private* is an indicator variable that equals one when the firm is private with limited liability, and zero when the firm is registered as public with limited liability. *Centrality* is the separate raw values of *Degree Centrality*, *Closeness Centrality*, *Brokerage Position*, and *Eigenvector Centrality*. Given that public firms are large and are significantly more likely to fall in the fifth quintile of centrality, in this specification, we use raw measures to exploit greater variation within the network centrality measures.[9] *Controls* is the same set of firm-level control variables as in Eq. (6). Our main variable of interest is the interaction term between *Private* and *Centrality*. If networks matter more for private firms than public firms, then we predict a posi-

[8] Larcker et al. (2013) add research and development (R&D) intensity as a control variable. Since this variable is almost non-existent for private firms and is largely unavailable for public firms in our sample, we add the capital expenditure ratio instead. Larcker et al. (2013) also do not use cash and tangibility ratios as additional variables. However, as Aktas, Croci, and Petmezas (2015) show that both cash and tangibility ratio can have important implications for firm performance. Therefore, we add them as control variables.

[9] In our sample, nearly half of all firm-year observations from public firms are in the top quintile, making it difficult to compare all public and private firms using quintiles of centrality scores.

tive and statistically significant coefficient on the interaction term. To help reduce the effect of firm size in this specification, we first use propensity score matching with one-to-one matching without replacement to find a size-matched private firm for every public firm.

4. Empirical analysis

4.1 Descriptive statistics

After estimating the raw network measures for each firm, we merge them with financial data from Orbis.[10] Panel A of Table 1 provides the summary statistics for our sample composition by year. Every year, we have between 18,692–20,455 firms. However, since we use the one-year-ahead values of the dependent variable in all our specifications, we lose one year of data. The final sample size is 97,562 firm-year observations after removing all public and private firms with missing accounting variables. For the sample on employee productivity, the information on employees is not available for all firms which reduces our sample size to 75,781 firm years. On average, there are 2.53 (246,807 ÷ 97,562 ≈ 2.53) directors per firm. The number of directors increases over time. This is consistent with the board's tasks becoming more complex and thus requiring more board expertise and members (Linck, Netter, and Yang, 2008). [11] Panel A also provides information on the number and percentage of isolated firms. We find that around 69 percent of our final sample are isolated firms.[12] Connected firms, on average, are connected to at least two other firms, as indicated by the average *Degree Centrality* score. The averages for *Closeness Centrality*, *Brokerage Position*, and *Eigenvector Centrality* of the connected firms are 0.130, 0.137, and 0.269, respectively.

Panel B of Table 1 provides the pooled descriptive statistics for our final sample.[13] *Firm Size* is a firm's total assets while *Total Sales* is a firm's total operating revenue and both are in millions of euros.[14] Our sample has a range of mostly small and medium-sized firms with a few large firms. The average (median) total assets for sample firms is €15.789 (€3.134) million. [15] The average (median) firm age is 23.814 (20.00) years. The average firm has 65 employees which is determined at the fiscal year-end. The average firm also has approximately 27.9 percent in non-current liabilities compared to total assets. The average (median) cash ratio is 0.124 (0.063) which indicates greater variation in the level of cash hoarding. Around 36.9 percent of a firm's total assets are tangible, and the average firm invests about 4 percent of its assets in capital expenditure. The average (median) firm has 8.5 (1.9) percent sales growth, 5.6 (3.9) percent return on assets, 11.4 (10.6) percent return on equity, 5.2 (1.4) percent growth in assets, and 5.2 (0.5) percent change in employee productivity.

[10] Orbis also provides delisting status, and delisting and initial public offering dates, which we use to classify firms as private or public when they are delisted or go public, respectively. We also exclude all subsidiaries from our sample since their decision-making as well as flow of information and capital is potentially affected by their parent companies.
[11] One potential issue with Orbis' director level data is the non-availability of director termination date for the majority of the directors. In cases where the termination date is not available, we assume the directorship to be active. In robustness checks, we also test whether our results hold if we limit our analyses to network size computed in the last year of the sample. This enables us to reduce the effect of non-availability of archival data in potentially driving our results because Orbis' current data is the most accurate. All our inferences remain unchanged if we use this methodology. Our main results are also valid if we limit our sample to only 2016.
[12] Given this large number, in robustness checks, we estimate our baseline results excluding the isolated firms. We obtain qualitatively similar results.
[13] We winsorize all continuous variables at the 1st and 99th percentile to reduce the effect of outliers.
[14] We choose euros as our currency when obtaining data from Orbis. To convert the currencies, Orbis allows to choose the fiscal year end date conversion rate. Hence, all our variables for the Swedish sample are converted to euros as of fiscal year end for the firms.
[15] To limit the number of micro firms, we place a limit of €1 million in total assets for all sample years. Our results are also robust to strictly following the definition of small and medium-sized enterprises (SMEs) provided by the European Commission and available at https://ec.europa.eu/growth/smes/sme-definition_en.. However, we include some micro and large firms in our final sample.

Table 1
Sample statistics.
Panel A provides a description of the sample and average (median) centrality scores for connected firms across the sample years. Isolated firms are those that are not connected to any other firms. Descriptions of *Closeness Centrality, Brokerage Position, Degree Centrality*, and *Eigenvector Centrality* are detailed in subsection 3.2. Panel B provides the pooled descriptive statistics. *Firm Size* is a firm's total assets while *Total Sales* is a firm's total operating revenue in millions of euros. *Number of Employees* is the total number of employees as of the end of the fiscal year. *Firm Age* is in years and is calculated as the difference between the fiscal year and the incorporation year of the firm. *Sales Growth* equals a firm's change in total operating revenue multiplied by 100. Leverage is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. *Return on Assets* is the firm's net income scaled by total assets multiplied by 100. *Return on Equity* is the firm's net income scaled by total shareholder funds multiplied by 100. *Assets Growth* equals a firm's change in total assets multiplied by 100. *ΔEmployee Productivity* is the change in a firm's total operating revenue divided by the number of employees multiplied by 100. Panel C contains pooled sample averages (medians) by firm size quintiles, and panel D presents variable averages by industry. We winsorize all continuous variables at the 1st and 99th percentile to reduce the effect of outliers.

PANEL A: SAMPLE AVERAGES BY YEAR

	2012	2013	2014	2015	2016	Total / Sample Mean
Number of firms	18,692	19,008	19,504	19,903	20,455	97,562
Number of directors	41,775	44,684	48,208	53,568	58,572	246,807
Isolated firms	13,594	13,466	13,554	13,376	13,375	67,365
Percent isolated firms	0.727	0.708	0.695	0.672	0.654	0.690
Degree Centrality	2.070	2.148	2.249	2.319	2.436	2.259
	(1.000)	(1.000)	(1.000)	(1.000)	(2.000)	(1.000)
Closeness Centrality	0.047	0.068	0.104	0.148	0.245	0.130
	(0.007)	(0.008)	(0.010)	(0.009)	(0.009)	(0.009)
Brokerage Position	0.109	0.122	0.132	0.147	0.163	0.137
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Eigenvector Centrality	0.232	0.251	0.291	0.274	0.287	0.269
	(0.065)	(0.081)	(0.095)	(0.105)	(0.109)	(0.093)

PANEL B: POOLED DESCRIPTIVE STATISTICS

	Observations	Mean	Std. Dev.	P25	Median	P75
Degree Centrality	97,562	0.699	1.533	0.000	0.000	1.000
Closeness Centrality	97,562	0.040	0.172	0.000	0.000	0.006
Brokerage Position	97,562	0.042	0.148	0.000	0.000	0.000
Eigenvector Centrality	97,562	0.083	0.284	0.000	0.000	0.054
Firm Size (in millions of €)	97,562	15.789	53.309	1.828	3.134	7.665
Total Sales (in millions of €)	97,562	13.823	42.782	0.797	3.049	8.688
Number of Employees	86,419	65.230	520.833	3.000	13.000	35.000
Firm Age	97,562	23.814	17.000	12.000	20.000	29.000
Sales Growth	97,562	8.473	45.968	-6.747	1.852	12.641
Leverage	97,562	0.279	0.279	0.028	0.192	0.460
Cash Ratio	97,562	0.124	0.154	0.014	0.063	0.176
Tangibility Ratio	97,562	0.369	0.336	0.040	0.283	0.666
Capital Expenditure	97,562	0.040	0.086	0.000	0.012	0.055
Return on Assets	97,562	5.615	9.411	0.510	3.880	9.420
Return on Equity	97,562	11.352	35.191	1.650	10.590	23.200
Assets Growth	97,562	5.229	20.429	-5.200	1.392	11.001
ΔEmployee Productivity	76,107	5.166	36.070	-8.942	0.481	11.111

PANEL C: SAMPLE AVERAGES (MEDIANS) BY FIRM SIZE QUINTILES

	1 (Small)	2	3	4	5 (Large)
Degree Centrality	0.307	0.403	0.586	0.829	1.392
	(0.000)	(0.000)	(0.000)	(0.000)	(1.000)
Closeness Centrality	0.015	0.019	0.027	0.045	0.098
	(0.000)	(0.000)	(0.000)	(0.000)	(0.006)
Brokerage Position	0.014	0.019	0.029	0.049	0.103
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Eigenvector Centrality	0.031	0.043	0.064	0.097	0.184
	(0.000)	(0.000)	(0.000)	(0.000)	(0.049)
ln(Firm Size)	1.379	2.039	3.212	6.556	67.585
	(1.383)	(2.017)	(3.147)	(6.115)	(25.852)
ln(Firm Age)	21.945	22.018	22.567	24.228	28.460
	(20.000)	(20.000)	(20.000)	(21.000)	(22.000)
Return on Assets	5.453	6.259	6.248	5.713	4.361
	(4.070)	(4.645)	(4.380)	(3.860)	(2.760)
Sales Growth	5.056	8.013	9.600	9.885	9.831
	(0.109)	(1.689)	(2.584)	(2.422)	(2.249)
Observations	19,616	19,464	19,725	19,811	18,946

PANEL D: SAMPLE AVERAGES BY INDUSTRY

	Obs.	*Degree Centrality*	*Closeness Centrality*	*Brokerage Position*	*Eigenvector Centrality*	*Firm Size*	*Firm Age*	*Return on Assets*
Consumer non-durables	5,547	0.494	0.035	0.031	0.053	8.882	25.371	4.792
Consumer durables	926	0.581	0.036	0.029	0.066	17.276	32.462	5.376
Manufacturing	7,847	0.555	0.028	0.030	0.063	13.111	28.519	6.411
Oil and gas	78	0.282	0.021	0.011	0.020	3.738	22.218	4.949
Business equipment	2,585	0.551	0.038	0.034	0.056	12.934	20.281	7.158
Telephone and television	283	1.293	0.154	0.126	0.136	61.489	30.343	3.804
Wholesale and retail	19,218	0.417	0.021	0.019	0.040	10.270	26.279	6.793
Healthcare and medical equip.	1,063	0.478	0.045	0.043	0.057	18.030	19.467	8.584
Utilities	1,870	1.464	0.100	0.126	0.156	49.209	27.182	1.569
All other industries	58,145	0.817	0.047	0.051	0.103	17.415	22.177	5.218

Panel C contains the pooled sample averages (medians) by firm size quintiles. The network measures are highly correlated with firm size. Therefore, to mitigate concerns of multi-collinearity, we follow Larcker et al. (2013) and calculate quintile ranks of network measures based on the quintile ranks of firm size measured as the natural logarithm of total assets. The difference between the fifth and fourth quintile average total assets indicates that there are fewer large firms in the sample. The averages across all variables are similar which indicates uniformity in the sample by size quintiles. It appears that large firms introduce skewness in the sample; however, their exclusion does not influence our results. Panel D provides mean values for selected variables across different industries. Based on firm size and degree centrality scores, firms in the utilities, telephone, and television industries are the largest and have the highest number of direct connections.

4.2 Boardroom centrality and firm performance: Tests of H1a

Table 2 presents our main results from regressing the firm-specific, one-year-ahead changes in *Return on Assets* and *Return on Equity* on the quintile ranks of four measures of boardroom centrality based on the regression specification in Eq. (6). In the first four columns, when we use one-year-ahead changes in *Return on Assets* as the dependent variable, the coefficients for our four measures of network centrality are positive and statistically significant at the 1 percent level. In the next four columns, when we use the one-year-ahead changes in *Return on Equity* as the dependent variable, we once again find that our four measures of boardroom centrality are positively associated with firm performance. This is in line with our predictions in the first hypothesis (*H1a*) that private firms with more central boards outperform those with less central boards. The results are also economically meaningful. For instance, from the coefficients for *Eigenvector Centrality* in columns (4) and (8), we can infer that firms in the highest (fifth) quintile experience on average an increase in *Return on Assets* and *Return on Equity* per year that is 0.236 percent [(5 – 1) × 0.059] and 0.920 percent [(5 – 1) × 0.230] more than firms in the lowest (first) quintile, respectively.

The coefficients for *Firm Size* are negative and statistically significant which indicates that larger firms have relatively lower performance than smaller firms. The coefficients for *Firm Age* are positive potentially because private firms are more likely to perform better as they grow older. The coefficients for *Leverage* are positive and statistically significant in all the models. This is consistent with Larcker (2013) and the concept that levered firms have performance metrics to meet and have better growth. Profitability is also negatively correlated with cash holdings (*Cash Ratio*) and tangible assets (*Tangibility Ratio*). In contrast, greater levels of capital expenditure are positively associated with firm performance. This is indicated by the positive and statistically significant coefficients for *Capital Expenditure*.

Table 2
Boardroom centrality and firm performance.
This table contains results from regressing firm-specific one-year-ahead changes in *Return on Assets* and *Return on Equity* on the quintile ranks of four measures of boardroom centrality. *Return on Assets* is the firm's net income scaled by total assets multiplied by 100. *Return on Equity* is the firm's net income scaled by stockholder's equity multiplied by 100. *Δ* indicates the one-year-ahead minus current year percentage change in the variable. Descriptions of *Degree Centrality*, *Closeness Centrality*, *Brokerage Position*, and *Eigenvector Centrality* are detailed in subsection 3.2. Quintile ranks are formed using the centrality measures from director information every year, where higher (lower) values are assigned a rank 5 (1). *Firm Size* equals the natural logarithm of total assets. *Firm Age* equals the natural logarithm of the firm's age. *Sales Growth* equals the firm's change in total operating revenue multiplied by 100. *Leverage* is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of the firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. Industry, country, and year fixed effects are included throughout. The *t*-statistics based on firm clustered robust standard errors are shown in parentheses. Levels of significance are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

DEPENDENT VARIABLE:	**ONE-YEAR-AHEAD** *ΔRETURN ON ASSETS*				**ONE-YEAR-AHEAD** *ΔRETURN ON EQUITY*			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Q(*Degree Centrality*)	0.058***				0.223***			
	(4.12)				(3.36)			
Q(*Closeness Centrality*)		0.059***				0.234***		
		(4.23)				(3.60)		
Q(*Brokerage Position*)			0.056***				0.296***	
			(2.96)				(3.20)	
Q(*Eigenvector Centrality*)				0.059***				0.230***
				(4.28)				(3.58)
Firm Size	-0.303***	-0.304***	-0.303***	-0.304***	-0.784***	-0.789***	-0.802***	-0.789***
	(-17.55)	(-17.59)	(-17.33)	(-17.60)	(-10.19)	(-10.22)	(-10.33)	(-10.23)
Firm Age	0.124***	0.124***	0.121***	0.125***	0.784***	0.785***	0.782***	0.785***
	(4.04)	(4.04)	(3.93)	(4.04)	(5.27)	(5.27)	(5.26)	(5.28)
Sales Growth	-0.017***	-0.017***	-0.017***	-0.017***	-0.053***	-0.053***	-0.053***	-0.053***
	(-16.96)	(-16.96)	(-16.95)	(-16.96)	(-15.07)	(-15.07)	(-15.06)	(-15.07)
Leverage	1.968***	1.968***	1.971***	1.968***	3.348***	3.348***	3.356***	3.348***
	(15.99)	(15.99)	(16.02)	(15.99)	(5.10)	(5.09)	(5.11)	(5.10)
Cash Ratio	-4.463***	-4.462***	-4.478***	-4.461***	-9.026***	-9.022***	-9.074***	-9.020***
	(-21.09)	(-21.09)	(-21.17)	(-21.08)	(-13.56)	(-13.56)	(-13.64)	(-13.55)
Tangibility Ratio	-0.774***	-0.773***	-0.781***	-0.773***	-0.278	-0.275	-0.298	-0.275
	(-7.88)	(-7.88)	(-7.96)	(-7.88)	(-0.59)	(-0.59)	(-0.63)	(-0.58)
Capital Expenditure	2.140***	2.140***	2.123***	2.141***	4.835***	4.840***	4.804***	4.842***
	(5.83)	(5.83)	(5.78)	(5.83)	(2.93)	(2.93)	(2.91)	(2.94)
Intercept	1.760***	1.763***	1.808***	1.765***	0.520	0.527	0.710	0.536
	(8.97)	(8.99)	(9.22)	(9.00)	(0.59)	(0.59)	(0.80)	(0.60)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.018	0.018	0.018	0.018	0.008	0.008	0.008	0.008
Observations	97,536	97,536	97,536	97,536	97,536	97,536	97,536	97,536

Table 3 presents the alternative test results for hypothesis (H1a) by replacing changes in Return on Assets and Return on Equity with growth in sales and assets as the dependent variables. The coefficients for the network measures remain positive and statistically significant in all these specifications. These regression results demonstrate that better networking firms outperform worse networking firms in terms of growth in sales and assets and are consistent with the concept that extended boardroom networks, ceteris paribus, provide a net gain to firms. The findings are also in line with our predictions in hypothesis H1b and the findings of Horton et al. (2012) and Larcker et al. (2013) who show that the connectedness and boardroom centrality positively influence the future performance and growth of the UK and US public firms, respectively.

4.3 Boardroom centrality and firm performance: Test of H1b

In the second part of our first hypothesis, *H1b*, we argue that private firms with more central boards hoard less cash and have greater employee productivity. To test this argument, we estimate the regression model in Eq. (6) and use the one-year-ahead cash ratio (*Cash Ratio*) and the one-year-ahead changes in sales per employee (Δ*Employee Productivity*) as the dependent variables. The results in Table 4 indicate that private firms with more central boards hoard less cash and cash equivalents, as indicated by the negative and statistically significant coefficients for all four measures of boardroom centrality. In columns (5)-(8), we find that well-connected private firms also have better employee productivity. These sets of results further support our predictions in *H1b* and show that greater network centrality provides private firms with more channels of information and resource exchange that can lead to more growth opportunities by decreasing the need to hoard cash and by improving employee productivity.

4.4 Boardroom centrality and firm performance in private and public firms: Test of H2

We next test *H2*. Specifically, we estimate the regression model in Eq. (7) and apply propensity score matching to control for the variation in sizes across public and private firms. To implement propensity score matching, we require a one-to-one match, without replacement, and a caliper of 0.05 to obtain a size-matched private firm for each public firm. This process results in a matched sample of 4,846 firm-year observations (2,423 public and 2,423 private firm-years). The reasoning behind matching on firm size is to allow for the correct estimation of the effect of network size on performance. Including all private firms in our model leads to an incorrect comparison of the small, medium, and large private firms pooled together against primarily large public firms.

Table 5 provides the results of this test. We use the one-year-ahead changes in *Return on Assets* and the one-year-ahead *Sales Growth* as proxies for the performance and growth of firms, respectively.[16] Our main variable of interest is the interaction term (*Private* × *Centrality*). We find that when we use the one-year-ahead changes in *Return on Assets* as our dependent variable and *Degree Centrality*, *Closeness Centrality*, and *Brokerage Position* as our main measures of network centrality in the first three columns, the interaction terms are negative and statistically insignificant. In column (4), when we use *Eigenvector Centrality*, the interaction term turns positive and is statistically significant at the 10 percent level. This significance indicates that while other forms of network centrality do not contribute to greater performance in private firms compared to public ones, having more influential connections (as captured by eigenvector centrality) is positively associated with better performance in private than in public firms. The

[16] The results are similar if we use *Return on Equity* and *Assets Growth*; therefore, for brevity, we only report the results based on *Return on Assets* and *Sales Growth*.

Table 3
Boardroom centrality and firm performance: Alternative measures of firm performance and growth.
This table contains results from regressing firm-specific one-year-ahead percentage *Sales Growth* and *Assets Growth* on the quintile ranks of four measures of boardroom centrality. *Sales Growth* equals the firm's change in total operating revenue multiplied by 100. *Assets Growth* equals the firm's change in total assets multiplied by 100. Descriptions of *Degree Centrality*, *Closeness Centrality*, *Brokerage Position*, and *Eigenvector Centrality* are detailed in subsection 3.2. Quintile ranks are formed using the centrality measures from director information every year, where higher (lower) values are assigned a rank 5 (1). *Firm Size* equals the natural logarithm of total assets. *Firm Age* equals the natural logarithm of the firm's age. *Leverage* is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of the firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. Industry, country, and year fixed effects are included throughout. The *t*-statistics based on firm cluster robust standard errors are shown in parentheses. Levels of significance are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

DEPENDENT VARIABLE:	**ONE-YEAR-AHEAD** *SALES GROWTH*				**ONE-YEAR-AHEAD** *ASSETS GROWTH*			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Q(*Degree Centrality*)	0.345***				0.175***			
	(3.64)				(3.87)			
Q(*Closeness Centrality*)		0.351***				0.171***		
		(3.75)				(3.87)		
Q(*Brokerage Position*)			0.366***				0.166***	
			(2.86)				(2.76)	
Q(*Eigenvector Centrality*)				0.356***				0.168***
				(3.83)				(3.80)
Firm Size	-0.399***	-0.404***	-0.407***	-0.407***	-0.475***	-0.476***	-0.475***	-0.476***
	(-3.28)	(-3.32)	(-3.32)	(-3.35)	(-8.10)	(-8.11)	(-8.04)	(-8.11)
Firm Age	-2.827***	-2.827***	-2.842***	-2.825***	-1.503***	-1.504***	-1.513***	-1.504***
	(-12.82)	(-12.83)	(-12.89)	(-12.81)	(-13.85)	(-13.86)	(-13.94)	(-13.86)
Sales Growth	-0.103***	-0.103***	-0.103***	-0.103***	0.006***	0.006***	0.006***	0.006***
	(-17.14)	(-17.14)	(-17.12)	(-17.14)	(3.40)	(3.40)	(3.42)	(3.40)
Leverage	2.943***	2.942***	2.958***	2.942***	-4.602***	-4.602***	-4.594***	-4.601***
	(3.29)	(3.29)	(3.31)	(3.29)	(-12.95)	(-12.95)	(-12.92)	(-12.94)
Cash Ratio	-11.534***	-11.532***	-11.621***	-11.525***	-1.611***	-1.613***	-1.658***	-1.612***
	(-10.28)	(-10.28)	(-10.37)	(-10.27)	(-3.03)	(-3.04)	(-3.13)	(-3.03)
Tangibility Ratio	-10.351***	-10.348***	-10.389***	-10.346***	-2.029***	-2.029***	-2.050***	-2.029***
	(-13.66)	(-13.65)	(-13.73)	(-13.65)	(-6.75)	(-6.75)	(-6.83)	(-6.75)
Capital Expenditure	40.836***	40.837***	40.752***	40.847***	15.907***	15.903***	15.856***	15.903***
	(20.70)	(20.71)	(20.68)	(20.71)	(18.06)	(18.06)	(18.01)	(18.06)
Intercept	17.975***	17.994***	18.263***	18.000***	12.363***	12.377***	12.507***	12.384***
	(13.45)	(13.46)	(13.66)	(13.47)	(19.20)	(19.22)	(19.46)	(19.24)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.027	0.027	0.027	0.027	0.023	0.023	0.023	0.023
Observations	97,536	97,536	97,536	97,536	97,536	97,536	97,536	97,536

Table 4

Boardroom centrality, financial slack, and employee productivity.

This table contains results from regressing firm-specific one-year-ahead *Cash Ratio* and change in *Employee Productivity* on the quintile ranks of four measures of boardroom centrality. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *ΔEmployee Productivity* is the change in the firm's total operating revenue divided by the number of employees multiplied by 100. *Δ* indicates the one-year-ahead minus current year percentage change in the variable. Descriptions of *Closeness Centrality*, *Brokerage Position*, *Degree Centrality*, and *Eigenvector Centrality* are detailed in subsection 3.2. Quintile ranks are formed using the centrality measures from director information every year, where higher (lower) values are assigned a rank 5 (1). *Firm Size* equals the natural logarithm of total assets. *Firm Age* equals the natural logarithm of the firm's age. *Sales Growth* equals the firm's change in total operating revenue multiplied by 100. *Leverage* is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of the firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. Industry, country, and year fixed effects are included throughout. The *t*-statistics based on firm clustered robust standard errors are shown in parentheses. Levels of significance are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

DEPENDENT VARIABLE:	**ONE-YEAR-AHEAD** *CASH RATIO*				**ONE-YEAR-AHEAD** *ΔEMPLOYEE PRODUCTIVITY*			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Q(*Degree Centrality*)	-0.001***				0.255***			
	(-3.08)				(2.87)			
Q(*Closeness Centrality*)		-0.001***				0.248***		
		(-3.08)				(2.85)		
Q(*Brokerage Position*)			-0.001***				0.299**	
			(-2.88)				(2.46)	
Q(*Eigenvector Centrality*)				-0.000***				0.242***
				(-3.01)				(2.80)
Firm Size	-0.003***	-0.003***	-0.003***	-0.003***	-0.685***	-0.686***	-0.689***	-0.686***
	(-16.06)	(-16.04)	(-15.81)	(-16.03)	(-6.30)	(-6.31)	(-6.35)	(-6.30)
Firm Age	-0.000	-0.000	-0.000	-0.000	-1.035***	-1.036***	-1.037***	-1.037***
	(-0.89)	(-0.88)	(-0.84)	(-0.88)	(-5.09)	(-5.10)	(-5.09)	(-5.10)
Sales Growth	-0.000**	-0.000**	-0.000**	-0.000**	-0.125***	-0.125***	-0.125***	-0.125***
	(-2.43)	(-2.43)	(-2.44)	(-2.43)	(-20.24)	(-20.24)	(-20.24)	(-20.24)
Leverage	-0.027***	-0.027***	-0.027***	-0.027***	4.055***	4.056***	4.058***	4.056***
	(-19.89)	(-19.90)	(-19.91)	(-19.90)	(4.70)	(4.70)	(4.70)	(4.70)
Cash Ratio	0.800***	0.800***	0.800***	0.800***	-7.763***	-7.765***	-7.830***	-7.764***
	(226.36)	(226.36)	(226.52)	(226.35)	(-8.09)	(-8.10)	(-8.17)	(-8.10)
Tangibility Ratio	-0.006***	-0.006***	-0.006***	-0.006***	-6.761***	-6.763***	-6.814***	-6.765***
	(-5.30)	(-5.30)	(-5.25)	(-5.30)	(-9.17)	(-9.18)	(-9.28)	(-9.18)
Capital Expenditure	0.004	0.004	0.004	0.004	12.468***	12.464***	12.434***	12.465***
	(1.44)	(1.44)	(1.47)	(1.44)	(6.89)	(6.89)	(6.87)	(6.89)
Intercept	0.054***	0.054***	0.053***	0.054***	15.889***	15.911***	16.042***	15.917***
	(21.61)	(21.60)	(21.47)	(21.59)	(12.52)	(12.54)	(12.65)	(12.54)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.688	0.688	0.688	0.688	0.029	0.029	0.029	0.029
Observations	97,536	97,536	97,536	97,536	75,781	75,781	75,781	75,781

Table 5

Boardroom centrality and firm performance in private versus public firms.

This table contains results from regressing firm-specific one-year-ahead changes in *Return on Assets* and one-year-ahead *Sales Growth* on the four measures of boardroom centrality using a sample of both private and public firms. *Return on Assets* is the firm's net income scaled by total assets multiplied by 100. *Sales Growth* equals the firm's change in total operating revenue multiplied by 100. *Δ* indicates the one-year-ahead minus current year percentage change in the variable. *Private* equals one if the firm is private with limited liability, and zero if the firm is public with limited liability. *Centrality* is one of the four measures of boardroom centrality. Descriptions of *Degree Centrality*, *Closeness Centrality*, *Brokerage Position*, and *Eigenvector Centrality* are detailed in subsection 3.2. *Firm Size* equals the natural logarithm of total assets. *Firm Age* equals the natural logarithm of the firm's age. *Leverage* is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of the firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. Industry, country, and year fixed effects are included throughout. The *t*-statistics based on firm clustered robust standard errors are shown in parentheses. Levels of significance are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

DEPENDENT VARIABLE:	ONE-YEAR-AHEAD *ΔRETURN ON ASSETS*				ONE-YEAR-AHEAD *SALES GROWTH*			
CENTRALITY MEASURE:	DEGREE CENTRALITY	CLOSENESS CENTRALITY	BROKERAGE POSITION	EIGENVECTOR CENTRALITY	DEGREE CENTRALITY	CLOSENESS CENTRALITY	BROKERAGE POSITION	EIGENVECTOR CENTRALITY
	(3)	(1)	(2)	(4)	(5)	(6)	(7)	(8)
Private	-0.176	-0.311	-0.080	-0.390	-3.236	-2.766	-2.775	-2.694
	(-0.43)	(-0.78)	(-0.18)	(-1.65)	(-1.18)	(-1.06)	(-1.07)	(-1.23)
Centrality	0.089	0.145	1.083*	0.040	-0.269	-2.779	-0.311	0.067
	(1.53)	(0.26)	(1.76)	(0.97)	(-0.72)	(-0.93)	(-0.09)	(0.36)
Private × *Centrality*	-0.022	-0.084	-0.409	0.137*	0.475	0.082	5.037	2.146**
	(-0.26)	(-0.10)	(-0.49)	(1.75)	(0.71)	(0.02)	(0.86)	(2.37)
Firm Size	-0.378***	-0.333***	-0.394***	-0.334***	-1.261	-1.141	-1.433**	-1.454**
	(-3.76)	(-3.19)	(-4.12)	(-3.47)	(-1.67)	(-1.62)	(-2.07)	(-2.12)
Firm Age	0.142	0.140	0.138	0.157	-4.440***	-4.496***	-4.437***	-4.276***
	(1.28)	(1.24)	(1.24)	(1.39)	(-3.82)	(-3.96)	(-3.95)	(-3.93)
Sales Growth	-0.013***	-0.013***	-0.013***	-0.013**	-0.021	-0.021	-0.020	-0.019
	(-2.71)	(-2.71)	(-2.71)	(-2.67)	(-0.84)	(-0.85)	(-0.83)	(-0.74)
Leverage	2.267***	2.282***	2.271***	2.275***	5.358	5.295	5.347	5.290
	(4.73)	(4.87)	(4.82)	(4.68)	(1.52)	(1.50)	(1.49)	(1.42)
Cash Ratio	-5.861***	-5.872***	-5.881***	-5.909***	3.568	3.698	3.556	3.718
	(-3.56)	(-3.60)	(-3.58)	(-3.57)	(0.38)	(0.39)	(0.38)	(0.40)
Tangibility Ratio	-1.208*	-1.291*	-1.192	-1.309*	-15.528***	-15.726***	-15.229***	-15.406***
	(-1.68)	(-1.77)	(-1.67)	(-1.86)	(-4.73)	(-5.08)	(-4.85)	(-5.14)
Capital Expenditure	15.222***	15.189***	15.237***	15.202***	60.656***	60.817***	60.661***	60.749***
	(4.43)	(4.41)	(4.42)	(4.47)	(4.44)	(4.45)	(4.44)	(4.25)
Intercept	-1.537	-1.912	-1.400	-1.845	19.148***	17.087**	20.821***	20.802***
	(-1.32)	(-1.50)	(-1.26)	(-1.56)	(2.89)	(2.34)	(3.26)	(3.15)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.024	0.024	0.025	0.025	0.034	0.034	0.034	0.038
Observations	4,846	4,846	4,846	4,846	4,846	4,846	4,846	4,846

results in columns (5)-(8) present a similar case in which the coefficients for the interaction terms in the first three columns are positive but statistically insignificant while the eigenvector centrality for the interaction term between *Private* and *Centrality* is positive and statistically significant at the 5 percent level. We, therefore, find some support for *H2* that networks are of more significance for the performance and growth of private than public firms.

4.5 Robustness checks

In this subsection, we examine the robustness of our results given different specifications. We first repeat our analysis for firms across different age groups and different mixes of capital structures. Firms strive towards optimizing their capital structure. In doing so, they can face different challenges. For instance, firms with lower debt can encounter constraints in acquiring external financing (Beck and Demirguc-Kunt, 2006). Extremely low levels of debt may also be associated with lower investment opportunities. In contrast, highly leveraged firms face agency problems (Fama and French, 1998) and bankruptcy costs (Baxter, 1967; Kim, 1978).

To tackle these challenges, the boardroom networks can play a vital role. Larcker et al. (2013) provide evidence that networks are more important for certain types of firms. Specifically, they show that younger firms and firms in financial distress benefit the most from boardroom networks and have stronger performance-centrality relationships. We provide consistent evidence in Table 6. The table presents the results of regressing the one-year-ahead changes in *Return on Assets* on boardroom centrality measures in samples of young (old) and low (high) leverage firms. The first two columns indicate that younger firms benefit more from the networks. Table 6 also shows that the performance-centrality relationship is stronger when firms have lower leverage.[17] This result is not consistent with Larcker et al. (2013) and can be attributed to the riskiness of private firms with larger debts. In untabulated results, we also find that central firms with negative growth in *Return on Assets* in the current year have better future performance. These results support the concept that firms in need of resources benefit more from boardroom networks.

Despite adding country-level fixed effects throughout, we also test whether our results are driven by country-level omitted explanatory variables by estimating profitability regressions separately for the Finnish and Swedish firms. The results in Table 6 show that our findings are robust at the country level. The effect seems to be slightly more positive for Finnish firms despite the smaller sample size.

Table 7 presents results from additional robustness tests. The first two columns present results with extended windows of performance. The two results indicate that firms with larger networks also outperform firms with fewer networks in the long run.[18] Column (3) presents results with industry-adjusted performance metrics. The coefficient for the quintile rank of our aggregate measure is positive and statistically significant at the 1 percent level which suggests that our results are robust to using alternative industry-adjusted measures of firm performance. In column (4), we apply two-way, firm, and year-clustered standard errors. The two-way clustering accounts for both cross-sectional and time-series dependence in the standard errors (Petersen, 2009). When we correct for both cross-sectional and time-series dependence in the standard errors, our *t*-statistics are lower but statistically significant at the 5 percent level.

[17] To test the statistical significance of these differences in coefficients of *Q(Network Centrality)*, we conduct an F-test. The associated chi-square value indicates that the difference in columns (1) and (2) is statistically significant at the 10 percent level while the difference in column (3) and (4) is statistically significant at the 5 percent level.
[18] In untabulated results, we also run year-by-year regressions and find that our results are statistically significant in three out of five years of our sample.

Table 6

Boardroom centrality and firm performance: Cross-sectional tests

This table contains cross-sectional tests for the centrality-performance relationship shown in Table 2. The dependent variable is one-year-ahead changes in *Return on Assets*. *Return on Assets* is the firm's net income scaled by total assets multiplied by 100. *Δ* indicates the one-year-ahead minus current year percentage change in the variable. *Network Centrality* is the first principal component formed through a principal component analysis of the four centrality measures described in subsection 3.2. Quintile ranks are formed using the first principal component every year, where higher (lower) values are assigned a rank 5 (1). Young (old) firms are defined as those falling in the bottom (top) terciles of firm age in a given year. Low (high) leverage firms are defined as those falling in the bottom (top) terciles of leverage in a given year. *Firm Size* equals the natural logarithm of total assets. *Firm Age* equals the natural logarithm of the firm's age. *Sales Growth* equals the firm's change in total operating revenue multiplied by 100. *Leverage* is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of the firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. Industry, country, and year fixed effects are included throughout. The *t*-statistics based on firm clustered robust standard errors are shown in parentheses. Levels of significance are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

DEPENDENT VARIABLE:	ONE-YEAR-AHEAD *ΔRETURN ON ASSETS*					
	YOUNG	OLD	LOW LEVERAGE	HIGH LEVERAGE	FINLAND	SWEDEN
	(1)	(2)	(3)	(4)	(5)	(6)
Q(*Network Centrality*)	0.066***	0.047**	0.098***	0.031	0.060**	0.055***
	(2.73)	(2.00)	(2.81)	(1.57)	(2.46)	(3.28)
Firm Size	-0.312***	-0.274***	-0.349***	-0.221***	-0.197***	-0.349***
	(-9.21)	(-10.37)	(-7.41)	(-8.80)	(-7.06)	(-16.25)
Firm Age	0.022	0.309***	0.083	0.156***	0.112**	0.128***
	(0.20)	(3.11)	(1.01)	(3.46)	(2.08)	(3.44)
Sales Growth	-0.013***	-0.021***	-0.018***	-0.011***	-0.019***	-0.016***
	(-8.61)	(-10.60)	(-9.69)	(-7.69)	(-10.57)	(-13.72)
Leverage	1.907***	1.967***	-3.652	2.064***	1.704***	2.125***
	(9.02)	(9.26)	(-0.87)	(8.35)	(8.94)	(13.76)
Cash Ratio	-5.002***	-3.969***	-3.873***	-5.389***	-3.977***	-4.634***
	(-12.37)	(-11.69)	(-12.22)	(-8.36)	(-10.00)	(-18.68)
Tangibility Ratio	-1.026***	-0.647***	0.144	-1.082***	-0.491***	-0.952***
	(-5.88)	(-3.80)	(0.50)	(-6.90)	(-3.22)	(-7.57)
Capital Expenditure	2.927***	1.766***	2.553*	1.527***	3.030***	1.901***
	(4.59)	(2.73)	(1.76)	(3.36)	(4.34)	(4.41)
Intercept	2.357***	0.757*	1.523***	1.450***	0.528	2.581***
	(5.66)	(1.72)	(2.64)	(4.79)	(1.41)	(11.11)
Industry Fixed Effects	Yes	Yes	Yes	Yes	No	No
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.017	0.017	0.014	0.013	0.023	0.018
Observations	32,615	31,545	27,842	34,901	24,242	73,294

Table 7
Boardroom centrality and firm performance: Robustness checks
This table contains robustness checks for our baseline model in Table 2. In columns (1) and (2) the dependent variable is two and three years of cumulative change in *Return on Assets*, respectively. In column (3), the dependent variable is industry-adjusted *Return on Assets*. In all other columns, the dependent variable is the one-year-ahead changes in *Return on Assets*, where *Return on Assets* is the firm's net income scaled by total assets multiplied by 100. *Network Centrality* is the first principal component formed through principal component analysis of the four centrality measures described in subsection 3.2. Quintile ranks are formed using the first principal component every year, where higher (lower) values are assigned a rank 5 (1). *Firm Size* equals the natural logarithm of total assets. *Firm Age* equals the natural logarithm of the firm's age. *Sales Growth* equals the firm's change in total operating revenue multiplied by 100. *Leverage* is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of the firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. Industry, country, and year fixed effects are included throughout. In column (3), the clustering is based on both firm and year to account for both cross-sectional and time-series dependence. In all other columns, the *t*-statistics based on firm clustered robust standard errors are shown in parentheses. Levels of significance are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

DEPENDENT VARIABLE:	*CUMULATIVE ΔRETURN ON ASSETS*	*CUMULATIVE ΔRETURN ON ASSETS*	**ONE-YEAR-AHEAD** *ΔRETURN ON ASSETS*	**ONE-YEAR-AHEAD** *ΔRETURN ON ASSETS*	**ONE-YEAR-AHEAD** *ΔRETURN ON ASSETS*	**ONE-YEAR-AHEAD** *ΔRETURN ON ASSETS*	**ONE-YEAR-AHEAD** *ΔRETURN ON ASSETS*
	LONGER WINDOW (TWO YEARS)	**LONGER WINDOW (THREE YEARS)**	**INDUSTRY ADJUSTED PERFORMANCE**	**TWO-WAY CLUSTERS**	**WITHOUT SIZE ADJUSTMENT**	**EXCLUDING ISOLATED FIRMS**	**FIRMS WITH NO CHANGE IN CENTRALITY**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Q(*Network Centrality*)	0.047**	0.076**	0.058***	0.058**	0.057***	0.164***	0.037**
	(2.03)	(2.54)	(4.22)	(2.09)	(4.23)	(2.82)	(2.08)
Firm Size	-0.336***	-0.275***	-0.303***	-0.304***	-0.311***	-0.199***	-0.312***
	(-11.66)	(-7.41)	(-17.55)	(-9.61)	(-17.58)	(-6.80)	(-13.48)
Firm Age	0.165***	0.230***	0.124***	0.124***	0.124***	0.034	0.181***
	(3.11)	(3.40)	(4.03)	(2.86)	(4.02)	(0.64)	(4.46)
Sales Growth	-0.017***	-0.018***	-0.017***	-0.017***	-0.017***	-0.013***	-0.021***
	(-14.72)	(-11.89)	(-16.98)	(-8.78)	(-16.96)	(-7.60)	(-15.32)
Leverage	2.660***	3.206***	1.960***	1.968***	1.968***	1.581***	1.908***
	(14.03)	(13.22)	(15.95)	(19.76)	(15.99)	(7.61)	(12.44)
Cash Ratio	-5.657***	-6.915***	-4.445***	-4.462***	-4.462***	-4.809***	-4.649***
	(-17.78)	(-16.68)	(-21.05)	(-15.64)	(-21.09)	(-10.53)	(-17.35)
Tangibility Ratio	-1.162***	-1.671***	-0.769***	-0.773***	-0.773***	-0.790***	-0.771***
	(-7.19)	(-7.90)	(-7.84)	(-5.48)	(-7.87)	(-4.61)	(-6.28)
Capital Expenditure	2.119***	1.880***	2.126***	2.140***	2.138***	4.258***	2.165***
	(4.50)	(3.30)	(5.80)	(2.67)	(5.82)	(6.17)	(4.91)
Intercept	1.803***	1.367***	1.708***	1.765***	1.825***	0.602	2.040***
	(5.34)	(3.23)	(8.72)	(3.80)	(9.30)	(1.15)	(8.18)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.022	0.026	0.017	0.018	0.018	0.015	0.021
Observations	70,493	48,537	97,536	97,536	97,536	30,176	63,575

Since the correlation between our network measures and firm size are not as high as those reported by Larcker et al. (2013), we repeat our analysis without the size adjustment. The results in column (5) indicate that our findings are robust to the size adjustment. Similarly, the percentage of isolated firms (firms with no connections) is considerably higher in our sample. We test our results after excluding the isolated firms. The results provided in column (6) of Table 7 are consistent with those in Table 2. The coefficient is positive and statistically significant at the 1 percent level. These robustness tests show that our results are in line with the concept that networks help in generating growth and improving profitability.

5. Alternative explanations and additional analyses

We acknowledge that there could be several alternative causal explanations for our results. For instance, profitable firms arguably may attract highly networked individuals (Masulis and Mobbs, 2014). This attraction can in turn increase a firm's overall centrality. Therefore, a case for reverse causality could be made. Larcker et al. (2013) address this issue and provide some causal evidence for boardroom centrality and future firm performance. In line with their work, we also use certain specifications that can mitigate the endogeneity concerns and show why a case for reverse causality is weak. First, we look at the centrality-performance relationship by regressing the one-year-ahead changes in profitability measures on current year quintiles of centrality measures. Second, we rerun our models on a subsample of firms for which there are no changes in a firm's degree centrality from the previous year. The results of these specifications are reported in column (7) of Table 7. Our main findings remain unchanged and signify that the future performance of connected firms is higher even in the sample of firms that have no changes in board connections from the previous year. This result mitigates the concern that board prestige can attract directors since the centrality of boards remains unchanged in our specification. Therefore, improvements in future performance can be attributed to the current connectedness of the firm. Finally, in tabulated results, we assess the determinants of board networks, and we find no evidence that past performance influences future changes in boardroom networks. This result means that the case for reverse causality is weak.

To further demonstrate the importance of board networks as well as their practical implications, we conduct additional analyses on newly interlocked boards. Specifically, we study a unique sample of firms that have no board interlocks in the previous year but establish one in the current year. We compare these firms against a group of firms that never establish an interlock during the entire sample period. The pooled results shown in Table 8 indicate that changes in first-degree linkages positively influence future firm performance. Our results are consistent with the notion that initiating directorship interlocks are associated with immediate economic benefits. However, our results do not mean that non-interlocking firms should initiate an interlock to achieve better performance. As Larcker et al. (2013) point out, firms in reality face financial and nonfinancial constraints in initiating an interlock, and the process may not be easy. Furthermore, our network measures are calculated relative to other firms and since firms almost never have any discretion on how connected other firms are, we cannot estimate the exact economic benefits a firm gets when increasing its board network.

Table 8

Boardroom centrality and firm performance of newly interlocked firms.

This table contains results from regressing firm-specific one-year-ahead changes in *Return on Assets* and *Return on Equity*, and *Sales Growth* and *Assets Growth* on a sample of newly interlocked and isolated firms. *Return on Assets* is the firm's net income scaled by total assets multiplied by 100. *Return on Equity* is the firm's net income scaled by stockholder's equity multiplied by 100. *Δ* indicates the one-year-ahead minus current year percentage change in the variable. *Sales Growth* equals the firm's change in total operating revenue multiplied by 100. *Assets Growth* equals the firm's change in total assets multiplied by 100. *Interlocking* equals one if the firm has any change in its first-degree network links after being previously isolated, and zero if the firm remains isolated for the entire sample period. First-degree links are defined as two firms sharing at least one board director. *Firm Size* equals the natural logarithm of total assets. *Firm Age* equals the natural logarithm of the firm's age. *Leverage* is the firm's non-current liabilities scaled by total assets. *Cash Ratio* is the firm's cash and cash equivalents divided by total assets. *Tangibility Ratio* equals the ratio of the firm's tangible assets scaled by total assets. *Capital Expenditure* is the ratio of the firm's capital expenditure scaled by total assets. Industry, country, and year fixed effects are included throughout. The *t*-statistics based on firm clustered robust standard errors are shown in parentheses. Levels of significance are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

	ONE-YEAR-AHEAD *ΔRETURN ON ASSETS*	**ONE-YEAR-AHEAD** *ΔRETURN ON EQUITY*	**ONE-YEAR-AHEAD** *SALES GROWTH*	**ONE-YEAR-AHEAD** *ASSETS GROWTH*
	(1)	**(2)**	**(3)**	**(4)**
Interlocking	0.438**	1.400	2.145***	2.472**
	(2.03)	(1.48)	(4.29)	(2.51)
Firm Size	-0.372***	-1.024***	-0.295***	-0.290*
	(-15.00)	(-9.99)	(-3.50)	(-1.82)
Firm Age	0.205***	0.943***	-1.584***	-2.154***
	(4.75)	(4.79)	(-10.36)	(-7.33)
Sales Growth	-0.024***	-0.066***	0.009***	-0.129***
	(-14.79)	(-13.01)	(3.47)	(-14.83)
Leverage	2.145***	5.649***	-5.093***	3.037**
	(12.31)	(6.31)	(-10.36)	(2.40)
Cash Ratio	-4.551***	-9.401***	-2.478***	-13.738***
	(-15.92)	(-10.50)	(-3.58)	(-9.65)
Tangibility Ratio	-0.742***	-1.545***	-1.578***	-9.183***
	(-5.47)	(-2.61)	(-3.86)	(-8.64)
Capital Expenditure	2.072***	4.119**	13.494***	34.274***
	(4.23)	(2.10)	(11.96)	(14.63)
Intercept	2.394***	3.543***	10.233***	11.987***
	(8.92)	(3.21)	(11.71)	(7.42)
Industry Fixed Effects	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adjusted R-squared	0.024	0.011	0.024	0.030
Observations	51,229	51,229	51,229	51,229

6. Limitations and conclusion

We acknowledge that there are limitations to our results. To begin with, our centrality measures are subject to several theoretical assumptions on the flow of information. First, we assume that formal boardroom networks represent the only channels of information exchange while in reality, social networks go beyond formal interlocks. Second, the measures are simple and may not necessarily reflect the complex settings in practice. For instance, information exchange might occur through indirect routes as opposed to the shortest path. The second limitation concerns the interpretation of the results and their practical implications. Except for sudden director deaths, board changes are rarely exogenous. Instead, the number of directors will typically change to a new optimum following a shock (Harris and Raviv, 2008). The effects of such shocks may vary by managerial ownership which has a nonlinear relationship with firm performance (Barnhart and Rosenstein, 1998; Morck, Yeung, and Yu, 2000). Hence, the unavailability of the managerial ownership data poses a potential limitation to our results. Nevertheless, our methodology is consistent with the dominant literature that does not control for ownership (e.g. Larcker, So, and Wang, 2013). Further, a firm's centrality measures are relative to the connections of other firms over which it may not have any control. Under these circumstances, the economic benefits that network extension can provide are conditional on the quality of available directors and the costs related to acquiring them. Therefore, our results do not indicate that initiating or increasing board interlocks always results in economic rents. Further, we cannot eliminate the endogeneity concerns even though we provide several specifications to mitigate them.

Boardroom centrality constitutes a nascent stream of literature in corporate finance. Studies linking boardroom centrality and firm performance have previously concentrated on public firms in the common law countries. We contribute to this strand of literature by constructing a boardroom network for private firms – a setting never explored before. We use data from Finland and Sweden to study the influence of network centrality on the future performance and efficiency of firms. We show that private firms, ceteris paribus, earn a net benefit from having an extended boardroom network. Specifically, we show that our network measures are positively correlated with the one-year-ahead growth in return on assets and other performance measures. We also find that firms with central boards have better performance efficiency. These results are robust to a range of sensitivity tests. We also show that private firms with greater eigenvector centrality outperform size-matched public firms. Further analyses also show that private firms benefit from networks when they need informational resources the most. Collectively, our results contribute to the social networks literature and provide a promising avenue for deepening our understanding of corporate finance and governance in private firms.

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Appendix A

Table A1

Variable definitions

DEPENDENT VARIABLES	
ΔReturn on Assets	One-year-ahead change in return on assets (i.e., FY1 minus current year *Return on Assets*) when *Return on Assets* is the firm's net income scaled by total assets multiplied by 100.
ΔReturn on Equity	One-year-ahead change in return on equity (i.e., FY1 minus current year *Return on Equity*) when *Return on Equity* is the firm's net income scaled by total stockholder's equity multiplied by 100.
Sales Growth	One-year-ahead change in total operating revenue multiplied by 100.
Assets Growth	One-year-ahead change in total assets multiplied by 100.
Cash Ratio	One-year-ahead cash and cash equivalents divided by total assets
ΔEmployee Productivity	One-year-ahead change in the firm's total operating revenue divided by the number of employees multiplied by 100.
Cumulative ΔReturn on Assets	Cumulative change in *Return on Assets* over the next two or three years, depending on the model.
Industry-Adjusted ΔReturn on Assets	One-year-ahead change in industry-adjusted return on assets (i.e., FY1 minus current year industry-adjusted *Return on Assets*) when industry adjustment is based on the annual average *Return on Assets* in the Fama and French (1997) 48-industry groupings.
CENTRALITY MEASURES	
Degree Centrality	A measure of network centrality that captures the total direct connections of a firm. For a more detailed description and an example, please see subsection 3.2 and Figure 1.
Closeness Centrality	A measure of network centrality that captures the average distance of all firms from the focal firm in a network. For a more detailed description and an example, please see subsection 3.2 and Figure 1.
Brokerage Position	A measure of network centrality based on Horton et al. (2012) that captures the ability of a firm to connect with loosely connected or unconnected networks. For a more detailed description and an example, please see subsection 3.2 and Figure 1.
Eigenvector Centrality	A measure of network centrality that captures the strength of both direct and indirect connections of a firm. For a more detailed description and an example, please see subsection 3.2 and Figure 1.
Network Centrality	First principal component formed through principal component analysis of the four centrality measures described in subsection 3.2.
OTHER INDEPENDENT VARIABLES	
Firm Size	Natural logarithm of total assets in thousands of euros.
Firm Age	Natural logarithm of the firm's age in years that is calculated as the difference between the fiscal year and incorporation year of the firm.
Sales Growth	Current year-over-year change in total operating revenue multiplied by 100.
Leverage	Non-current liabilities scaled by total assets.
Cash Ratio	Cash and cash equivalents divided by total assets.
Tangibility Ratio	Tangible assets scaled by total assets.
Capital Expenditure	Capital expenditure scaled by total assets, where capital expenditure is estimated as fixed assets in the current year minus fixed assets in the previous year plus depreciation and amortization in the current year.
Private	Equals one if the firm is private with limited liability, and zero if the firm is public with limited liability.
Centrality	A variable denoting one of the four measures of boardroom centrality described in subsection 3.2.
Interlocking	Equals one if the firm has any change in its first-degree network links after being previously isolated, and zero if the firm remains isolated for the entire sample period. First-degree links are defined as two firms sharing at least one board director.