Do Directors Provide Technological Advisory Assistance to their CEOs? *

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Abstract

We identify a director technological advisory channel by examining directors with an outside board seat on a firm operating in a matching patent tech industry class. After excluding directorships with simultaneous product market industry pairings, we find that 14% of directorships among innovative firms uniquely involve tech related industry pairings (TRIPs). TRIPs provide innovative assistance to the CEO with less fear of appropriation, and they increase firm value by 7%. This increase is concentrated among incumbent firms seeking protection from outside threats in volatile industries, and it is driven by cost-saving process patenting and breakthrough patent production.

JEL Classification: *G34, O16, O32, O33*

Keywords: Director advising, Industry expertise, Innovation

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Abstract

We identify a director technological advisory channel by examining directors with an outside board seat on a firm operating in a matching patent tech industry class. After excluding directorships with simultaneous product market industry pairings, we find that 14% of directorships among innovative firms uniquely involve tech related industry pairings (TRIPs). TRIPs provide innovative assistance to the CEO with less fear of appropriation, and they increase firm value by 7%. This increase is concentrated among incumbent firms seeking protection from outside threats in volatile industries, and it is driven by cost-saving process patenting and breakthrough patent production.

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1 Introduction

One of the primary functions of the board of directors is to provide strategic advice to the CEO. The importance of director advisory assistance has been highlighted in many studies (e.g., Adams and Ferreira, 2007; Coles, Daniel, and Naveen, 2008), and in 2009 the SEC amended Item 401 of Regulation S-K to increase the disclosure of director experience and skills. Numerous recent studies emphasize director product market tech expertise to overcome information asymmetries within their product industry (e.g., Dass et al., 2014; Von Meyerinck, Oesch, and Schmid, 2016; Wang, Xie, and Zhu, 2015; Faleye, Hoitash, and Hoitash, 2018; Drobetz, Von Meyerinck, Oesch, and Schmid, 2018; Burns, Minnick, and Smith, 2021). One recent survey finds that 43% of directors among S&P 500 firms had technology backgrounds.[1] However, these prior product market director studies are unclear as to what characteristics of a director's tech expertise are most important to the CEO. Do CEOs seek director expertise on the technologies used to develop their products, or do they simply prefer information on current developments within their product market?

On the one hand, CEOs may simply want to receive information on dynamic changes in their product market environment; i.e., timely warnings on new competing products or changes within their supply chain (e.g., Dass et al., 2014; Faleye, Hoitash, and Hoitash, 2018). This approach is safer and easier than seeking innovative help. Innovation is a long, uncertain, and inherently risky endeavor, and a significant tolerance for failure must be provided to encourage innovative pursuits (Holmstrom, 1989; Manso, 2011). Besides the fear of information leakage to competitors (which would be especially important to incumbent firms), CEOs may fear discipline from sharing deep details of their innovative pursuits that reveal failures or uncertainties (Faleye,

[1] "Corporate boards are putting tech expertise higher on their hiring wish list" by Aman Kidwai, *Fortune*, December 21, 2021.

Hoitash, and Hoitash, 2011). This negative information would also be harmful if leaked to capital providers, who could raise borrowing costs due to heightened perceptions of risk. Taken together, these fears might lead CEOs to underutilize the advisory capabilities of their tech expert directors. The *product market dynamics hypothesis* argues that CEOs only obtain information about changes and risks in their product market from their directors. Despite the value potential of additionally sharing details of their innovations, especially in innovative industries[2], CEOs are not willing to take the risk.

On the other hand, the *tech collaboration hypothesis* argues that CEOs actually prefer to share innovative details with directors over other outside collaborators. By carefully building relationships with tech directors and vetting them for trustworthiness, managers can overcome the "paradox of openness" (Arrow, 1962; Laursen and Salter, 2014) in which outside collaboration benefits innovation but also exposes the firm to risks of appropriation by competitors (which is a greater concern to industry incumbents who typically hold the most product industry knowledge). Directors' fiduciary duties of loyalty and care also provide the CEO added confidence that information can be shared safely. This makes directors possibly the most trusted members of a CEO's network of advisors, and it provides a discrete means of seeking innovative help that can outweigh monitoring costs and fears of discipline. Anecdotal evidence in Appendix A supports this hypothesis. This hypothesis also provides a channel explaining how beneficial tech spillover effects dominate detrimental product market spillovers to rivals, as documented by Bloom, Schankerman, and Van Reenen (2013).

We find strong support for the *tech collaboration hypothesis* by studying the effects of tech related industry pairings (TRIPs) between a firm and a director's outside board positions on firm

[2] For example, Drobetz, Von Meyerinck, Oesch, and Schmid (2018) note that product market industry expertise, while helpful, may provide less benefits in fast-changing, dynamic industries with high R&D expenditures and competitive threats – times when detailed innovative assistance is most critical.

valuation. These pairings uniquely identify director connections to related technologies distant from the firm's product markets using the United States Patent Classification (USPC) categories of the firm's prior patents.[3] We find that the presence of a TRIP on a board increases firm value (*Tobin's Q*) by almost 7% among patenting firms. We also find that these results hold and are similar using alternative measures of valuation such as *Bartlett and Partnoy's Tobin's Q* and *Market-to-Book Ratio*. Furthermore, we find evidence that TRIPs have a direct individual impact on valuation, as we find that young TRIPs that are new to a firm induce greater improvements to firm value. They bring fresh ideas to the CEO and support risk-taking. We also find that TRIPs only have an impact when they are willing or able to act on their novel information, which we proxy for using their level of attendance at board meetings and an indicator showing that they are not the CEO (so they are not burdened by running the firm).

We also examine mechanisms through which TRIPs positively impact firm value, and we find that TRIPs are critically important to industry incumbents. The technology life cycle literature argues that a few powerful incumbent firms eventually dominate an industry. This leads the firms to complacency, which encourages challenges from new entrants with radical new innovations. The incumbents incur financial stress from these challenges, and they fight back with new innovations of their own. Because these incumbent firms possess much firm-specific and industry-specific knowledge that could be beneficial to these new entrants, they cannot easily find trustworthy partners to develop their innovations without fear of information spillover to the new entrants. In addition, the leakage of news that they are seeking help with their innovations could send a negative signal to capital markets and increase their financing costs. TRIPs provide a trustworthy and valuable means for incumbents to revamp their innovations with significantly less

[3] The USPC classification is function based, not product based, and thus can uniquely identify director connections to related technology fields distant the firm's product markets. We describe this in more detail later in our study.

fear of information leakage. Supporting this argument, we find that TRIPs are most beneficial to incumbents when industry competitor and employment volatility is high, and in situations of high financial constraints. In addition, we find that TRIPs are positively associated with the production of cost-saving process patents (e.g., Klepper, 1996; Bena, Ortiz-Molina, and Simintzi, 2021) and breakthrough product patents which counter threats from new entrants.

We address potentially endogenous relationships in the following ways. In our baseline models we control for year and industry fixed effects and firm / industry level controls similar to Dass et al. (2014). Because our TRIP measure is based on prior patent filings, there is potential for sample selection bias from firms that are less innovative or choose not to patent. We thus apply three primary filters. First, we limit our sample to include only firms that have patented during our sample period. Second, we exclude firms headquartered in California and Massachusetts due to potential innovation bias from these states (Kong, 2020; Lerner and Seru, 2021). Third, we rerun our baseline tests using a propensity score matched sample to better match on innovation drivers. Our results hold throughout these restrictions. We also consider potential bias due to firms' endogenous choice of TRIPs. Because our findings show that TRIPs are particularly helpful when industries are going through dynamic and turbulent change, it is possible that the same factors affecting decisions to add TRIPs simultaneously affect firm value. We address this concern using two-stage least squares analysis with the following two instrumental variables that affect the supply of potential directors for the firm: 1) the percentage of directors within a 100 mile radius of the focal firm who have a TRIP connection between at least of one of their directorship pairs and a TRI connection with the focal firm, and 2) the percentage of directors within a 60 mile radius of the focal firm who have a TRI connection with the focal firm, weighted by the number of process claims to non-process claims in their patent stock. We add further robustness to these results using additional combinations of firm, industry, and region (state and county) fixed effects, and limiting our sample to innovative industries (Hirshleifer, Low, and Teoh, 2012). We find results similar to our baseline models throughout these tests.

Our study makes three important contributions to the literature. First, we contribute to the director expertise literature focused on related industry experience. As opposed to numerous recent studies focused on product market tech directors (Dass et al., 2014; Von Meyerinck, Oesch, and Schmid, 2016; Faleye, Hoitash, and Hoitash, 2018; Drobetz, Von Meyerinck, Oesch, and Schmid, 2018; Burns, Minnick, and Smith, 2021), we uniquely examine the role of non-product market tech directors in sharing detailed innovative product and process ideas that can enhance a manager's innovative path. Second, we contribute to the tech spillover and "paradox of openness" literatures (Bloom, Schankerman, and Van Reenen, 2013; Laursen and Salter, 2014). These studies examine how the general positive benefits of innovative knowledge-sharing between firms contrasts with the negative effects of business-stealing risks by product market competitors. Our study provides evidence of a channel through which CEOs can gain the benefits of tech spillovers by discretely sharing their innovative ideas and struggles through direct board connections, while better avoiding business-stealing risk. Third, we contribute to the product / technology life cycle literatures (e.g., Chandy and Tellis, 2000; Hill and Rothaermel, 2003) by presenting a mechanism that incumbents can use to introduce new technologies or cost-saving processes to their firms to ward off challenges from weaker rivals or new entrants.

The remainder of the paper is organized as follows. Section 2 discusses our motivation and related literature. Section 3 describes our sample data and presents summary statistics. Section 4 presents baseline regressions results, robustness tests, and identification strategies. Section 5 examines the influence of mechanisms through which TRIPs affect firm value. Section 6 concludes the paper.

2 Motivation and Related Literature

2.1 "Paradox of Openness" and the Advantage of TRIPs to Incumbent Firms

Motivating CEOs to pursue innovation is a challenging process. Innovation is long-term and uncertain, and it faces numerous delays, setbacks, and failures along its path to completion (Holmstrom, 1989; Manso, 2011). Firms investing heavily in innovation inherently exhibit high information asymmetry due to their desire 1) to avoid appropriation of their research stream by competitors and 2) to reduce the chance that equity markets unfairly discount the firm's shares (due to temporary setbacks) which could lead to hostile takeovers (Stein, 1988). Firms may also be forced to make partial information disclosures (Bhattacharya and Ritter, 1983) due to their need for additional financing or to avoid price discounting by shareholders simply due to their uncertainty in the firm's future prospects. These partial disclosures pose the consequence of potentially benefitting rivals. Despite these risks, innovation greatly benefits from collaboration with outside actors that can provide feedback and fresh ideas.

This leads to what has been called the "paradox of openness" (Arrow, 1962; Laursen and Salter, 2014) in which firms benefit from sharing news of both their innovative successes and failures with potential collaborators, but at the same time risk having their ideas stolen by competitors. Bloom, Schankerman, and Van Reenen (2013) make a similar argument and note that technological improvements from information sharing outweigh the negative effects of business-stealing risks by product market rivals, and thus firms are likely to share information despite the risks. However, other studies suggest the type of innovation shared via public channels is less valuable. For example, high tech spillover environments (Byun, Oh, and Xia, 2021) and greater board independence (Balsmeier, Fleming, and Manso, 2017) can lead to exploitative and incremental innovation, which produce quicker results but lower value. The focus on exploitation over exploration provides short-term benefits but also leads to competency traps and obsolescence in the long-run.

We argue that TRIPs are a "win-win" solution to this paradox and that they provide particular value to large, incumbent firms that dominate a product market. Incumbents possess detailed knowledge of the intricacies of existing product technology, and thus face difficulty soliciting help for further product development without revealing key secrets. Related to this security issue, lack of trust can increase contracting costs for information (Cline and Williamson, 2021). TRIPs can provide incumbent CEOs the time and the level of trust to share their innovative challenges and ideas without fear of discipline or leakage to competitors. Because the largest threat to incumbents is the emergence of a radical new innovation superior to their current product design, TRIPs can help incumbents discretely develop their own radical innovations to counter outsider threats. TRIPs can also help with process innovations, which typically come from outside of the firm's product market industry (Levin, Klevorick, Nelson, and Winter, 1987; Cohen and Klepper, 1996) and are used for cost reductions (Klepper, 1996; Bena, Ortiz-Molina, and Simintzi, 2021). Large incumbents have the size and scale to utilize cost-cutting process innovations more effectively than smaller rivals. In sum, the presence of TRIP directors reduces the need for the CEO to follow more revealing paths in an effort to build collaborative relationships, which could lead to appropriation by competitors, potential discounting by shareholders, and the threat of hostile takeovers.

2.2 Product Life Cycle – Importance of TRIPs Following Industry Disruption

In modern models of Schumpeterian growth theory, technological change in an industry is often brought about by the creative destruction of incumbent firms by new entrepreneurial entrants (e.g., Aghion and Howitt, 1992). The classic product life cycle view in the innovation literature

(Abernathy and Utterback, 1978; Klepper, 1996; Chandy and Tellis, 2000; Hill and Rothaermel, 2003) argues that incumbent firms in a product market will fail to recognize challenges from new entrants, allowing the entrants to gain a foothold and develop disruptive and radical technological changes to the incumbent's existing products. Pressure from the new entrants creates dynamic and volatile conditions within the industry. This leads to the eventual decline and demise of the incumbent, who is then replaced by the challenger, and the cycle starts over.

In contrast, while the early stages of this cycle are widely accepted in the literature, numerous studies suggest incumbents fight back and may be able to survive and resist these challenges (e.g., Chandy and Tellis, 2000; Hill and Rothaermel, 2003). Incumbent firms do this by developing new technologies of their own that allow them to maintain their profit margins, neutralize the threat, and ultimately increase firm value (Rong and Xiao, 2017). Cohen and Klepper (1996) note that incumbent firms in an industry are price-takers and will maximize firm value via new product and process technologies in different ways. Product innovations add new features and benefits which increase the price buyers are willing to pay, thus allowing the firm to increase their price-to-cost ratio (since cost stays constant). Process innovations work at the other end of the spectrum and produce cost-reducing manufacturing and servicing methods that help a firm reduce costs while maintaining the price at a constant level, thus also expanding their profit margin.

Incumbents are well placed to implement both product and process improvements due to their size and scalability, and hypothetically should be able to effectively fight back. So why are new entrants so often able to displace incumbents? One reason is that dominant incumbent firms are much more sensitive to information leakage than the weaker rivals in their industry or the new entrants, as we have discussed. Incumbents possess significant organization capital in their employees (Eisfeldt and Papanikolaou, 2013) and have greater levels of unprotected trade secrets which rivals could exploit and appropriate. The leakage of innovative struggles by the incumbents against the entrants could also significantly damage previously favorable terms from creditors, curtailing the low borrowing cost advantage once held by the incumbents over the high financial hurdle rates often faced by the new entrants. We argue that TRIPs are especially beneficial to dominant incumbents when faced with imminent threats from new entrants, as they provide a discrete mechanism for the sensitive sharing of tech information when the consequences of information leakage are high. We present a combination of the class product life cycle timeline with our *tech collaboration hypothesis* of TRIP influence in Figure 1. Anecdotal evidence in Appendix A also supports this argument through a director channel.

3 Data and Methodology

We obtain financial data from CRSP and Compustat, director data from ISS Riskmetrics, and patent data from the NBER patent database of Hall, Jaffe, and Trajtenberg (2001). We identify the number of process and non-process claims per patent filing using data from Bena, Ortiz-Molina, and Simintzi (2021). Our main sample ranges from 1996-2013, includes only firms with director data in ISS-Riskmetrics, and excludes any firms that have never filed a patent.[4]

3.1 The USPC Patent Classification System, "Proximate Function" Industries, and the Advantage of our TRIP Director Proxy

The 2005 U.S. Patent and Trade Office (USPTO) Handbook of Classification defines patent industries by their "fundamental, direct, or necessary function", which they call "proximate function", as opposed to their product market industry (SIC or NAICS). Proximate function

[4] Our sample is limited to this data range for two reasons. First, ISS Riskmetrics director data begins in 1996, limiting the start date of our sample. Second, the USPTO transitioned to the Cooperative Patent Classification (CPC) system in 2013, which mixes function and product use and does not use proximate function as its guiding philosophy (Lobo and Strumsky, 2019). Although other firm-linked patent datasets with more recent data are available, they do not contain the USPC classification which is more appropriate for our study. Crosswalks used to ex-post classify patents have proven unreliable in the past (Hirabayashi, 2003), so extending the data forward could introduce biases.

industries are typically very different from product industries. For example, the same winding technology used to wind line on a fishing reel could be used to wind copper thread into an electric motor, and both would appear in the same proximate function industry. This aids examiners in comparing prior art and reduces the risk of granting a patent for essentially the same idea.

We use the 428 USPC patent technology classes of the USPTO which existed during our sample period to identify patent industries and create our TRIP measure. Because this classification system groups patents by actual function and not on supplier or customer industries (e.g., Johnson, 2002; Hirabayashi, 2003), our industry classification is able to differentiate from product market-related directors who may be contributing information on product sales prospects (Dass et al., 2014) or monitoring skills related to the product market (Wang, Xie, and Zhu, 2015). We build our TRIP measure between a director's firm and their various outside board positions based on USPC industry connections between each firm's 5-year prior patents. We also apply several additional filters to exclude TRIP pairings from directorship firms in the same product market industry, as we explain further in our data section. This helps us uniquely capture director connections to important related technologies distinct from their product market connections.

3.2 Tech Related Industry Pairings (TRIPs)

We identify TRIPs using several steps as follows. We first compute technological connections between directorships at different firms based on the different technology classes of the USPC. This is done similar to how Jaffe (1986) computes technological proximity. We then use the average share of patents per firm in each technology class in the preceding five years as our measure of technological closeness between firms, which we call a tech related industry (*TRI*). F_i (F_j) represent vectors of firm *i*'s (*j*'s) share of patents in each technology class.

$$TRI_{i,j} = \frac{F_i F_j'}{\left[(F_i F_i{}')(F_j F_j{}')\right]^{\frac{1}{2}}} \tag{1}$$

The value of *TRI* is between zero and one, depending on the degree of closeness in technology class. A zero value indicates that firm i and firm *j* have no overlapping tech relationship, while a value equal to one implies firm *i* and firm *j* share the same technology class for all prior patents. By construction, $TRI_{i,j}$ is equal to $TRI_{j,i}$ for any i, j, $j \neq i$. We then identify a direct tech connection between directorships[5] if a director sits on an outside board whose portfolio of patents contains at least a 5% concentration in one of the same USPC patent tech classes (based on patents filed in the current and prior four years) as the focal firm (i.e., *TRI* ≥ 5%).

Although USPC patent classes group innovations by function instead of product market, it is still possible that they identify director connections based on similar technologies within a product market, so we apply three more filters in our second through fourth steps. Our second step requires each patent to include at least one processing claim (Bena, Ortiz-Molina, and Simintzi, 2021) to reduce the risk of a product market connection, as most process innovation improvements come from outside of the product market.[6] The third step excludes any director pairs in the same four-digit SIC code. This distinguishes our sample from the DRI (director-related industry) measure of Dass et al. (2014), which in contrast embraces the four-digit SIC code of a firm and its segments to identify directors from the focal firm's product supply chain. In our fourth step, we exclude any directors identified in ISS Riskmetrics as having an affiliation or link with the firm (which includes directors employed by suppliers or customers). In addition, Section 8 of the Clayton Act disallows directors from serving on the boards of competing firms in their product

[5] While prior literature documents many forms of board interlocks, we limit our analysis to these direct connections. This is central to our argument that only close board connections will allow enough trust to build between a CEO and a director for the CEO to share intimate details of their innovation strategy. In addition, indirect board interlocks are less likely with our proxy since it focuses on non-product markets more distant to the firm.

[6] This is based on survey data from Levin, Klevorick, Nelson, and Winter (1987) and arguments from Cohen and Klepper (1996).

markets due to antitrust concerns. After applying these filters, we identify a firm as having a TRIP connection if at least one of their directors has one of these *TRI* connections.

3.3 Summary Statistics

Table 1 provides descriptive statistics for our main sample. About 14% of firm-year observations indicate the presence of a TRIP board member. R&D spending amounts to around 11% of revenue, and firms file on average 35 patents per year. Process claims amount to around 21% of total patent claims. Approximately 71% of board members are classified as outside directors, and 62% of CEOs are also chairs. The average director in our sample is 60 years old, and the average director tenure is 8.66 years. The presence of at least one breakthrough patent filing in the top 1% of future external patent citations occurs in around 10% of firm-years.

In Table 2 Panel A we examine the use of TRIP directors across Fama French 12 industries. TRIPs are widely distributed across all industry groups, but are much more prevalent in chemicals, oil and gas, and the healthcare industries. TRIPs are less common in consumer nondurables, utilities, and wholesale and retail. Because TRIPs are most helpful in industries going through dynamic change, these results make sense and suggest there is some selection effect by firms choosing TRIPs to strengthen their firm's competitive position. For this reason, we carefully consider selection effects in our identification strategy in the following sections. Panel B of Table 2 splits our sample into two time periods by their presence in an innovative industry. We follow Hirshleifer, Low, and Teoh (2012) and classify firms into approximately two equal groups (using the full sample of Compustat firms) based on whether their industry ranks above or below the median for innovation. TRIPs are more common during the volatile innovation years of the Internet Bubble, with almost 15.7% of firm-years containing TRIPs. The presence of TRIPs was less common during the 2005-2013 period (which was marked by the volatility of the less innovation-related Financial Crisis) with around 12.3% of firm-years with TRIPs. We note that TRIPs are more common in innovative firms during the Internet Bubble. This is not a surprise, and we attribute this to greater innovative pursuits by traditionally non-innovative firms during this time. During the Internet Bubble, a multitude of firms wanted to express a connection to the internet (e.g., firms that wanted to add ".com" to their product lines), especially to keep up with competitors. Despite this occurrence in our sample, we find little change in our baseline or 2SLS regression results over time. In addition, we exclude non-innovative firms in later tests and find that our results do not materially change.

4 Results

4.1 Baseline Regression Analysis

We begin our analysis by conducting baseline OLS regressions in a multivariate framework to examine the relationship between the presence of a TRIP director and various measures of firm value. We design our tests similar to Dass et al. (2014), using our TRIP director measures for tech industries in place of their DRI director measures for product industries. Specifically, we use the following model to test firm value around TRIP director presence:

$$\begin{aligned} \text{Value}_{i,t+1} = {} & \beta_0 + \beta_1 \text{TRIP Director}_{i,t} + \beta_2 \ln(\text{Total Assets}_{i,t}) + \beta_3 \text{Tangibility}_{i,t} \\ & + \beta_4 \ln(\text{Book Leverage}_{i,t}) + \beta_5 \ln(\text{Volatility}_{i,t}) + \beta_6 \text{CEO-Chair}_{i,t} \\ & + \beta_7 \text{Board Size}_{i,t} + \beta_8 \ln(\text{Pct Outside Dirs}_{i,t}) + \beta_9 \text{R\&D}_{i,t} \\ & + \beta_{10} \text{ROA}_{i,t} + \beta_k \text{Industry}_i + \beta_j \text{Year}_t + \varepsilon_{i,t} \end{aligned} \quad (2)$$

where i and t represent firm and year, respectively. We define *Value* using three measures of firm value including *Tobin's Q*, *BP Tobin's Q* using the adjustment of Bartlett and Partnoy (2020), and *M/B Ratio*. We identify *TRIP Director* as the presence of at least one board member with a TRIP connection to an outside directorship. We include control variables (defined in Appendix B) following Dass et al. (2014). We follow Dass et al. (2014) and include two-digit SIC industry and year fixed effects, and we cluster standard errors by firm.

We report our baseline OLS results in Table 3. We find a positive and highly significant relationship between *TRIP* and our main valuation measure *Tobin's Q* in Model (1) using our full sample. We exclude firms headquartered in California or Massachusetts in this model and throughout our study, as these states uniquely file large numbers of patents and may skew our findings (Kong, 2020; Lerner and Seru, 2021). Nevertheless, in Model (2) we rerun our baseline tests from Model (1) including all 50 states and adding state-level fixed effects, and we find that our results are similar. We then build a one-to-one nearest neighbor propensity score matched sample (without replacement) with a caliper width of 0.01 using all of our control variables, matching to *TRIP* in the same year and two-digit SIC industry. In untabulated covariate tests, we validate our match by finding no significant differences between *TRIP* firm determinants and their matched non-*TRIP* counterparts. We repeat Model (1) using our PSM sample in model (3) and find similar results. Models (4) and (5) repeat Model (1) substituting alternative measures of valuation using *BP Tobin's Q* and *M/B Ratio*, respectively. Both models find a positive and statistically significant relationship between *TRIP*s and valuation similar to Model (1). Taken together, these results provide strong support for our argument that TRIPs have a positive impact on firm valuation.[7]

4.2 Direct Impact of TRIPs on Firm Value

Our results thus far provide support for the *tech collaboration hypothesis* and show that CEOs can gain valuable non-product market innovation advice from their TRIP directors.

[7] In untabulated results we also exclude firms in non-innovative industries as classified by Hirshleifer, Low, and Teoh (2012), and we find similar results.

However, this beneficial exchange will only take place if both parties are willing and able to put forth the effort required to make the exchange of information successful. We argue that young TRIP directors with short tenures are more willing to take innovative risks and bring fresh ideas to the firm. These qualities are especially valuable when a firm is faced with a need for strategic change. Jia (2017) finds that long tenured directors produce less innovative output and less explorative innovations. Castro et al. (2009) finds that firms are more likely to change strategic direction when their directors currently have very short tenures and feel the need to prove themselves. They cite other studies that find long-tenured boards are associated with rigidity and commitment to established firm routines, which hinders the processing of new information.

In Panel A of Table 4, we repeat our baseline regressions of Eq. (2) on *Tobin's Q* and divide our sample into high and low annual quantiles on various characteristics of the TRIPs related to their age and tenure.[8] We predict that TRIPs are more valuable when they are young, new to the firm, and bring fresh ideas and the willingness to take risks. We compare these subsample results to our full sample baseline regression results using Eq. (2) which we term our benchmark coefficient. In models (1), (2), (5), and (6) we confirm our predictions and find that TRIPs have a stronger positive effect on firm value when TRIPs are younger than average or have shorter tenures with their firms. It is also possible that there are synergistic effects by having young, fresh TRIP directors on older and more experienced boards, so we next create a ratio of TRIP age/tenure to the average age/tenure of their boards. We find similar results in models (3), (4), (7), and (8) to our prior findings and confirm our predictions that a low age/tenure ratio has a stronger positive effect on firm value. In addition, outside CEO directors may provide synergistic guidance and mentoring for these young TRIPs. We provide evidence of this in the Internet Appendix.

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[8] Sun and Bhuiyan (2020) conduct an extensive review of studies on board tenure effects, and they find that director age and director tenure are typically closely related. Thus, we use director age and tenure effects as alternative and synonymous tests.

In Table 4 Panel B we test whether the motivation of TRIP board members impacts the effect of TRIPs on valuation using high and low quantiles by year of average TRIP board attendance. Stein and Zhao (2019) find that poor board attendance leads to lower firm performance and value. Panel B Model (1) repeats our main test following Eq. (2), but it excludes TRIP firm-years in which TRIP absenteeism exceeds 75%. We note a slight improvement in firm valuation over our Benchmark Coefficient in Panel A. In Panel B Model (2) we perform a within-sample comparison between 1) TRIPs experiencing >75% absenteeism rates in a given year and 2) those that experience less absenteeism, and we examine the effect on firm value following Eq. (2). We find a much stronger positive impact on valuation in the TRIP sample with low absenteeism.[9]

Taken together, our results suggest TRIPs are more likely to build firm value when they are young, new to the firm, are not overly busy with duties running the firm as CEO, and do not show distraction and lack of commitment due to missed board meetings. These tests also help ensure that TRIPs are driving our results and not an endogenous factor related to TRIP presence.

4.3 Identification Using Instrumental Variables

One concern is that directors from innovative firms may be attracted to other innovative firms, creating an endogenous relationship. Although we attempt to mitigate this bias by 1) using a sample of patenting firms and 2) excluding the uniquely innovative states of CA and MA, there may be some other unobservable factor creating a spurious relationship. We therefore construct two IVs based on local director labor market supply similar to prior literature (e.g., Knyazeva, Knyazeva, and Masulis, 2013; Dass et al., 2014; Faleye, Hoitash, and Hoitash, 2018).

[9] This impact can also apply to the entire board, as TRIP directors and the CEO might need help in their pursuits from other board members. The lack of monitoring by other board members may also lead the CEO to neglect TRIPs. We find similar negative effects when including missed board meetings by all directors in the Internet Appendix.

Our first measure identifies all of the directors within a 100 mile radius of the focal firm that 1) have a TRI connection between any of their directorships (representing a TRIP pairing between the two firms), and 2) also have a TRI connection with the focal firm (even though the director is not on the board of the focal firm). The existing TRIP pairing shows these directors already likely share tech knowledge between firms, suggesting an enhanced TRIP contribution if hired by the focal firm. Our second measure identifies all directors within a 60 mile radius who have a TRI connection with the focal firm, weighted by the ratio of process claims to non-process claims in their patent stock. Process patents are often used by firms for cost savings, suggesting an enhanced TRIP contribution if hired by the focal firm. We use firm headquarter locations from Compustat and geographic coordinates from the U.S. Census (2000) Gazetteer.

We present the first-stage regression results of the two IVs on *TRIP* using a two-stage least squares (2SLS) model in Table 5 Model (1). To be valid instruments, variables must satisfy two conditions: 1) relevance as shown through a correlation with the endogenous variable, tested using under-identification and weak-identification tests, and 2) exogeneity as shown through a distribution independent of the error process, found using an orthogonality test. We find that our IVs meet relevance and exogeneity requirements based on the following analysis. First, we find that the coefficients for both IVs are statistically significant at the 1% level in the first-stage model, establishing their relevance. Second, we test under-identification using the Kleibergen-Paap Lagrange Multiplier (LM) statistic.[10] We find that our results strongly reject under-identification, although we acknowledge that the threshold for rejection is low with this test as noted in papers using this methodology (e.g., Kaufmann, Mehrez, and Gurgur, 2019). Third, we confirm that our instruments are not jointly weak using the Kleibergen-Paap F-Statistic, which strongly exceeds the

[10] This test is robust to heteroscedasticity, which makes it more robust than similar models such as the Anderson canonical correlation LM which assumes homoscedastic errors.

Stock-Yogo 10% maximal relative bias critical values.[11] Finally, given the many duties of directors for both monitoring and advising, we argue that the exclusion restriction is met because it is implausible that a higher rate of local area directors with a 5% connection in a related technology that is not in the same product market has any effect on the focal firm's valuation. The large p-value from the Hansen's J-statistic supports our exclusion argument, as it fails to reject the null that the instruments are uncorrelated with the error process.

We then examine the impact of *Instrumented TRIP* on firm value in the second stage in Table 5 models (2) through (4). We find positive and statistically significant results for *Tobin's Q*, *BP Tobin's Q*, and *M/B Ratio*, supporting our baseline findings. We repeat Panel A Model (2) in Panel B and apply a number of robustness tests. First, we apply additional combinations of fixed effects based on firm and region (state-level and county-level). Although the use of year and industry fixed effects in our prior models follows Dass et al. (2014), these added tests confirm that our results are not driven by unique firm or regional characteristics. Second, we restrict our sample to innovative industries following Hirshleifer, Low, and Teoh (2012). Faleye, Hoitash, and Hoitash (2018) find that directors with tech expertise are more valuable for their advisory assistance in innovative industries that are more likely to experience dynamic change in their product markets. Even though our primary sample is restricted to only include patenting firms, this added filter helps reduce the chance that our patent-based TRIP measure introduces biases to our tests. We also exclude Singleton groups (groups with only one observation) in both stages for robustness (Correia, 2015), and we present the number of groups excluded in the 1st stage. In all five models in Panel B, we find that *Instr TRIP* is positively and significantly related to *Tobin's Q*.

[11] In untabulated results, we find our F-statistics reject the null hypothesis of weak IVs using the traditional Cragg-Donald statistic of Stock and Yogo (2005) that assume homoscedastic i.i.d. errors. However, the Kleibergen-Paap F-Statistic is robust to heteroscedasticity and thus provides better confidence in our findings.

5 TRIP Mechanisms of Influence

Our prior results find that the presence of TRIPs on a board yields a significant positive impact on firm value, providing support for our *tech collaboration hypothesis* that CEOs seek detailed innovative assistance from their directors beyond simply obtaining information on recent changes in their product markets. We next examine mechanisms used by firms with TRIPs to increase firm value. We first provide evidence that dominant incumbents in an industry are more likely to use TRIPs. We then examine how dominant incumbents use TRIPs to respond to new entrant threats. This product life cycle stage is marked by intense volatility in firm entrances, exits, and employment levels, and this stage exacerbates financial constraints in firms facing price wars and the need for increased innovative spending. We thus measure the effectiveness of TRIP firms when facing volatile industry conditions and financial constraints. Finally, we explore TRIP-enabled mechanisms incumbents use to counter new entrant threats such as process and product improvements.

5.1 TRIPs and the Protection of Incumbents from Information Leakage

In this section, we look for evidence that TRIPs are particularly beneficial to dominant incumbent firms. CEOs of incumbent firms have the most to lose from information leakage, which could lead to 1) appropriation of non-patented trade secrets and other ideas by weaker rivals, and 2) increasing costs from equity and credit markets who sense heightened financial risk based on the firm's innovative struggles. Each of these could lead to a price decline and the risk of takeover. We thus expect TRIPs to be most beneficial in concentrated industries where dominant incumbents seek to stave off challenges from new entrants.

We do not expect TRIPs to be particularly helpful when there are no dominant firms; i.e,, in industries that are widely dispersed with many similar strength industry players. Byun, Oh, and

Xia (2021) find that the presence of many closely aligned and similar tech firms reduce the chance of breakthrough patents. These firms can more easily exploit related technologies when potential spillovers from closely related tech firms are high. In dispersed industries, firms would neither desire nor need to seek out distant, unrelated technological ideas from TRIPs that could lead to rapid change.

We test our arguments in Table 6 using the measure of firm competitive power from Hoberg and Phillips (2016). In Panel A we divide our sample into high and low quantiles based on firm competitive power in year (t). We observe that TRIP directors bring a positive and significant influence on valuation for high industry competitive power in all models, indicating TRIP directors bring positive impacts for powerful incumbent firms. In Panel B we include the interaction of *TRIP* with industry competitive power. We perform OLS regressions in models (1 – 2) with *Tobin's Q* and *M/B Ratio* as the dependent variables, respectively, and find a positive and significant impact on firm value for our interaction term. We also see a similar pattern in models (3) and (4) using our 2SLS model. Overall, we find persuasive evidence that TRIP directors bring a positive and significant impact on firm value when utilized by powerful incumbent firms.

5.2 TRIP Incumbents and the Influence of Product Life Cycle Effects

We expect dominant incumbents to receive the most benefit from TRIPs when faced with challenges from new entrants. The traditional view of the life cycle of a product / technology (Abernathy and Utterback, 1978; Klepper, 1996) proceeds as follows. After intense competition between rival firms, a few superior designs emerge that result in a shakeout of firms with inferior competing products. The result is that only a small number of large, dominant firms remain in the industry. This reduces the fear of threats from rivals, and innovation slows down and shifts to lower-value incremental and exploitative innovations. However, this shift of attention away from product development along with the reduction of incumbent fear entices new entrants to enter the industry and challenge the incumbents. At this point, the industry sees two primary changes, as noted in Figure 1. First, the industry begins to go through dynamic and intense product competition, with new entrant firms arriving and weak competitors being eliminated. Employment changes are also dynamic, as emerging firms rapidly hire and weaker firms increase layoffs. Second, the industry experiences increases in investment spending by successful new entrants and declines in profit margins among weaker rivals. Together with the general increase in competitive pressure, this leads to greater financial constraints in the industry.

In Table 7 we look for preliminary evidence that incumbent firms utilize TRIPs more effectively to build firm value when facing the added product life cycle pressures of industry volatility and financial constraints. In Panel A models (1-3) we present univariate regression evidence of the particularly strong relationship between incumbent competitive power and the presence of TRIPs on their boards, suggesting they understand the importance of TRIPs to their innovation strategies and long-term value. Model (4) introduces industry volatility (*EntryExVol*) and financial constraints (*WW Index*), which are mostly insignificant in their relationship to TRIP presence. This suggests they may work more as moderating factors in the relationship between incumbent TRIP usage and firm value.

We explore this moderating effect further in Panels B-D. Models (1-8) of each panel examine the impact of TRIP presence on *Tobin's Q* among double sorts by 1) low vs high quantiles of firm competitive power in their industry (with high levels representing powerful incumbent firms), and 2) low vs. high quantiles of firms entering and exiting an industry as a measure of industry volatility. Model (1) presents the coefficient on *TRIP* using Eq. (2) when both quantiles are low, Model (2) when competitive power is low and entry / exit volatility is high, Model (3) when competitive power is high and entry / exit volatility is low, and Model (4) when both quantiles are high. Models (5-8) repeat models (1-4) using our instrumented measure of TRIP. Finally, models (9-16) repeat models (1-8) after sorting the sample by the bottom two quintiles vs. the top three quintiles of each sorting variable. We use this uneven split to better isolate times when TRIPs should not provide benefit to incumbents, to see if TRIPs may sometimes prove a hindrance to firms when they are not appreciated.

We find that TRIPs have a strong positive and statistically significant impact on Tobin's Q in models (4), (8), (12), and (16) of Panel B and Panel C. We also note that the coefficient in Model (9) of Panel B is negative and significant, and seven of the eight low-low group coefficients in these two panels are negative. This suggests TRIPs do not contribute firm value to financially secure firms that do not face adverse industry conditions, and that they may even be detrimental in promoting radical innovations the firm will not support. It also suggests a moderating role from entry / exit volatility. We also measure Wald tests of the difference in coefficients between the high-high groups and the low-low groups, and we find strong significance for both panels. This confirms the impact of TRIPs on firm value does indeed vary with incumbent power and industry volatility.

The product life cycle literature also suggests firms become financially constrained when an industry is disrupted by new entrants, so in Panel D we repeat panels B and C substituting the Whited-Wu financial constraints index for industry volatility. We find similar results, and we note that Model (9) shows negative significance in the low-low group, similar to Panel B. Together these results exemplify the moderating effect of industry volatility and financial constraints on the effective usage of TRIPs by incumbents, and they highlight the importance of the product life cycle stage to these firms. The following sections examine these two product life cycle effects in more detail with added robustness.

5.3 TRIP Importance Within Industries Facing Dynamic Change

The product life cycle literature argues that dominant incumbents become complacent and are eventually disrupted by new entrants. This leads to increasingly dynamic industry changes, as incumbent firms decline and disappear while new entrants rise to take their place. This also leads to significant reallocation of labor resources, as employees depart from the declining incumbent firms and the new entrants expand their hiring. These classic views on creative destruction and the changes in both industry membership and employment are detailed in the innovation literature that describes periods when new entrants rise to challenge incumbent firms in an industry (Chandy and Tellis, 2000; Hill and Rothaermel, 2003).

We build on our prior findings and argue that TRIPs are especially effective during these times of dynamic industry change, and in this section we search for evidence that TRIPs are most effective at preserving firm value for incumbents when these major industry changes are occurring. We proxy for dynamic industry change using census data on 1) public and private firm entry and exit within an industry and 2) public and private firm employment changes within an industry. In Table 8 we follow Billett, Garfinkel, and Yu (2017) and examine public and private firm entry and exit in the product market for each firm. We also construct a seven-year period of firm entry and exit around our measurement of TRIPs similar to Billett, Garfinkel, and Yu (2017).

In Panel A we divide our sample into high and low quantiles in year (t) based on industry entry and exit volatility in models (1-8). We proxy for volatility using the sum of the absolute value of the percentage change in public and private firm births and deaths over the surrounding seven-year period using census data from the Small Business Administration (SBA). We use four-digit NAICS codes to capture the product market industry. To avoid forward-looking bias from our seven-year volatility measure extending past our dependent variable time of (t+1) in models (1-4), we repeat our tests using Tobin’s Q at (t+4) in models (5-8). Panel A models (9-16) split the sample annually into high and low quantiles similar to models (1-8) but substitute employment increases and decreases for firm births and deaths. We find that our results are statistically significant only in the high volatility quantiles for all models. Wald tests also confirm that our subsample results are statistically different across quantiles for five of our eight tests, adding more confidence to our findings.

We build further confidence in our findings in Panel B, where we build an interaction term between our volatility measures and *TRIP* and repeat our regression results for the full sample. We apply industry, year, and state fixed effects as specified. Our TRIP measure remains significant in all models, with the coefficient size for our interaction term being much larger in all OLS models. This suggests a large part of our TRIP effect is driven by firms in industries facing dynamic change. The interaction term is barely insignificant for our 2SLS model using industry entry and exit volatility, but we do see significance using our 2SLS industry employment volatility model.

5.4 Benefit of TRIPs to Financially Constrained Firms

Our preceding results and the product / tech life cycle literature suggest firms may utilize TRIPs to ward off new entrant threats via 1) the pursuit of cost-cutting process innovations or 2) the development of radical new "breakthrough" patents. In both cases, incumbent firms would only be motivated to act if they perceived an imminent and credible threat to their financial stability from new entrants. Lev, Radhakrishnan, and Tong (2016) argue that incumbent firms precommit to both higher levels of R&D and higher levels of capital expenditures to ward off new entrants. High R&D to stave off new entrants would be consistent with breakthrough patenting (Aghion et al., 2009), while high Capex would be consistent with an increase in capital/labor ratios brought about by process innovations (Bena, Ortiz-Molina, and Simintzi, 2021).[12] The use of such insurance would be costly, and it suggests significant financial pressures on the firm even before an outsider threat emerges.

Even if some incumbents precommit to these expenditures at the first sign of new entrant threats, often these strategies are deployed only when the firm is already facing significant pressure from new entrants. The traditional view from the tech life cycle literature suggests incumbents initially have significant financial resources and do not take seriously any threats of outside pressure. In this scenario, TRIPs would be deemed ineffective and unused by the incumbents, as they have less incentive to engage in innovative activity versus new entrants (Arrow, 1962).[13] Incumbents would not employ new entrant deterrents until the threat of new entrants was greatly increased, or when they were already under serious financial pressure and faced significant threats of their own survival. Lev, Radhakrishnan, and Tong (2016) present arguments that incumbent firms often fail to adopt disruptive technologies in a timely manner, and they end up incurring significant restructuring costs in an effort to retool their businesses to keep up with rising new entrants. Even if incumbents seek to neutralize this threat soon after arising, significant financial and reputational damage can occur before they formulate a response. Taken together, these arguments suggest that firms only utilize TRIPs to pursue process innovations and radical breakthrough innovations when facing serious financial constraints from new entrant pressure.

We test for the impact of financial constraints on TRIP value generation in Table 9. We first divide our sample into high and low quantiles in year (t) based on three measures of financial

[12] This response has been shown in other scenarios when firms come under financial pressure. For example, Aghion, Bergeaud, and Van Reenen (2021) find that firms facing an exogenous increase in costs from new labor regulations will reduce their lower value incremental innovation and will instead try to "swing for the fence" with more radical and labor-saving (i.e. process) innovations.

[13] This argument, referred to as the "Arrow Effect", states that incumbents would only gain the difference in expected profits between the new technology and the old technology, while new entrants would gain the full expected profit from the new technology. Incumbents would also face restructuring costs.

constraints: 1) The Whited-Wu index of Whited and Wu (2006), 2) the KZ index of Kaplan and Zingales (1997), and 3) the SA index of Hadlock and Pierce (2010). We repeat our regressions following Eq. (2) using both OLS and 2SLS in models (1-12). We find that our results are statistically significant in the high financial constraint quantiles in all models. Furthermore, the significance is greater and coefficient magnitudes are larger in the high financial constraints quantile in all tests versus the low financial constraints quantile. Wald tests in models (1-4) confirm that our subsample results are statistically different across quantiles for the Whited-Wu index, adding more confidence in our findings.

We build further confidence in our findings in Panel B, where we build an interaction term between our Whited-Wu index and *TRIP* and repeat our regression results for our full sample. We also apply a variety of industry, year, and state fixed effects. Our TRIP measure remains significant in all models, with the coefficient size for our interaction term being even larger in all OLS models. This suggests a large part of our TRIP effect is driven by financially constrained firms. The interaction term is not significant for our 2SLS model, giving us a little concern. However, our coefficient estimates were larger and more significant for all of our 2SLS results in the subsample tests in Panel A.

5.5 Production of Future Process Innovations

Process innovations provide a key means of reducing financial constraints for incumbent firms, and evidence of process innovations among TRIP firms would provide robustness to our previous results. Process innovations can reduce manufacturing capital requirements or substitute more efficient capital for labor. One classic example is Henry Ford's assembly line, which resulted in huge increases in capital-labor ratios and revolutionized a wide range of product market industries (Bena, Ortiz-Molina, and Simintzi, 2021). The tech life cycle literature argues that firms will gradually shift from a primary focus on product innovation to more process innovation over time (Klepper, 1996; Adner and Levinthal, 2001). This view suggests that an emerging market will eventually reach a dominant product design that cannot be improved upon, and product innovation levels off. As copycat entrants arrive and replicate these products, prices drop, and dominant incumbents turn to process innovations to cut costs in order to maintain their profit margins. Dominant incumbents have a better opportunity to appropriate rents from customers in this scenario, as their size allows them to take advantage of the scalability of their operations and incorporate cost-cutting process innovations that reduce manufacturing and delivery costs (Klepper, 1996).

We offer several arguments for why TRIPs may be an especially effective means for incumbent firms to incorporate process innovations and defend against tech life cycle deterioration. First, process innovations tend to not come from within an industry due to the ease with which processes can be appropriated by rival firms (Levin, Klevorick, Nelson, and Winter, 1987; Cohen and Klepper, 1996). One reason is because process improvements do not show up publicly in the product and are thus more easily hidden from public view. This makes it more difficult for the incumbent firm to protect their property rights, and for that reason they prefer to be discrete in their addition of process improvements. Second, actively seeking process improvements in a more public forum could be seen as a negative signal to markets by suggesting that the firm is struggling to maintain profit margins. This could also encourage challenges from new entrants. Third, dominant incumbents can attract better directors with more extensive networks, and their firms are typically larger and have the size and scalability advantage necessary for process innovation (Klepper, 1996).

Despite the desire of incumbent firms to keep new process innovations secret in many cases, the use of process innovation trade secrets is still likely to be highly correlated with future process innovation that can be patented with less fear of illegal appropriation by rivals. For example, Banholzer et al. (2019) find that trade secrets are complements to patented process innovations rather than substitutes.

In Table 10 we examine the tendency for TRIP firms to file future process patents. If firms increase valuation by adding cost-saving process improvement ideas from TRIPs, it is likely they develop related future process innovations to help them improve their specific firm processes. In Model (1) we examine the impact of *TRIP* on the number of process patent claims across all firm patents in years (t+1) to (t+5). We use an OLS multivariate regression model following Eq. (2), and we control for the lag of the dependent variable in years (t-4) to (t) to avoid effects due to potential persistence in firms' abilities to produce process patent claims. We find statistically significant results that indicate TRIPs increase process patent claim production in the 5-year period after TRIP presence is indicated. In Model (2) we add an alternative control for time-invariant firm characteristics by excluding the lagged dependent variable and adding firm fixed effects. We then turn to causality tests to ensure our results are driven by TRIPs and show the second stage results of a 2SLS model utilizing our local director IVs in Model (3). Through all of these results, we find that TRIP presence leads to an increase in process patent claims in the following 5-year period.

5.6 "The Best Defense is a Good Offense": TRIPs and the Production of Breakthrough Patents

Incumbents do not only face pricing pressure from new entrants that bring low-cost substitutes against the dominant industry product. The classic argument in the innovation literature is that incumbents will eventually succumb and go into decline after new entrants enter an industry with radical and disruptive innovations (e.g., Chandy and Tellis, 2000; Hill and Rothaermel, 2003). In order to survive, Henkel, Ronde, and Wagner (2015) find that incumbent firms that do not have a similarly revolutionary product design must make costly acquisitions of these emerging radical innovators in their industry. Their study notes that this is often desirable to the new entrant, as they often want to be acquired. They do not have the size or access to networks that is needed to scale up, commercialize their products, and effectively compete with the incumbents. While an acquisition might ensure survival, this approach can significantly deplete incumbent firm resources, reduce the value of the firm, and make them more susceptible to the next new entrant challenge.

However, other studies and anecdotal evidence suggest that these outcomes are not inevitable.[14] To avoid these situations, incumbents may seek to proactively insure against their presumably eventual decline or forced acquisition strategy. Many studies find that incumbents can go "on the offensive" and create their own radical innovations to counter challenges from outsiders. Chandy and Tellis (2000) note that incumbents with large technological capabilities likely become aware of breakthrough innovations by competitors early, and they have the resources to counter with their own radical innovations. They note that General Electric established its well-known research laboratory in 1900 to serve this purpose. GE has survived countless new entrant challenges for over a century since that time. Jiang, Tan, and Thursby (2010) find that incumbents are highly proactive in searching for novel ideas and seeking out alliances with distant partners. They find that incumbents often develop breakthrough innovations early in a product cycle that are well outside of the dominant product design. Hervás-Oliver, Albors-Garrigos, Estelles-Miguel, and Boronat-Moll (2018) note that technology-distant knowledge is a necessary

[14] A 2018 Harvard Business Review study that reviewed 40 years of research on low-impact "disruptive" innovation vs. high-impact "radical" innovation states "While Marc Andreesen expects many industries to be disrupted by software, with new firms overtaking incumbents, technology may at the same time enable the incumbents to radically transform their businesses, especially with new customer-centric business models embedded in product-service-ecosystems. Many examples highlight how radical innovation may help incumbents to insure against disruption." From "What 40 Years of Research Reveals About the Difference Between Disruptive and Radical Innovation" by Christian Hopp, David Antons, Jermain Kaminski, and Torsten Oliver Salge, *Harvard Business Review*, April 9, 2018.

condition for radical innovation, and that new entrants often utilize that knowledge to break into a market. However, they argue that access to leading incumbent's networks are also a necessary condition for the radical innovation to become successful. It is also worth pointing out that these studies do not necessarily suggest that the classic tech life cycle does not occur. Adner and Levinthal (2001) note that while process innovation increases over time as predicted by the tech life cycle theory, product innovation also remains high among dominant industry players.

Taken together, these studies suggest that incumbent firms with the ability to develop radical innovations can successfully deter new entrant challenges. TRIPs are an ideal means for incumbents to pursue the technologically-distant knowledge necessary for this insurance strategy, while also avoiding negative market signals or leakage of their innovative pursuits to weaker rivals. Knowledge of closely related "proximate function" product patents gained via TRIPs would likely spur the production of highly influential and radical innovations.

Table 11 examines whether TRIPs do indeed lead to breakthrough innovations. In Panel A Model (1) we examine the impact of *TRIP* on an indicator variable showing whether a top 5% breakthrough patent was filed by the firm in year (t+1). We use an OLS multivariate regression model following Eq. (2). We lag the dependent variable to avoid effects due to potential persistence in firms' abilities to produce breakthrough patents. We find statistically and economically significant results indicating TRIPs increase breakthrough patent production by almost 6% in the following year.

We test this result using multiple robustness tests in additional models. Because our dependent variable is binary, we substitute a negative binomial regression in Model (2). It is also possible that our results are biased based on sample selection. For that reason, we build a nearest-neighbor propensity score matched sample without replacement using a 0.1 caliper width in Model (3). Even though our primary sample is restricted to only include patenting firms, in Model (4) we limit our sample to innovative industries following Hirshleifer, Low, and Teoh (2012) to reduce the chance that our patent-based TRIP measure introduces biases to our tests. We next add an alternative control for time-invariant firm characteristics. Although in all models thus far we have controlled for persistence in breakthrough patent production ability by lagging the dependent variable, in Model (5) we exclude the lagged dependent variable and add firm fixed effects. We then turn to causality tests to ensure our results are driven by TRIPs by utilizing our local director IVs in a 2SLS model, and we show the second stage results in Model (6). Lastly, although the uniquely innovative states of California and Massachusetts could bias our results (Kong, 2020; Lerner and Seru, 2021), we include firms headquartered in these two states in Model (7) using our baseline OLS model for further robustness.

Through all of these filters, additional controls, and alternative models, we find that our results remain significant. We also repeat these tests in Table 11 Panel B using top 1% breakthrough patent presence as our dependent variable. We find significant results and similar coefficients in all models.

6 Conclusion

The continuous technological improvement of a firm's portfolio of products and processes is a vital and necessary condition for long-term growth and survival, and directors play a key advisory role. However, academic evidence is unclear as to whether tech directors provide detailed assistance with the innovative pursuits of the CEO or simply provide product market information. Innovative development prior to patent filing is highly uncertain and can be appropriated by rival firms given improper leakage of information. In addition, information leakage could reveal setbacks in the firm's innovation stream and deter capital providers. Directors can provide a discrete means for CEOs to obtain assistance on struggling innovative pursuits or explore new strategic directions. In this study, we propose the *tech collaboration hypothesis* which argues that the close relationships many directors build with their CEOs, along with their fiduciary responsibilities helping to ensure an environment of trust, work to provide the CEO confidence in sharing closely-held proprietary information about their innovations.

We find that the presence of directors from non-product market firms that perform similar technological functions (TRIPs) generate a significant positive impact on firm valuation. Specifically, we find that the introduction of these innovative ideas to an unrelated product market via TRIP directors leads to a 7% increase in firm value. Our findings persist through numerous robustness and endogeneity tests, including propensity score matching and two-stage least squares regressions using instrumental variables based on local labor markets.

Our results also show that TRIPs are most prevalent among dominant industry incumbents in concentrated industries. TRIPs are more effective at bolstering firm value when 1) incumbents come under significant pressure from new entrants to their product markets, and 2) dynamic and turbulent changes are affecting firm survival and employment within their industry. TRIPs help introduce cost-saving process innovations and novel product-related ideas that lead to higher probabilities of breakthrough patents. Our study contributes to existing research on the advisory role of directors, the tech spillover and "paradox of openness" literatures, and the product / tech life cycle literature.

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Appendix A: Anecdotal Examples of TRIP Usage[15]

- "For example, a director of a traditional operations-focused company reported seeking board members with experience leading exceptional customer-service-oriented companies. *Tom Wilson, the CEO of Allstate, pointed out that it was a board member from the manufacturing sector working with OEMs and some of the hot start-ups in the connected car space who was able to offer unique insights into consumer behavior*." (Source: "The Board's New Innovation Imperative" by Linda A. Hill and George Davis, *Harvard Business Review*, November-December 2017).

- "Together with management, directors must look ahead three to five years to *find trends in their industry, and in adjacent industries, that may spawn new disruptions and unleash new types of challengers*… Boards are in a unique position to help their companies redefine the future through pre-emptive innovation." (Source: "Leading Boards Rethinking Strategy and Enabling Innovation" by Steve Klemash and Kris Pederson, *Harvard Law School Forum on Corporate Governance*, February 9, 2020).

- "Forward-thinking companies actively develop … a shared set of assumptions about where their industry and markets are going so that they are prepared to make the right risk/reward judgment calls together with management. *Nearly half of the directors we spoke with bring in experts from different or adjacent industries to hold "master classes"*. …. Directors reported that all these activities prompt important discussions about their appetite for innovation by exposing them to "next practices," not just best practices." (Source: "The Board's New Innovation Imperative" by Linda A. Hill and George Davis, *Harvard Business Review*, November-December 2017).

[15] Italics added for emphasis.

Appendix B: Variable Descriptions

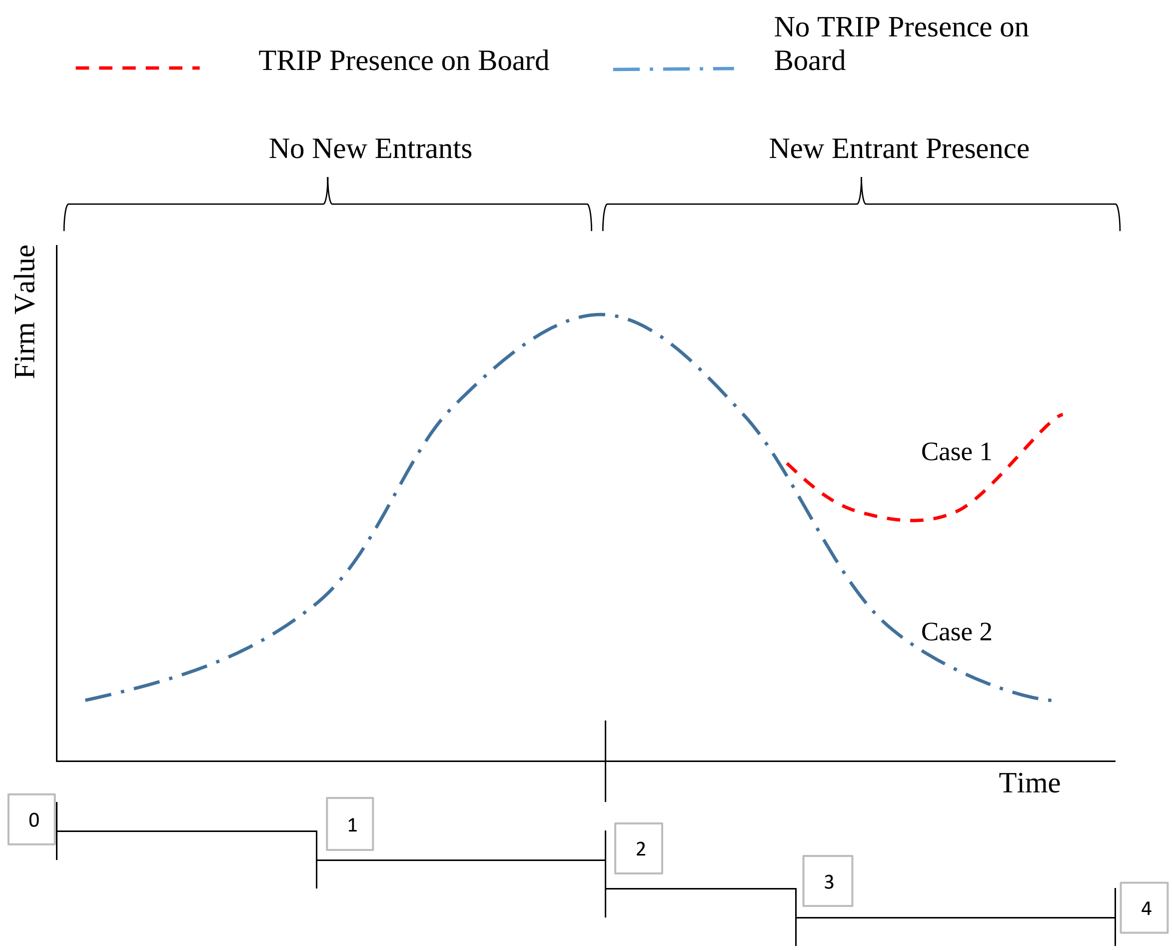
Technology Related Industry Pair (TRIP) Variables	
TRIP	Equals 1 if at least one of the firm's directors has two board seats that share a tech related industry (TRI) connection between their firms, zero otherwise. A TRI connection exists where each firm has over 5% of their current and prior 4-year stock of patent filings in the same USPC patent class. TRI connections are excluded where four-digit SIC codes match between firms, where either director is classified as linked in ISS Riskmetrics (i.e., they may have product market connections with the firm), or where patent stock does not contain at least one process-based patent claim as defined by Bena, Ortiz-Molina, and Simintzi (2021). Calculated for patenting firms.
Local Pairs	Percentage of directors within a 100 mile radius of the focal firm who have a TRI connection (at least 5% of patents filed within the current and prior four years at both firms are in the same patent industry classification) between any of their directorships (ie., the focal firm or other outside firms), while at the same time at least one of their directorship firms has a TRI connection with the focal firm. Calculated from all firms, not just patenting firms.
Local Direct Connection Pairs	Percentage of directors within a 60 mile radius of the focal firm who have a TRI connection (at least 5% of patents filed within the current and prior four years at both firms are in the same patent industry classification) directly with the focal firm, weighted by the ratio of process claims to non-process claims in their patent stock using process claim data from Bena, Ortiz-Molina, and Simintzi (2021). Calculated from all firms, not just patenting firms.

Dependent and Control Variables	
Tobin's Q	Log of equity market value plus liabilities market value of the firm divided by replacement cost (total assets). Compustat variables (((csho*prcc_f) - ceq + at)/at). *Source: Compustat*
BP Tobin's Q	Log of equity market value plus liabilities market value of the firm without scaling by total assets. *Source: CRSP and Compustat following Bartlett and Partnoy (2020)*
M/B Ratio	Log of market capitalization of the firm ((prc*shrout) / total assets (at)) measured at the end of fiscal year t. *Source: CRSP*, *Compustat*
Total Assets	Log of total assets (at). *Source: Compustat*
Tangibility	[PP&E net total (ppent)/Total assets (at)] per fiscal year. *Source: Compustat*
Book Leverage	Log of (Long-term debt (dltt) plus debt in current liabilities(dlc)) / Total assets (at)) measured at the end of fiscal year t. *Source: Compustat*
Volatility	Log of standard deviation of monthly stock returns over the past fiscal year. *Source: CRSP*
CEO-Chair	Equals one if the CEO is also Chairman of the Board; zero otherwise. *Source: ISS Riskmetrics*
Board Size	Annual count of the total number of directors on the board. *Source: ISS Riskmetrics*
% Outside Dirs	Annual count of outside directors divided by the total directors. *Source: ISS Riskmetrics*
R&D	Log of annual research and development expenditures (with missing values set to zero), scaled by total revenue. *Source: Compustat*
Return on Assets	Net Income/Book Assets: ni/at. *Source: Compustat*

Miscellaneous Variables	
Firm Patent Filings	Log of total annual number of patent filings per firm. *Source: PatentsView and Noah Stoffman's Patent Database.*
Firm Process Innovation %	Percentage of claims on patent filings in years (t-4 to t) that are identified as process claims by Bena, Ortiz-Molina, and Simintzi (2021).
WW Index	Financial constraints index following Whited and Wu (2006) models. *Source: Compustat*
KZ Index	Financial constraints index following Kaplan and Zingales (1997) models. *Source: Compustat*
SA Index	Financial constraints index following Hadlock and Pierce (2010) models. *Source: Compustat*
Breakthrough Patent 1% (5%) Level	Equals 1 if firm-year has at least one patent in the top 1% (5%) of total future external citations from patents filed that year, scaled by the year-to-year "deflate" method of Hall, Jaffe, and Trajtenberg (2001).
Ind Comp Power	Log of the measure of firm competitive power within a fixed-industry classification (FIC) based on a Herfindahl-type index developed by Hoberg and Phillips (2016).
EntryEx Volatility	Sum of the absolute value of the percentage change in public and private firm births and deaths over the surrounding seven-year period. Calculated per four-digit NAICS code based on census data. *Source: Small Business Administration (SBA), Billett, Garfinkel, and Yu (2017).*
Employ Volatility	Sum of the absolute value of the percentage change in public and private firm employment expansion and contraction over the surrounding seven-year period. Calculated per four-digit NAICS code based on census data. *Source: Small Business Administration (SBA), Billett, Garfinkel, and Yu (2017).*
Average Board Attendance %	Percentage of directors attending board meetings during the fiscal year. *Source: ISS Riskmetrics*
Director Age	Average age of directors on the board during the fiscal year. *Source: ISS Riskmetrics*
Director Tenure	Average tenure of directors on the board during the fiscal year. *Source: ISS Riskmetrics*
Outside CEOs (%)	Total number of outside directors that are also another firm's CEO, divided by the total number of outside board members in a given year. *Source: ISS RiskMetrics*

Figure 1. Product Life Cycle and TRIP Usage by Incumbents

This figure details the sequence of events affecting firm value for a firm that was a new entrant in the previous cycle and is a dominant incumbent firm in the current cycle. The figure is based off of the timeline of events as described by the product life cycle literature (e.g., Abernathy and Utterback, 1978; Klepper, 1996; Chandy and Tellis, 2000; Hill and Rothaermel, 2003), with (t=0) representing the start of the cycle, and (t=4) representing the end of the cycle. The curve simulates the change in value for an incumbent firm over the cycle. Estimates of the impact of TRIPs based on the *tech collaboration hypothesis* are given for period (t=3) to (t=4). In Case 1 at (t=3), CEOs make the decision to utilize TRIPs. In Case 2 at (t=3), CEOs choose not to utilize TRIPs.



0-1 Entrants from previous cycle gain market share, force out weak competitors, and dominate industry.

1 Dominant firms become complacent, focus on lower value incremental innovation, and raise prices.

2 New entrants arrive with lower prices or radical new product innovations. Industry more volatile.

2-3 Industry becomes more volatile as incumbents are forced to lower prices or invest in new innovation. Financial constraints increase. Incumbents increase layoffs while new entrants hire.

3 CEOs decide whether to seek innovative assistance through TRIP directors.

3-4 CASE 1: CEOs use TRIPs, develop process and breakthrough innovations, and prevent information leakage. This helps them avoid appropriation by competitors and it prevents increases in the cost of capital. Firm value begins to increase.

3-4 CASE 2: CEOs do not use TRIPs. They either do not innovate for fear of appropriation, focus on lower value incremental innovation, or pursue radical innovation through a less secure innovation channel. Competitors appropriate their ideas, and costs of capital increase due to risk concerns among investors. Firm value stagnates or declines.

Table 1. Summary Statistics

This table reports the descriptive statistics for firms that 1) recorded at least one patent filing during our sample period and 2) contain board of director data in ISS Riskmetrics. The full sample consists of 12,596 firm-year observations between fiscal year 1996 and 2013. All variables are described in Appendix B.

Variables	N	Mean	Std. Dev	5% Perc.	Median	95% Perc.
TRIP (%)	12,596	14.16	34.86	0.00	0.00	1.00
Local Pairs (%)	12,596	0.94	1.69	0.00	0.00	5.23
Local Direct Connection Pairs (%)	12,486	0.83	1.87	0.00	0.00	4.67
Tobin's Q	12,591	2.04	1.74	0.95	1.57	4.54
BP Tobin's Q	12,591	20,786.56	85,592.60	297.86	2,961.15	78,623.28
M/B Ratio	12,395	3.76	15.46	0.76	2.25	8.78
Total Assets	12,596	14,447.38	76,805.34	181.23	1,659.81	44,145.10
Tangibility	12,596	0.25	0.21	0.03	191.00	0.70
Book Leverage	12,596	0.52	0.23	0.15	0.53	0.90
Volatility	12,596	0.12	0.07	0.04	0.10	0.25
CEO-Chair	12,596	0.62	0.49	0.00	1.00	1.00
Board Size	12,596	9.27	2.61	6.00	9.00	14.00
% Outside Dirs	12,596	0.71	0.17	0.38	0.75	0.91
R&D	12,596	0.11	2.22	0.00	0.01	0.25
Return on Assets	12,596	0.03	0.20	-0.14	0.05	0.16
Firm Patent Filings	12,596	35.84	191.12	0.00	2.00	139.00
Firm Process Innovation (%)	12,596	20.59	23.40	0.00	12.50	63.89
WW Index	12,532	-0.24	1.29	-0.51	-0.33	0.13
KZ Index	11,348	-0.75	18.76	-12.42	0.68	8.60
SA Index	12,596	-3.98	0.55	-4.64	-3.98	-3.11
Breakthrough Patent - 5% level (%)	12,596	0.25	0.43	0.00	0.00	1.00
Breakthrough Patent - 1% level (%)	12,596	0.10	0.31	0.00	0.00	1.00
Industry Competitive Power	12,488	573.13	1,618.48	0.03	9.44	3,857.13
Firm Entry / Exit Volatility	4,797	-0.13	0.32	-0.72	-0.14	0.42
Firm Employment Volatility	4,797	-0.04	0.22	-0.39	-0.05	0.34
Average Board Attendance (%)	12,596	98.51	4.50	88.89	100.00	100.00
Director Age	12,596	60.15	4.31	52.60	60.40	66.60
Director Tenure	11,764	8.66	5.15	3.33	8.09	15.80
Outside CEOs (%)	12,596	12.60	16.76	0.00	0.00	50.00

Table 2. TRIP Directors Across Industries

This table presents descriptive statistics for the prevalence of TRIP directors per firm-year across industry and time. Panel A splits the sample by Fama French 12 industry classifications. Panel B presents a double sort by industry and time, splitting the sample 1) into two equal nine-year periods based on the range of our sample from 1996-2013, and 2) into non-innovative and innovative industries following Hirshleifer, Low, and Teoh (2012). Both panels present 1) the number of sample observations for that industry and 2) the average number of firm-year observations with a TRIP director present on the board.

Panel A. TRIP Presence per Fama French 12 Industry	N	Mean		N	Mean
1) Consumer Nondurables (Food, Textile)	863	0.090	7) Telephone and Television Transmission	270	0.174
2) Consumer Durables (Cars, Furniture)	522	0.121	8) Utilities	553	0.049
3) Manufacturing (Machinery, Trucks)	2,305	0.115	9) Wholesale, Retail, and Some Services	945	0.083
4) Oil, Gas, and Coal Extraction and Products	487	0.170	10) Healthcare, Medical Equipment, and Drugs	1,269	0.180
5) Chemicals and Allied Products	548	0.257	11) Financials	593	0.170
6) Business Equipment - Computers, Software	3,140	0.178	12) Other - Mines, Trans, Hotels, Entertainment	1,100	0.103

Panel B: TRIP Director Presence in Innovative Industries over Time		1996-2004	2005-2013	*Total*
Non-Innovative Industry (% TRIP)		0.179	0.106	0.139
	Obs	*2,408*	*2,938*	*5,346*
Innovative Industry (% TRIP)		0.145	0.142	0.144
	Obs	*4,406*	*2,844*	*7,250*
Total		0.157	0.123	0.141
	Obs	*6,814*	*5,782*	*12,596*

Table 3. TRIP Director Presence and Firm Value

This table examines the relationship between firms with a TRIP director on their board and firm valuation using OLS modeling. Model (1) includes *Tobin's Q* as the dependent variable and excludes firms headquartered in California and Massachusetts. Model (2) repeats model (1), including firms headquartered in all 50 states. Model (3) repeats model (1) using the controls from Eq. (2) to create a nearest-neighbor propensity score matched (PSM) sample, without replacement, and with a 0.1 caliper width. Models (4) and (5) repeat model (1), substituting *BP Tobin's Q* and *M/B Ratio* as the dependent variables, respectively. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. Two-digit SIC industry, year, and state fixed effects are applied as specified. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively.

	CA and MA Excluded	All States Included	PSM Sample	Alternative Valuation Measures	
	Tobin's Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*BP Tobin's* Q_{t+1}	*M/B Ratio*$_{t+1}$
Variables	(1)	(2)	(3)	(4)	(5)
TRIP$_t$	0.068***	0.048**	0.069***	0.062**	0.078**
	(0.003)	(0.012)	(0.007)	(0.016)	(0.029)
Total Assets$_t$	-0.012	-0.007	0.001	0.980***	-0.012
	(0.142)	(0.349)	(0.913)	(0.000)	(0.368)
Tangibility$_t$	-0.152**	-0.102*	-0.192**	-0.158**	-0.203*
	(0.015)	(0.086)	(0.046)	(0.017)	(0.065)
Book Leverage$_t$	0.029	0.040	-0.103	-0.002	1.155***
	(0.647)	(0.484)	(0.342)	(0.972)	(0.000)
Volatility$_t$	-0.215*	-0.093	-0.273	-0.258*	-0.378
	(0.089)	(0.416)	(0.232)	(0.087)	(0.129)
CEO-Chair$_t$	0.009	-0.006	-0.003	0.015	-0.003
	(0.539)	(0.642)	(0.921)	(0.330)	(0.905)
Board Size$_t$	-0.042	-0.062	-0.092	-0.061	-0.030
	(0.304)	(0.120)	(0.215)	(0.171)	(0.680)
% Outside Dirs$_t$	-0.028	0.009	-0.153	-0.062	0.181*
	(0.591)	(0.854)	(0.108)	(0.277)	(0.066)
R&D$_t$	1.604***	1.318***	1.508***	1.763***	2.453***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Return on Assets$_t$	2.008***	1.746***	2.098***	2.601***	3.219***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SIC2D FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
State FE	No	Yes	No	No	No
Obs	9,428	12,041	2,155	9,428	9,296
R-squared	0.374	0.368	0.425	0.935	0.310

Table 4. Direct Influence of TRIPs on Firm Value

This table examines the impact of TRIP board presence on firm value in multivariate OLS models following Eq. (2) given varying TRIP characteristics. The dependent variable in all models is *Tobin's Q* in year (t+1). Panel A examines the relationship between specific board-level TRIP characteristics and Tobin's Q, excluding the TRIP firm-year observations that do not exhibit that characteristic. Characteristics are averaged for all TRIPs if multiple TRIPs are present on the board that year. Models (1) and (2) examine TRIP impact on firm value in high or low quantiles by their raw age. Models (3) and (4) repeat models (1) and (2) and split the sample by the ratio of TRIP ages with the age of the entire board. Models (5-8) repeat models (1-4), substituting TRIP tenure and board tenure for TRIP and board age. The Benchmark Coefficient is produced from the relationship between TRIP board presence and *Tobin's Q* in year (t+1) for the full sample without any exclusions, following Eq. (2). Panel B Model (1) examines the full sample relationship between TRIPs and firm value for TRIPs that have not experienced absenteeism over 75% for board meetings that year. Model (2) repeats Model (1) but performs a within-sample analysis considering only firm-year observations in which a TRIP is present on the board. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. Controls, industry, and year fixed effects are applied in all models following Eq. (2), p-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively.

					Performance vs. Full Sample		
Panel A. TRIP Characteristics		Coeff	P-value	Obs	Bench Coeff	Pred	Actual
TRIP Age - Low	(1)	0.116***	(0.000)	8,913	0.068***	+	+
TRIP Age - High	(2)	0.019	(0.465)	8,926	0.068***	-	-
TRIP Age Ratio ≤ 1	(3)	0.086***	(0.003)	8,913	0.068***	+	+
TRIP Age Ratio > 1	(4)	0.048	(0.123)	8,926	0.068***	-	-
TRIP Tenure - Low	(5)	0.072**	(0.012)	8,932	0.068***	+	+
TRIP Tenure - High	(6)	0.062**	(0.030)	8,907	0.068***	-	-
TRIP Tenure Ratio ≤ 1	(7)	0.083***	(0.005)	8,916	0.068***	+	+
TRIP Tenure Ratio > 1	(8)	0.051*	(0.057)	8,923	0.068***	-	-

Panel B. TRIP Motivation		Coeff	P-value	Obs
TRIP Attendance - Full Sample	(1)	0.074***	(0.001)	9,428
TRIP Attendance - Within Sample	(2)	0.223**	(0.016)	1,015

Table 5. Identification - Instrumental Variables Approach

This table addresses endogeneity between TRIP director presence and firm value using two-stage least squares (2SLS) regressions. Panel A Model (1) reports the first-stage regression results with *TRIP* as the dependent variable using two instruments as the key independent variables. *Local Pairs* identifies directors within a 100 mile radius of the focal firm who have a TRI connection (at least 5% of patents filed within the current and prior four years at both firms are in the same patent industry classification) with any of their other directorships (ie., the focal firm or other outside firms), while at the same time at least one of their directorship firms has a TRI connection with the focal firm. *Local Direct Connection Pairs* identifies directors within a 60 mile radius of the focal firm who have a TRI connection directly with the focal firm, weighted by the ratio of process claims to non-process claims in their patent stock using process claim data from Bena, Ortiz-Molina, and Simintzi (2021). Models (2) through (4) use *Instrumented TRIP* (the predicted probability of a TRIP director being on the board) from the first-stage regression as an independent variable and repeat the regressions for the three main firm value variables from Eq. (2). Controls, two-digit SIC industry, and year fixed effects are applied as specified. Panel B repeats Panel A models (1) and (2) showing the second stage using alternative combinations of fixed effects for innovative industries (Hirshleifer, Low, and Teoh, 2012). Singleton observations (shown for the 1st stage in Panel B) are excluded in both stages for both panels (Correia, 2015). Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. ‡‡ and ‡ denote Stock-Yogo critical values of maximal relative bias of 19.93 (10%) and 11.59 (15%) , respectively, for weak identification. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively.

	1st Stage - IV	2nd Stage - IV		
Panel A: 2SLS Regressions on Innovation Measures	*TRIP $_t$*	*Tobin's Q_{t+1}*	*BP Tobin's Q_{t+1}*	*M/B $Ratio_{t+1}$*
	(1)	(2)	(3)	(4)
Local Pairs $_t$	3.484*** (0.000)			
Local Dir Con Pairs $_t$	5.916*** (0.000)			
Instr TRIP $_t$		0.298*** (0.001)	0.280*** (0.003)	0.351** (0.019)
Controls	Yes	Yes	Yes	Yes
Ind/Yr FE	Yes	Yes	Yes	Yes
Obs	9,325	9,325	9,325	9,197
R-squared	0.184	0.359	0.935	0.307
Kleibergen-Paap LM Statistic	*110.163****			
Kleibergen-Paap F Statistic	*63.678‡‡*			
Hansen's J (p-value)		*0.263*	*0.105*	*0.137*

Panel B: Robustness - Innovative Industries and Fixed Effects	Dependent Variable				
	Tobin's Q_{t+1}	*Tobin's Q_{t+1}*	*Tobin's Q_{t+1}*	*Tobin's Q_{t+1}*	*Tobin's Q_{t+1}*
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Instr Trip $_t$	0.421***	0.149*	0.149*	0.216**	0.216**
	(0.001)	(0.090)	(0.084)	(0.020)	(0.021)
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	No	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	No	No
County FE	No	Yes	No	No	No
State FE	No	No	Yes	No	Yes
SIC2D-Year FE	Yes	No	No	Yes	Yes
State-Year FE	Yes	No	No	No	No
Obs	4,653	4,750	4,772	4,594	4,594
1st Stage Singleton Obs	*222*	*106*	*107*	*280*	*280*
Adj Rsq	0.330	0.695	0.709	0.743	0.740

Table 6. TRIP Importance for Powerful Industry Incumbents

This table examines the relationship between TRIP directors and firm value using multivariate regressions following Eq. (2) given a firm's competitive power within its industry. Panel A splits the sample annually into high and low quantiles based on the Hoberg and Phillips (2016) measure of firm competitive power within a fixed-industry classification (FIC) based on a Herfindahl-type index. The dependent variable is *Tobin's Q* in models (1) and (3), and *M/B Ratio* in models (2) and (4). Models (1) and (2) use ordinary least squares regressions, while models (3) and (4) report the second stage of two-stage least squares regressions. Panel B interacts the presence of a TRIP director on the board (*TRIP* and *Instr TRIP*) with firm competitive power. The dependent variable is *Tobin's Q* in models (1) and (3), and *M/B Ratio* in models (2) and (4). Models (1) and (2) use ordinary least squares regressions, while models (3) and (4) report the second stage of two-stage least squares regressions. Controls, industry, and year fixed effects are applied in both panels following Eq. (2). Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively (‡ represents significance at the 15% level for the Wald statistic only).

Panel A. Subsample Tests by Quantiles of Industry Competitive Power (Hoberg and Phillips, 2016)	OLS		2SLS	
	Tobin's Q$_{t+1}$	*M/B Ratio*$_{t+1}$	*Tobin's Q*$_{t+1}$	*M/B Ratio*$_{t+1}$
	(1)	(2)	(3)	(4)
Low Industry Competitive Power	0.019	0.006	0.144	0.154
	(0.581)	(0.910)	(0.188)	(0.433)
High Industry Competitive Power	0.080***	0.093**	0.388***	0.438**
	(0.002)	(0.027)	(0.001)	(0.030)
Wald Statistic	2.28‡	1.95	2.65‡	1.10
Controls	Yes	Yes	Yes	Yes
Ind/Yr FE	Yes	Yes	Yes	Yes

Panel B: Interaction of TRIP with Industry Competitive Power (Hoberg and Phillips, 2016)	*Tobin's Q_{t+1}*	*M/B $Ratio_{t+1}$*	*Tobin's Q_{t+1}*	*M/B $Ratio_{t+1}$*
	OLS		*2SLS*	
	(1)	(2)	(3)	(4)
$TRIP_t$	-0.003	-0.059		
	(0.929)	(0.256)		
Instr $TRIP_t$			(0.105)	(-0.018)
			(0.330)	(0.921)
Comp Power $_t$	0.017***	0.026***	0.013***	0.020**
	(0.000)	(0.000)	(0.001)	(0.010)
Comp Power x TRIP $_t$	0.016**	0033***		
	(0.024)	(0.002)		
Comp Power x Instr TRIP $_t$			0.048**	0.095**
			(0.030)	(0.012)
Controls	Yes	Yes	Yes	Yes
Ind/Yr FE	Yes	Yes	Yes	Yes
Obs	9,327	9,199	9,225	9,101
R-squared	0.384	0.320	0.386	0.323

Table 7. Incumbent Firms and the Influence of Product Life Cycle Effects

This table examines the relationship between incumbent firms, the usage of TRIPs, and moderating effects on TRIP usage. Panel A presents univariate OLS regressions of firm competitive power, industry volatility, and financial constraints on TRIP presence in a firm. Models (1), (3), and (4) use *TRIP* as the dependent variable, while Model (2) uses the instrumented TRIP measure. Model (3) includes firms headquartered in all states, while models (1), (2), and (4) exclude firms headquartered in California and Massachusetts. Two-digit SIC industry, year, and state fixed effects are applied as specified. Panel B examines the impact of TRIP presence on firm value following Eq. (2) within double-sorted subsamples by firm competitive power (*CompPower*) and industry volatility (*EntryExVol*). Models (1-4) sort by quantiles of *CompPower* and *EntryExVol* into (low, low), (low,high), (high, low), and (high, high) groups, respectively. Models (5-8) repeat these sorts in the same order. Models (9-16) perform similar sorts, using the bottom two quintiles as the low group and the top three quintiles as the high group. Models (1-4) use OLS regressions, while models (5-8) report the second stage of 2SLS regressions using the instrumented TRIP variable from Table 5 Panel A Model (2). Panel C and D repeat Panel B, replacing the sort variable *ExtryExVol* with *EmployVol* and *WWIndex*, respectively. Wald statistics represent the coefficient differences between (high, high) and (low, low) groups, and two-digit SIC industry and year fixed effects are applied as specified in Panels B through D. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively.

	CA and MA Excluded	CA and MA Excluded	All States Included	CA and MA Excluded
	$TRIP_t$	*Instr $TRIP_t$*	*$TRIP_t$*	*$TRIP_t$*
Panel A: Univariate Analysis	(1)	(2)	(3)	(4)
$CompPower_t$	0.014***	0.012***	0.013***	0.012***
	(0.000)	(0.000)	(0.000)	(0.000)
$EntryExVol_t$				-0.018
				(0.630)
$WW\ Index_t$				-0.040*
				(0.074)
SIC2D FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
State FE	No	No	Yes	No
Obs	10,956	10,716	14,122	3,624
R-squared	0.064	0.317	0.081	0.072

Panel B. Double Sort: *CompPower x EntryExVol*	OLS (Baseline Model)				2SLS (IV Model)			
Double Sort - Quantiles	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$TRIP_t$	-0.079 (0.133)	0.135* (0.081)	0.013 (0.786)	0.126*** (0.001)				
Instr $TRIP_t$					-0.007 (0.964)	-0.061 (0.775)	-0.077 (0.633)	0.569*** (0.000)
Wald Stat (High - Low)	10.88***				7.26***			
Double Sort - Quintiles	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
$TRIP_t$	-0.128** (0.034)	0.093 (0.248)	0.063 (0.205)	0.104*** (0.002)				
Instr $TRIP_t$					-0.102 (0.561)	-0.035 (0.873)	-0.085 (0.633)	0.391*** (0.004)
Wald Stat (High - Low)	12.28***				5.40**			

Panel C. Double Sort: *CompPower x EmployVol*	OLS (Baseline Model)				2SLS (IV Model)			
Double Sort - Quantiles	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$TRIP_t$	-0.032 (0.566)	0.084 (0.246)	0.016 (0.693)	0.107*** (0.003)				
Instr $TRIP_t$					0.005 (0.976)	-0.063 (0.759)	-0.144 (0.363)	0.567*** (0.000)
Wald Stat (High - Low)	4.79**				6.80***			
Double Sort - Quintiles	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
$TRIP_t$	-0.095 (0.162)	0.052 (0.479)	0.024 (0.546)	0.112*** (0.001)				
Instr $TRIP_t$					-0.055 (0.781)	-0.040 (0.852)	-0.092 (0.580)	0.378*** (0.007)
Wald Stat (High - Low)	7.98***				3.47*			

Panel D. Double Sort: *CompPower x WWIndex*	OLS (Baseline Model)				2SLS (IV Model)			
Double Sort - Quantiles	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$TRIP_t$	-0.008 (0.799)	0.045 (0.366)	0.043* (0.091)	0.139*** (0.009)				
Instr $TRIP_t$					0.054 (0.638)	0.181 (0.214)	0.155 (0.223)	0.700*** (0.000)
Wald Stat (High - Low)	6.05**				10.25***			
Double Sort - Quintiles	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
$TRIP_t$	-0.061** (0.029)	0.025 (0.574)	0.049** (0.045)	0.131*** (0.003)				
Instr $TRIP_t$					-0.055 (0.691)	0.142 (0.333)	0.169 (0.178)	0.542*** (0.000)
Wald Stat (High - Low)	14.91***				9.46***			

Table 8. Industry Competitor Presence and Employment Volatility

This table examines the relationship between TRIP directors and firm value using multivariate regressions following Eq. (2) given the volatility of competitor presence and employment within its industry. Panel A models (1-8) split the sample annually into high and low quantiles based on the sum of the absolute value of the percentage change in public and private firm births and deaths over the surrounding seven-year period per four-digit NAICS code based on census data from the Small Business Administration (SBA). Panel A models (9-16) split the sample annually into high and low quantiles based on the sum of the absolute value of the percentage change in public and private firm employment over the surrounding seven-year period per four-digit NAICS code based on census data from the SBA. Models (1-4) and (9-12) utilize the dependent variable *Tobin's Q* at (t+1), while models (5-8) and (13-16) utilize *Tobin's Q* at (t+4). Models (1-2), (5-6), (11-12), and (15-16) use ordinary least squares regressions, while models (3-4), (7-8), (11-12), and (15-16) report the second stage of two-stage least squares regressions. Panel B interacts the presence of a TRIP director on the board (*TRIP* and *Instr TRIP*) with the volatility of competitor presence and employment. The dependent variable is *Tobin's Q*. Models (1-2) and (4-5) use ordinary least squares regressions, while models (3) and (6) report the second stage of two-stage least squares regressions. Controls, industry, and year fixed effects are applied in both panels following Eq. (2), with additional fixed effects applied as specified. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively (‡ represents significance at the 15% level for the Wald statistic only).

Panel A: Subsamples by Volatility of Firm Entry and Exit

Volatility of Firm Entry and Exit Within an Industry			Coeff	P-value	Wald Statistic	Obs	R-sq
OLS $_{t+1}$	*Low*	(1)	-0.020	(0.592)	11.08***	1,637	0.389
OLS $_{t+1}$	*High*	(2)	0.141***	(0.000)		1,691	0.456
2SLS $_{t+1}$	*Low*	(3)	0.005	(0.968)	3.29*	1,618	0.390
2SLS $_{t+1}$	*High*	(4)	0.313**	(0.024)		1,682	0.454
OLS $_{t+4}$	*Low*	(5)	0.002	(0.967)	1.38	1,378	0.387
OLS $_{t+4}$	*High*	(6)	0.071*	(0.089)		1,392	0.383
2SLS $_{t+4}$	*Low*	(7)	0.161	(0.312)	1.07	1,361	0.389
2SLS $_{t+4}$	*High*	(8)	0.385**	(0.016)		1,383	0.389
Volatility of Firm Employment Within an Industry			**Coeff**	**P-value**	**Wald Statistic**	**Obs**	**R-sq**
OLS $_{t+1}$	*Low*	(9)	0.007	(0.839)	4.23**	1,664	0.396
OLS $_{t+1}$	*High*	(10)	0.102***	(0.004)		1,664	0.464
2SLS $_{t+1}$	*Low*	(11)	-0.003	(0.979)	2.48‡	1,649	0.396
2SLS $_{t+1}$	*High*	(12)	0.266*	(0.060)		1,651	0.465
OLS $_{t+4}$	*Low*	(13)	-0.011	(0.810)	2.01	1,406	0.357
OLS $_{t+4}$	*High*	(14)	0.068*	(0.079)		1,364	0.417
2SLS $_{t+4}$	*Low*	(15)	0.089	(0.551)	2.25‡	1,391	0.358
2SLS $_{t+4}$	*High*	(16)	0.414**	(0.013)		1,353	0.425

Panel B: Interaction of TRIP Measures with Industry Volatility	Industry Entry and Exit Volatility			Industry Employment Volatility		
	Tobin's Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}
	OLS	*OLS*	*2SLS*	*OLS*	*OLS*	*2SLS*
	(1)	(2)	(3)	(4)	(5)	(6)
$TRIP_t$	0.083*** (0.005)	0.084*** (0.003)		0.072** (0.010)	0.073*** (0.007)	0.184* (0.083)
$Instr\ TRIP_t$			0.190* (0.072)			
$EntryExVol_t$	-0.020 (0.507)	-0.023 (0.438)	-0.016 (0.593)			
$EntryExVol \times TRIP_t$	0.161** (0.039)	0.170** (0.030)				
$EntryExVol \times Instr\ TRIP_t$			0.115 (0.122)			
$EmployVol_t$				-0.022 (0.667)	-0.027 (0.586)	-0.021 (0.671)
$EmployVol \times TRIP_t$				0.191* (0.086)	0.232** (0.033)	
$EmployVol \times Instr\ TRIP_t$						0.201* (0.067)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
SIC2D FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	No	Yes	Yes	No	Yes	Yes
Obs	3,328	3,328	3,300	3,328	3,328	3,300
R-squared	0.415	0.434	0.434	0.415	0.434	0.435

Table 9. Impact of TRIP on Firm Value in Financially Constrained Firms

This table examines the relationship between TRIP directors and firm value using multivariate analysis following Eq. (2) given the presence of financial constraints. Panel A splits the sample annually into high and low financial constraints quantiles based on 1) the WW Index of Whited and Wu (2006), 2) the KZ Index of Kaplan and Zingales (1997), and 3) the SA index of Hadlock and Pierce (2010). The dependent variable is *Tobin's Q* in all models. Models (1-2), (5-6), and (9-10) utilize ordinary least squares (OLS) regressions, while models (3-4), (7-8), and (11-12) report the second stage of two-stage least squares (2SLS) regressions. Panel B interacts the presence of a TRIP director on the board (*TRIP* and *Instr TRIP*) with the WW Index of financial constraints. Models (1-4) exclude the unique innovative states of California and Massachusetts, while models (5-7) include all states. All models use *Tobin's Q* as the dependent variable except for Model (7) which uses M/B Ratio. Models (1, 4-7) use OLS regressions, while Model (2) uses the controls from Eq. (2) to create a nearest-neighbor propensity score matched (PSM) sample, without replacement, and with a 0.1 caliper width. Model (3) reports the second stage using 2SLS regression modeling. Controls, industry, and year fixed effects are applied in both panels following Eq. (2), with alternative fixed effects applied in Panel B as specified. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively (‡ represents significance at the 15% level for the Wald statistic only).

Panel A: Subsamples by Financial Constraints

WW Index			Coeff	P-value	Wald Statistic	Obs	R-sq
OLS	*Low*	(1)	0.034	(0.128)	2.89*	4,710	0.488
OLS	*High*	(2)	0.107***	(0.006)		4,677	0.322
2SLS	*Low*	(3)	0.114	(0.267)	4.11**	4,643	0.495
2SLS	*High*	(4)	0.411***	(0.001)		4,641	0.323

KZ Index			Coeff	P-value	Wald Statistic	Obs	R-sq
OLS	*Low*	(5)	0.058**	(0.021)	1.75	4,265	0.415
OLS	*High*	(6)	0.116***	(0.003)		4,255	0.411
2SLS	*Low*	(7)	0.214*	(0.072)	0.27	4,207	0.414
2SLS	*High*	(8)	0.289***	(0.016)		4,211	0.412

SA Index			Coeff	P-value	Wald Statistic	Obs	R-sq
OLS	*Low*	(9)	0.029	(0.231)	0.69	4,741	0.460
OLS	*High*	(10)	0.064*	(0.087)		4,687	0.344
2SLS	*Low*	(11)	0.166	(0.183)	0.54	4,687	0.464
2SLS	*High*	(12)	0.285**	(0.010)		4,638	0.345

Panel B: Interaction of TRIP Measures with Whited-Wu Financial Constraints	CA and MA Excluded				All States Included		
	Tobin's Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*M/B* $Ratio_{t+1}$
	OLS	*PSM*	*2SLS*	*OLS*	*OLS*	*OLS*	*OLS*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$TRIP_t$	0.107*** (0.001)	0.123*** (0.003)		0.091*** (0.002)	0.084*** (0.000)	0.075*** (0.002)	0.082** (0.011)
Instr $TRIP_t$			0.316*** (0.003)				
WW Index $_t$	0.010 (0.670)	-0.016 (0.757)	0.017 (0.604)	-0.029 (0.124)	-0.016 (0.362)	-0.013 (0.437)	0.001 (0.969)
WW Index x TRIP $_t$	0.125** (0.047)	0.168** (0.037)		0.120** (0.034)	0.123** (0.011)	0.115** (0.017)	0.122* (0.089)
WW Index x Instr TRIP $_t$			0.072 (0.672)				
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SIC2D FE	Yes	Yes	Yes	No	No	No	No
SIC3D FE	No	No	No	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	No	No	No	Yes	No	Yes	No
Obs	9,390	2,145	9,287	9,389	11,981	11,981	11,825
R-squared	0.373	0.424	0.374	0.478	0.427	0.441	0.377

Table 10. TRIP Influence on Process Innovation

This table examines the relationship between TRIP directors and process-oriented patents. The models examine the relationship between the presence of a TRIP director on the board (*TRIP* and *Instr TRIP*) and the number of process patent claims filed by the firm in the following 5-year period. The dependent variable in all models is the number of process claims filed by the firm in the 5-year period from (t+1) to (t+5). Models (1) and (2) use OLS regression modeling, while model (3) reports the second stage of 2SLS regression modeling. Controls, firm, industry, and year fixed effects are applied following Eq. (2). Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. ‡‡ and ‡ denote Stock-Yogo critical values of maximal relative bias of 19.93 (10%) and 11.59 (15%), respectively, for weak identification. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively.

	Process Patent Claims$_{(t+1\ to\ t+5)}$		
	OLS	*OLS*	*2SLS*
Relation to Innovation Output and the Proportion of Process Patents	(1)	(2)	(3)
TRIP$_t$	1.326*** (0.000)	0.323** (0.023)	
Instr TRIP$_t$			4.801*** (0.000)
Process Patent Claims$_{(t-4\ to\ t)}$	0.372*** (0.000)		0.423*** (0.000)
Controls	Yes	Yes	Yes
Firm FE	No	Yes	No
SIC2D FE	Yes	No	Yes
Year FE	Yes	Yes	Yes
Obs	5,571	5,464	5,525
R-squared	0.480	0.827	0.429
Kleibergen-Paap LM Statistic			*67.676****
Kleibergen-Paap F Statistic			*42.738*‡‡
Hansen's J (p-value)			*0.747*
First-Stage Estimates:			
Local Pairs t			4.741*** (0.000)
Local Dir Con Pairs t			5.165*** (0.000)

Table 11. TRIP Influence on the Production of Breakthrough Patents

This table examines the relationship between the presence of TRIP directors on a board and the production of breakthrough patents. Panels A and B examine the impact of TRIP and Instr TRIP on the following dependent variables, respectively: 1) the production of a top 5% breakthrough patent in year (t+1), and 2) the production of a top 1% breakthrough patent in year (t+1), both scaled by the year-to-year deflate method of Hall, Jaffe, and Trajtenberg (2001). Models (1-6) exclude the unique innovative states of California and Massachusetts, while Model (7) includes all states. Models (1), (4), (5), and (7) utilize ordinary least squares (OLS) regressions, Model (2) uses a negative binomial model, Model (3) uses a nearest-neighbor propensity score matched (PSM) sample, without replacement, and with a 0.1 caliper width, and Model (6) reports the second stage of two-stage least squares (2SLS) regression model. Controls from Eq. (2) are applied in all models, and the lag of the dependent variable in year (t-1) is included where specified. Industry and year fixed effects are applied in both panels following Eq. (2), with alternative fixed effects applied as specified. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. ‡‡ and ‡ denote Stock-Yogo critical values of maximal relative bias of 19.93 (10%) and 11.59 (15%), respectively, for weak identification. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively.

Panel A: Top 5% Breakthrough Patent Presence (Dependent Variable)	CA and MA Excluded						All States Included
	OLS	*NEGBIN*	*PSM*	*OLS*	*OLS*	*2SLS*	*OLS*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$TRIP_t$	0.058***	0.158***	0.062***	0.076***	0.027*		0.055***
	(0.000)	(0.001)	(0.002)	(0.001)	(0.072)		(0.000)
Instr $TRIP_t$						0.359***	
						(0.000)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lagged DV_{t-1}	Yes	Yes	Yes	Yes	No	Yes	Yes
Industries	All	All	All	Innov	All	All	All
SIC2D FE	Yes	Yes	Yes	Yes	No	Yes	Yes
Firm FE	No	No	No	No	Yes	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	No	No	No	No	No	No	Yes
Obs	8,084	8,084	1,866	4,254	9,322	7,996	10,299
Rsq / Pseudo Rsq	0.462	0.288	0.474	0.476	0.609	0.418	0.491
Kleibergen-Paap LM						*96.872****	
Kleibergen-Paap F						*54.357‡‡*	
Hansen's J (p-value)						*0.485*	
First-Stage Estimates:							
Local Pairs t						3.299***	
						(0.000)	
Local Dir Con Pairs t						5.847***	
						(0.000)	

Panel B: Top 1% Breakthrough Patent Presence (Dependent Variable)	CA and MA Excluded						All States Included
	OLS	*NEGBIN*	*PSM*	*OLS*	*OLS*	*2SLS*	*OLS*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$TRIP_t$	0.032*** (0.007)	0.227*** (0.008)	0.295** (0.049)	0.047*** (0.008)	0.026* (0.051)		0.046*** (0.000)
Instr $TRIP_t$						0.133*** (0.002)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lagged DV_{t-1}	Yes	Yes	Yes	Yes	No	Yes	Yes
Industries	All	All	All	Innov	All	All	All
SIC2D FE	Yes	Yes	Yes	Yes	No	Yes	Yes
Firm FE	No	No	No	No	Yes	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	No	No	No	No	No	No	Yes
Obs	8,084	8,084	1,866	4,254	9,322	7,996	10,299
Rsq / Pseudo Rsq	0.387	0.351	0.393	0.407	0.519	0.383	0.406
Kleibergen-Paap LM						*100.66****	
Kleibergen-Paap F						*55.992*‡‡	
Hansen's J (p-value)						*0.554*	

Internet Appendix

to

Do Directors Provide Technological Advisory Assistance to their CEOs?

Abstract

We identify a director technological advisory channel by examining directors with an outside board seat on a firm operating in a matching patent tech industry class. After excluding directorships with simultaneous product market industry pairings, we find that 14% of directorships among innovative firms uniquely involve tech related industry pairings (TRIPs). TRIPs provide innovative assistance to the CEO with less fear of appropriation, and they increase firm value by 7%. This increase is concentrated among incumbent firms seeking protection from outside threats in volatile industries, and it is driven by cost-saving process patenting and breakthrough patent production.

JEL Classification: *G34, O16, O32, O33*
Keywords: Director advising, Industry expertise, Innovation

Outside CEO Director Influence

In this section we examine whether a complementary director relationship exists from the presence of an outside CEO director on the board with a TRIP director. Outside CEO directors can provide a certification benefit for the appointing firm (Fahlenbrach, Low, and Stulz, 2010) that can be especially beneficial when faced with new entrant threats. These outside CEO directors are often from local firms with similar investment policies (Fahlenbrach, Low, and Stulz, 2010) and thus are not expected to be TRIPs themselves. However, we find that they can provide particular synergistic benefits by mentoring and advising young TRIP directors. Kang, Kim, and Lu (2018) find that independent director CEOs help guide firms toward more value-added R&D investments and are particularly beneficial in dynamic, competitive industries.

We explore this hypothesis in Table IA.1 and examine the relationship between TRIP directors and firm value (*Tobin's Q and M/B Ratio)*. We use OLS regressions in models (1), (3), (5), and (7). We observe that the interaction of outside CEO % and TRIP directors brings a positive benefit to firm value in model (7), with almost significant interaction results in models (3) and (5). This provides modest evidence that TRIP directors provide complementary support when accompanying an outside CEO director on their board. We find stronger evidence in models (2), (4), (6), and (8) using 2SLS regressions. In all four models we find positive and significant coefficients for our interaction term. Taken together, these results suggest outside CEOs provide synergistic benefits to firm value when accompanying a TRIP director.

Table IA.1. TRIP Director Influence - Percentage of Outside CEO Directors on the Board

This table examines the relationship between TRIP directors and firm value using multivariate regressions following Eq. (2) given the percentage of outside directors who are CEOs of another firm. The models interact the presence of a TRIP director on the board (*TRIP* and *Instr TRIP*) with the percentage of outside CEOs (*Out CEO %*) and examine the impact in year (t+1) on 1) the dependent variable *Tobin's Q* in models (1-4) and 2) the dependent variable *M/B Ratio* in models (5-8). Models (1-2) and (4-5) exclude the states of California and Massachusetts, while models (3-4) and (7-8) include all states. Models (1), (3), (5), and (7) use ordinary least squares regression models, while models (2), (4), (6), and (8) report the second stage of two-stage least squares regressions. Controls, industry, and year fixed effects are applied in all models following Eq. (2), with additional fixed effects applied as specified. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively.

	Dependent Variable: Tobin's Q_{t+1}				Dependent Variable: M/B $Ratio_{t+1}$			
	CA / MA Excluded		All States		CA / MA Excluded		All States	
Interaction of TRIP Measures with Percentage of Outside CEO Directors	*OLS*	*2SLS*	*OLS*	*2SLS*	*OLS*	*2SLS*	*OLS*	*2SLS*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$TRIP_t$	0.051* (0.079)		0.027 (0.230)		0.043 (0.316)		0.008 (0.801)	
Instr $TRIP_t$		0.265*** (0.002)		0.229*** (0.000)		0.301** (0.043)		0.249*** (0.004)
Out CEO $\%_t$	0.095* (0.059)	0.093* (0.065)	0.028 (0.529)	0.025 (0.571)	0.170** (0.048)	0.177** (0.038)	0.086 (0.229)	0.092 (0.196)
Out CEO % x $TRIP_t$	0.109 (0.303)		0.141 (0.108)		0.229 (0.145)		0.299** (0.023)	
Out CEO % x Instr $TRIP_t$		0.182** (0.027)		0.160** (0.032)		0.265** (0.045)		0.257** (0.028)
SIC2D FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	No	No	Yes	Yes	No	No	Yes	Yes
Obs	9,428	9,325	12,041	11,936	9,296	9,197	11,884	11,783
R-squared	0.375	0.377	0.368	0.371	0.312	0.315	0.306	0.309

Table IA.2. TRIP Director Influence - Board Motivation

This table examines the relationship between firms with a TRIP director on their board and firm valuation based on varying levels of board motivation. Panel A splits the sample annually into two groups based on whether there were attendance problems in year (t). The dependent variable is *Tobin's Q* in models (1) and (3) and *M/B Ratio* in models (2) and (4). Models (1) and (2) use OLS regression modeling, while models (3) and (4) use 2SLS regression modeling. Panel B interacts the presence of a TRIP director on the board (*TRIP* and *Instr TRIP*) with a dummy variable (*Motivation*) equal to one if there were no director absences, and zero if any director absences were reported. The dependent variable is *Tobin's Q* in models (1-2) and (4-5) and *M/B Ratio* in models (3) and (6). Models (1-3) use ordinary least squares regressions, while models (4-6) report the second stage of two-stage least squares regressions. Variable definitions are reported in Appendix B, and continuous variables are winsorized at the 1% and 99% level. Controls, industry, and year fixed effects are applied following Eq.(1), with alternative fixed effects applied in Panel B as specified. P-values are reported in parentheses, and robust standard errors are clustered by firm. *,**,*** represent significance at the 10%, 5%, and 1% level, respectively (‡ represents significance at the 15% level for the Wald statistic only).

	Average Board Attendance %			
	OLS (Baseline Model)		2SLS (IV Model)	
	Tobin's Q_{t+1}	*M/B Ratio* $_{t+1}$	*Tobin's* Q_{t+1}	*M/B Ratio* $_{t+1}$
Subsample Results	(1)	(2)	(3)	(4)
Attendance Problems	-0.033	-0.045	0.230	0.186
	(0.441)	(0.525)	(0.214)	(0.538)
No Attendance Problems	0.086***	0.104***	0.315***	0.392***
	(0.000)	(0.005)	(0.000)	(0.009)
Wald Statistic	8.32***	4.51**	0.250	0.520
Controls	Yes	Yes	Yes	Yes
Ind/Yr FE	Yes	Yes	Yes	Yes

Panel B: Interaction of TRIP Measures with Board Motivation	*Tobin's Q_{t+1}*	*Tobin's Q_{t+1}*	*M/B $Ratio_{t+1}$*	*Tobin's Q_{t+1}*	*Tobin's Q_{t+1}*	*M/B $Ratio_{t+1}$*
	OLS	*OLS*	*OLS*	*2SLS*	*2SLS*	*2SLS*
	(1)	(2)	(3)	(4)	(5)	(6)
$TRIP_t$	-0.016 (0.684)	-0.021 (0.612)	-0.022 (0.732)			
Instr $TRIP_t$				0.238*** (0.005)	0.257*** (0.007)	0.279* (0.062)
Motivation $_t$	-0.010 (0.536)	-0.009 (0.624)	-0.024 (0.372)	-0.009 (0.558)	-0.007 (0.657)	-0.026 (0.296)
Motivation x TRIP $_t$	0.098*** (0.009)	0.111*** (0.005)	0.117* (0.064)			
Motivation x Instr TRIP $_t$				0.065*** (0.005)	0.073*** (0.003)	0.076** (0.039)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
SIC2D FE	Yes	No	Yes	Yes	No	Yes
Year FE	Yes	No	Yes	Yes	No	Yes
SIC2D-Year FE	No	Yes	No	No	Yes	No
State-Year FE	No	Yes	No	No	Yes	No
Obs	9,428	9,193	9,296	9,325	9,087	9,197
R-squared	0.375	0.390	0.311	0.377	0.392	0.314