More Disclosure, Fewer Outside Opportunities? Accelerated Patent Disclosure and Market for Managerial Human Capital†

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Abstract

This paper studies whether and how enhanced firm-level disclosures can spill over to the managerial labor market by exploiting an institutional reform that regulates the early publication of patent filings. Consistent with increased disclosures crowding out market demand for private information, I find that directors of firms that disclose patent documents more timely suffer deteriorating external employment prospects. This effect is stronger when the perceived value of disclosed information is higher and when directors have less expertise in the disclosing firm. Furthermore, their declining human capital value is priced in their compensation and reflected by the diminishing advisory role on corporate innovation. Collectively, these results shed light on how disclosure regulation shapes the boundaries of the managerial labor market by substituting private information flows.

Keywords: Patent disclosure, directors, human capital, innovation, American Inventor's Protection Act

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Abstract

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1 Introduction

Companies rely on technological knowledge to foster innovation, which is vital for sustaining a competitive edge and driving growth (Romer, 1990; DeCarolis and Deeds, 1999). Among the various factors that affect innovation outcomes, managerial human capital has garnered widespread attention, as top management can broadly influence organizational attention, resource commitment, and strategy implementation (Kaplan, 2008). This study investigates how disclosure regulation on innovation investments shapes firms' demand for and deployment of managerial human capital.[1] On the one hand, disclosures can generate direct information spillovers across firms (Roychowdhury, Shroff, and Verdi, 2019), potentially dampening the market demand for managers' knowledge and private information. On the other hand, enhanced transparency can reduce labor market frictions for managers and improve their employment prospects (Cao, Li, and Ma, 2022). By unpacking this theoretical tension, we can better understand the value of managerial human capital and the spillover effects of disclosure on firms' resource allocation.

Specifically, this paper investigates how accelerated disclosure of patent filing documents impacts the outside job opportunities of board directors, using a unique setting: the American Inventors Protection Act (AIPA). AIPA was enacted on November 29, 2000, to enhance the timeliness and scope of patent disclosures to the public domain. This regulation mandates the early disclosure of US patent applications 18 months after filing, regardless of whether these applications are eventually approved or rejected. Before AIPA, only US patents were disclosed when they were granted. The disclosed patent applications contain substantial technical and strategic information, which can be costly for the disclosing firm (Hegde, Lev, and Zhu, 2018; Kim and Valentine, 2021). Prior research indicates that technological knowledge is a critical

[1] In the paper, I study the board of directors' labor market. Prior literature has widely embraced and documented the importance of the *managerial role* of boards in addition to their supervisory role (e.g., Schwartz-Ziv and Weisbach, 2013). Therefore, I focus on the directors' labor market as an integral part of the managerial human capital market.

factor in hiring managers and directors (Howard, Withers, and Tihanyi, 2017; Bereskin, Byun, and Oh, 2022). Therefore, AIPA provides a relevant setting to examine how knowledge diffusion from increased disclosures affects the market demand for managerial capital.

I posit that enhanced disclosure can have a dual effect on directors' external work opportunities, depending on the first-order motives of hiring these directors and the nature of the knowledge being transferred (Zander and Kogut, 1995; Wu, Jin, and Hitt, 2018; Barrios and Gallemore, 2021). If directors are valued primarily for their information conduit role (i.e., *information dependence*), they may suffer deteriorating employment prospects due to otherwise accessible information through public disclosures. In this context, the information propagated from the focal firm to other connected firms (i.e., firms that hire directors from the focal firm) is more explicit in nature and easily sharable. However, if other firms appoint these directors because of their in-depth expertise in managing and monitoring innovation activities, disclosed information from the focal firm can reduce the information friction of assessing directors' human capital value and improve their outside employment. Under this circumstance, the knowledge possessed by directors is more tacit, accumulated through personal experience, and well-suited to specific environments. Such knowledge is embedded in individuals and not easily transferable via disclosure, and its value is less susceptible to external information availability.

To empirically estimate the effects of enhanced patent disclosures, I first conduct a firm-level analysis of changes in directors' outside seats in other firms following the enactment of AIPA. I use a sample of 13,887 firm-years from 1996 to 2005 and employ a difference-in-differences (DiD) design to compare firms with high and low information spill-outs due to the disclosure regulation. I build on Kim and Valentine (2021) to gauge relative information spill-outs by considering a firm's patenting activities and expected accelerated time in publishing patents. Specifically, firms with higher patenting intensity and longer disclosure lags relative to industry peers in the pre-AIPA period will divulge more valuable and timely technological information after the regulation. I find that these treated firms with a relatively high level of information spill-outs have an average of 0.403 decreases in directors' outside seats every year after AIPA, representing a 23.6% decline from the average number of outside seats per firm. Furthermore, directors at treated firms gain fewer new seats and lose more current positions after AIPA. These results support the information dependence view and suggest that enhanced disclosures can impair the informational value of acquiring managerial human capital from disclosing firms.

Next, I perform firm-level cross-sectional analyses to explore how different innovation characteristics moderate the disclosure effects. I find that the effects of disclosure on directors' job opportunities are more pronounced when the focal firm is situated in a more homogenous and competitive product market. This is possibly because, in such markets, firms place much reliance on credible and timely patent information to survive intense technological competition (Hoberg, Phillips, and Prabhala, 2014). Additionally, I document that the disclosure effects are more salient when the focal firm invests across a broader set of technology fields and generates more novel inventions. The timely disclosure of these explorative inventions enhances the market's awareness of emerging technologies and ongoing innovation trajectories (Kaplan, 2008), thereby leading to a decline in the value of directors' private information. Moreover, when disclosing firms rely more on internal knowledge to develop their patents, the substitutive effect of disclosures on directors' outside hiring becomes stronger. This indicates that disclosed documents can provide valuable insights into these firms by unveiling their unique knowledge. Lastly, I find that when the readability of patent abstracts is low, the disclosure effects are only marginal. This is consistent with the prediction that inferior disclosure quality impedes other firms from learning and producing follow-on innovation (Dyer, Glaeser, Lang, and Sprecher, 2020). Overall, these results shed light on the importance of innovation contingencies in understanding the disclosure effects on directors' outside employability.

Further, I conduct analyses on the individual director level to provide corroborating evidence and gain deeper insights into the heterogeneous effects of various director characteristics. Consistent with the findings at the firm level, I find that individual directors working at treated firms have about 0.15 fewer outside seats after AIPA, representing a 23.2% decline from their average number of outside positions (0.67 per director). The director-level cross-sectional analysis reveals that this decline in job opportunities is more pronounced among directors with shorter tenures, those serving as non-executive directors, and those working on larger boards. These directors are likely to have less firm-specific experience, a less in-depth understanding of the firm, and are less involved in the firm's day-to-day operations, making their human capital value more vulnerable to the disclosure regulation. Thus, my findings support the prediction that enhanced disclosures mainly impair the directors' value of providing general and explicit knowledge.

Finally, I offer suggestive evidence of changes in directors' information value, proxied by their compensation and affiliated firms' innovation outputs. By aggregating directors' total compensation across all firms they serve in a given year, I find that those with positions in treated firms experience a 6.3% decrease in their total annual compensation relative to the pre-AIPA level. This finding indicates that the diminishing informational value provided by these directors is likely reflected in their remuneration. In addition, I investigate how directors' connections to treated firms affect the connected firms' innovation outcomes. Before AIPA, board ties with treated firms can improve the quantity of innovation output, as measured by the number of patent applications. However, this effect dissipates after AIPA, suggesting that unconnected firms can plausibly obtain relevant information directly from public disclosures, thereby undermining the advisory role of well-connected directors. Taken together, these findings suggest that the decreasing value of directors' information has important implications for their compensation and the innovation outcomes of their affiliated firms.

This paper contributes to several streams of literature. First, it provides fresh evidence on the real effects of non-financial information disclosure on the managerial labor market (Christensen, Hail, and Leuz, 2016). Accounting literature usually accepts the premise that corporate disclosure can impact managers' careers by revealing their abilities (e.g., Healy and Palepu, 2001; Ali, Li, and Zhang, 2019). Several recent studies support this view that firm-level disclosures help mitigate information asymmetry in the labor market for executives (Cao et al., 2022) and rank-and-file employees (Armstrong, Glaeser, and Park, 2020). This paper identifies a new channel for how disclosure can shape the boundaries of the managerial labor market: increased disclosure dampens the outside employability of directors by reducing the information demand from other firms.

Moreover, this paper adds to the literature on the interplay between different inter-firm information transfer channels. This vein of research usually builds on a collusion setting and studies how coordination needs or private communication channels among competitors affect firms' public disclosure of financial information (Bourveau, She, and Žaldokas, 2020; Bertomeu, Evans, Feng, and Tseng, 2021; Kepler, 2021). In doing so, these studies have documented that private communication with competitors can reduce the coordination benefits of public disclosure (e.g., Kepler, 2021). My results suggest that enhanced disclosures can crowd out private information flows through board ties. This finding advances prior research by showing that this substitute effect between private and public information channels not only exists in an anti-competition context but also sustains scenarios where firms leverage non-financial information to gain a competitive edge.

Lastly, the study enriches the literature on managerial human capital and organizational learning. Although much literature has examined how a well-connected board can facilitate knowledge diffusion across organizations (see Shropshire, 2010, for a review), there is still scant evidence on (1) to what extent such often coarse-grained information or knowledge acquired by directors can be fungible for the firm (Tuschke, Sanders, and Hernandez, 2014); (2) whether information dependence is a first-order motive of hiring an interlocking board member; and (3) how different cross-organization learning channels interact with each other.[2] By exploiting a quasi-exogenous institutional reform that increases direct information spillover, this study pinpoints the substitute between public disclosures and appointing well-connected directors, which has the potential to fill these voids in current research.[3] In addition, the study complements the literature on the relationship between board networks and corporate innovation by (1) disentangling directors' information role from their governance role, (2) showing that knowledge diffused through board connectedness is, to a large extent, explicit in nature, and (3) investigating technological and organizational contingencies that influence directors' human capital value. These nuanced insights have implications for companies' talent acquisition and incentive designs.[4]

2 Institutional Background and Hypothesis Development

2.1 Institutional Background: American Inventors Protection Act (AIPA)

The enactment of AIPA stipulated the public pre-grant disclosure of patents filed after November 29, 2000. Prior to AIPA, applications at the US Patent and Trademark Office (USPTO) were published only upon patent grant, and the median period to grant all the patents

[2] Although prior studies are suggestive about information access as an outcome of board connections, information dependence is typically not regarded as a first-order antecedent among other explanations about the existence of board interlocks, such as resource dependence (financial or operational resources other than information) (Dooley, 1969; Burt, 1980), monitoring (Carpenter and Westphal, 2001; Gulati and Westphal, 2016), signaling (Gulati and Higgins, 2003; Connelly, Certo, Ireland, and Reutzel, 2010), or simply because of a small pool of candidates (Stokman, Van Der Knoop, and Wasseur, 1988).

[3] Prior work primarily relies on observed adoption and diffusion of corporate behaviors to illustrate the value of board connection, which overlooks the two sub-processes: *contact* and *choice* (Lamb and Roundy, 2016). The information transfers typically happen first (*contact*) before a firm decides on whether to implement the strategic action (*choice*). Treating these two sub-processes as unitary can obfuscate the understanding of interlocking directors' role in knowledge diffusion, and can therefore fail to find any associations between board interlocks and corporate decisions (Mizruchi, 1996). This paper seeks to understand these directors' value from an input-based (i.e., hiring) rather than an output-based perspective (i.e., adoption of policies or observed performance), which circumvents the abovementioned problems.

[4] For example, if knowledge is tacit and embedded in directors, in order to acquire such knowledge, other firms need to hire these directors and further design incentive systems to elicit them to use the knowledge.

filed in 2000 was around 32.5 months (Hegde and Luo, 2018). Under AIPA, the default disclosure time is 18 months after the patent's earliest application date, also known as the "priority date," which aligns with the disclosure requirement of other jurisdictions, such as Japan, Canada, and European countries.[5] Only a small number of patents that do not seek foreign protection are exempt from this requirement.[6] Typically, a patent disclosure contains comprehensive textual and graphic information about patented technology and is readily available at the USPTO. Hence, AIPA considerably reduced the disclosure delay and has been regarded as the "biggest change to patent law since 1952" (Ergenzinger, 2006).

The timely and comprehensive disclosure enabled by AIPA offers market participants and competitors access to information about firms' innovation investments and recent technological breakthroughs, generating significant knowledge spillover. Studies have shown that this regulation greatly improves financial analysts' forecast accuracy (Beyhaghi, Khashabi, and Mohammadi, 2022) and assists capital providers in valuing patenting firms (Saidi and Žaldokas, 2021). Furthermore, accelerated patent disclosures inform competitors about the disclosing firm's innovation strategies and recent changes in innovation trajectories, allowing them to either follow on these innovation investments or promptly differentiate their products (Glaeser and Landsman, 2021; Hegde, Herkenhoff, and Zhu, 2022).

An illustrative example of how pre-grant patent disclosure can reveal groundbreaking corporate innovation is Apple Inc.'s (Apple) revolutionary progress in touchscreen technology, which has been applied to most of the company's flagship products. One of Apple's essential patents, titled "*Gestures for touch sensitive input devices*," was filed on July 30, 2004, and

[5] Before AIPA, US patents initially filed at foreign patent offices were subject to accelerated disclosure, but they represented less than half of the total patent applications at the USPTO (Chondrakis, Serrano, and Ziedonis, 2020). The processing costs of these patent disclosures by foreign patent offices are also very high due to language barriers, unavailable search channels, non-digitalized information, and a lack of public records linking US patent applications with foreign equivalents (Hegde and Luo, 2018).

[6] Specifically, inventors could opt out of an 18-month publication by agreeing not to file the application, or its equivalent, in any foreign country that required an 18-month publication (Hegde and Luo, 2018). However, only a small proportion of firms resort to pre-grant secrecy (Graham and Hegde, 2015).

disclosed 18 months later on February 2, 2006.[7] The patent file describes methods and systems for processing touch inputs for a multipoint sensing device in vivid detail (see Appendix B), which garnered widespread attention from other companies and the public.

In addition to revealing product innovation, patent disclosures can also unveil significant shifts in corporate strategy and resource deployment. A case in point is Amazon Inc.'s (Amazon) strategic move to open its e-commerce platform to third parties. The crucial patent filed on January 27, 2004, specifies the technology to provide the marketplace of third-party web services (Hegde et al., 2018). Forbes news highlights the role of disclosed patent documents in divulging Amazon's business plan by commenting that "*[r]etailing powerhouse Amazon.com seldom pulls back the curtain on its high-tech operating secrets…[b]ut there's one place where the online retailer is garrulous as can be: its filings with the US Patent Office*."[8] Therefore, regulated pre-grant patent disclosures by AIPA can also provide direct insights into incoming strategic changes implemented by the disclosing firms.

2.2 Literature Review and Hypothesis Development

2.2.1 Board Network and Information Transfer

Prior research suggests that the presence of overlapping board members, commonly referred to as "board interlock," facilitates the exchange of information and knowledge across organizations (Davis and Greve, 1997). The observed board interlocks in practice are "too prevalent to be random," but rather indicate meaningful corporate control (Hallock, 1997).[9] A wide spectrum of corporate strategies and policies have been found to propagate through board connectedness, such as corporate finance decisions (Fracassi, 2017), accounting and disclosure policies (Teoh, Chiu, and Tian, 2013; Cai, Dhaliwal, Kim, and Pan, 2014), mergers and

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[7] The publication number of the 18-month disclosure: US20060026521A1. The patent information is available at: https://patents.google.com/patent/US8479122B2/en

[8] The news is available at: https://www.forbes.com/sites/georgeanders/2013/11/14/amazons-1263-patents-reveal-retailings-high-tech-future/?sh=584e260ccd0d

[9] The Clayton Act prohibits board interlocks among direct competitors but not necessarily intra-industry or cross-industry interlocks (Brown and Drake, 2014).

acquisitions (Haunschild, 1993), and innovation investments (Chang and Wu, 2021).

Serving on boards of other companies allows board members to gain firsthand insight into new businesses, technologies, and practices (Lorsch and Young, 1990). The board network serves as a credible and efficient communication channel between organizations (Haunschild, 1993). Burt (1992) and Gulati (1998) outline three primary informational benefits of the social network: access, timing, and referrals. In the context of board networks, access and timing provide an essential advantage by keeping firms abreast of the latest decision-relevant news (Li, 2021). *Access* refers to interlocked directors' ability to acquire knowledge by observing the practices and decisions in other firms. *Timing* is also a crucial attribute of information flows transmitted through the board network, as market players actively pursue secrecy and withhold private knowledge in a competitive environment (Castellaneta, Conti, and Kacperczyk, 2017). Moreover, directors frequently exchange information about current or future strategies, greatly expanding their knowledge set beyond what they observe (Carter and Lorsch, 2003). By leveraging the knowledge gained from their board members' inter-firm connections, companies can revise their own strategies in a timely and proactive manner and avoid missing out on valuable market opportunities.[10]

In light of these advantages, directors' connections and networks constitute a crucial part of their human capital value. However, what type of information flows across these networks has long been debated in the sociology and management literature (Stinchcombe, Mizruchi, and Schwartz, 1990, p. 381; Shropshire, 2010). While there have been numerous studies on how board networks impact organizational outcomes, few have examined the extent to which

[10] Previous studies have broadly discussed the possibility that information regarding strategic or innovation investments is transmitted via board connections (e.g., Chuluun, Prevost, and Upadhyay, 2017; Howard et al., 2017; Cheng, Rai, Tian, and Xu, 2021). Howard et al. (2017), for example, provide anecdotal evidence that Freescale Semiconductor built on innovations of interlocking companies to develop several significant technologies. Specifically, Freescale appointed several new members to its board of directors, including Kevin J. Kennedy, chief executive officer (CEO) of JDS Uniphase. The new microelectro-mechanical sensors (MEMS) technologies drew on fabrication methods developed and patented by JDS Uniphase, and the authors conjecture that the directors' access to connected firms is indispensable in fostering these technologies.

the private information gained through these networks is unique or cannot be replaced by other mechanisms. Furthermore, existing research has primarily been documenting the diffusion of new corporate practices or policies as an outcome of these connections, rather than investigating whether information dependence is a first-order motive for hiring connected directors.

2.2.2 Disclosure Mandate and Directors' Outside Job Opportunities

Enhanced disclosures of a firm's strategic investments may provide a relatively cheap and reliable channel for competitors to learn about new inventions, which can crowd out the need for learning from connected board members if both learning mechanisms are equally effective in resolving uncertainty (Cheng et al., 2021). The enactment of AIPA requires detailed and timely disclosure of a firm's innovation projects, which allows competitors to stay up-to-date with new technological advancements (Hegde and Luo, 2018). As a result, this knowledge can improve other firms' project selection and continuation decisions (Kim and Valentine, 2021). Given the rich information available from patent application disclosures, the value of forming ties with disclosing firms might decrease, making it less necessary for firms to hire connected directors.

Notwithstanding, the extent to which disclosed information can replace the interlocking board's informational role remains questionable. While pre-grant patent disclosures can provide insights into the fields a focal firm is exploring, it is still difficult for outsiders to piece together a holistic strategic blueprint of the firm. In contrast, a well-connected board network can "provide detail and insight as to the design and implementation of practices in other firms that cannot be easily observed by outsiders" (Shropshire, 2010, p. 248). Additional information, such as the performance of preemptors after implementing new strategies, can help follower firms assess the costs and benefits of investing in the same technology or adopting similar strategies (Connelly, Johnson, Tihanyi, and Ellstrand, 2011). For instance, Apple filed and published a total of 248 automobile-related patents since 2000, indicative of its intention to enter the self-driving business.[11] However, despite the growing number of patents filed, the plan for producing autonomous vehicles remained hazy for a long time, and the company had not publicly addressed related rumors until 2016.[12] As one commentator notes, "*[t]he work on the car has shifted several times and there were moments when it looked like a full car was not going to happen*."[13] Hence, Apple's example demonstrates how strategic considerations such as a precautionary patenting motive or product-launching time cannot be easily inferred from patent filing disclosures alone. In many cases, insider views from the disclosing firm are still needed to complement the available patent information.

In general, the decision of whether to rely on public disclosures or interlocking board members to obtain strategic knowledge depends on the type of knowledge the firm demands. Patent disclosures contain information codified in verbal descriptions or graphs, which is an essential source of explicit knowledge.[14] This type of knowledge can increase the awareness of existing practices or technologies in other organizations. However, directors working for other organizations may accumulate and possess tacit knowledge not embodied in written protocols or observable inventions. This tacit knowledge includes creating a nurturing environment for innovative ideas, identifying strategic synergies between early-stage discoveries and current business activities, and designing innovation trajectories for the organization, among others. Therefore, if tacit knowledge is crucial to other firms, the value of directors' human capital is less susceptible to public disclosures of explicit knowledge.

Furthermore, increased public disclosure may even boost the market demand for managerial human capital for several reasons. First, according to the theory of "institutional

[11] The news available at: https://asia.nikkei.com/Business/Automobiles/Apple-s-patent-history-reveals-a-major-push-into-autos
[12] The news available at: https://www.bbc.com/news/business-38199880
[13] The news available at: https://www.macrumors.com/2022/07/25/apple-car-patent-applications/
[14] For instance, Nonaka and von Krogh (2009, p. 636) define explicit knowledge as "knowledge that is uttered, formulated in sentences, and captured in drawings and writing."

isomorphism" (DiMaggio and Powell, 1983), increased information about new discoveries and technological advancement puts competitive pressure on firms to imitate these technologies. During this process, hiring interlocking directors can provide the mimicking firm with legitimacy (Salancik and Pfeffer, 1978) because it signals that the firm has acquired critical human capital and thus gains exposure to the knowledge about the operations of the mimicked firms (Shropshire, 2010). Second, directors' advisory roles can be complementary to available information from patent disclosures. For example, patent disclosures enhance the awareness of emerging technology and thus promote the need for a deeper understanding of its strategic use. This can be achieved by consulting experienced board members from companies that adopt or invent such technology (Cheng et al., 2021). Lastly, greater transparency about investments and innovation progress can provide relevant information for other firms to evaluate the managerial competence of the focal firms' directors.[15] As a result, mandating disclosure can also help reduce labor market frictions (Cao et al., 2022), thereby assisting directors in finding external job opportunities. Considering all these countervailing forces that impact the role of disclosure in shaping the labor market for directors, I pose a null hypothesis as follows:

H: *Following the enactment of AIPA, accelerated patent disclosures do not affect the outside job opportunities of a disclosing firm's directors.*

3 Data and Research Design

3.1 Research Design

3.1.1 Variable Construct: Changes in the Number of Directors' Outside Seats

To investigate the impact of the focal firm's disclosure on its directors' outside job opportunities, I examine changes in the number of directors' seats on external boards. Instead

[15] An increasing strand of research suggests that expertise in innovation investments is a crucial consideration when hiring external executives (e.g., Cummings and Knott, 2018; Bereskin et al., 2022). Patent disclosures can reflect directors' expertise in certain technological domains, such as hiring and retaining talent, converting inventions into marketable products, and identifying emerging opportunities and threats.

of directly counting the number of interlocks, I calculate the number of terminated and newly established interlocks in a given year, separately. Additionally, I impose two timing criteria. Firstly, if an interlocking relationship is terminated, the affected director must still serve on the focal firm's board after the termination. Secondly, if an interlocking relationship is established, the director should have already worked at the focal firm. These criteria help account for the symmetrical changes in board interlocks between affected and less-affected firms and potential confounding factors associated with individual directors.[16] By subtracting the number of terminated interlocks from the number of newly established ones for a focal firm, I obtain the main dependent variable: changes in the number of directors' outside positions in other firms' boards, denoted as *#Change Seats*.

3.1.2 Variable Construct: Relative Information Spill-Outs under AIPA

The enactment of AIPA strengthened the information spill-outs from patenting firms, with its magnitude mainly depending on two factors: a firm's patenting activities and the time lag of patent disclosure prior to AIPA. Considering these two dimensions and building on Kim and Valentine (2021), I construct a measure of relative information spill-outs ($Spillout_i$) using the following formula:

$$Spillout_i = \ln\left(\frac{w_i \times Publag_i}{(\sum_{j \neq i} w_j \times Publag_j)/n}\right) \tag{1}$$

where *i* denote the focal firm and *j* represents all peer firms in the same SIC-2 industry. *Publag* is a firm's average filing-to-grant lag for all patents filed by the firm in the 20 years prior to the enactment of AIPA. I weight each publication lag by w_i, the percentile of the total value of patents filed by the firm in the 20-year pre-AIPA period (patent value calculated following

[16] Consider a simplified scenario of only two firms, firm A is the disclosing firm, and firm B is the non-disclosing firm. If the disclosure of firm A reduces the need for B to hire directors from firm A's board, both the number of interlocks for firm A and firm B will decrease. Therefore, this mechanically symmetric change in the number of interlocks can bias the results. Moreover, if a director leaves the labor market (e.g., due to retirement or personal issues), it will also confound the counting of director interlocks. Imposing timing criteria can better distinguish the directional effect of disclosure and mitigate confounding noise from individual directors.

Kogan, Papanikolaou, Seru, and Stoffman (2017); henceforth, KPSS value).[17] With regard to the denominator, I follow a similar procedure to sum the publication lag for peer firms in the same industry and divide it by the number of peer firms (n) to adjust for different industry sizes. The measure is then transformed using a natural log function to minimize the impact of outliers. To better interpret the economic magnitude, I create a dummy variable, *Treat*, that equals one if the $Spillout_i$ is higher than the sample median of the year 2000, which indicates a relatively high level of information spill-outs from a focal firm.

3.1.3 Empirical Design for Main Analysis

I employ a difference-in-differences (DiD) design to examine the effects of accelerated patent disclosure under AIPA on directors' outside job opportunities in the focal firm. The model is specified as follows:

$$\#Change\ Seats_{i,t} = \alpha + \beta\ Treat_i \times Post_{i,t} + \gamma' Controls + Firm\ FE + Industry\text{-}Year\ FE + \varepsilon_{i,t} \quad (2)$$

where *#Change Seats* denotes the changes in the number of directors' outside board seats, and *Treat* is a dummy variable indicating treated firms with relatively higher information spill-outs. To control for other firm-level characteristics, I include a set of firm fundamentals, including cash holdings (*Cash*), intangibility (*Intangibility*), total assets (*Asset*), leverage ratio (*Leverage*), sales (*Sale*), R&D intensity (*R&D*), return on assets (*ROA*), book-to-market ratio (*BM*), and industry Herfindahl index (*Ind HHI*). Moreover, I control for board characteristics, including the proportion of female board members (*Female*), the proportion of independent directors (*Independent*), board size (*Boardsize*), and whether the CEO serves a dual role as the board's chairman (*Duality*). To capture unobservable firm-specific invariant heterogeneity and to filter

[17] The method of weighting differs from Kim and Valentine (2021), who use the decile rank of the number of patents the firm files during the 20-year historical period. This is due to two reasons: First, many firms have a low number of patents (one or two patents), and therefore the weight metric based on decile rank is too coarse. Second, the value of patents can better capture the economic importance of the information contained in patent disclosure. I confirm that my results are not sensitive to the selection of weighting method.

out industry-specific time trends, I include firm and industry-year fixed effects. Coefficient β is the DiD estimator of the effect of accelerated patent disclosure on the board members' outside job opportunities.

3.2 Data and Sample

To compute the relative information spill-out measure, I begin with a sample of US public firms with patent filing records from 1981 to 2000 in the dataset of Kogan et al. (2017). Information on changes in board members' outside jobs and board characteristics is obtained from the BoardEx database, supplemented with the ISS database. Firm-level fundamentals data is collected from Compustat. I restrict the sample years to the period between 1996 and 2005 to ensure a balanced panel before and after AIPA. After merging different datasets and preserving observations with non-missing values, the final sample consists of 13,887 firm-year observations and 1,636 unique firms. Table 1 presents the sample distribution across different SIC-2 industries and years. Although there is an imbalance in the number of treated and control firms across some industries, as shown in Panel A, this is due to heterogeneity in industry dynamics and firms' exposure to AIPA. Panel B of Table 1 shows the number of firm-year observations and average changes in board seats for control and treated firms between 1996 and 2005.

Table 2 reports descriptive statistics of firm-level main variables. The information spill-out measure (*Spillout*) in Table 2 has a mean value of -4.978 and a standard deviation of 1.466, indicating a rich variation in the relative information spill-outs under AIPA. On average, the board members of a firm can gain 1.589 new seats outside the firm and lose 1.376 positions from other organizations each year, leading to an overall annual increase of 0.213 in the number of seats.

4 Empirical Results

4.1 Main Results: AIPA and Changes in Directors' Outside Seats

I conduct a firm-level analysis to examine the changes in the number of board directors' outside job seats following the implementation of AIPA. Table 3 presents the estimation results of Equation (2), with different sets of covariates and decompositions of seat changes. The coefficients on *Treat* × *Post* in Columns (1) to (3) are all significantly negative, indicating that firms with a higher level of information spill-outs experience a decrease in the number of board directors' outside seats by approximately 0.403 (Column (3): *t*-statistics = -3.66). In economic terms, this translates to a decline of 23.6% in board connections and 0.235 (= 0.403/1.712) standard deviations of changes in the number of seats.[18] By decomposing the seat changes into newly obtained and lost seats in a given year, the results reported in Columns (4) and (5) suggest that increased information spill-outs from patent disclosure both hinder directors from finding outside opportunities and make them lose current seats in other firms. Furthermore, Figure 1 displays the dynamic effects of AIPA, which are estimated by replacing *Post* from Equation (2) with several event-year indicators. The figure indicates no apparent differences between treated and control firms in terms of directors' outside employment positions leading up to the enactment of AIPA (November 29, 2000). However, after 2000, treated firms experience a sharp decline in the number of directors' outside seats. The observed pattern confirms the parallel trend assumption and reinforces the causal inference. Overall, these findings reject the null hypothesis and suggest that enhanced technology disclosure impairs board members' outside job opportunities.

To ensure the robustness of the findings, I conduct a battery of robustness tests and report these results in Table 4. First, I take out all fixed effects and covariates and examine how treated

[18] The average number of board interlocks (number of directors' outside seats) per firm is about 8.55 in the pre-AIPA period. Therefore, the magnitude translates into around a 23.6% (0.403*5/8.55) decrease in the five years after AIPA.

firms differ in their board members' outside seats before and after AIPA. Results from Column (1) indicate that, unconditional on other factors, directors of treated firms enjoy better external employment prospects, but such prospects deteriorate after the mandated pre-grant patent disclosure. This is consistent with the inference that hiring directors from treated firms provides informational value in the pre-AIPA period, which is subsequently undermined after the regulation. Results still hold after including firm and year fixed effects (Column (2)). The model in Column (3) includes state-year fixed effects to filter out confounding state-level regulation changes (e.g., the Inevitable Disclosure Doctrine) and time-variant local labor market constraints, which yields a comparative coefficient to the main specification (-4.03 v.s. -4.60).

In addition, I use two matching procedures to further mitigate the observable differences between the treated and control firms. In Column (4), I perform a coarsened exact matching test (Iacus, King, and Porro, 2012), where I coarsen the covariates using four equally spaced cutoff points and create strata with an equal number of treated and control observations. In Column (5), I use the entropy matching method, where observations are weighted to equate means for out-of-balance control variables between the treated and control firm. Following these two matching methods, I find qualitatively similar results. As shown in Column (6), when I use the number of board interlocks as the dependent variable and adopt a Poisson model to estimate the effect, the treated focal firm experiences a sharp decrease of 14.7% (= $e^{0.137}$-1) in its board members' interlocks with other firms.[19] In Column (6), the discrete treatment variable is replaced with the continuous variable *Spillout*, and the DiD estimator remains significant and negative. Finally, I follow some studies (Saidi and Žaldokas, 2021; Beyhaghi et al., 2022) and use only the firm-level pre-AIPA disclosure lag as the treatment. Although this method

[19] Cohn, Liu, and Wardlaw (2022) advocate using a fixed-effects Poisson model to estimate the effects on count-based outcomes (with a mass at zero) instead of linear or log-linear regressions. I also follow this practice to estimate all other count variables in the rest of my analyses.

may introduce measurement errors by not considering the patenting intensity (i.e., only considering the acceleration in disclosure time rather than information quantity), it can be a more exogenous treatment measure in this setting.[20] The result reported in Column (7) is robust to this alternative construct, suggesting that timely access to patent application information itself can depreciate the directors' human capital value.

4.2 Firm-Level Cross-Sectional Analysis

To explore how firm characteristics interact with technological information spillover in influencing directors' career prospects, I examine the moderating effects of factors related to firms' product markets and innovation investments, which are particularly relevant in the context of this study.

Firstly, I investigate the moderating role of technological competition. The informational value of well-connected directors hinges on access and timing (Li, 2021). I posit that peers' access to the focal firm's technological information is more valuable when the product similarity is higher. Patent disclosures are more relevant in this scenario as they help revise product development plans to avoid overlapping products and direct competition (Lück, Balsmeier, Seliger, and Fleming, 2020; Glaeser and Landsman, 2021). Furthermore, I predict that the informational benefits of pre-grant patent disclosure are more prominent when technologies in the market are more frequently updated. To measure the high state of flux in a competitive environment, I use the "product market fluidity" measure from Hoberg et al. (2014). This measure evaluates to what extent words used by a firm in its business descriptions of the 10-K report are included or dropped by its peers. A higher fluidity measure indicates that a focal firm's product overlaps more with the changes in the product market, thereby increasing the informational benefits of timely patent disclosure.

[20] For instance, Kim and Valentine (2021) find that after AIPA, the spill-out firms shrink their innovation inputs, which might also contribute to the decline of managerial human capital value. This alternative treatment measure only relies on the expected acceleration in disclosing time and therefore helps to isolate the disclosure effects from the effects of strategic changes in investments after AIPA.

In Table 5 Panel A, I present the results of splitting the sample based on two technological competition measures. First, I split the sample based on whether a focal firm has a higher product similarity to its peers and report the results in Columns (1) and (2). The coefficients for Columns (1) and (2) are both negative, with a slightly larger economic magnitude (coefficient = -0.510, *t*-statistic = -3.00) for firms with high product similarity to peers. However, the coefficient difference between high and low product similarity groups is not statistically significant at the conventional level (*p*-value of difference = 0.17). Next, I partition the sample based on relative product market fluidity in Columns (3) and (4), using the "product market fluidity" measure from Hoberg et al. (2014) to capture the state of flux in a competitive environment. The results indicate that, on average, firms' directors lose 0.282 (*p*-value of difference = 0.09) more outside jobs in a more fluid market relative to a more stable one. Collectively, the results suggest that directors may face bleaker employment prospects when the information spill-outs happen in a more homogenous and fluid market, but the differences are not very pronounced. This could be due to the fact that inter-firm connections created by interlocking boards are also meaningful in absorbing investment uncertainties in such markets (Beckman and Haunschild, 2002).

Secondly, I examine the moderating effect of the broadness of a firm's innovation areas on the relationship between disclosure regulation and directors' career prospects. Eggers and Kaplan (2009) find that management's awareness of and attention to emerging technology can facilitate faster adaption and strategic reorientation. Firms with more diverse and explorative investments in various technological areas have a more uncertain trajectory for future innovation (March, 1991). Patent filings can provide insights into a firm's recent resource deployment and strategic focus, which helps peer firms identify new opportunities and reconfigure their capabilities (Katila and Ahuja, 2002). I predict that when the focal firm is involved in broader fields of innovation, transfers of explicit information are relatively more important for other firms, by enhancing their awareness and mitigating the risk of being "caught off guard" (Highsmith, 2009).

I define the broadness of innovation as the extent to which firms' patent holdings span across different technological spaces (Katila and Ahuja, 2002). Specifically, I utilize the Herfindahl-Hirschman Index (HHI) based on the number and KPSS value of patents a firm filed within each USPTO technology class in the past 20 years. A lower HHI indicates more diversified innovation investments and broader innovation areas. In Table 5 Panel B, I report the results of partitioning the sample based on calculated HHI values. The coefficients on the interaction term are only significant when HHI values are lower, and the differences in coefficients are significant for both number- and value-based HHI (p-value of difference = 0.01 and 0.02, respectively). Therefore, the substitute effect between information disclosure and board connections is stronger for firms with a broader scope of innovation. This finding indicates the informational role of hiring directors from explorative firms and highlights the fragility of managerial human capital accumulated in diversified firms under direct information spill-outs through disclosure.

Thirdly, I explore how technological novelty influences the effects of disclosure. New inventions are likely to be part of firms' recent or ongoing trajectory and are developed to meet the market's demand (Katila, 2002). Moreover, these emerging technological domains are less crowded and have better commercial potential (Zhang, Chen, and Wang, 2021). Therefore, it is plausible that disclosure of such novel technologies can provide strategically important information to the public. I follow Zhang et al. (2021) and measure the novelty of a patent with the average age of patents cited by the focal patent. The age of a cited patent is the time elapsed since its application. I divide the sample based on the average novelty of patents filed by the firm in the past 20 years, with firms citing newer patents designated into the "High" novelty group and others into the "Low" group. The results, presented in Table 5 Panel C, indicate that the effect of disclosure is stronger for firms with relatively novel inventions (coefficient = -0.727, *t*-statistic = -3.62), whereas it is insignificant for firms with more obsolete technologies. Thus, the novelty of underlying technologies can enhance the spillover effects of disclosure.

Fourthly, I investigate how the source of a firm's knowledge affects the relationship between disclosure and outside director hiring. When firms generate new ideas and discoveries from internal knowledge sources, the resulting product advancements and operational processes cannot be easily foreseen or imitated by outsiders (Wang, Zhao, and Chen, 2017). Consequently, firm-specific knowledge is more likely to create greater economic value and superior long-run returns (Hall, Jaffe, and Trajtenberg, 2005; Wang, He, and Mahoney, 2009). Compared to inventions based on external knowledge, those built on intra-organizational knowledge can reveal important information about a firm's specific competitive advantages to outsiders. To examine this, I partition the sample into firms with higher proportions of self-citations out of the total citations for their past patents, indicating a greater reliance on internal knowledge sources, and those with lower proportions, indicating more reliance on external knowledge sources. The results presented in Table 5 Panel D show that the substitutive effect between disclosure and board connections is more pronounced among firms that rely more on internal knowledge, with a 0.348 greater loss in job positions relative to those that rely more on external knowledge sources (*p*-value of difference = 0.11). These findings suggest that firms that draw on internal knowledge to develop their technologies may potentially divulge critical inside information through patent disclosures.

Lastly, I consider the moderating role of patent disclosure quality. The quality of patent disclosure can determine how effectively outsiders can extract useful information from patent documents. Dyer et al. (2020) find that patents with better readability and higher disclosure quality generate more follow-on innovation. To measure the disclosure quality of the patents filed by the firms in my sample, I conduct a textual analysis using the Fog index (Gunning,

1952) of the patent abstracts. I divide the sample into two groups based on the average Fog index of the patent abstracts filed by the firm in the past 20 years. Firms with an average lower Fog index are classified as the "High" readability group, while others are designated as the "Low" group. The subsample analysis results are presented in Table 5 Panel E. The results show that the effect of AIPA on directors' job opportunities is significant for firms with more readable patents, with the coefficient on *Treat* × *Post* being significant and negative (coefficient = -0.648, t-statistic = -2.72). In contrast, the coefficient for firms with low patent readability is much smaller and insignificant (coefficient = -0.202, t-statistic = -1.31). Therefore, low disclosure quality of patents can significantly temper the adverse disclosure effects on the market demand for directors.

4.3 Information Spill-Outs and Outside Opportunities: Director-Level Analysis

I conduct additional director-level analysis to corroborate firm-level analysis and shed further light on how director characteristics moderate the disclosure effects. Specifically, I estimate the following equation:

$$\#Change\ Seats\_D_{d,i,t} = \alpha + \beta\ Treat_i \times Post_{i,t} + \gamma' Controls + Director\ FE \\ + Industry\text{-}Year\ FE + \varepsilon_{i,t} \quad (3)$$

where $\#Change\ Seats\_D_{d,i,t}$ is director d's changes in the number of outside board seats (i.e., seats in firms other than firm i) in year t. The treatment and control variables are identical to the previous firm-level analysis. In addition, I include director-level fixed effects to absorb director-specific unobservable factors that could affect their career opportunities. To ensure the sample directors are not newly recruited, I require them to have worked for the focal firm in the previous year.[21]

The results are reported in Table 6. Similar to the firm-level analysis, directors working in

[21] As I focus on the discussion of the information value of directors, recently-hired directors may not be able to establish effective information channels and may introduce confounding noise. All results are robust to removing this criterion.

firms with strong information spill-outs experienced a decrease in outside job opportunities after the enactment of AIPA. Before AIPA, these directors were more likely to gain positions in other organizations, with a net increase in seats of 0.049 (coefficient = 0.049, *t*-statistics = 3.53). This is consistent with the information dependence theory, which suggests that a board's connection with innovation-intensive firms can bring value to other firms. However, this advantage is undermined once the proprietary information is disclosed to the market. On average, directors in treated firms experience a net decrease in their outside positions by 0.03 every year (coefficient = -0.031, *t*-statistics = -3.38), which is economically significant, considering the average outside seats of an individual director in the sample is 0.669 (a 0.031*5/0.669 = 23.2% decrease after AIPA). Figure 2 displays the dynamic effects of information spill-outs on individual directors' outside job changes. The treatment effect mainly emerges after 2000, when AIPA was formally enacted. In summary, the results from the director-level analysis are aligned with the findings of the firm-level analysis, both demonstrating that mandatory patent disclosure dampens directors' human capital value.

4.4 Director-Level Cross-Sectional Analysis

To gain a deeper understanding of how the effects of mandatory patent disclosures on employment opportunities are moderated by different director characteristics, I perform further analyses at the director level. These analyses yield valuable insights into the circumstances under which the appointment of well-connected directors is particularly advantageous.

One important characteristic that can moderate the disclosure effects is a director's relative experience within a firm. As Vafeas (2003) notes, directors can accumulate firm-specific experience over time, and those with longer tenures are expected to have a profound understanding of the firm's operational environment (Kesner, 1988). Experienced board members also have greater control over the flow of information and can facilitate knowledge transfers between organizations (Shropshire, 2010). To test whether board members with longer tenures are better equipped to generate unique insights and tacit knowledge about the firm, I use years of tenure as a proxy for a director's experience within the focal firm and partition directors based on their length of tenure. The results, reported in Table 7 Panel A, suggest that directors with relatively short tenures suffer more from mandatory patent disclosures, experiencing a 0.063 (coefficient = -0.063, *t*-statistics = -3.40) annual decline in their outside seats. The difference in coefficients between the two groups is also statistically significant (*p*-value of difference = 0.02). This finding supports that longer tenures can lead to incremental firm-specific expertise that is not susceptible to information spillover from disclosures.

Next, I consider the heterogeneous effects of directors' roles by distinguishing between the executive and non-executive directors. I contend that executives possess broader knowledge about firms' strategies and plans that cannot be easily extrapolated from disclosures, as the executives oversee the firm's everyday operations and can gain a more nuanced understanding of the firm compared to outside directors (Finkelstein, 1992). Their unique expertise and experience in orchestrating strategies can be applied in new contexts and are greatly valuable to other firms (Boivie, Bednar, Aguilera, and Andrus, 2016). Studies also find that board interlocks formed by executives are more influential in facilitating knowledge transfers and shaping connected firms' strategic investments (Li, 2021). Therefore, I predict that the disclosures primarily affect interlocks created by non-executive directors. In Table 7 Panel B, I partition the sample directors based on their roles in the focal firm, with those serving as executives bifurcated into the "Yes" column and others into the "No" column. I find that executives are, in general, less affected by the accelerated disclosures of patents, and the coefficient is also statistically insignificant (coefficient = -0.008, *t*-statistics = -1.05). Conversely, non-executive directors experience a salient deterioration in their outside employment, with an average of 0.053 (coefficient = -0.053, *t*-statistics = -3.33) fewer outside jobs in each year after AIPA. This finding suggests a boundary condition of the information dependence theory: board ties established by non-executive directors work as an information conduit, but those established by executives can have alternative uses in addition to sharing explicit knowledge.

Last, I explore how board size moderates the disclosure effects. Previous research has shown that a larger board size can hinder communication and coordination, leading to reduced board effectiveness and performance (Yermack, 1996). Cheng et al. (2021) theorize that active communication among directors can enhance the transfer of decision-relevant information and strengthen social learning. When there are fewer directors on the board, they have more opportunities to interact with each other and gain detailed knowledge about the strategic motives behind the firm's innovation investments. Additionally, a smaller board size may indicate a higher human capital value and a core decision-making group, which can provide legitimacy for external hiring (Jensen, 1993). Based on these arguments, I posit that directors who work for a small board are less affected by disclosures. To test this hypothesis, I split the sample based on the median size of the board in my sample and report relevant results in Table 7 Panel C. The results are consistent with my prediction: directors working on a larger board experience a greater loss of outside positions compared to those on a smaller board, with a difference of 0.042 positions per year (p-value of difference = 0.07). This finding suggests that board members who have more opportunities to actively exchange insights and information on a smaller board are less susceptible to the negative effects of mandatory patent disclosures.

4.5 Director-Level Compensation

To provide evidence on the value of access to firms with more proprietary information, I analyze how directors' compensation changes after AIPA. I use the director-level compensation data from BoardEx's Annual Remuneration, with a major caveat that the dataset only covers the year 1999 onwards, which leads to significant sample attrition and a relatively short panel of data before AIPA.

I aggregate the total compensation at the individual director-year level. In doing so, I can account for the effects of both compensation level and seat number changes. I estimate the following equation to examine how individual-level total compensation changes after AIPA:

$$Log(Total\ Comp)_{d,t} = \alpha + \beta_1\ Connected_{d,t} + \beta_2\ Connected_{d,t} \times Post_{d,t} + \gamma' Controls + Director\ FE + Year\ FE + \varepsilon_{d,t} \quad (4)$$

where the dependent variable *Log(Total Comp)* is the natural log of aggregated director-level compensation. *Connected* is an indicator variable that takes the value of one if directors have at least one seat in a treated firm and zero otherwise. I collapse all firm-level covariates to the director level by taking their average, and I also include one additional control variable, which counts the total number of board seats a director owns. Director and year fixed effects are included to remove any unobservable director-related and year-specific factors. In this equation, β_2 measures compensation changes for well-connected directors, i.e., directors with access to the treated firm, before and after AIPA.

The sample for this test covers 32,575 director-year observations, with an average annual total compensation of 138.9 (= $e^{4.934}$) thousand dollars. Approximately 72.2% of these directors have seats in at least one treated firm. The results of estimating Equation (4) are reported in Table 8. In Column (1), the coefficient on $Connected \times Post$ is significantly negative (coefficient = -0.063, *t*-statistics = -2.35), indicating that directors with access to information-rich firms experience a 6.3% decline in their annual compensation after AIPA. To address the potential effects of AIPA on directors' networks, I also use an alternative measure of directors' connections to treated firms in 2000 (*Connected2000*). The results reported in Column (2) are quantitively similar. Overall, this finding directly speaks to the decreasing human capital value of directors who work at or have connections to treated firms. After the mandate of accelerated patent disclosures, the benefits of accessing technical information from other firms are reduced, which is ultimately reflected in the remuneration paid to these connected directors.

4.6 Board Connections and Innovation Outcomes

The previous analyses focus on treated firms and their directors, under the assumption that other firms would derive less value from hiring affected directors after AIPA. To explore the impact of disclosure reform on other firms connected to treated firms, I execute additional tests. Previous literature has established that board networks can enhance a firm's innovation output (Faleye, Kovacs, and Venkateswaran, 2015; Chuluun et al., 2017; Chang and Wu, 2021). Building on this strand of literature, I study the changes in innovation outcomes of firms connected to treated firms by using a fixed-effects Poisson model to estimate the following equation:

$$\begin{aligned} Innovation\ Outcomes_{i,t+3} = \alpha + \ \beta_1\ ConnToTreat_{i,t} + \ \beta_2\ ConnToTreat_{i,t} \times Post_{i,t} \\ +\gamma' Controls + Director\ FE + \ Year\ FE + \varepsilon_{i,t} \quad (5) \end{aligned}$$

where *Innovation Outcomes* are measured using three proxies for innovation quantity and quality: the number of patents, forward citations, and KPSS value of patents. To account for the lag between innovation investments and patent applications, I used the three-year-ahead measures (e.g., He and Tian, 2013).[22] *ConnToTreat* is an indicator variable that takes the value of one if firm *i* has at least one director sitting on the board of other treated firms, and zero otherwise. A comprehensive set of control variables is included in this analysis. I also control for the number of board interlocks to isolate the specific effects of board networks on innovation.

As reported in Table 9 Panel A, the sample used in the test consists of 15,289 firm-year observations, with 84.4% having at least one connected director with treated firms, indicating

[22] The results are robust to using other year-ahead measures, for instance, two-year-ahead.

that forming ties with others is pervasive among innovation-intensive firms.[23] The regression results of Equation (5) are presented in Panel B. In Column (1), the coefficient on *ConnToTreat* is significantly positive (coefficient = -0.195, t-statistics = 2.29), suggesting that connections to other treated firms boost a firm's innovation outputs in terms of patent quantity, as firms can access valuable investment-related information through these board connections. However, this benefit seems to subsequently disappear after AIPA, as indicated by the negative coefficient on $ConnToTreat \times Post$. There are no observable effects on patent quality, measured by the patent citations and KPSS value of patents. Taken as a whole, the disclosure regulation impairs well-connected directors' advising role on innovation by reducing connected firms' patent applications relative to unconnected firms.

5 Conclusion

This paper examines the impact of mandatory patent disclosures on the managerial labor market, specifically how these disclosures affect the outside employment opportunities of directors. Patent disclosures reveal valuable strategic and technological information to the public, which can have spillover effects on the information value of directors for other firms. I find that when firms are required to disclose substantial patent application information, their directors experience a decline in outside employment opportunities by around 23%, indicating that disclosure creates information spill-outs that substitute the informational value for other firms to hire these directors. This effect is more pronounced for firms operating in homogenous and fast-changing product markets, with a broader scope of innovation, more novel inventions, more reliance on internal knowledge, and more readable patent disclosures.

Further analysis on the director level indicates that this effect is more significant for directors with shorter tenures, non-executive positions, and sitting on larger boards, who may

[23] The Poisson model eliminates sample firms with constant dependent variables. These firms mostly have no innovation outputs during the sample period and, therefore, no variation in innovation outcome measures. A relatively high proportion of firms with board ties to treated firms suggests that such inter-firm connections can be of value to innovation-intensive firms.

be valued more for their information conduit role than for their in-depth understanding of the firm. Moreover, directors with positions in regulated firms experience a drop in their annual total compensation, suggesting a decrease in their human capital value. The study also finds that the positive effects of well-connected directors on a firm's innovation outcomes diminish after AIPA.

Overall, this study makes three major contributions. First, it provides evidence of how disclosure reform affects the boundaries of the managerial labor market. Second, it adds to the literature on the substitute effects between public disclosure and private communication channels by presenting a non-coordination channel and focusing on the substitute effects of public disclosure. Third, it identifies information dependence as the first-order antecedent of director interlock formation and has implications for understanding the human capital value of directors in managing firms' innovation.

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Figure 1. Dynamic Effects on Firm-Level Directors' Outside Job Opportunities

The figure displays the dynamic effects of information spill-outs resulting from the enactment of AIPA on firm-level directors' outside employment opportunities. I estimate Equation (2) by saturating *Post* with several event-year indicators. The full set of control variables with firm and industry-year fixed effects in Equation (2) are included. The benchmark event year 0 is the year 2000, with 1 indicating the year 2001, and so on. The estimated coefficients of event-year indicators are plotted with 95% confidence intervals.

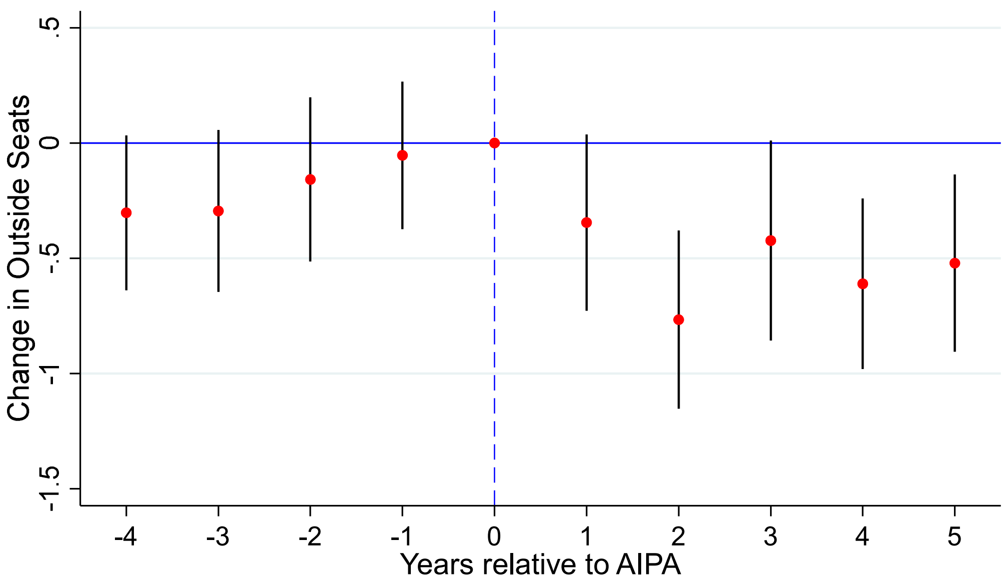

Figure 2. Dynamic Effects on Individual Directors' Outside Job Opportunities

The figure displays the dynamic effects of information spill-outs resulting from the enactment of AIPA on individual directors' outside employment opportunities. I estimate Equation (3) by saturating *Post* with several event-year indicators. The full set of control variables with firm and industry-year fixed effects in Equation (3) are included. The benchmark event year 0 is the year 2000, with 1 indicating the year 2001, and so on. The estimated coefficients of event-year indicators are plotted with 95% confidence intervals.

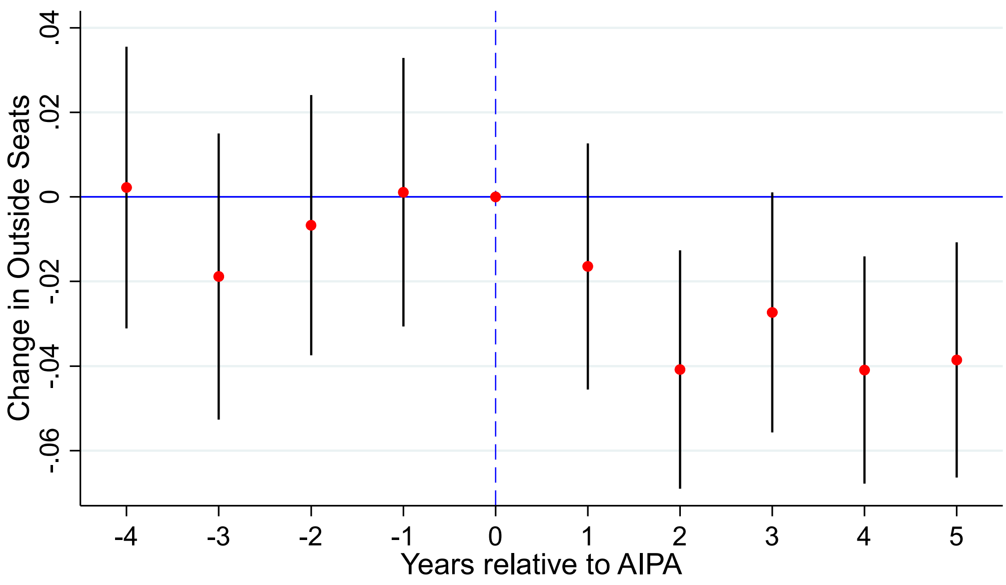

Table 1. Sample Distribution

This table presents the sample distribution by industry and year (#unique firms = 1,636). Panel A reports the numbers of treated and control firms across different SIC2 industries. Panel B reports the distribution of firm-year observations and the mean value of changes in outside board seats (*#Change Seats*) by year. ***, ***, * indicate statistical significance of differences at 1%, 5%, and 10%, respectively.

Panel A: Treated and control firms distribution by SIC2 industries

SIC2 Industry Code	# Treated Firms	# Control Firms	SIC2 Industry Code	# Treated Firms	# Control Firms
1	2	0	44	1	0
10	8	0	45	6	0
13	16	14	47	3	0
14	4	0	48	15	20
15	2	0	49	48	0
16	2	0	50	16	10
17	1	0	51	13	1
20	31	9	53	3	0
21	2	0	55	1	0
22	9	1	56	4	0
23	10	0	57	1	0
24	10	0	58	4	0
25	13	1	59	10	1
26	1	23	60	12	0
27	13	1	61	7	0
28	147	92	62	10	0
29	0	10	63	14	1
30	20	3	64	2	0
31	6	0	65	2	1
32	8	2	67	9	3
33	24	1	72	1	1
34	21	8	73	64	119
35	8	153	75	1	0
36	5	215	78	1	0
37	0	57	79	7	0
38	136	48	80	12	1
39	17	1	82	4	0
40	3	0	87	24	3
42	4	1	99	0	17
			Total Number:	818	818

Panel B: Sample distribution and change in board seats by years

	Control Firms		Treated Firms		
Year	N	Mean(#*Change Seats*)	N	Mean(#*Change Seats*)	Mean (Diff.)
1996	508	0.258	543	0.637	-0.379***
1997	556	0.320	582	0.600	-0.280***
1998	648	0.276	642	0.506	-0.230***
1999	704	0.317	702	0.590	-0.273***
2000	813	0.264	811	0.418	-0.154*
2001	769	-0.101	766	0.197	-0.299***
2002	748	-0.100	751	-0.075	-0.026
2003	739	0.041	735	0.201	-0.161*
2004	738	0.111	727	0.048	0.063
2005	705	0.030	700	0.001	0.028

Table 2. Descriptive Statistics

This table provides descriptive statistics of firm-level variables. All continuous variables are winsorized at the 1st and 99th percentiles. Panel A reports summary statistics, and Panel B reports the pairwise correlation between the main variables. * indicates significance at the 5% level.

Panel A: Summary statistics of firm-level variables

Variables	N	Mean	SD	p25	p50	p75
Firm-Level Variables:						
#Change Seats	13,887	0.213	1.709	0.000	0.000	1.000
#New Seats	13,887	1.589	2.456	0.000	1.000	2.000
#Lost Seats	13,887	1.376	2.172	0.000	1.000	2.000
Spillout	13,887	-4.978	1.458	-5.864	-5.069	-4.259
Treat	13,887	0.501	0.500	0.000	1.000	1.000
Cash	13,887	0.222	0.246	0.028	0.113	0.356
Intan	13,887	0.127	0.153	0.002	0.067	0.199
Asset	13,887	5.964	2.211	4.310	5.820	7.463
R&D	13,887	0.074	0.112	0.000	0.026	0.099
Leverage	13,887	0.465	0.252	0.256	0.460	0.635
Sales	13,887	5.620	2.404	3.970	5.685	7.323
Ind_HHI	13,887	0.255	0.196	0.114	0.204	0.324
ROA	13,887	0.054	0.223	0.017	0.104	0.173
BM	13,887	0.587	0.527	0.254	0.458	0.751
Female	13,887	0.082	0.083	0.000	0.071	0.133
Independent	13,887	0.431	0.180	0.308	0.400	0.538
Boardsize	13,887	17.510	12.610	9.000	14.000	22.000
Duality	13,887	0.619	0.486	0.000	1.000	1.000
Executive-Level Variables:						
#Change Seats	147,288	0.005	0.372	0.000	0.000	0.000
Tenure	147,288	4.464	2.056	3.083	4.125	5.356
Executive	147,288	0.560	0.496	0.000	1.000	1.000
Log(Total Comp)	32,575	4.934	1.677	3.555	4.500	6.397
Connect	32,575	0.722	0.448	0.000	1.000	1.000
Connect2000	25,599	0.732	0.443	0.000	1.000	1.000

Panel B: Pairwise correlation of main variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) *#Change Seats*	1.000								
(2) *#New Seats*	0.505*	1.000							
(3) *#Lost Seats*	-0.217*	0.733*	1.000						
(4) *Spillout*	0.043*	0.202*	0.195*	1.000					
(5) *Treat*	0.048*	0.184*	0.170*	0.763*	1.000				
(6) *Cash*	-0.040*	-0.078*	-0.056*	-0.125*	-0.064*	1.000			
(7) *Intan*	-0.022*	0.093*	0.122*	0.015	0.035*	-0.307*	1.000		
(8) *Asset*	0.110*	0.474*	0.450*	0.437*	0.299*	-0.386*	0.188*	1.000	
(9) *R&D*	-0.024*	-0.068*	-0.058*	-0.124*	-0.042*	0.567*	-0.169*	-0.429*	1.000
(10) *Leverage*	0.043*	0.180*	0.169*	0.214*	0.143*	-0.490*	0.100*	0.423*	-0.216*
(11) *Sales*	0.097*	0.406*	0.382*	0.366*	0.233*	-0.559*	0.192*	0.922*	-0.529*
(12) *Ind_HHI*	0.012	0.004	-0.005	-0.047*	-0.024*	-0.194*	0.072*	0.017*	-0.171*
(13) *ROA*	0.037*	0.090*	0.072*	0.089*	0.037*	-0.469*	0.118*	0.392*	-0.625*
(14) *BM*	-0.030*	-0.105*	-0.095*	-0.060*	-0.076*	-0.208*	0.035*	0.021*	-0.232*
(15) *Female*	0.033*	0.226*	0.230*	0.229*	0.198*	-0.052*	0.064*	0.289*	-0.066*
(16) *Independent*	-0.010	-0.268*	-0.295*	-0.075*	-0.054*	-0.006	-0.101*	-0.275*	0.062*
(17) *Boardsize*	0.070*	0.599*	0.623*	0.297*	0.237*	-0.160*	0.189*	0.691*	-0.172*
(18) *Duality*	0.024*	0.111*	0.106*	0.130*	0.088*	-0.134*	0.055*	0.255*	-0.143*

Variables	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(10) *Leverage*	1.000								
(11) *Sales*	0.461*	1.000							
(12) *Ind_HHI*	0.048*	0.093*	1.000						
(13) *ROA*	0.107*	0.568*	0.104*	1.000					
(14) *BM*	-0.025*	0.045*	0.058*	0.009	1.000				
(15) *Female*	0.125*	0.259*	-0.005	0.091*	-0.067*	1.000			
(16) *Independent*	-0.046*	-0.253*	-0.016	-0.112*	0.122*	-0.193*	1.000		
(17) *Boardsize*	0.271*	0.624*	0.035*	0.188*	-0.130*	0.359*	-0.538*	1.000	
(18) *Duality*	0.166*	0.253*	0.068*	0.118*	0.008	0.090*	-0.113*	0.198*	1.000

Table 3. Information Spill-Outs and Changes in Directors' Outside Seats

This table reports the effects of information spill-outs resulting from the enactment of AIPA on changes in directors' outside seats. The dependent variable of the first three columns, *#Change Seats*, is the change in the number of directors' outside board seats. *#New Seats* and *#Lost Seats* are the numbers of newly obtained and recently terminated outside seats, respectively. The independent variable *Treat* is an indicator variable indexing a firm with relatively high information spill-outs under AIPA, and *Post* indexes years after 2000. Detailed definitions of all variables are provided in Appendix A. All specifications include firm and industry-year fixed effects. The *t*-statistics are reported below coefficient estimates in parentheses and are calculated based on standard errors clustered by firm. ***, ***, * indicate statistical significance at 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)
Dep. Var.=	***#Change Seats***	***#Change Seats***	***#Change Seats***	***#New Seats***	***#Lost Seats***
Treat* × *Post	**-0.435*** **	**-0.429*** **	**-0.403*** **	**-0.172* **	**0.231*** **
	(-4.10)	**(-4.01)**	**(-3.66)**	**(-1.67)**	**(2.78)**
Cash		-0.096	-0.094	0.028	0.121
		(-0.63)	(-0.61)	(0.18)	(0.81)
Intan		-0.440*	-0.401*	-0.053	0.348
		(-1.93)	(-1.76)	(-0.21)	(1.47)
Asset		0.026	0.036	0.112**	0.076
		(0.53)	(0.72)	(2.16)	(1.62)
R&D		0.526*	0.551*	0.559*	0.008
		(1.69)	(1.77)	(1.87)	(0.03)
Leverage		0.041	0.043	0.011	-0.032
		(0.32)	(0.34)	(0.08)	(-0.26)
Sales		0.013	0.018	0.020	0.003
		(0.32)	(0.44)	(0.44)	(0.07)
Ind_HHI		0.311	0.308	0.348	0.039
		(1.26)	(1.25)	(1.48)	(0.16)
ROA		0.170	0.152	0.031	-0.120
		(1.28)	(1.14)	(0.23)	(-0.95)
BM		0.049	0.045	-0.035	-0.081**
		(1.28)	(1.18)	(-0.88)	(-2.21)
Female			0.064	0.218	0.153
			(0.19)	(0.62)	(0.49)
Independent			0.000	0.592***	0.592***
			(0.00)	(3.83)	(4.09)
Boardsize			-0.009	0.066***	0.075***
			(-1.61)	(10.65)	(14.53)
Duality			0.018	-0.050	-0.068
			(0.36)	(-0.91)	(-1.36)
Observations	13,887	13,887	13,887	13,887	13,887
R-squared	0.180	0.181	0.181	0.627	0.620
Firm FE	YES	YES	YES	YES	YES
Ind-Year FE	YES	YES	YES	YES	YES

Table 4. Robustness Tests

This table reports the robustness tests of the results. Columns (1) and (2) present results of models with lower dimensions of fixed effects, and the model in Column (3) includes state-year fixed effects in addition to the baseline fixed effects. Columns (4) and (5) present results with additional matching procedures. In Column (4), the model is estimated with a coarsened exact matching sample to ensure the balance within the covariate-coarsened buckets. In Column (5), I present the entropy matching case where observations are weighted to equate means for out-of-balance control variables between the treated and control firms. Column (6) adopts the Poisson regression model to estimate the effects on an alternative dependent variable, *#Interlocks*, the number of total board interlocks in a firm. In Columns (7) and (8), I employ alternative continuous treatment variables: the raw information spill-out measure (*Spillout*) and firm-level pre-AIPA patent disclosure lag (*FirmLag*), respectively. Detailed definitions of all variables are provided in Appendix A. The *t*-statistics are reported below coefficient estimates in parentheses and are calculated based on standard errors clustered by firm. ***, ***, * indicate statistical significance at 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Specifications	Alternative Fixed Effects			Coarsened Exact Matching	Entropy Matching	Number of Interlocks	Alternative Treatment Measures	
Dep. Var.=	***#Change Seats***			***#Change Seats***		***#Interlocks***	***#Change Seats***	
Post	-0.291***							
	(-7.98)							
Treat	0.253***							
	(5.43)							
Treat* × *Post	**-0.171*****	**-0.142****	**-0.460*****	**-0.409*****	**-0.444*****	**-0.137*****		
	(-2.67)	**(-2.10)**	**(-3.55)**	**(-2.96)**	**(-3.19)**	**(-3.55)**		
Spillout* × *Post							**-0.212*****	
							(-5.88)	
FirmLag* × *Post								**-0.233****
								(-2.07)
Observations	13,964	13,958	12,176	8,676	13,887	12,899	16,140	14,764
R-squared	0.015	0.141	0.231	0.257	0.200	0.680 (Pseudo)	0.192	0.194
Controls	NO	YES	YES	YES	YES	YES	YES	YES
FE	NO	Firm, Year	Firm, Ind-Year, State-Year	Firm, Ind-Year		Firm, Ind-Year	Firm, Ind-Year	

Table 5. Firm-Level Cross-Sectional Tests

This table reports the results of firm-level cross-sectional tests. Panel A presents the moderating effects of product similarity and product market fluidity. The sample in Panel A Columns (1) and (2) is partitioned based on product similarity (Hoberg and Phillips, 2016), with similarity scores higher than the year median classified as the "High" group and others as the "Low" group. The sample in Panel A Columns (3) and (4) is partitioned based on product market fluidity (Hoberg et al., 2014), with fluidity measures higher than the year median designated into the "High" group and others into the "Low" group. Panel B presents the moderating effects of the firm's broadness of the innovation scope. The sample is partitioned based on the number- or the value-based HHI of the firm's patent filings across USPTO patent classes in the past 20 years, with HHI higher than the year median designated into the "Narrow" scope groups and others into the "Broad" groups. Panel C presents the moderating effects of the firm's innovation novelty, with the firms' past patents citing relatively new patents designated into the "High" novelty group and others into the "Low" group. The newness of patents is gauged by the time elapsed from the patent application date to the citing date. Panel D presents the moderating effects of knowledge sources for firms to create new inventions. Specifically, I calculate the proportion of the firm's self-citations out of the total citations to evaluate its knowledge sources. Firms with a higher-than-year-median ratio of self-citations are partitioned into the "Internal" group and others into the "External" group. Panel E reports the moderating effects of patent abstract readability. Firms with lower-than-year-median average FOG index (Gunning, 1952) of patent abstracts are classified as the "High" readability group and others as the "Low" group. Detailed definitions of all variables are provided in Appendix A. The *t*-statistics are reported below coefficient estimates in parentheses and are calculated based on standard errors clustered by firm. ***, ***, * indicate statistical significance at 1%, 5%, and 10%, respectively.

Panel A: Moderating effects of product similarity and product market fluidity

	(1)	(2)	(3)	(4)
	Product Similarity		Product Market Fluidity	
	High	Low	High	Low
Dep. Var.=	*#Change Seats*			
Treat × Post	**-0.510***** **(-3.00)**	**-0.288*** **(-1.76)**	**-0.540***** **(-3.27)**	**-0.258*** **(-1.85)**
Diff. in Coeff.	0.222		0.282	
p-value of (Diff.>0)	0.17		0.09	
Observations	6,565	6,585	6,415	6,444
R-squared	0.212	0.236	0.208	0.236
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Ind-Year FE	YES	YES	YES	YES

Panel B: Moderating effects of firms' innovation scope

	(1)	(2)	(3)	(4)
Scope measured by	HHI (Number of Patents)		HHI (KPSS Value of Patents)	
	Broad	Narrow	Broad	Narrow
Dep. Var.=	***#Change Seats***			
Treat* × *Post	**-0.833*****	**-0.164**	**-0.775*****	**-0.187**
	(-3.34)	**(-1.21)**	**(-2.95)**	**(-1.39)**
Diff. in Coeff.	0.669		0.587	
p-value of (Diff.>0)	0.01		0.02	
Observations	6,677	6,669	6,656	6,670
R-squared	0.234	0.253	0.238	0.254
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Ind-Year FE	YES	YES	YES	YES

Panel C: Moderating effects of firms' innovation novelty

	(1)	(2)
	Innovation Novelty	
	High	Low
Dep. Var.=	***#Change Seats***	
Treat* × *Post	**-0.727*****	**-0.075**
	(-3.62)	**(-0.56)**
Diff. in Coeff.	0.652	
p-value of (Diff.>0)	<0.01	
Observations	6,498	6,554
R-squared	0.252	0.199
Controls	YES	YES
Firm FE	YES	YES
Ind-Year FE	YES	YES

Panel D: Moderating effects of knowledge sources

	(1)	(2)
	Knowledge Source	
	Internal	External
Dep. Var.=	***#Change Seats***	
Treat* × *Post	**-0.602***** **(-2.74)**	**-0.273*** **(-1.88)**
Diff. in Coeff.	0.329	
p-value of (Diff.>0)	0.11	
Observations	6,522	6,545
R-squared	0.237	0.222
Controls	YES	YES
Firm FE	YES	YES
Ind-Year FE	YES	YES

Panel E: Moderating effects of patent readability

	(1)	(2)
	Patent Abstract Readability	
	High	Low
Dep. Var.=	***#Change Seats***	
Treat* × *Post	**-0.648***** **(-2.72)**	**-0.202** **(-1.31)**
Diff. in Coeff.	0.446	
p-value of (Diff.>0)	0.06	
Observations	5,993	5,966
R-squared	0.247	0.248
Controls	YES	YES
Firm FE	YES	YES
Ind-Year FE	YES	YES

Table 6. Director-Level Analysis

This table reports the director-level analysis of how AIPA affects individual directors' outside employment. All dependent variables are reconstructed at the individual director level, which are calculated as the number of changes in a director's outside board seats (*#Change Seats_D*) and the newly obtained or lost seats (*#New Seats_D* and *#Lost Seats_D*). The independent variable *Treat* is consistent with the firm-level construct, which indexes whether a firm has relatively high information spill-outs under AIPA. Detailed definitions of all variables are provided in Appendix A. Director and industry-year fixed effects are included. The *t*-statistics are reported below coefficient estimates in parentheses and are calculated based on standard errors clustered by director. ***, ***, * indicate statistical significance at 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
Dep. Var.=	***#Change Seats_D***	***#Change Seats_D***	***#New Seats_D***	***#Lost Seats_D***
Treat	0.049***	0.050***	0.019	-0.031**
	(3.53)	(3.48)	(1.31)	(-2.16)
Treat* × *Post	**-0.030*** **	**-0.029*** **	**-0.019** **	**0.010**
	(-3.38)	**(-3.25)**	**(-2.50)**	**(1.35)**
Observations	147,288	147,288	147,288	147,288
R-squared	0.134	0.134	0.358	0.346
Controls	NO	YES	YES	YES
Director FE	YES	YES	YES	YES
Ind-Year FE	YES	YES	YES	YES

Table 7. Director-Level Cross-Sectional Tests

This table reports the results of director-level cross-sectional tests. Panel A presents the moderating effects of director tenure. The sample in Panel A is divided based on the length of tenure at the firm, with tenure longer than the sample median classified as the "Long" group and others as the "Short" group. Panel B presents the moderating effects of the director role. The sample in Panel B is partitioned based on whether the director serves as an executive at the focal firm. Panel C presents the moderating effects of board size. The sample is partitioned based on the board size, with the number of board members smaller than the sample median designated into the "Small" groups and others into the "Large" groups. Detailed definitions of all variables are provided in Appendix A. The *t*-statistics are reported below coefficient estimates in parentheses and are calculated based on standard errors clustered by director. ***, ***, * indicate statistical significance at 1%, 5%, and 10%, respectively.

Panel A: Moderating effects of director tenure

	(1)	(2)
	Tenure	
	Long	Short
Dep. Var.=	***#Change Seats_D***	
Treat	0.027	0.076***
	(1.46)	(2.65)
Treat × Post	**-0.017**	**-0.063*** **
	(-1.32)	**(-3.40)**
Diff. in Coeff. on *Treat* × *Post*	0.046	
p-value of Diff.>0	0.02	
Observations	71,608	71,184
R-squared	0.165	0.250
Controls	YES	YES
Director FE	YES	YES
Ind-Year FE	YES	YES

Panel B: Moderating effects of the director role

	(1)	(2)
	Executives?	
	YES	NO
Dep. Var.=	***#Change Seats_D***	
Treat	0.095**	0.063***
	(2.34)	(3.38)
Treat* × *Post	**-0.008**	**-0.053*** **
	(-1.05)	**(-3.33)**
Diff. in Coeff. on *Treat* × *Post*	0.045	
p-value of Diff.>0	<0.01	
Observations	82,158	64,546
R-squared	0.210	0.139
Controls	YES	YES
Director FE	YES	YES
Ind-Year FE	YES	YES

Panel C: Moderating effects of board size

	(1)	(2)
	Board Size	
	Small	Large
Dep. Var.=	***#Change Seats_D***	
Treat	0.044**	0.081**
	(2.39)	(2.23)
Treat* × *Post	**-0.022** **	**-0.064** **
	(-2.12)	**(-2.45)**
Diff. in Coeff. on *Treat* × *Post*	0.042	
p-value of Diff.>0	0.07	
Observations	75,062	67,732
R-squared	0.163	0.184
Controls	YES	YES
Director FE	YES	YES
Ind-Year FE	YES	YES

Table 8. Director-Level Compensation Changes

This table reports the changes in directors' compensation after AIPA. The dependent variable *Log(Total Comp)* is the log of aggregated total compensation earned by a director across firms where she has a board position in a given year. *Connected* is an indicator variable that equals one if the director has at least one seat in a treated firm and zero otherwise. *Connected2000* indicates whether a director holds a seat in any treated firm in 2000. Firm-level covariates are collapsed by being averaged at the director-year level and are included in the estimation. Director and year fixed effects are controlled. Detailed definitions of all variables are provided in Appendix A. The *t*-statistics are reported below coefficient estimates in parentheses and are calculated based on standard errors clustered by director. ***, ***, * indicate statistical significance at 1%, 5%, and 10%, respectively.

	(1)	(2)
Dep. Var.=	***Log(Total Comp)***	
Connected	0.042	
	(0.41)	
Connected* × *Post	**-0.063****	
	(-2.35)	
Connected2000* × *Post		**-0.061****
		(-2.05)
Observations	32,575	25,599
R-squared	0.884	0.877
Controls	YES	YES
Director FE	YES	YES
Year FE	YES	YES

Table 9. Board Connections and Innovation Outcomes

This table reports the results of board connections to treated firms on innovation outcomes. Panel A presents the descriptive statistics of the sample used in the tests. Panel B presents the Poisson regression estimation results. Dependent variables are the number, forward citations, and KPSS value of patents filed by the firm in year *t*+3. The independent variable *ConnToTreat* is an indicator variable that takes the value of one if firm *i* has at least one director sitting on the board of other treated firms, and zero otherwise. All models are estimated with Poisson regressions. Firm and industry-year fixed effects are controlled. Detailed definitions of all variables are provided in Appendix A. The *t*-statistics are reported below coefficient estimates in parentheses and are calculated based on standard errors clustered by director. ***, ***, * indicate statistical significance at 1%, 5%, and 10%, respectively.

Panel A: Descriptive statistics

Variable	N	Mean	SD	p25	p50	p75
$\#Patent_{t+3}$	15,289	27.230	178.100	0.000	1.000	7.000
$\#Citation_{t+3}$	15,289	392.900	2736.000	0.000	5.000	85.000
$Value_{t+3}$	15,289	403.300	2352.000	0.000	1.117	30.190
ConnToTreat	15,289	0.844	0.363	1.000	1.000	1.000
Log(#Interlocks)	15,289	1.937	1.102	1.099	2.079	2.708
Cash	15,289	0.234	0.250	0.031	0.129	0.380
Intan	15,289	0.129	0.156	0.004	0.068	0.201
Asset	15,289	5.962	2.215	4.293	5.786	7.465
R&D	15,289	0.077	0.112	0.000	0.031	0.107
Leverage	15,289	0.457	0.254	0.245	0.447	0.629
Sales	15,289	5.585	2.402	3.911	5.604	7.288
Ind_HHI	15,289	0.250	0.194	0.112	0.198	0.316
ROA	15,289	0.055	0.221	0.016	0.105	0.174
BM	15,289	0.550	0.484	0.242	0.434	0.716
Female	15,289	0.084	0.082	0.000	0.074	0.136
Independent	15,289	0.420	0.176	0.296	0.400	0.500
Boardsize	15,289	18.150	12.890	9.000	15.000	23.000
Duality	15,289	0.614	0.487	0.000	1.000	1.000

Panel B: Regression results

	(1)	(2)	(3)
Dep. Var.=	$\#Patent_{t+3}$	$\#Citation_{t+3}$	$Value_{t+3}$
ConnToTreat	**0.195****	**0.127***	**-0.067**
	(2.29)	**(1.80)**	**(-0.55)**
ConnToTreat* × *Post	**-0.263*****	**-0.165**	**-0.271**
	(-2.63)	**(-1.30)**	**(-1.00)**
Observations	15,289	14,957	15,289
Controls	YES	YES	YES
Firm FE	YES	YES	YES
Ind-Year FE	YES	YES	YES

Appendix A. Variable Definitions

Variable	Definitions	Data Source
Main Dependent Variables		
#New Seats$_{i,t}$	The number of newly-obtained outside positions by all directors at focal firm *i* in year *t*. The timing of taking the outside seat should be after the director worked at the focal firm.	BoardEx
#Lost Seats$_{i,t}$	The number of terminated outside positions by all directors at focal firm *i* in year *t*. The director should still work at the focal firm when terminating the outside seat.	BoardEx
#Change Seats$_{i,t}$	The number of newly-obtained outside positions by all directors minus the number of terminated outside positions. (= *#New Seats*$_{i,t}$ - *#Lost Seats*$_{i,t}$)	BoardEx
#Interlocks$_{i,t}$	The number of board interlocks.	BoardEx
#New Seats_D$_{d,i,t}$	The number of newly-obtained outside positions by director *d* at focal firm *i* in year *t*. The timing of taking the outside seat should be after the director worked at the focal firm.	BoardEx
#Lost Seats_D$_{d,i,t}$	The number of terminated outside positions by director *d* at focal firm *i* in year *t*. The director should still work at the focal firm when terminating the outside seat.	BoardEx
#Change Seats_D$_{i,t}$	The number of newly-obtained outside positions by director *d* minus the number of terminated outside positions. (= *#New Seats_D*$_{i,t}$ - *#Lost Seats_D*$_{i,t}$)	BoardEx
Log(Total Comp)$_{d,t}$	The log of the total compensation for director *d* across all firms she works at in year *t*.	BoardEx
#Patent$_{i,t+3}$	The number of patents filed by firm *i* in year *t*+3.	Kogan et al. (2017)
#Citation$_{i,t+3}$	The number of citations received on the firm's patents filed in year *t*+3.	Kogan et al. (2017)
Value$_{i,t+3}$	The KPSS value of patents filed in year *t*+3.	Kogan et al. (2017)
Independent Variables		
Spillout$_i$	A measure of relative information spill-out, calculated as follows: $Spillout_i = ln\left(\frac{w_i \times Publag_i}{(\sum_{j \neq i} w_j \times Publag_j)/n}\right)$ where *i* denote the focal firm and *j* stands for all peer firms in the same SIC-2 industry. *Publag* is a firm's average filing-to-grant lag for all patents filed by the firm in the 20 years prior to the enactment of the AIPA. I weight each publication lag by w_i, the percentile of the total KPSS value of patents filed by the firm in the 20-year period. In the denominator, I follow a similar procedure to sum the publication lag for peer firms in the same industry and divide it by the number of peer firms (*n*) to adjust for different industry sizes. The measure is then transformed using a natural log function to minimize the impact of outliers.	USPTO; Kogan et al. (2017)
Treat$_i$	An indicator variable equal to one if a firm's relative information spill-outs (*Spillout*) is higher than the sample's median value in 2000, and zero otherwise.	USPTO; Kogan et al. (2017)

Appendix A (Continued)

Variable	Definitions	Data Source
FirmLag$_i$	The log of a firm's average filing-to-grant lag for all patents filed by the firm in the 20 years prior to the enactment of the AIPA.	USPTO; Kogan et al. (2017)
Post$_{i,t}$	An indicator variable that equals one for fiscal years after 2000, and 0 otherwise.	
Connected$_{i,t}$	An indicator variable that equals one if the director has at least one seat in a treated firm and zero otherwise.	BoardEx
Connected2000$_{i,t}$	An indicator variable that equals one if the director has at least one seat in a treated firm in 2000 and zero otherwise.	BoardEx
ConnToTreat$_{i,t}$	An indicator variable that takes the value of one if firm *i* has at least one director sitting on the board of other treated firms, and zero otherwise.	BoardEx
Control Variables		
Cash$_{i,t}$	Cash holdings scaled by total assets.	Compustat
Intangibility$_{i,t}$	Intangible assets scaled by total assets.	Compustat
Asset$_{i,t}$	The log of total assets.	Compustat
Leverage$_{i,t}$	Total liabilities divided by total assets.	Compustat
Sale$_{i,t}$	The log of total sales.	Compustat
R&D$_{i,t}$	R&D expenditures scaled by total assets. Missing values are set to zero.	Compustat
ROA$_{i,t}$	Earnings before extraordinary items, scaled by total assets.	Compustat
BM$_{i,t}$	The ratio of the book value to the market value of the equity.	Compustat
Ind HHI$_{i,t}$	The sum of the squared market share of each publicly traded company in the same four-digit SIC code as firm *i* in a given year. Market share is calculated as a company's sales divided by the SIC code's total Compustat sales.	Compustat
Female$_{i,t}$	The percentage of female directors on the board in a given year.	BoardEx
Independent$_{i,t}$	The percentage of independent directors on the board in a given year.	BoardEx
Boardsize$_{i,t}$	The number of directors on the board in a given year.	BoardEx
Duality$_{i,t}$	An indicator variable that equals one if the CEO is also the chairman of the board, and zero otherwise.	BoardEx

Appendix B. Apple's patent filing: "Gestures for touch sensitive input devices"

On February 2, 2006, the US Patent and Trademark Office published Apple's patent application titled "Gestures for touch-sensitive input devices." This 56-page document includes 38 images that provide detailed technical information and application contexts. Exhibit 1 displays the cover page of the patent application, and Exhibit 2 highlights one of the figures (Fig. 25) from the filing document, which illustrates the technology's application on a virtual keyboard.

Exhibit 1. Cover page

US 20060026521A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0026521 A1**

Hotelling et al. (43) **Pub. Date: Feb. 2, 2006**

(54) **GESTURES FOR TOUCH SENSITIVE INPUT DEVICES**

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(73) Assignee: **Apple Computer, Inc.**

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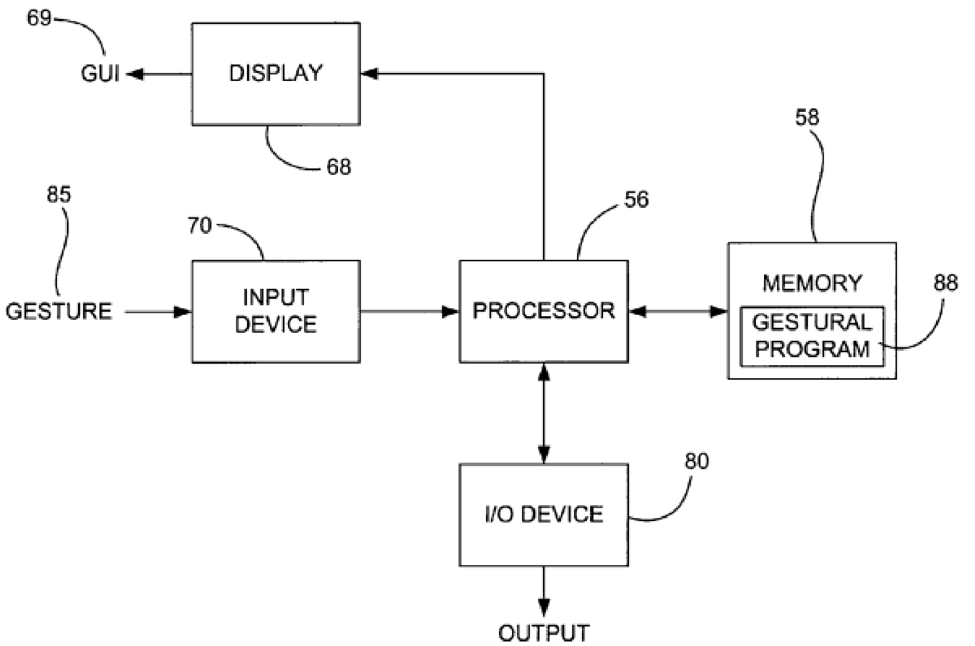
(52) **U.S. Cl.** **715/702**; 715/863

(57) **ABSTRACT**

Methods and systems for processing touch inputs are disclosed. The invention in one respect includes reading data from a multipoint sensing device such as a multipoint touch screen where the data pertains to touch input with respect to the multipoint sensing device, and identifying at least one multipoint gesture based on the data from the multipoint sensing device.



Appendix B (Continued)

Exhibit 2. Display keyboard on a touchscreen

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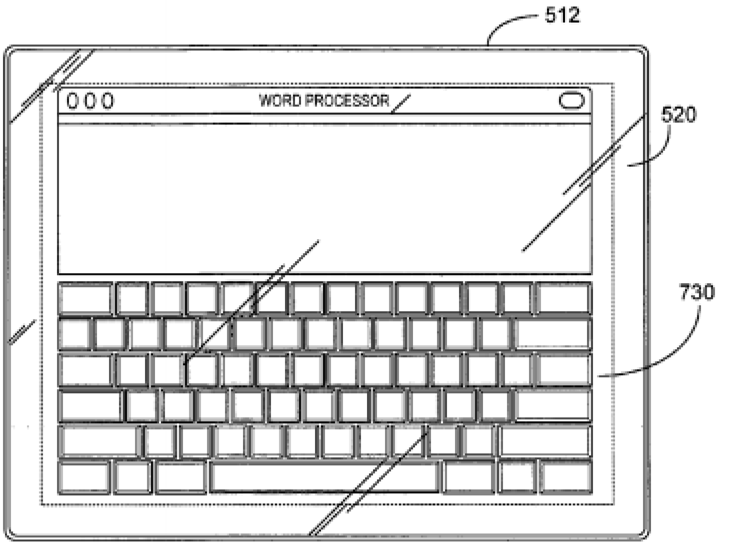

FIG. 25A

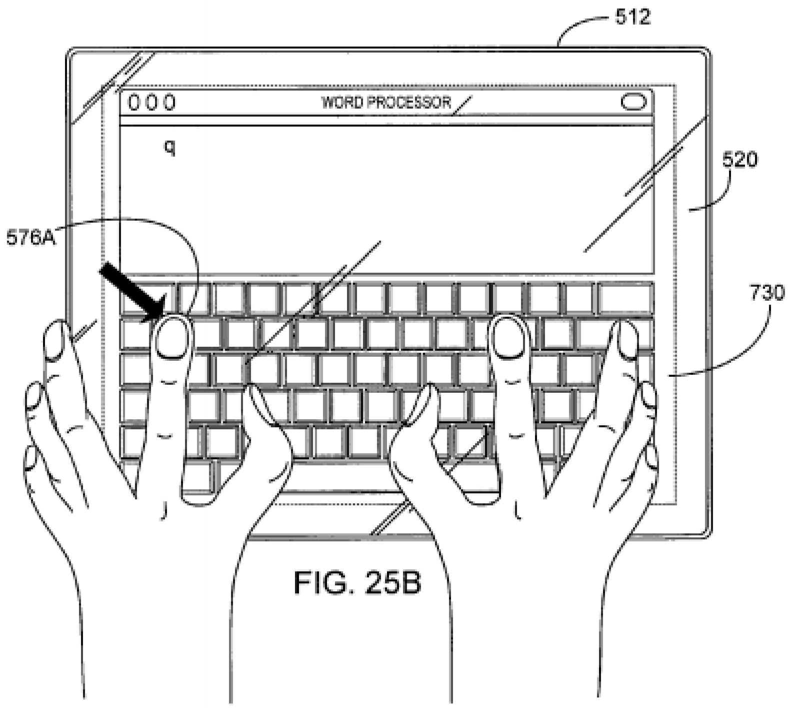

FIG. 25B