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# CEO-CIO Shared Understanding of the Role of Technology: Outcomes for Technological Innovation Value

*Short Paper*

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## **Abstract**

*In this paper, we propose that contextual “language style matching” between CEO and CIO - a form of similarity in verbal style based on the unconscious use of function words - can provide insight into the quality of collaboration between CEO and CIO. Following upper echelon and managerial cognition research, we argue that high levels of language style matching between the CEO and CIO when discussing the role of technology for the business reflects a shared understanding of the role of technology. As CEO-CIO shared understanding aligns technology innovation with overall business strategy, the economic value of the firm’s technological innovations increases. Counterintuitively, we expect the relationship to weaken when CEOs are overly optimistic, as CEOs are less likely to question technological innovation from a business standpoint. Thus, the shared understanding of the CEO and CIO is misguided. Using panel data, we find empirical support for these predictions.*

**Keywords:** Upper echelons theory, chief executive officer, chief information officer, language style matching, technological innovation value, CEO optimism

## Introduction

Information Technology (IT) is often considered a driver of competitive advantage and strategic differentiation (e.g., Mata et al. 1995). Indeed, top management executives frequently turn to their IT departments to suggest innovative ways to improve products and processes, ultimately creating business value (e.g., Banker et al. 2011; Roepke et al. 2000). To ensure successful technological innovation, managers must align business strategies with information technology strategies (e.g., Burn 1996). This alignment begins with a good working relationship between the Chief Executive Officer (CEO) and the Chief Information Officer (CIO), which is essential for a strong business-IT partnership (e.g., Benlian and Haffke 2016). The CIO is the highest-level IT executive in a firm and is responsible for strategic technology decisions, while the CEO is responsible for the overall business strategy (e.g., Banker et al. 2011). As such, these two collectively drive decisions and investments in technological innovation within the upper echelon of the firm (e.g., Karahanna and Preston 2013) and, *ceteris paribus*, heavily influence the derived technological innovation value. Since the CEO and CIO are the critical decision-makers within the top management team (TMT) with respect to technological innovation (e.g., Watts and Henderson 2006), the CEO-CIO dyad is the centerpiece of our study.

Several studies have found that the ability to respond to opportunities for exploratory innovation is a function of TMT cognition (e.g., Kaplan 2008). The response is significantly shaped by the existing cognitive maps (e.g., Hambrick and Mason 1984). However, CEOs and CIOs likely have different levels of knowledge and expertise, leading to difficulties in business-IT alignment and cognitive conflict. Cognitive conflict occurs when group members disagree about the content of tasks, including having different viewpoints and ideas (e.g., Qian et al. 2013). For example, research shows that one potential source of cognitive conflict is that CEOs and CIOs agree on the contribution of information systems (IS) but not on how IS strategy makes that contribution. CEOs seem to have a more exploitative view of technology, while CIOs have a more exploratory view (e.g., Johnson and Lederer 2013). Although studies show cognitive conflict benefitting teams and organizations (e.g., Amason 1996), researchers have found mixed results regarding the value of technological innovation. On the one hand, cognitive conflict and heterogeneity are beneficial for steering innovation activities toward riskier, but potentially more valuable, innovations (e.g., Hansen et al. 2011). On the other hand, CEOs and CIOs need to align a technological invention with business strategy to create value “in context” for it to become a relevant innovation (e.g., Keen and El Sawy 2010). In a similar vein, Johnson and Lederer (2010) show that CEO-CIO shared understanding improves the alignment of business and IT for different strategic orientations. This alignment includes an inclination to apply creative solutions to business problems. However, channels through which the CEO-CIO shared understanding may benefit the firm’s technological innovation lie outside the scope of their study. Moreover, most research has focused on the cognitive aspects, or what CEOs or CIOs think about technology (e.g., Kaplan 2008). Far less research has focused on how the CEO and CIO’s minds work regarding the role of technology in the business context. This study aims to address this research gap and respond to scholars’ calls to investigate further the CEO-CIO dyad’s characteristics in specific decision-making situations such as research and development (R&D) alignment and corporate strategy (e.g., Shi et al. 2019).

Following research on the upper echelon (e.g., Hambrick and Mason 1984), a common approach is to examine the demographic characteristics of the CEO or CIO to infer the quality of their relationship and thinking styles. We seek to go beyond demographic characteristics to increase the predictive capability of the upper echelons theory (e.g., Hambrick 2007). Thus, our study focuses on the verbal similarity of *how* CEOs and CIOs discuss the firm’s digital strategy orientation. We rely on contextual “language style matching” (LSM) between the CEO and CIO to capture their shared understanding of the role of technology. LSM determines the similarity between two individuals in their relative use of nine function word categories (e.g., Ireland et al. 2011; Ireland and Pennebaker 2010). Function words (e.g., propositions, pronouns) differ from content words (e.g., nouns, verbs). While content words represent what people say, function words capture how people talk and think (unconsciously) about a topic (e.g., Pennebaker 2011). Therefore, CEOs’ and CIOs’ LSM in a given setting (e.g., earnings calls) can provide insights into their thinking in other settings that are not directly accessible (e.g., Shi et al. 2019). For example, related studies leverage LSM to analyze the integration of opinions on financial decisions (e.g., Zhang et al. 2021) or social interactions between the CEO and CFO (e.g., Shi et al. 2019). To increase the validity of our measurements, we focus on discussions of the firm’s digital strategy in the question and answer (Q&A) section of the earnings calls. Building on previous research on the CEO-CIO relationship (e.g., Feeny et al. 1992), we argue that the CEO

and CIO LSM in the Q&A portion of earnings calls reflect a mutual understanding of the role of technology and can predict organizational outcomes for the firm.

In managerial cognition literature, ample evidence has suggested that executive cognition is subject to various biases influencing thinking styles and decision-making (e.g., Kahneman et al. 2011). The CEO optimism bias is a particularly significant cognitive bias concerning the link between technological innovation and business capabilities. Overly optimistic CEOs positively affect firm-level innovation output (e.g., Galasso and Simcoe 2011). However, we argue that there is an attenuating effect on the relationship between shared understanding and technological innovation value. Specifically, excessively optimistic CEOs overestimate positive outcomes and downplay threats. We argue that particularly optimistic CEOs are less likely to challenge their own, and the CIO's beliefs, about the benefits of technological innovation in the business context. Necessary constructive debates may not occur, affecting the quality of shared understanding of the role of technology. As a result, the firm may pursue less fitting technological innovations and create less business value.

To probe our theorizing, we create a panel dataset using recent advances in measuring CEO and CIO contextual LSM. We use the quarterly earnings calls of Standard & Poor's 1500 (S&P 1500) firms between the third quarter in 2002 and the third quarter in 2020 and KPSS patent database (e.g., Kogan et al. 2017). Our results show that CEO-CIO LSM positively affects the value of technological innovation and CEO optimism negatively moderates this relationship. Overall, we contribute to the information systems literature and upper echelons research by examining the CEO-CIO dyad and shedding light on the crucial implications of business and IT alignment. We find that a shared understanding of the role of technology at the upper echelon holds predictive capability for the value of technological innovations.

## **Theory and Hypotheses**

Upper echelon theory (e.g., Hambrick and Mason 1984) posits that executive characteristics can influence various strategic decisions, such as R&D activities and product and technology innovation. Particularly, the dynamics within the "sub-teams" of TMTs in certain decision-making situations influence why a firm makes decisions and what actions are taken (e.g., Hambrick 2007). However, as TMT social interactions are not readily observable to outsiders, studies on the CEO-CIO dyad have been limited to single points in time (for a review, see Benlian and Haffke 2016). Nevertheless, significant contributions have been made, for example, regarding IT's exploitation capabilities (e.g., Feeny et al. 1992) or shared domain knowledge (e.g., Preston and Karahanna 2009). However, to take a more dynamic perspective and examine the impact on R&D activities over time, we use a specific behavioral similarity to draw implications for the CEO-CIO relationship: verbal similarity. Verbal similarity builds rapport and sympathy (e.g., Ireland and Pennebaker 2010). For instance, IT and business executives using similar language display a greater understanding of each other's objectives, improving decision-making quality (e.g., Reich and Benbasat 2000). Likewise, Shi et al. (2019) show that a higher LSM indicates opinion similarity among TMT members. Moreover, LSM predicts relationship initiation and stability (e.g., Ireland et al. 2011). In contrast, people who do not want to engage with each other show less verbal similarity (e.g., Niederhoffer and Pennebaker 2002).

### ***CEO-CIO Shared Understanding of the Role of Technology and Technological Innovation Value***

CIOs are becoming increasingly important for planning and initiating change (e.g., Carter et al. 2011). We argue that a shared understanding of the role of technology between the CEO and the CIO fosters business-IT alignment, leading to a higher value of technological innovation as measured by the stock market.

When technological leadership in the form of the CIO enters the TMT, the exploration orientation of the firm is advanced (e.g., Bendig et al. 2022). We argue that a shared understanding between the CEO and the CIO leads to better decision-making regarding technological innovation. Leaders who agree on digital positioning and related issues would develop high-quality, interconnected business and IS plans (e.g., Tan and Gallupe 2006). When the shared understanding between the CEO and CIO is high (i.e., high CEO-CIO LSM), the executives' awareness of each other's future needs (e.g., Benlian and Haffke 2016) and opinions (e.g., Shi et al. 2019) is likely to be high. Furthermore, verbal similarity builds trust and empathy, helping to bridge potential gaps between the CEO and CIO (e.g., Lakin and Chartrand 2003; Preston and Karahanna 2009). Less shared understanding (i.e., low CEO-CIO LSM) leads to more significant uncertainty about organizational issues, actions, and attitudes (e.g., Johnson and Lederer 2010). Completing innovation

projects without prior alignment may be inconsistent with organizational goals and strategies (e.g., Stepanovich and Mueller 2002). In contrast, a prior shared understanding of the role of technology means less uncertainty and less information search costs, effectively aligning the business and technology strategies (e.g., Johnson and Lederer 2010). In addition, with less agreement, technological innovation will likely be judged by outsiders as less suitable for the business model and, consequently, less valued.

In sum, a shared understanding of the role of technology, reflected in a high LSM between the CEO and the CIO, improves alignment between the business and IT. In the context of exploration, this mutual understanding leads to a better fit between business and technological innovation. Therefore, we hypothesize:

*H1: CEO-CIO LSM is positively associated with a focal firm's technological innovation value.*

### ***Shared Technology Understanding, CEO Optimism, and Technological Innovation Value***

The CEO is the leader among a firm's senior executives, seeking out new business opportunities and setting the agenda and direction for the firm's future growth. At the same time, other TMT members play supporting roles by providing important input to the CEO's decisions (e.g., Shi et al. 2019). In the CEO-CIO dyad, the CEO is expected to look beyond the horizon and set new business goals, while the CIO is increasingly expected to act in an entrepreneurial capacity, becoming a change agent who plans and initiates change (e.g., Bendig et al. 2022; Carter et al. 2011). We hypothesize that overly optimistic CEOs are less likely to play the "devil's advocate" role in decision-making processes, steering the way CEOs and CIOs think about the role of technology toward a misalignment of overall business strategy and IT strategy.

Following Ahmed and Duellman (2013), we use the term "CEO optimism" to refer to CEOs who systematically overestimate future returns from their firms' projects and overestimate (underestimate) the probability of good (bad) firm performance. Put simply, they downplay risks and overestimate positive outcomes. Excessively optimistic CEOs have the illusion of control over the outcome of technological innovation (e.g., Guo and Ding 2020) and are less willing to accept failure or respond to disconfirming evidence (e.g., Kahneman and Lovallo 1993). In most firms, the CEO is the primary decision maker and the direct supervisor of the other TMT executives. Therefore, the CEO determines the CIO's reporting structure and evaluates the CIO's performance, which may directly or indirectly affect the CIO's compensation (e.g., Banker et al. 2011). This power imbalance in the CEO-CIO dyad leads to strong incentives for the CIO to integrate with the CEO (e.g., Shi et al. 2019). Thus, any shared understanding with an overly optimistic CEO may be misguided and affect the quality of decision-making related to technological innovation. Less viable and overly daring technological innovation projects become likely. When the CEO is optimistically biased, less constructive opposition occurs, and synergies from the business-IT connection become uncertain (e.g., Wagner and Weitzel 2012). In contrast, more dissenting opinions are expressed if the CEO is not optimistically biased, leading to higher quality strategies and improved decision quality under uncertainty (e.g., Schwenk 1990). Moreover, it becomes difficult for shareholders to assess technological innovation value when the quality of business and technology strategy alignment declines (e.g., Benner 2007).

In sum, we predict that CEO optimism negatively affects the CEO-CIO LSM relationship and the value of technology innovation by driving the firm toward a lower quality alignment of business and IT. This lower quality alignment creates uncertainty that makes it more challenging to determine the value of technological innovation as reflected by the stock market. Thus, we hypothesize:

*H2: CEO optimism negatively moderates the relationship between CEO-CIO LSM and technological innovation value.*

## **Methods**

The sample selection commenced with all earnings calls transcript data from the Thomson Reuters StreetEvents database for firms within the S&P 1500 between 2002 and 2020. The quarterly data was matched with the ExecuComp, Compustat Fundamentals Quarterly, and the KPSS patent databases to obtain data on firm accounting, demographic characteristics, and R&D activities. The dependent variable of the study is the value of technological innovation at the firm level. The most broadly available data on innovation is patent-based. Therefore, we develop an estimated market value of technological innovation using the data from Kogan et al. (2017). The market value estimate of a given patent is based on the

fluctuations in the stock price of innovating firms following the granting of a patent. Following Kogan et al. (2017), we first measure the total dollar value of innovation produced by a given firm ( $f$ ) in quarter ( $t$ ) based on the stock market by adding up all the values of patents ( $j$ ) granted to that firm in a quarter. To ensure that variations in firm size do not drive variations in innovation output, we scale the measures by firm size. Therefore, the value of technological innovation represents the value of innovation in millions of nominal dollars scaled by book assets. We lead the technological innovation value by one quarter ( $t + 1$ ) because it can take some time for CEO-CIO characteristics to manifest in patent value (e.g., Galasso and Simcoe 2011).

To assess our main explanatory variable, CEO-CIO LSM, we used the measure developed by Ireland and Pennebaker (2010) when either the CEO or CIO discussed the firm's digital strategy orientation. Since senior IT executives often do not explicitly carry the title of "Chief Information Officer," we follow similar studies (e.g., Bendig et al. 2022) and include related executive titles such as "Head of Information Technology" or "Head of Information Systems" (referred to as "CIO" in the following). First, we extracted all spoken words by the CEO and the CIO during the Q&A section of earnings calls. In the Q&A, the TMT members take turns answering analysts' questions. Compared to prepared remarks or other firm documents (e.g., letters to shareholders), the answers are relatively unscripted and spontaneous, emanating directly from the executive's thinking style (e.g., Shi et al. 2019). Next, we looked at "keywords in context" (KWIC) using the digital strategy orientation word lists of Kindermann et al. (2021). The word lists comprise four dimensions: digital technology scope, digital capabilities, digital ecosystem coordination, and digital architecture configuration. The context in which the words appeared was saved in separate files containing the surrounding words (60 words to the left and right) (e.g., Fridman et al. 2021). We then context-analyzed the CEO and CIO files using the Linguistic Inquiry and Word Count (LIWC) program (e.g., Pennebaker et al. 2007). The LIWC output is the percentage of words from each category used during the Q&A section. We focused on the percentage of total words in a text that could be assigned to nine categories of function words (i.e., personal pronoun, impersonal pronoun, articles, auxiliary verbs, adverbs, prepositions, conjunctions, negations, and quantifiers). The nine category-level language similarity scores are summed and averaged to obtain a composite LSM score. A higher number represents a higher LSM level between the CEO and the CIO (e.g., Ireland et al. 2011; Ireland and Pennebaker 2010).

Our main moderator is CEO optimism. We capture CEO optimism with a dichotomous variable that takes the value of 1 if capital expenditures deflated by lagged total assets in a given quarter are greater than the median capital expenditure relative to lagged total assets for the firm's three-digit Standard Industry Classification Code (SIC) in that quarter and takes the value of zero otherwise (e.g., Ahmed and Duellman 2013). The measurement is derived from findings that particularly optimistic CEOs tend to overinvest in capital projects and spend more on capital (e.g., Malmendier and Tate 2008).

We include the following control variables. We introduce a one-quarter lag on the dependent variable, technological innovation value, to control for serial correlation. At the CEO level, we control for CEO tenure as this may influence decision-making related to technological innovation (e.g., Galasso and Simcoe 2011). At the firm level, we account for firm size (log of total assets) and firm performance (ROA), as the adoption of firm strategies may vary by firm size and past performance (e.g., Cummings and Knott 2018). In addition, innovation activities may be related to a firm's slack resources. We, therefore, control for absorbed slack (based on S&GA) (e.g., Nohria and Gulati 1996). We introduce the firm's leverage ratio (ratio of the sum of long-term debt and debt in current liabilities to total assets) and R&D intensity (e.g., Xue et al. 2012) into our models to control for financial constraints that may affect a firm's strategic risk preferences. We also control for asset tangibility (e.g., Patel and Cooper 2014). Furthermore, to account for technological turbulence in a market, we introduce the median industry R&D intensity for each three-digit SIC code (e.g., Titus et al. 2017). We also control for firm innovation output using quarterly weighted patent citations. This variable was scaled with firm size using book assets (e.g., Kogan et al. 2017). Finally, we include firm and quarter fixed effects to control for unobserved heterogeneity over time and time-invariant firm effects. Our final sample consists of 424 firm-quarter observations. All continuous variables were winsorized at the 1st and 99th percentiles to ensure our results are not sensitive to outliers.

Following related studies (e.g., Shi et al. 2019), we analyze our panel dataset using a fixed-effects regression. The fixed-effects regression allows us to examine only the time-varying components of the CEO-CIO LSM and take advantage of longitudinal and cross-sectional variation in our data (e.g., Wooldridge 2013). Standard errors are robust and clustered by firms. Variance inflation factors (VIFs) ranged from 1.39 to 2.5, well below standard multicollinearity thresholds.

## Results

The fixed-effects regression results testing the relationship between contextual CEO-CIO LSM and firm technological innovation value, including the results of the moderating effect of CEO optimism, are shown in Table 1. Model 1 in Table 1 shows a positive and statistically significant direct effect of CEO-CIO LSM ( $\beta = 0.01330$ ; SE = 0.00598, CI = 0.30021, 0.79479,  $p = .028$ ). The results support Hypothesis 1, which states that an increase in the level of CEO-CIO LSM increases the technological innovation value of the focal firm in the stock market. Model 3 shows that the direct effect of CEO-CIO LSM ( $\beta = 0.01181$ ; SE = 0.00594, CI = 0.00043, 0.02511,  $p = .043$ ) and the interaction term of CEO optimism and CEO-CIO LSM are significant negative ( $\beta = -0.01134$ ; SE = 0.006214, CI = -0.02365, 0.00098,  $p = .071$ ) at  $p < .1$ . The direct effect of CEO optimism in Model 3 is positive and tentatively significant ( $\beta = 0.00968$ ; SE = 0.00575, CI = -0.00172, 0.02108,  $p = .095$ ). These results support Hypothesis 2, which states that an increase in CEO optimism decreases the rate of change in the focal firm's technological innovation value induced by CEO-CIO LSM.

In unreported robustness checks, the results were not significantly affected when (i) we introduced an additional firm size control (total market value, i.e., outstanding common stock multiplied by month-end share price) to address concerns regarding the relationship between firm size, R&D spending, and patent activity, (ii) we lead our dependent variable by three years to consider a longer time horizon for the CEO-CIO decisions to manifest, (iii) we run the baseline model with industry (based on four-digit SIC) and year-fixed specifications (e.g., Cummings and Knott 2018; Galasso and Simcoe 2011).

## Discussion

This study suggested that LSM between TMT members can provide important cues for understanding their ways of thinking about technology. The need for a shared understanding of the role of technology between the CEO and CIO is a recurring theme in information management literature (e.g., Benlian and Haffke 2016). However, in our study, we shifted the focus from the overall alignment of business and IT to the implications for a specific decision-making setting - technological innovation. Consistent with our first hypothesis, the LSM between CEO and CIO is positively related to the value of technological innovation of the focal firm. This reasoning is consistent with the upper echelon theory, which suggests that the characteristics of top managers shape firm outcomes (e.g., Hambrick and Mason 1984) and that the relationship dynamics of sub-teams of the TMT are particularly relevant in certain decision-making situations (e.g., Hambrick 2007). Our results indicate that CEO-CIO dyads with a shared understanding of technology can successfully address the alignment challenges of inherently dynamic business and technology strategies (e.g., Bharadwaj et al. 2013), increasing the value of technological innovations.

Consistent with our second hypothesis, the results show a negative moderation effect of CEO optimism on the relationship between CEO-CIO LSM and technological innovation value. This result suggests that CEO optimism affects the proposed underlying mechanisms and leads to less constructive discussions and synergies of improved business-IT alignment, reducing the value of technological innovation. This finding is consistent with upper echelon research (e.g., Shi et al. 2019) and behavioral finance scholars (e.g., Malmendier and Tate 2008). For instance, our results complement Malmendier and Tate (2008), who show that the stock market reacts negatively to overconfident or excessively optimistic managers. We extend this finding toward the value of technological innovation when looking at the CEO-CIO dyad.

This study contributes to management and information systems research in at least three important ways. First, we respond to researchers' call to study the characteristics of sub-teams of TMT to enhance the predictive power of the upper echelon theory (e.g., Hambrick 2007; Shi et al. 2019). Second, we analyze the CEO-CIO dyad in context and over time, filling an important gap in the information systems literature and introducing a more dynamic view of CEO-CIO shared understanding and the value of technological innovation. In particular, the results show that for the examined relationship, on average, the benefits of a shared understanding of the role of technology in the business context outweigh the potential benefits of a more heterogeneous understanding. Moreover, we complement the findings by Johnson and Lederer (2010) and highlight one key channel through which business-IT alignment at the upper echelon can benefit organizational performance: increasing the value of technological innovation. Third, we acknowledge the CIO's incentives to integrate with the CEO and show a spillover effect of CEO characteristics (i.e., CEO optimism) on the CEO-CIO dyad. More specifically, the results indicate that the cognitive biases of the CEO may enter the shared cognition with other key decision-makers.

Our study also has important implications for practitioners. Boards of directors and other stakeholders can leverage the insights of LSM to assess social interactions between business and IT leaders carefully. Our results suggest that high verbal similarity when the CEO or CIO discusses technology in a business context can reflect strategic alignment and improve perceptions of the value of technological innovation. In addition, high similarity coupled with specific CEO characteristics may evoke the need for critical reflection on the alignment of technological innovation with overall business strategy.

Of course, our study has several limitations that provide opportunities for further research. First, our study focuses on the CEO-CIO dyad, but other studies also show the important role that middle managers play in innovation (e.g., Watts and Henderson 2006). Therefore, we suggest that studies extend our findings beyond upper management and explore a common understanding of the role of technology throughout the firm. Second, the data used in this study are limited to publicly traded firms in the S&P 1500. Therefore, we encourage researchers to examine the generalizability of our results, for instance, using samples of firms in other countries. Third, our dependent variable is based on the value of technological innovation of all patents granted to the firm. Future studies could focus on specific patent categories (e.g., Hall et al. 2001).

## Conclusion and Outlook

Promoting alignment between business and IT and the impact of a shared understanding between CEO and CIO regarding the role of technology are recurring themes in conversations between academics and practitioners. This study takes a novel approach in examining the LSM between CEO and CIO to analyze shared understanding and its impact on the value of technology innovation. Our results suggest that a shared understanding of technology is among the key benefits to value of technological innovation. We believe that our study can make an important contribution to the upper echelon theory and information systems literature by focusing on sub-teams of managers in a specific context and providing a more dynamic approach to the shared understanding of the role of technology. In addition to rigorously developing our hypotheses, we will further substantiate our analysis by addressing potential endogeneity concerns. Therefore, we will construct suitable instruments and check the robustness of our findings in light of exogenous shocks (e.g., Wooldridge 2013). As we continue our work, we will refine our approach to untangle the impact of the CEO-CIO's shared understanding on the value of technological innovation.

	(1)	(2)	(3)
	Linear Model	Linear Model with Moderator	Interaction Model
CEO-CIO LSM	0.01330** (0.00598)	0.01277** (0.00622)	0.01181** (0.00594)
CEO Optimism		0.00065 (0.00087)	0.00968* (0.00575)
CEO-CIO LSM x CEO Optimism			-0.01134* (0.006214)
Controls	Included	Included	Included
Firm Dummies	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes
Constant	0.02972 (0.02934)	0.02924 (0.02902)	0.01677 (0.02043)
R <sup>2</sup>	0.6786	0.6770	0.7046

Notes: N= 424. \*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ . Controls are not shown for brevity. Standard errors are in parentheses. Standard errors are robust and clustered by firm. Unstandardized coefficients are used except for variables included in interactions. The dependent variable is the technology innovation value (t+1). All continuous variables are winsorized at 1%.

**Table 1. Regression Results**



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