CEO PERSONAL CHARACTERISTICS AND CORPORATE INNOVATION

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Abstract
We examine how personal traits of the chief executive officer (CEO) influence the levels of innovation within the firms they manage. Using an open-language processing tool developed by Harrison et al (2019), five personality traits of CEOs (openness, extraversion, agreeableness, conscientiousness, and neuroticism) are extracted from speech transcripts during Q&A sections of earnings calls. We measure firm innovation using research and development expenditures (input), the number of patents generated (output), and citations and stock market value of the patents (quality). We find that CEOs with a higher level of openness, extraversion and agreeableness positively influence R&D expenditures, the number of patents generated, the number patent citations, and the market value associated with patents. In contrast, we find that CEOs with high levels of conscientiousness and neuroticism invest less in R&D, generate less patents and those patents are of lower quality. Together, our results suggest that CEO personal characteristics are an important factor that affect the firm’s innovation level.
I. **Introduction**

In this paper, we examine how the personal traits of the chief executive officer (CEO) influence the levels of innovation within the firms he/she manages. In particular, following research in psychology (Goldberg 1990, Costa and McCrae 1992), we examine whether CEO personality traits (i.e., openness, extraversion, agreeableness, conscientiousness, and neuroticism) influence innovation inputs (i.e., research and development (R&D) expenditures), innovation outputs (e.g., the number of new patents generated), and the quality of innovation outputs (i.e., the total citations (weighted) of new patents and the total stock market value of new patents). Based on upper echelons theory (Hambrick and Mason 1984), which predicts that firm performance is influenced by the personal traits of top executives, we examine the impact of CEO personality traits on corporate innovation, an important antecedent of firm performance and value.

In psychology research, the *Big Five* factor traits model (Goldberg 1990, Costa and McCrae 1992) is widely used to classify complex human intrinsic characteristics into the following five personality traits: openness, extraversion, agreeableness, conscientiousness, and neuroticism. Openness indicates a high-level curiosity, imaginativeness, and creativity, whereas extraversion indicates ambition, need for recognition, and self-confidence. Agreeableness captures the need for social harmony, sympathy, kindness and/or trustworthiness. In contrast, conscientiousness captures carefulness, caution and/or stubbornness. Lastly, neuroticism is characterized by anxiety and depression. Based on these descriptions and theory (Goldberg 1990, Costa and McCrae 1992), we predict CEOs with higher level of openness, extraversion and agreeableness
will have a positive impact of the firm’s level of innovation. On the other hand, we predict CEOs with high level of conscientiousness and neuroticism to prefer the status quo and thus negatively impact the firm’s level of innovation.

Prior research has attempted to measure the personality of executives (Bertrand and Schoar 2003, Malmendier and Tate 2005, Dyreng et al. 2010). Many techniques have been adopted to develop proxies for personal characteristics of CEOs. A prominent method is to conduct surveys directly with CEOs to obtain their personality traits. An obvious limitation of this method is that administering a survey on a large scale is very difficult and impractical. A recent alternative approach is to measure CEO’s characteristics and personality traits using their documented speech in reports such as annual reports (10-Ks) and conference calls. Studies on psychology and psycholinguistics show that spoken language can reveal the speaker’s personality aspects. In particular, a recent study by Harrison et al. (2019) has developed a computer algorithm to extract the big five personal traits from the transcripts of CEOs’ speeches, as captured in conference calls related to earnings releases. In this study, to construct the proxies for the big five personal characteristics, we apply the open-language processing tool developed by Harrison et al. (2019) to a dataset of CEO speeches during earnings call transcripts from 2008 to 2016.

After constructing the Big Five personality traits for each CEO in the sample, we examine the relationship between CEO’s Big Five personality traits and the firm’s innovation level. Studies in accounting and management have documented the influence of top executives’ personalities on firms’ performance and financial reporting quality. The level of innovation is an important aspect of firm performance, which signals many meaningful information signals about firm value to investors (Solow 1957; and Hall et al. 2005; Eisdorfer and Hsu 2011). Across industries, but more notably in technology and manufacturing, the level of innovativeness is
especially important since patents of new technology and products are tied to accounting performance and firm value directly. We use five proxies to measure the level of firm innovation: the level of annual R&D expenditures, the number of patents granted to the firm during the year, the total number of patents the firm holds at each year-end, the total number of citations (weighted) of new patents at each year-end, and the market value associated with new patent granted at each year-end. In those five proxies, the total R&D expenditure captures the level of innovation input of a firm. The next two proxies capture the level of innovation outputs of the firm, and the last two proxies captures the quality of the innovation process.

Controlling for economic determinants that influence the firm innovation level (Cook et al 2019), our main results show that firms with CEOs who have higher levels of openness, extraversion, and agreeableness experience a higher level of innovation. In terms of innovation inputs, CEOs with higher openness, extraversion, and agreeableness lead firms to invest more on R&D. In terms of patents, CEOs with higher scores in these measures generate more patents. When focusing on proxies of patent quality (e.g., total citations and total market value associated with patents), we find that CEOs with a higher level of openness, extraversion and agreeableness not only help stimulate firms’ innovation level but also boost the quality of firms’ innovation output. In contrast, CEOs with higher levels of conscientiousness and neuroticism invest less in R&D, generate less patents and those patents are of lower quality. Collectively, these results indicate that CEOs’ personality traits affect both the innovation input (R&D expenditures), the innovation output (number of patents) and the quality of innovation of their firms.

Our study contributes to the literature in several ways. First, we contribute to the line of research measuring the personality traits of top executives. By applying a Harrison et al.’s (2019) algorithm to analyze the transcripts of CEOs’ speech during earnings release calls to
extract speakers’ personalities, our paper contributes to a new line of work (Park et al. 2015; Hrazdil et al. 2019) in this area. This method is very promising as it represents an efficient way to investigate the personal characteristics of top executives in large scale. Through the effective measurement of the personality traits with less noise, our study draws the connection between CEOs’ personality traits and their firm innovation level with some degree of confidence.

Second, our paper contributes to the line of research examining the influence of CEO intrinsic characteristics on firm innovation. Prior studies have examined different aspects of CEO characteristics, such as narcissism (Ham et al. 2017), overconfidence (Galasso and Simcoe 2011, Hirshleifer et al. 2012), or sensation seeking (Sunder et al. 2017), as well as their impacts on firms’ innovation. However, each of those studies depicts limited or a narrow aspect of the very complex concept of CEO characteristics; further, they have not successfully examined CEO’s characteristics comprehensively. Our study expands the scope of prior research through studying both the individual impact and the joint impacts of all Big Five personality traits on firm innovation. Since the Big Five personality traits may be the root for all complex human being characteristics, our paper has the possibility of shedding light on how CEO personality traits affect innovation, a key determinant of firm performance.

Third, our study findings have practical implications for investors and boards of directors. By understanding the relationship between CEO characteristics and the firm’s level of innovation, investors could potentially utilize the CEO characteristics as an add-on predictor for firm’s potential innovation. Since innovation is an important indicator growth, profitability, and market value (Solow 1957; Eisdorfer and Hsu 2011; Change et al. 2015), being able to predict the firm innovation level through CEO characteristics would be beneficial for investors. Moreover, understanding the connection between the CEO characteristics and the firm’s innovation
environment can be beneficial to the board of directors when hiring a new CEO for the firm. Through observing the characteristics of potential future CEOs during the interviewing process, the board of directors can partially predict if the CEOs will be suitable for the firm innovative culture or if the CEO is capable of enhancing the firm’s innovation level.

The remainder of the paper is organized as follows: Section II discusses the related literature in more detail as well as develops the main hypothesis. Section III details the research methodology. Section IV reports the results. Finally, section V concludes the study and points out a few limitations of the study.

II. Literature review and hypothesis development

1. Determinants of firm innovation

Understanding innovation has been an important topic in accounting, management, and financial research. The innovation process starts with an idea and, through development and testing, results in a new product, process or service that serves an important need in the marketplace (Edwards and Gordon 1984; Katila and Shane 2005; Cook et al. 2019). Solow (1957) indicates that innovation is an antecedent of economic growth, while Eisdorfer and Hsu (2011) find that the capacity to innovate is a better predictor of bankruptcies than credit ratings. Regarding the quality and market value of a patent, Hall et al. (2005) finds that “an extra citation per patent boosts market value by 3%”. As stated in Change et al. (2015), “Innovation has become a core strategy to enhance a firm’s competitiveness in the new millennium.”

Other than being an important antecedent of firm performance, understanding innovation is important for accounting and finance researchers, given the substantial investment decisions that managers need to make in the innovation process. Holmstrom (1989) states that “innovation
decisions are just investment decisions and as such part of the standard problem of how to allocate capital”. In principle, through the innovation process, firms can achieve breakthrough products or services, which would significantly increase their competitiveness in the market. However, many investments in research and development (R&D) that occur in the innovation process end up as failures (Holmstrom 1989). Indeed, prior research finds that R&D investment is a risky decision, as many R&D attempts do not end up in meaningful innovations. Given the conflict between the positive and negative aspects of investing in innovation, a natural question arises: what are the factors that drive firms to allocate more resources into the innovation process?

Many studies have tried to answer this question. The first strand of studies investigates the impact of external environmental factors on firms’ innovation. He and Tian (2013) documents that firms that are followed by a large number of analysts often generate fewer patents and have a lower level of innovation, a result possibly due to the pressure analyst impose on firms to focus on delivering short-term earnings. Amore et al. (2013) document that banking deregulation significantly improves both the quantity and quality of innovation activities and thus concludes that banking development is an important factor that facilitates innovation. Flammer and Kacperczyk (2016) document that firms from states that have constituency statues generate more patents and patents with higher quality and argue that stakeholder orientation help drive innovation.

The second strand of studies examine the internal factors responsible for firms’ innovation. Chang et al. (2013) find that firms with a high level of accounting conservatism are less likely to be innovative, while Park (2018) documents a positive relationship between financial reporting quality and the firm innovation level. These two papers show that accounting-based measures
can affect innovation in significant ways. Regarding managerial incentives, Chang et al. (2015) provide evidence that firms that grant stock options to employees have a higher number of patents and patent citations. Similarly, focusing on firms’ ownership structure, Wang and Zhao (2015) show that firms which have higher hedge fund ownership experience higher quantity and quality of patents. More recently, Cook et al. (2019) document that firms with relatively higher levels of Corporate Social Responsibility (CSR) are also more innovative.

Among different internal factors, CEOs themselves can be an important factor that helps facilitate firms’ innovation. Custodio et al. (2017) documents that CEOs who have more general human capital (i.e., skills that are transferable across firms or industries) simulate higher levels of innovation in their current firms. Both Galasso and Simcoe (2011) and Hirshleifer et al. (2012) find that overconfident CEOs, who expect fewer negative results from innovation investment, help firms achieve more innovation success. Sunder et al. (2017) examine CEOs with high sensation-seeking levels and find these CEOs stimulate firm’s innovation, while Ham et al. (2018) documents that narcissistic CEOs spend more resources on R&D expenditures, which is an important determinant of innovation. Our study complements these studies by examining the intrinsic personal characteristics of CEOs and how these affect the innovation productivity of the firms.

2. CEOs personality traits

Understanding the impact of executives’ personality traits on firm performance and value has been of great interest to researchers. However, measuring executives’ personality traits have long been a challenge for researchers. One of the most traditional methods to capture personality traits is through surveys and questionnaires, such as the 50-item International Personality Item Pool (IPIP) survey. However, conducting and administering such a survey on a large scale,
especially with a very special target population such as the S&P500 top executives, is impractical. For that reason, researchers have tried several different methods to capture the intrinsic characteristics of top executives. One well-known method is the “black box” approach (Bertrand and Schoar 2003; Dyreng et al. 2010; Ge et al. 2011), where researchers track executives who have worked for more than one firm and observe the managerial “fixed effect” that the executives have on the firm before and after they leave. Although this method is good in observing the unique impacts that each executive has on the firm, it does not capture the underlying psychological factors that drive the executives’ styles.

The second common approach is to infer the underlying executives’ personalities through the observable actions that they take. For example, Sunder et al. (2017) proxy the sensation seeking level of CEOs using the hobby of flying airplanes, while Ham et al. (2017) capture the narcissism aspect of CEO characteristics through the size of their signature on the financial reports. Malmendier and Tate (2005), Galasso and Simcoe (2011) and Hirshleifer et al. (2012) construct a measure of CEOs’ overconfidence by observing their stock-option exercising behavior. Specifically, if CEOs hold their in-the-money stock options after they are fully vested for too long, then that signal the CEOs are overconfident. Through different observable actions of CEOs as mentioned above, researchers can partially infer different intrinsic characteristics of executives. Although this method is easier to conduct than the surveying method and provides a finer look into the intrinsic factors of executives, there are still a few limitations. Some measurements require time-consuming and costly hand-collection efforts. In addition, some measurements such as the one used in Sunder et al. (2017) can only generate an indicator variable which points out whether a CEO is a high sensation seeker or not. This is a major
limitation of the measurement since, for example, we cannot compare the level of sensation seeking between two CEOs who are both classified as sensation seekers.

More recently, a new approach has been attracting attention from researchers: extracting the executives' personality characteristics through their speeches. In psychology, marketing, and linguistic studies, language has been theorized to signal the speaker’s personality and emotional states. To extract personality characteristics through speech, early research would follow the closed-language approach. First, a dictionary containing words was identified and related to certain characteristics. In this prior approach, the researcher would capture the frequencies of words in a speech and compare that to the closed-language dictionary to point to the characteristics of the speakers. A more advanced approach is the open-language approach. Instead of constructing and comparing speech to a dictionary with pre-selected words only, the open-language approach looks at more dimensions in a speech to capture the speaker’s personalities more accurately. As indicated in Park et al. (2015), the method looks at four dimensions: (1) single, uncategorized words, (2) non-word symbols such as punctuations, (3) multiword phrases, and (4) clusters of semantically related words identified through unsupervised methods, or topics. In this study, following Harrison et al. (2019), we adopt the open-language approach due to its advantages in multi-dimensional and accuracy in capturing CEO characteristics through their speech.

3. Influences of CEOs’ Big Five personalities scores on firms’ innovation level

To explore CEO personality traits, we use the Big Five factor traits (Goldberg 1990; Costa and McCrae 1992) that have been widely adopted in psychology literature. Under the Big Five factors model, a person’s personality is defined through five major factors: openness, extraversion, agreeableness, conscientiousness, and neuroticism. Individuals high in openness
are characterized as being adventurous, imaginative, intellectually curious, or willing to challenge conventional values. Individuals with high levels of extraversion are associated with attributes, such as energetic, outgoing, and sociable. Individuals who score high on agreeableness are concerned with social harmony and are often described as kind, sympathizing and/or trustworthy. Individuals with high levels of conscientiousness are more dutiful, orderly, persistent and self-assured, while individuals who score high on neuroticism experience high emotional instability and tend to be anxious, depressed, or moody.

The main premise of our study is that managers’ characteristics have strong explanatory power on a firms’ innovation levels (Cho et al. 2015). Adopting the upper echelons perspective, we theorize that CEOs’ Big Five personalities will partially influence their firms to be more innovative. There are two main channels for the CEOs to impact their firm innovation level. First, the CEOs can directly impact the innovation level of their firms by increasing the R&D levels and the degree of coordination as their firms pursue the generation of patents. Holmstrom (1989) states that “innovation decisions are just investment decisions and as such part of the standard problem of how to allocate capital.” Hence, by directly allocating more of the firm’s resources into R&D activities, the CEOs can facilitate the innovation progress of the firm. Second, CEOs can indirectly influence the innovation level of their firms through several methods. For example, CEOs can enhance the innovative environment of the firms by adopting policies to stimulate employees’ creativity. A good example of such policies is Google’s “20% time” policy where employees are encouraged to “spend 20% of their time working on what they think will most benefit Google.” Such policy has resulted in the development of many profitable products, including Gmail and Google News. In addition, CEOs can also indirectly influence the
An individual who scores high on openness is more creative, imaginative, curious, willing to try out new experiences or challenge conventional thinking. Exploring divergent thinking, which is the thought process to generate creative ideas, McCrae (1987) finds that divergent thinking is strongly associated with openness. Extraversion is another important aspect expected to lead to innovation. Individuals with higher level of extraversion experience higher need for recognition, higher self-confident and higher self-esteem. Feist (1998) indicates that openness to experience and extraversion are positively related to creativity and innovation. In Dyer et al. (2011), through their survey of 5,000 executives, conclude that successful innovators will constantly test new ideas and trying new experiences. In addition to openness and extraversion, agreeable individuals are concerned more for social harmony and are often described as being kind, sympathizing or trustworthy. Prior research in psychology finds that agreeableness is an important determinant of innovation-supportive national cultural practices and national-level innovation (Steel et al. 2011; Rossberger 2014) as this type of innovation requires effective management of social networks, business partners, and business relationships. Thus, a CEO with high level of openness, extraversion, and agreeableness are expected to implement new changes, explore new products/services, look for new opportunities, and maintain open channels both with internal and external business relationships. Based on this line of thought, we predict that CEOs who possessing higher levels of openness, extraversion, and agreeableness would allocate more
firm resources into the innovation process, which ultimately results in higher levels of innovation output (e.g., patents) for the firm they are managing.¹

CEOs who possess high levels of conscientiousness and neuroticism are expected to be less open to innovation. High conscientious individuals tend to be self-assured, cautious and stubborn. Further, individuals with high level of neuroticism display high emotional instability, tend to be anxious, depressed and/or moody. Since the innovation process involves many challenges that require the innovator to be flexible and creative to overcome those obstacles, individuals with high levels of conscientiousness are less likely to be good innovators. Similarly, since the innovation process is challenging and long-term in nature, highly neurotic people could find it difficult to take on and follow this process to the end. In a psychology study, Feist (1998) documents that higher levels of conscientiousness and neuroticism are suppressors of innovation and creativity. For that reason, CEOs with high levels of conscientiousness and neuroticism may be less inclined to foster an environment that nurtures innovation. More importantly, these CEOs are less likely to invest the firm’s limited resources in activities and projects with highly uncertain outcomes – e.g., R&D by nature can be highly uncertain and risky.

¹ Prior research (Feist 1998; Batley and Furnham 2006, Hunter and Cushingberry 2015) present mixed views regarding the impact of agreeableness on creativity and innovation. On one hand, high level of agreeableness indicates that the individual is supportive, warm, empathic, and socially harmonized. On the other hand, low levels of agreeableness indicates that the individual is aggressive, hostile, and suspicious. Some studies used to adopt the view that lower level of agreeableness will lead to better innovation (Feist 1998; Batley and Furnham 2006) because a more hostile and aggressive individual are better in sticking to his/her original idea and protect it from criticism during the implementing process. A more recent study by Hunter and Cushingberry (2015) adopt an opposite view that the low level of agreeableness can be harmful for the innovation process. Given the two-sided argument, the direction of impact of agreeableness on innovation can be ambiguous.
Based on all of the preceding arguments, the main research hypotheses (in alternate form) of the study are as follows:

**H1a:** Innovation inputs, outputs and quality are positively related to the CEO’s levels of openness, extraversion, and agreeableness.

**H1b:** Innovation inputs, outputs and quality are negatively related to the CEO’s levels of conscientiousness and neuroticism.

III. **Research methods**

1. **Data sources**

   The data for this study comes from different sources. First, to obtain the content of the CEO speech, earnings call transcripts for S&P500 firms are collected from the website SeekingAlpha.com over the period 2008 through 2016. Instead of using the earnings call transcript in its entirety; we focus on the Q&A section where CEOs answer questions from financial analysts. Although the CEOs speak mainly in earnings calls, the financial reporting parts of the earnings calls do not capture the CEOs’ personal characteristics well since the speech is prepared, scripted, and can be uniform across CEOs. On the other hand, the speech when CEOs answer analysts’ questions is less likely to be scripted ahead of time. In addition, the CEOs’ answers to analysts will better represent their natural language. For that reason, the CEOs’ speech during the Q&A sections will more accurately capture their personal characteristics. Second, data regarding the firm’s innovation level comes from Compustat (in the case of R&D) and from Kogan et al. (2017), who collect patent data from the U.S. Patent Office (USPTO). The patent dataset (Kogan et al. 2017), available from 1926 to 2010, contains three proxy measures of innovation: (1) number of new patents granted each year, (2) total citations
(weighted) of new patents, and (3) total stock market value of new patents. Third, data used to generate control variables comes from Compustat and Execucomp. Fourth, the data that captures executives’ risk-taking incentives (Delta and Vega) comes from Coles et al. (2006) as they make it available on their website. Fifth, because we also control for managerial ability following Demerjian et al. (2012), we use the data made available through their website.

2. Measurement of CEO’s Big Five personality traits

Harrison et al. (2019) developed a tool to analyze CEOs’ personality traits using CEO speech. The researchers develop a program that applies machine learning to overcome many challenges that other researchers had when analyzing top executive personalities. The tool adopts an open-language approach (as opposed to closed-language) to better capture CEO personality scores. Figure 1 in the Appendix section presents the visualization of the mechanism of the program developed by Harrison et al. (2019). To develop the tool, Harrison et al. (2019) start with a first group (the main sample group) of more than 100,000 transcripts from 3,573 CEOs of S&P1500 firms. In addition to the first large group, there is a second validation group with transcripts of 207 CEOs’ speeches. The Big Five personalities scores of those 207 CEOs are available from Hill et al. (In press), a psychology research paper. In Hill et al. (In press), three trained psychology doctoral students watch publicly available video recordings of the 207 CEOs and then rate each of these CEOs using the 50-item IPIP (Goldberg, 2000). The scores of these 207 CEOs are validated through different methods. The second group (the test group) is comprised of more than 100,000 transcripts from 3,573 CEOs of S&P1500 firms.

In the first stage, from the large group of more than 100,000 transcripts, the researchers use the Word2Vec software to generate multiple word vectors from the transcripts. With hundreds of vectors representing different groups of words and phrases in stage one, the researchers then
build different regression models to estimate each of the Big Five personality scores for the group of 207 CEOs. In the training stage, the models are trained with three objectives: (1) maximizing the correlation between predicted scores and observed scores, (2) replicating the patterns of variance for each trait, and (3) replicating the patterns of zero-order correlations between traits. The regression model for each trait that best satisfies the three requirements is selected to be the regression model for that trait. In the final stage, the best model for each of the five traits is applied back to the large group of more than 100,000 transcripts and 3,573 CEOs to generate the Big Five personality scores. Harrison et al. (2019) also conduct various tests to check the convergent validity, discriminant validity and reliability for the scores generated by the tool. The results show that the tool developed in Harrison et al. (2019) is both valid and reliable.

We apply the open-language processing program developed in Harrison et al. (2019) to acquire the CEO’s Big Five personalities scores. Figure 2 displays the steps involved in the procedure. Once the CEO speech transcripts are downloaded and each CEO identity variable is matched with their speech transcripts, the data is then loaded into the open-language tool from Harrison et al. (2019), and the Big Five personal traits score for each CEO is generated. Our CEO data consist of 2,800 CEOs across 2,800 firms. All Big Five personality scores are on a 7-point scale. It is important to notice that the personality traits of CEOs are assumed to be stable and consistent throughout the sample period. For that reason, the big five personality scores are time-invariant variables.

3. Measurement of the firm’s innovation level

Following many prior studies on innovation (Galasso and Simcoe 2011; Kogan et al. 2017; Cook et al. 2019), we adopt different measurements for innovation. First, the main innovation input variable is firm’s R&D expenditure (RD) by the end of each year. Second, to capture
innovation output, we use the total number of patents held by the firm at the end of each year (TPAT), and the number of new patents that the firm generate firm at the end of each year (NPAT). In addition, we examine the two variables that capture the quality of patents: total number of citations (weighted by the average number citations that patents granted in the same year received) for new patents at the end of each year (TCW), and total stock market value of firm’s new patents at the end of each year (TSM). According to Kogan et al. (2017), the TCW of a firm i in year t with j new patents granted is calculated as follows:

\[
TWC_{i,t} = \sum_{j=1}^{j} \left(1 + \frac{C_j}{\bar{C}_j}\right)
\]

Where, \(C_j\) is the total number of citations of a patent counting from the granted year \(t\) until the end of the sampling period (i.e. year 2010, following Kogan et al. 2017. \(\bar{C}_j\) is the average number of forward citations from all patents that were granted in the same year \(t\) as patent \(j\). TSM is calculated by adding up all the stock market values associated with the granted patents \(j\). Stock market value associated with each patent is identified by examining the abnormal stock return during the three-day window (starting with the announcement day of the new patent granted) and filtering out stock movement unrelated to the patent granted event.

TPAT captures the overall innovation process of the firm, NPAT captures the firm’s ability to generate new patents each year, and TCW and TSM capture the quality of newly generated patents each year. Two assumptions are made when building innovation-related variables. First, if data regarding R&D expenditures of a firm is missing for any year in Compustat, we assume that the firm does not spend money on R&D activity in that year, so we replace the value with a zero. Second, if we cannot match an observation (firm-year) in Compustat with the patents
dataset from Kogan et al. (2017), we assume that the firm does not have any patent generated in that year. To create the total number of patents that the firm holds at year $t$, we aggregate the number of patents from all prior years in the sample until year $t$.

4. **Empirical multivariate models**

4.1 **Models**

To examine the impact of CEO’s Big Five characteristics on innovations input, we use the following baseline model:

$$RD_{adj,i,t} = \alpha_0 + \alpha_1 BigFive_i + \Sigma \alpha_j Controls_{j,i,t-1} + \epsilon_{i,t} \quad (1)$$

$RD$ in equation (1) is the firm’s R&D expenditure ($RD$). To control for the industry- and time-related effects, we generate an industry-average for each industry based on the Fama-French 48 on a year-by-year basis and subtract each firm observation with its matching industry-average. To further control for the skewed distribution of R&D expenditure observed in the sample, we take the natural log of the dependent variable. The final variable we come up with after all the necessary adjustments is called $RD_{adj}$. $BigFive$ is the variable of interest, which represents each of the personality characteristics in the Big Five model: Openness ($open$), Conscientiousness ($consc$), Extraversion ($extra$), Agreeableness ($agree$), and Neuroticism ($neuro$). Based on the discussion above, we expect positive and significant coefficients on $open$ and $extra$, and we expect negative and significant coefficients on $consc$ and $neuro$. Lastly, the expectation on $agree$ is ambiguous.

To examine the impact of CEO’s characteristics on firm innovation output, we re-estimate model (1) but replace R&D with the two new dependent variables of interests:

$$Innovation\ Output_{i,t} = \beta_0 + \beta_1 BigFive_i + \Sigma \beta_j Controls_{j,i,t-3} + \epsilon_{i,t} \quad (2)$$
As discussed above, the innovation output aspect of the firm is captured using two variables: the number of total patents held by the firm in year-end \( (TPAT) \), and the number of new patents generated during the year \( (NPAT) \). We also transform the two dependent variables of interest through adjusting for industry-year effect and taking the log transformation. After taking necessary adjustment, all two dependent variables for equation (2) are \( TPAT\_adj \) and \( NPAT\_adj \). We expect \( \beta_1 \) to be positive and significant coefficients on \( open \) and \( extra \), and we expect negative and significant coefficients on \( consc \) and \( neuro \).

Finally, to test the influence of CEO’s characteristics on the quality of innovation outputs, we re-estimate model (1) but replace the dependent variables with variables which capture the quality of innovation outputs:

\[
\text{Innovation Quality}_{i,t} = \gamma_0 + \gamma_1 \text{BigFive}_t + \Sigma \gamma_j \text{Controls}_{j,t-3} + \epsilon_{i,t} \tag{3}
\]

The \textit{Innovation Quality} variable can be either the total number of citations (weighted) for the firm’s new patents \( (TCW) \) or the total stock market value of the firm’s new patents \( (TSM) \). Both variables are transformed and adjusted similarly as documented in section 4, model (1) discussion above. Our dependent variables used to estimate equation (3) are either \( TCW\_adj \) or \( TSM\_adj \). We expect \( \gamma_1 \) to be positive and significant coefficients on \( open \) and \( extra \), and we expect negative and significant coefficients on \( consc \) and \( neuro \).

\textbf{4.2 Discussion related to independent variables}

We follow prior studies (Galasso and Simcoe 2011; Sunder et al. 2017; Cook et al. 2019) control for possible simultaneity by lagging all explanatory variable by one year. Since \textit{BigFive} \((open, consc, extra, agree, \text{ and } neuro)\) is a time invariant variable, there is no different between the
lagged value and the current value. For that reason, in equation (1), all control variables are lagged by one year and *BigFive* variables are at current year.

Sunder at al. (2017) documents an average lag of two years between the date of patent granted and the date of patent application. Further, since firms have incentives to accelerate the patent application for their newly developed products or services, there is generally no lag between when the innovative products are invented and patent application date. For that reason, if a firm receives a patent for a newly developed product in year \( t \), it has already successfully developed the innovative product at year \( (t-2) \), on average. In our study, all measurements related to firm’s patents are recorded at the patent grant date instead of patent application date. Thus, to control for the two-year gap between the year where actual innovative products are invented and the year where their patents are granted, all explanatory variables require to be lagged by additional two years. In total, for equation (2) and equation (3), all controls variables are lagged by three years.

We follow Cook et al. (2019) to control for the following aspects that have been shown to influence the level of innovation level of a firm. First, we control for the CEO aspects that could potentially influence the CEO’s risk-taking incentive and innovativeness including the CEO’s age (*Age*), CEO’s tenure (*Tenure*), and CEO’s gender (*Female*). In addition, we also include the square terms of the CEO’s age (*Age2*) and CEO’s tenure (*Tenure2*) to control for the possible non-linear impact of these two variables on innovation. In addition, CEO’s inclination to innovate can be impacted by their equity compensation’s sensitivity to the change in stock price (*Delta*) and stock price volatility (*Vega*) (Core and Guay 2002). For that reason, we also include the natural logarithm of Delta and Vega (*lnDelta* and *lnVega*) in our models. Lastly, we also control for the managerial ability (*MA*) documented in Demerjian et al. (2012) by including the natural log of this variable (*MA_score*) as control variables in all models.
Second, to control for firm-specific aspects that could potentially influence the firm’s level of innovation, we include the natural logarithm of sales (\(\ln\text{Sale}\)), total assets (\(\ln\text{Asset}\)), firm age (\(\ln\text{FirmAge}\)), and firm stock market return in year-end (\(\ln\text{Return}\)) to control for firm size, firm age, and stock performance. In addition, we also control for employee productivity as suggested by prior studies (Sunder et al. 2017; Cook et al. 2019) by including the natural logarithm of the ratio of PP&E over the total number of employee (\(\ln\text{PPEEmp}\)). The firm’s level of institutional holders would also potentially influence its tendency to innovate; thus, we include the natural log of the average firm’s level of institutional holders (\(\ln\text{Institution}\)). Finally, since Cook et al. (2019) find that a firm’s Corporate Social Responsibility (CSR) score can impact firm innovation level, we control for CSR in our models.

IV. Results

Table 1 shows the distribution of our sample by both year and industry. We also document two separate sample sets we used in the study: R&D Sample is used to estimate model (1), while Patent Sample is used to estimate model (2) and model (3). In Panel A, our R&D Sample covers a period of 23 years (1992 to 2015) while the Patent Sample only cover from 1995 to 2010. The Patent Sample get cut off in 2010 because the data from Kogan et al. 2017 stop in 2010. The number of observations for the earlier period of only takes a small portion of our two sample sets. For instant, in R&D Sample, for the first 10 years from 1992 to 2002, the total number of firms reporting R&D only consist of less than 5% of our R&D Sample. Similarly for Patent Sample, observations from 1996 to 2002 are only accountable for less than 6% of the sample. Most of the observations in our two sample sets are from the more current period. For R&D Sample, more than half of the sample are from 2010 to 2015. In Panel B, we observe that the Patent sample covered most of the industries of the Fama French 48 industries. In that, Business
Services, Electronic Equipment, and Retail are the three industries with the largest representation. In the R&D Sample, these three industries are also the majority. We also observe a few industry which did not report R&D expenditure although they generate some new patents in the sampling period, such as Candy and Soda or Transportation.

Table 2 shows the distribution of new patents granted and R&D expenditure by year and by industry, where we report the average number of new patents granted and the average R&D expenditures. There is an increasing trend in average R&D expenditure reported from the beginning of the sampling period to 2002. After 2002, the average R&D reported declined slightly and take the upward trend toward the end of the sampling period. There is an increasing trend in new patents granted from 1995 to 2006. After that, there is a slightly decreasing trend in average new patents granted from 2006 to 2010. Figure 3 illustrates the trend of average R&D expenditures and average number of patents granted through year more clearly. In Panel B of Table 2, Electronic Equipment and Business Services are the two industries that generated the greatest number of new patents. Interestingly, looking at the average number, firms in the Defense and Electronic Equipment industries are more innovative and generate higher average numbers of new patents. Firms in Agriculture industry, on average, spend the highest amount in R&D expenditure, followed by Pharmaceutical Products industry.

Descriptive statistics are reported in Table 3. In panel A, the average R&D expenditure reported is $250 million, with the median value of much less of $27 million. In Panel B, the average number of total patents a firm holds in a given year is around 413 patents when the average number of new patents granted that a firm receives in a year is around 36 patents. The average total citations a firm has in a year is 82 citations, and the average extra stock market value of all the new patents granted in a firm-year is $609 million. The distributions of raw
innovation output measurements are all highly skewed, in that the median value and the 25th percentile of all four measurements are zero. In addition, the raw measurements all suffered from severe outliers, in that the maximum value is far beyond the three standard deviations distance from the mean value. After the adjustment for industry average by each year and other appropriate transformations, all dependent variables of interest are more normally distributed, with mean and median values are more similar.

Openness (openn), has a mean of 4.62 which also matches its median, and the min of 3.12 and the max of 6.69. Similar to openness, in untabulated histograms, the other four measurements of the Big Five personality traits are also normally distributed. Although the Big Five scores can range from 1 to 7, we do not observe any extremely low value close to 1 in our sample of CEOs.

Table 4 reports the correlations between dependent and independent variables of interest. R&D is highly correlated with the four measurements of patents quantity and quality, with correlation score about 0.7. This strong correlation shows the connection between the innovation input and innovation outputs. Although higher investment in R&D does not guarantee higher quantity and quality of innovation outputs, R&D expenditure, in general, would result in higher level of innovation outputs. Most of the Big Five personal characteristic traits are not highly correlated with the five measurement of innovation. It is worth notice that our predictions are correct; openness, extraversion and agreeableness are positively correlated with the five measurement of innovation. In opposite, conscientiousness and neuroticism are negatively correlated with dependent variable of interest. In untabulated table, there is no observable extreme correlation between independent variables that could possibly lead to multicollinearity issues.
Tables 5 to 9 present the main results of the study. Table 5 reports the impacts of CEO’s Big Five personalities on R&D expenditures, the input of innovation. Column (1) captures the joint impact of all Big Five personalities of the CEO on the firm R&D expenditure. Column (2) captures the influence of CEO’s openness on firm’s R&D expenditure. Similarly, column (3) to (6) captures the influence of CEO’s conscientiousness, extraversion, agreeableness, and neuroticism on R&D expenditure in that order. Columns (2), (4) and (5), show that CEO’s openness (openn), extraversion (extra) and agreeableness (agree) positively and significantly impacts the firm's R&D expenditure. These results suggest CEOs who are more creative, more willing to try new things, and more curious, more active, more confident, more sociable, more recognition seeking, more empathy and more supportive, in general, drive their firms to spend more on R&D. On the other hand, CEOs with higher level of neuroticism (neuro) impact the firm's R&D activities negatively and significantly. We do not find evidence showing conscientiousness significantly impact firm’s reported R&D expenditure. In column (1), when we examine the impacts of all Big Five characteristics together on the firm level of innovation input, with the exception of openness and neuroticism level, which loses its significance, the signs and level of significance of the other characteristics remain similar. Collectively, these results suggest that CEOs’ personal traits affect the firm’s input to the innovation process.

Table 6 and Table 7 capture the impacts of the CEO’s Big Five characteristics on the firm’s level of innovation output. Table 6 captures the firm’s total number of patents they hold, and Table 7 captures firm’s ability to generate new patents. Columns (2), (4) and (5) of Table 6 show the coefficient of openness (openn), extraversion (extra) and agreeableness (agree) to be positive and significant, which indicates CEOs who are more creative, more willing to try new things, more sociable, more recognition seeking, have more empathy, and are more supportive in
general, generates higher innovation outputs. On the other hand, in columns (3) and (6), CEOs with higher levels of conscientiousness (consc) and neuroticism (neuro) impact the firm's generation of patents in a negative way. These results suggest that CEOs that tend to be more stubborn, more anxious, and more depressed tend to emphasize innovative efforts to a lesser degree. Column (1) of Table 6 documents the joint impacts of all Big Five personalities on the total number of patents firms hold. The level of conscientiousness and agreeableness are the remaining two characteristics which significantly impact the level of innovation output significantly. The results in Table 7, which resemble the results in Table 6, are noteworthy in that these tests capture the number of new patents the firm generates.

Lastly, Table 8 and Table 9 both capture the impacts of the CEO’s Big Five personality traits on the quality of firm’s innovation. In Table 8, the main dependent variable is the firm’s total forward citations (weighted) of all new patents granted in a year. In Table 9, the dependent variable of interest is the total stock market value of all new patents granted in a year. The results are also similar to prior tables discussed above. Columns (2), (4) and (5) of Tables 8 and 9 show the coefficient of openness (openn), extraversion (extra) and agreeableness (agree) to be positive and significant, which suggests CEOs who are more creative, more willing to try new things, more sociable, more recognition seeking, have more empathy, and are more supportive in general, generates patents that are of higher quality, as measured by both citations and the stock market value associated with the patents. On the other hand, columns (3) and (6), show that CEOs with higher level of conscientiousness (consc) and neuroticism (neuro) impact the quality of the patents in a negative way. Collectively, the main results of our study suggest that CEO’s personality traits are significant determinants of the innovation input, the innovation output, and the quality of innovation.
V. Conclusion

We examine the impacts of the CEO's personal characteristics on the firm’s level of innovation. We use the CEO’s Big Five personality scores by applying the open-language processing tool developed in Harrison et al. (2019) to the transcripts of CEO speeches (i.e., Q&A section) during earnings conference calls. To measure the level of innovation, we utilize five measurements: total R&D expenditures reported, total patents firms hold at year-end, new patents granted at year-end, total number of citations (weighted) for newly granted patents, and total stock market value generated by patents. The empirical results indicate that openness, extraversion and agreeableness affect innovation in a positive manner, while conscientiousness and neuroticism affect innovation in a negative way.

This study carries important contributions to the literature as well as practical implications. First, our paper adds to the very limited literature that incorporates advanced computational power to construct variable measurements. Especially, this study applies an open-language processing tool developed recently in Harrison et al (2019) to construct proxies of CEO personal characteristics. Second, the paper contributes to the literature examining the CEOs influence on firm innovation. Prior literature has independently shown that aspects of CEO characteristics such as risk-aversion, overconfidence, or sensation seeking affect the firm level of innovation. However, most of the prior personal characteristics examined earlier are only representative of a very small fragment of CEO characteristics. Our study expands the scope of prior research through studying all Big Five personality traits individually and jointly. Third, our study carries practical implications for different parties, such as investors and boards of directors who are actively evaluating CEO performance. Investors could potentially utilize the CEO characteristics as an indicator and predictor for firm’s innovation level, which is an important indicator of
growth and profitability. Since the CEO characteristics can impact the firm innovation culture, understanding this connection can be beneficial for the board of directors during CEO hiring process to select the best candidate whose characteristics align with the firm’s strategic and forward-looking direction.

There are three major limitations of our study. First, we acknowledge that, although mass extracting CEOs’ characteristics through their speech transcript is efficient, the traditional method of conducting surveys or interviewing directly with top executives remains the most accurate technique to capture CEO’s personal characteristics. Since the tool developed in Harrison et al. (2019) rely on the 207 CEO characteristics acquired indirectly through video-metric approach in Hill et al. (In press), there is room for errors to occur. We propose that for future studies, researchers could further improve the accuracy of the model by following the direct survey methods such as the one used in Graham et al. (2005) to gather and build the training dataset. In that way, the computer can learn and predict characteristics more accurately.

Second, using R&D expenditures does not fully capture the firm’s total level of innovation input. From earlier discussion, a CEO can influence his/her firm level of innovation by either directly focusing more on R&D actions, or indirectly through building a working environment where innovation is highly encouraged or rewarded. Thus, R&D expenditures cannot capture any of the indirect methods that either the firm or the CEO implements to boost the firm’s level of innovation. For instance, the CEO chooses to enhance the firm level of innovation through hosting monthly workshops teaching employees creative thinking skills, or through rewarding employees with 5% bonus for any new patent. In this case, although the firm can report zero in R&D expenditures in that year, the innovative environment is strongly enhanced which could highly result in more breakthrough innovation outputs for the firm. Constructing a more
complete measurement for innovation input is challenging but would be a meaningful extension for future studies.

The third major limitation of our study is the use of total patents and new patents counts to measure the level of innovation output. There is a well-known issue related to this proxy for innovation level using patents: Not all innovative products/processes/services are patent-worth or require a patent application; they do not receive a patent grant. For example, if a firm switches from storing all printed documents in file cabinets to saving electronic versions of those documents to a central server, then that change in document handling process is an innovative outcome that does not result in any new patents. For that reason, the patent counts can only capture a portion of firm’s total innovation level. However, until today, there is still no other better measurement to capture the firm’s total level of innovation more comprehensively. This would be an interesting extension for future research.
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Figure 1: Application of open-language processing tool from Harrison et al. (2019)

207 CEOs' speech videos publicly available

- Using 504-gram RUPP (Goldberg, 2000)
- Grade independently

Videos

3 trained psychology doctoral students

Initial Big 5 Scores for 207 CEOs

Validate

Big 5 Scores for 207 CEOs

Hill et al. (In press)

Group 1
Large group

100,000 transcripts

Word2vec

Vectors (representing multiple words and phrases)

Computer

Generate multiple regression models with these vectors to predict available scores of the 207 CEOs

Model 1
Model 2
...
Model n

Multiple models generated

3 objectives:
1. Maximizing the correlation between predicted scores and observed scores
2. Replicating the patterns of variance for each trait
3. Replicating the patterns of zero-order correlations between traits

Group 2
Train group

Transcripts of 207 CEOs

Observed scores

Compare

Predicted scores

BEST MODELS (for each Big 5)

Harrison et al. (2019)

Transcript of 207 CEOs

Big 5 scores from Hill et al. (In press)
Figure 2: Program developed in Harrison et al. (2019)

Step 1: Download earnings call transcripts from SeekingAlpha.com
Step 2: Process transcript and match text data to executives
Step 3: Download open-language processing tool (written in R) from Harrison et al. (2019)
Step 4: Input transcripts to the download tool and extract CEO’s Big 5 Scales

Figure 3: Trend in New Patent Granted and R&D expenditure reported
Table 1: Year and Industry distribution  

Panel A: Year Distribution

| Fiscal Year | R&D Sample | Patent Sample |
|-------------|------------|---------------|
|             | Obs.       | Percent       | Cum. Percentage | Obs.       | Percent       | Cum. Percentage |
| 1992        | 4          | 0.06          | 0.06            |            |               |                |
| 1993        | 4          | 0.06          | 0.12            |            |               |                |
| 1994        | 4          | 0.06          | 0.18            |            |               |                |
| 1995        | 6          | 0.09          | 0.27            | 6          | 0.16          | 0.16            |
| 1996        | 6          | 0.09          | 0.36            | 9          | 0.24          | 0.4             |
| 1997        | 10         | 0.15          | 0.5             | 12         | 0.32          | 0.71            |
| 1998        | 16         | 0.24          | 0.74            | 16         | 0.42          | 1.13            |
| 1999        | 21         | 0.31          | 1.05            | 23         | 0.61          | 1.74            |
| 2000        | 34         | 0.5           | 1.56            | 36         | 0.95          | 2.69            |
| 2001        | 77         | 1.14          | 2.7             | 50         | 1.32          | 4.01            |
| 2002        | 92         | 1.36          | 4.06            | 71         | 1.87          | 5.89            |
| 2003        | 216        | 3.2           | 7.26            | 94         | 2.48          | 8.37            |
| 2004        | 261        | 3.87          | 11.13           | 181        | 4.78          | 13.14           |
| 2005        | 306        | 4.54          | 15.67           | 230        | 6.07          | 19.21           |
| 2006        | 358        | 5.31          | 20.98           | 446        | 11.77         | 30.98           |
| 2007        | 499        | 7.4           | 28.38           | 545        | 14.38         | 45.37           |
| 2008        | 582        | 8.63          | 37.01           | 619        | 16.34         | 61.7            |
| 2009        | 606        | 8.98          | 45.99           | 661        | 17.45         | 79.15           |
| 2010        | 614        | 9.1           | 55.09           | 790        | 20.85         | 100             |
| 2011        | 613        | 9.09          | 64.18           |            |               |                |
| 2012        | 623        | 9.24          | 73.42           |            |               |                |
| 2013        | 604        | 8.95          | 82.37           |            |               |                |
| 2014        | 601        | 8.91          | 91.28           |            |               |                |
| 2015        | 588        | 8.72          | 100             |            |               |                |
| Total       | 6,745      | 100           |                 | 3,789      | 100           |                 |
| Industry                              | R&D Sample | Patent Sample |
|--------------------------------------|------------|---------------|
| Agriculture                          | 13         | 0.19%         | 14         | 0.37%   |
| Food Products                        | 145        | 2.15%         | 89         | 2.35%   |
| Candy & Soda                         | 0          | 0.00%         | 14         | 0.37%   |
| Beer & Liquor                        | 11         | 0.16%         | 14         | 0.37%   |
| Tobacco Products                     | 32         | 0.47%         | 13         | 0.34%   |
| Recreation                           | 51         | 0.76%         | 30         | 0.79%   |
| Entertainment                        | 47         | 0.70%         | 17         | 0.45%   |
| Printing and Publishing              | 9          | 0.13%         | 25         | 0.66%   |
| Consumer Goods                       | 165        | 2.45%         | 102        | 2.69%   |
| Apparel                              | 41         | 0.61%         | 51         | 1.35%   |
| Healthcare                           | 134        | 1.99%         | 58         | 1.53%   |
| Medical Equipment                    | 400        | 5.93%         | 131        | 3.46%   |
| Pharmaceutical Products              | 465        | 6.89%         | 150        | 3.96%   |
| Chemicals                            | 368        | 5.46%         | 156        | 4.12%   |
| Rubber and Plastic Products          | 47         | 0.70%         | 20         | 0.53%   |
| Textiles                             | 37         | 0.55%         | 13         | 0.34%   |
| Construction Materials               | 199        | 2.95%         | 112        | 2.96%   |
| Construction                         | 14         | 0.21%         | 69         | 1.82%   |
| Steel Works Etc.                     | 55         | 0.82%         | 64         | 1.69%   |
| Fabricated Products                  | 9          | 0.13%         | 2          | 0.05%   |
| Machinery                            | 520        | 7.71%         | 261        | 6.89%   |
| Electrical Equipment                 | 119        | 1.76%         | 58         | 1.53%   |
| Automobiles and Trucks               | 193        | 2.86%         | 85         | 2.24%   |
| Aircraft                             | 112        | 1.66%         | 50         | 1.32%   |
| Shipbuilding, Railroad Equipment     | 20         | 0.30%         | 9          | 0.24%   |
| Defense                              | 21         | 0.31%         | 9          | 0.24%   |
| Precious Metals                      | 0          | 0.00%         | 10         | 0.26%   |
| Non-Metallic and Industrial Metal Mining | 22   | 0.33%         | 35         | 0.92%   |
| Coal                                 | 0          | 0.00%         | 9          | 0.24%   |
| Petroleum and Natural Gas            | 109        | 1.62%         | 198        | 5.23%   |
| Communication                        | 59         | 0.87%         | 64         | 1.69%   |
| Personal Services                    | 21         | 0.31%         | 44         | 1.16%   |
| Business Services                    | 653        | 9.68%         | 416        | 10.98%  |
| Computers                            | 330        | 4.89%         | 127        | 3.35%   |
| Electronic Equipment                 | 769        | 11.40%        | 355        | 9.37%   |
| Measuring and Control Equipment      | 301        | 4.46%         | 116        | 3.06%   |
| Business Supplies                    | 149        | 2.21%         | 90         | 2.38%   |
| Shipping Containers                  | 46         | 0.68%         | 28         | 0.74%   |
| Transportation                       | 0          | 0.00%         | 100        | 2.64%   |
| Category                  | Wholesale | 2.02% | 118 | 3.11% |
|--------------------------|-----------|-------|-----|-------|
| Retail                   | 685       | 10.16%| 332 | 8.76% |
| Restaurants, Hotels, Motels | 166      | 2.46% | 95  | 2.51% |
| Other                    | 72        | 1.07% | 36  | 0.95% |
| Total                    | 6,745     | 100.00%| 3,789| 100%  |
Table 2: Distribution of R&D expenditure and New Patents by year and by industry

| Fiscal Year | R&D Sample | Patent Sample |
|-------------|------------|---------------|
|             | Obs.       | Total R&D reported | Average R&D expenditure reported | Obs.       | Total new patents granted | Average new patents granted |
| 1992        | 4          | 405.46          | 101.37                        | 6          | 122                       | 20.33                        |
| 1993        | 4          | 283.80          | 70.95                         | 9          | 175                       | 19.44                        |
| 1994        | 4          | 357.16          | 89.29                         | 12         | 520                       | 43.33                        |
| 1995        | 6          | 662.47          | 110.41                        | 16         | 1,113                     | 69.56                        |
| 1996        | 6          | 874.69          | 145.78                        | 23         | 1,433                     | 62.30                        |
| 1997        | 10         | 1,493.08        | 149.31                        | 36         | 2,053                     | 57.03                        |
| 1998        | 16         | 2,327.77        | 145.49                        | 50         | 4,782                     | 95.64                        |
| 1999        | 21         | 3,986.62        | 189.84                        | 71         | 7,165                     | 100.92                       |
| 2000        | 34         | 6,578.10        | 193.47                        | 94         | 8,123                     | 86.41                        |
| 2001        | 77         | 18,755.30       | 243.58                        | 181        | 9,654                     | 53.34                        |
| 2002        | 92         | 24,408.20       | 265.31                        | 230        | 13,803                    | 60.01                        |
| 2003        | 216        | 33,368.08       | 154.48                        | 230        | 13,803                    | 60.01                        |
| 2004        | 261        | 44,628.12       | 170.99                        | 346        | 18,372                    | 41.19                        |
| 2005        | 306        | 56,643.16       | 185.11                        | 454        | 18,145                    | 33.29                        |
| 2006        | 358        | 85,036.73       | 237.53                        | 619        | 17,172                    | 27.74                        |
| 2007        | 499        | 109,493.00      | 219.42                        | 661        | 18,985                    | 28.72                        |
| 2008        | 582        | 128,966.30      | 221.59                        | 790        | 17,251                    | 21.84                        |
| 2009        | 606        | 116,244.20      | 191.82                        | 800        | 17,251                    | 21.84                        |
| 2010        | 611        | 117,044.10      | 190.63                        |            |                           |                              |
| 2011        | 613        | 165,917.40      | 270.66                        |            |                           |                              |
| 2012        | 621        | 178,321.00      | 286.23                        |            |                           |                              |
| 2013        | 604        | 174,533.30      | 288.96                        |            |                           |                              |
| 2014        | 601        | 201,247.70      | 334.85                        |            |                           |                              |
| 2015        | 588        | 214,576.00      | 364.93                        |            |                           |                              |
Table 2: Distribution of R&D expenditure and New Patents by year and by industry

Panel B: Industry Distribution (based on Fama French 48 industry codes)

| Industry                        | R&D Sample | Patent Sample |
|---------------------------------|------------|---------------|
|                                 | Obs.       | Total R&D reported | Average R&D expenditure reported | Obs.       | Total new patents granted | Average new patents granted |
| Pharmaceutical Products         | 465        | 459,486.40      | 988.14                           | 150        | 4,609.00                   | 30.73                        |
| Electronic Equipment            | 769        | 255,460.20      | 332.20                           | 355        | 47,131.00                  | 132.76                       |
| Business Services               | 653        | 243,047.40      | 372.20                           | 416        | 19,232.00                  | 46.23                        |
| Automobiles and Trucks          | 193        | 119,875.40      | 621.12                           | 85         | 3,311.00                   | 38.95                        |
| Machinery                       | 520        | 74,794.52       | 143.84                           | 261        | 8,223.00                   | 31.51                        |
| Computers                       | 330        | 63,957.38       | 193.81                           | 127        | 4,258.00                   | 33.53                        |
| Medical Equipment               | 400        | 63,242.07       | 158.11                           | 131        | 2,446.00                   | 18.67                        |
| Retail                          | 685        | 42,331.34       | 61.80                            | 332        | 102.00                     | 0.31                         |
| Measuring and Control Equipment | 301        | 40,331.25       | 133.99                           | 116        | 3,640.00                   | 31.38                        |
| Aircraft                        | 112        | 38,058.29       | 339.81                           | 50         | 1,660.00                   | 33.20                        |
| Petroleum and Natural Gas       | 109        | 36,567.33       | 335.48                           | 198        | 6,750.00                   | 34.09                        |
| Consumer Goods                  | 165        | 27,804.13       | 168.51                           | 102        | 4,021.00                   | 39.42                        |
| Business Supplies               | 149        | 27,793.70       | 186.53                           | 90         | 4,910.00                   | 54.56                        |
| Chemicals                       | 368        | 22,123.55       | 60.12                            | 156        | 1,684.00                   | 10.79                        |
| Agriculture                     | 13         | 14,924.00       | 1,148.00                         | 14         | 1,523.00                   | 108.79                       |
| Electrical Equipment            | 119        | 13,128.70       | 110.33                           | 58         | 1,353.00                   | 23.33                        |
| Communication                   | 59         | 11,391.62       | 193.08                           | 64         | 1,900.00                   | 29.69                        |
| Food Products                   | 145        | 10,200.08       | 70.35                            | 89         | 136.00                     | 1.53                         |
| Tobacco Products                | 32         | 9,782.00        | 305.69                           | 13         | 276.00                     | 21.23                        |
| Defense                         | 21         | 9,608.21        | 457.53                           | 9          | 1,357.00                   | 150.78                       |
| Recreation                      | 51         | 7,682.54        | 150.64                           | 30         | 735.00                     | 24.50                        |
| Construction Materials          | 199        | 7,495.71        | 37.67                            | 112        | 4,048.00                   | 36.14                        |
| Wholesale                       | 136        | 5,118.35        | 37.63                            | 118        | 38.00                      | 0.32                         |
| Beer & Liquor                   | 11         | 4,873.90        | 443.08                           | 14         | 29.00                      | 2.07                         |
| Entertainment                   | 47         | 2,643.74        | 56.25                            | 17         | 5.00                       | 0.29                         |
| Rubber and Plastic Products     | 47         | 1,574.60        | 33.50                            | 20         | 94.00                      | 4.70                         |
| Steel Works Etc                | 55         | 1,185.16        | 21.55                            | 64         | 60.00                      | 0.94                         |
| Shipping Containers             | 46         | 951.47          | 20.68                            | 28         | 28.00                      | 1.00                         |
| Textiles                        | 37         | 928.45          | 25.09                            | 13         | 85.00                      | 6.54                         |
| Shipbuilding, Railroad Equipment| 20         | 526.55          | 26.33                            | 9          | 14.00                      | 1.56                         |
| Apparel                         | 41         | 351.86          | 8.58                             | 51         | 41.00                      | 0.80                         |
| Restaurants, Hotels, Motels     | 166        | 132.10          | 0.80                             | 95         | 12.00                      | 0.13                         |
| Fabricated Products             | 9          | 86.99           | 9.66                             | 2          | 2.00                       | 1.00                         |
| Non-Metallic and Industrial Metal Mining | 22  | 54.62          | 2.48                             | 35         | 2.00                       | 0.06                         |
| Printing and Publishing         | 9          | 36.26           | 4.03                             | 25         | 3.00                       | 0.12                         |
| Construction                    | 14         | 34.90           | 2.49                             | 69         | 15.00                      | 0.22                         |
| Category          | Count | Cost  | Cost % | Count1 | Cost1  | Cost % |
|-------------------|-------|-------|--------|--------|--------|--------|
| Healthcare        | 134   | 16.41 | 0.12   | 58     | 4.00   | 0.07   |
| Personal Services | 21    | 4.60  | 0.22   | 44     | 3.00   | 0.07   |
| Transportation    | 0     | 0.00  | 0.00   | 100    | 14.00  | 0.14   |
| Other             | 72    | 68,546.06 | 952.03 | 69     | 15,114.00 | 418.86 |
Table 3: Descriptive Statistics

Panel A: R&D Sample

| Variable | Obs. | Mean  | 25th | Median | 75th | Std Dev | Min   | Max  |
|----------|------|-------|------|--------|------|---------|-------|------|
| RD       | 6745 | 249.99| 6.50 | 37.19  | 135.11| 894.72  | 0.00  | 12540.00|
| RD_adj   | 6745 | 0.00  | -0.75| -0.12 | 0.70 | 1.39    | -3.46 | 4.26 |
| openn    | 6745 | 4.73  | 4.32 | 4.74  | 5.11 | 0.57    | 2.88  | 6.86 |
| consc    | 6745 | 5.03  | 4.64 | 4.96  | 5.40 | 0.53    | 3.35  | 7.00 |
| extra    | 6745 | 4.87  | 4.47 | 4.87  | 5.29 | 0.66    | 1.83  | 7.00 |
| agree    | 6745 | 4.14  | 3.59 | 4.08  | 4.66 | 0.76    | 2.56  | 6.63 |
| neuro    | 6745 | 3.15  | 2.86 | 3.13  | 3.45 | 0.47    | 1.80  | 5.07 |
| age      | 6745 | 54.71 | 50.00| 55.00 | 59.00| 6.80    | 29.00 | 79.00|
| executenure | 6745 | 7.11  | 3.00 | 6.00  | 10.00| 6.76    | -16.00| 45.00|
| age2     | 6745 | 3039.97| 2500.00| 3025.00| 3481.00| 754.11  | 841.00| 6241.00|
| executenure2 | 6745 | 96.26 | 9.00 | 36.00 | 100.00| 180.13  | 0.00  | 2025.00|
| female   | 6745 | 0.04  | 0.00 | 0.00  | 0.00 | 0.19    | 0.00  | 1.00 |
| lnDelta  | 6745 | 5.38  | 4.42 | 5.37  | 6.37 | 1.59    | 0.00  | 13.24|
| lnVega   | 6745 | 3.59  | 2.22 | 4.20  | 5.24 | 2.23    | 0.00  | 9.06 |
| MA_score | 6745 | 0.02  | -0.07| -0.02 | 0.06 | 0.15    | -0.30 | 0.68 |
| lnSale   | 6745 | 7.41  | 6.30 | 7.37  | 8.49 | 1.55    | 2.71  | 10.59|
| lnAsset  | 6745 | 7.52  | 6.33 | 7.41  | 8.51 | 1.56    | 3.01  | 11.64|
| lnFirmAge| 6745 | 2.99  | 2.56 | 3.00  | 3.61 | 0.80    | 0.00  | 4.28 |
| lnReturn | 6745 | 0.04  | -0.16| 0.08  | 0.28 | 0.44    | -2.49 | 2.30 |
| lnPPEEmp | 6745 | 0.00  | 0.00 | 0.00  | 0.00 | 0.00    | 0.00  | 0.00 |
| CSR      | 6745 | -0.01 | -0.33| 0.00  | 0.14 | 0.55    | -1.98 | 3.50 |
| lnInstitution | 6475 | 0.59  | 0.54 | 0.60  | 0.65 | 0.10    | 0.12  | 0.73 |
Table 3: Descriptive Statistics

| Variable  | Obs. | Mean  | 25th | Median | 75th | Std Dev  | Min   | Max  |
|-----------|------|-------|------|--------|------|----------|-------|------|
| TPAT      | 3789 | 413.18| 0.00 | 14.00  | 172.00| 1573.30  | 0.00  | 19730.00 |
| NPAT      | 3789 | 36.65 | 0.00 | 1.00   | 12.00 | 157.35   | 0.00  | 2901.00  |
| TCW       | 3789 | 81.90 | 0.00 | 1.00   | 25.10 | 366.68   | 0.00  | 7106.58  |
| TSM       | 3789 | 609.26| 0.00 | 1.21   | 95.86 | 3139.96  | 0.00  | 67800.52 |
| TPat_adj  | 3789 | 0.00  | -1.11| -0.28  | 1.12  | 1.90     | -4.45 | 5.19   |
| NPAT_adj  | 3789 | 0.00  | -0.85| -0.09  | 0.56  | 1.38     | -2.73 | 4.35   |
| TCW_adj   | 3789 | 0.00  | -1.06| -0.13  | 0.73  | 1.62     | -3.29 | 4.91   |
| TSM_adj   | 3789 | 0.00  | -1.47| -0.30  | 1.08  | 2.23     | -4.22 | 6.29   |
| openn     | 3789 | 4.62  | 4.24 | 4.94   | 5.36  | 0.53     | 3.12  | 6.69   |
| consc     | 3789 | 5.01  | 4.64 | 4.94   | 5.36  | 0.53     | 3.35  | 7.00   |
| extra     | 3789 | 4.71  | 4.29 | 4.76   | 5.18  | 0.72     | 1.83  | 6.81   |
| agree     | 3789 | 3.97  | 3.42 | 3.91   | 4.39  | 0.74     | 2.16  | 6.63   |
| neuro     | 3789 | 3.29  | 2.91 | 3.21   | 3.59  | 0.59     | 1.58  | 6.30   |
| age       | 3783 | 54.30 | 50.00| 54.00  | 58.00 | 6.44     | 35.00 | 80.00  |
| executenure| 3783 | 2989.75| 2500.00| 2916.00| 3364.00| 707.94| 1225.00| 6400.00 |
| age2      | 3789 | 6.79  | 3.00 | 5.00   | 9.00  | 6.58     | -14.00| 44.00  |
| executenure2 | 3789 | 89.35 | 9.00 | 25.00  | 81.00 | 179.09  | 0.00  | 1936.00 |
| female    | 3789 | 0.03  | 0.00 | 0.00   | 0.00  | 0.18     | 0.00  | 1.00   |
| lnDelta   | 3789 | 5.37  | 4.42 | 5.39   | 6.35  | 1.62     | 0.00  | 12.86  |
| lnVega    | 3789 | 3.83  | 2.80 | 4.40   | 5.36  | 2.15     | 0.00  | 8.78   |
| MA_score  | 3783 | 0.01  | -0.08| -0.03  | 0.05  | 0.15     | -0.30 | 0.66   |
| lnSale    | 3784 | 3.12  | 2.64 | 3.09   | 3.66  | 0.67     | 0.00  | 4.28   |
| lnAsset   | 3789 | 7.77  | 6.70 | 7.68   | 8.73  | 1.45     | 3.02  | 11.64  |
| lnFirmAge | 3789 | 7.70  | 6.68 | 7.65   | 8.69  | 1.44     | 0.00  | 10.59  |
| lnReturn  | 3784 | 0.01  | -0.22| 0.06   | 0.28  | 0.49     | -2.49 | 2.30   |
| lnPPEEmp  | 3789 | 0.00  | 0.00 | 0.00   | 0.00  | 0.00     | 0.00  | 0.00   |
| CSR       | 3702 | -0.11 | -0.38| -0.13  | 0.13  | 0.48     | -2.42 | 2.63   |
| lnInstitution | 3786 | 0.59 | 0.54 | 0.61 | 0.66 | 0.11 | 0.12 | 0.73 |
|        | RD_adj | TPAT_adj | NPAT_adj | TCW_adj | TSM_adj | openn | consc | extra | agree | neuro |
|--------|--------|----------|----------|---------|---------|-------|-------|-------|-------|-------|
| RD_adj | 1.00   |          |          |         |         |       |       |       |       |       |
| TPAT_adj | 0.71  | 1.00     |          |         |         |       |       |       |       |       |
| NPAT_adj | 0.70  | 0.86     | 1.00     |         |         |       |       |       |       |       |
| TCW_adj | 0.70  | 0.85     | 0.99     | 1.00    |         |       |       |       |       |       |
| TSM_adj | 0.72  | 0.84     | 0.93     | 0.93    | 1.00    |       |       |       |       |       |
| openn  | 0.07  | 0.03     | 0.03     | 0.04    | 0.03    | 1.00  |       |       |       |       |
| consc  | -0.03 | -0.04    | -0.04    | -0.04   | -0.03   | 0.58  | 1.00  |       |       |       |
| extra  | 0.11  | 0.08     | 0.08     | 0.07    | 0.06    | 0.52  | 0.31  | 1.00  |       |       |
| agree  | 0.13  | 0.09     | 0.09     | 0.10    | 0.08    | 0.68  | 0.44  | 0.41  | 1.00  |       |
| neuro  | -0.10 | -0.07    | -0.05    | -0.05   | -0.06   | -0.63 | -0.43 | -0.54 | -0.50 | 1.00  |
Table 5: Influence of CEO’s Big Five Personalities on Firm’s R&D

|                  | (1)    | (2)    | (3)    | (4)    | (5)    | (6)    |
|------------------|--------|--------|--------|--------|--------|--------|
|                  | RD_adj | RD_adj | RD_adj | RD_adj | RD_adj | RD_adj |
| openn            | 0.0445 | 0.138**| 0.0318 | 0.0362 | 0.0309 | 0.0320 |
|                  | (0.586)| (0.022)| (0.421)| (0.356)| (0.424)| (0.422)|
| consc            | -0.312***| -0.0989| (0.586)| (0.022)|        |
|                  | (0.000)| (0.122)| (0.000)| (0.122)|        |
| extra            | 0.0924* |        |        |        | 0.153***| (0.001)|
|                  | (0.053)|        |        |        | (0.001)|        |
| agree            | 0.207***|        |        |        | 0.198***| (0.000)|
|                  | (0.000)|        |        |        | (0.000)|        |
| neuro            | -0.128 |        |        |        | -0.200***| (0.005)|
|                  | (0.123)|        |        |        | (0.005)|        |
| L1_age           | 0.0387 | 0.0304 | 0.0318 | 0.0362 | 0.0309 | 0.0320 |
|                  | (0.296)| (0.448)| (0.421)| (0.356)| (0.424)| (0.422)|
| L1_executenure   | 0.00918| 0.0106 | 0.00847| 0.0112 | 0.00881| 0.0106 |
|                  | (0.303)| (0.220)| (0.327)| (0.191)| (0.305)| (0.218)|
| L1_age2          | -0.000412| -0.000359| -0.000381| -0.000411| -0.000353| -0.000376|
|                  | (0.214)| (0.315)| (0.282)| (0.241)| (0.304)| (0.289)|
| L1_executenure2  | -0.000540| -0.000523| -0.000444| -0.000531| -0.000507| -0.000484|
|                  | (0.108)| (0.135)| (0.191)| (0.125)| (0.140)| (0.160)|
| L1_female        | -0.177 | -0.242 | -0.197 | -0.223 | -0.239 | -0.233 |
|                  | (0.302)| (0.150)| (0.246)| (0.181)| (0.149)| (0.167)|
| L1_InDelta       | 0.0657**| 0.0584*| 0.0725**| 0.0622*| 0.0627*| 0.0619*|
|                  | (0.047)| (0.098)| (0.044)| (0.076)| (0.073)| (0.081)|
| L1_InVega        | -0.000844| 0.000849| -0.00164| 0.00387| -0.00292| 0.000393|
|                  | (0.964)| (0.966)| (0.935)| (0.846)| (0.883)| (0.984)|
| L1_MA_score      | 0.779***| 0.976***| 1.137***| 1.025***| 0.828***| 0.986***|
|                  | (0.000)| (0.000)| (0.000)| (0.000)| (0.000)| (0.000)|
| L1_InSale        | -0.0587| -0.155**| -0.160**| -0.151**| -0.108*| -0.167***|
|                  | (0.382)| (0.013)| (0.012)| (0.016)| (0.091)| (0.007)|
| L1_InAsset       | 0.609***| 0.690***| 0.684***| 0.680***| 0.649***| 0.697***|
|                  | (0.000)| (0.000)| (0.000)| (0.000)| (0.000)| (0.000)|
| L1_InFirmAge     | -0.0665| -0.0587| -0.0813*| -0.0707| -0.0538| -0.0667|
|                  | (0.158)| (0.215)| (0.092)| (0.135)| (0.258)| (0.159)|
| L1_InReturn      | -0.0472| -0.0381| -0.0447| -0.0447| -0.0401| -0.0432|
|                  | (0.336)| (0.476)| (0.394)| (0.407)| (0.452)| (0.416)|
| L1_InPPEEmp      | 211.5  | 38.43  | 328.8  | 138.7  | 48.06  | 122.2  |
|                  | (0.734)| (0.952)| (0.595)| (0.824)| (0.938)| (0.846)|
| L1_CSR           | 0.297***| 0.338***| 0.370***| 0.338***| 0.312***| 0.335***|
|                  | (0.000)| (0.000)| (0.000)| (0.000)| (0.000)| (0.000)|
Table 5: Influence of CEO’s Big Five Personalities on Firm’s R&D (cont)

|          | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  |
|----------|------|------|------|------|------|------|
|          | RD_adj | RD_adj | RD_adj | RD_adj | RD_adj | RD_adj |
| L1_Institution | 0.683** | 0.744** | 0.762** | 0.777** | 0.708** | 0.745** |
|          | (0.032) | (0.019) | (0.016) | (0.013) | (0.023) | (0.018) |
| _cons    | -5.075*** | -5.819*** | -4.617*** | -6.046*** | -6.052*** | -4.539*** |
|          | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| N        | 6032 | 6032 | 6032 | 6032 | 6032 | 6032 |
| F        | 278.0 | 313.3 | 302.1 | 317.9 | 327.6 | 315.7 |
| R2       | 0.536 | 0.519 | 0.517 | 0.521 | 0.525 | 0.520 |

p-values in parentheses * p<0.10 ** p<0.05 *** p<0.010
|      | (1)       | (2)       | (3)       | (4)       | (5)       | (6)       |
|------|-----------|-----------|-----------|-----------|-----------|-----------|
|      | TPAT_adj  | TPAT_adj  | TPAT_adj  | TPAT_adj  | TPAT_adj  | TPAT_adj  |
| openn| 0.132     | 0.150*    |           |           |           |           |
|      | (0.317)   | (0.053)   |           |           |           |           |
| consc| -0.356*** | -0.136*   |           |           |           |           |
|      | (0.000)   | (0.081)   |           |           |           |           |
| extra| 0.0849    |           | 0.132**   |           |           |           |
|      | (0.176)   |           | (0.015)   |           |           |           |
| agree| 0.200***  |           |           | 0.179***  |           |           |
|      | (0.009)   |           |           | (0.002)   |           |           |
| neuro| -0.00467  |           |           |           | -0.118*  |           |
|      | (0.959)   |           |           |           | (0.086)  |           |
| L3_age| -0.0328   | -0.0252   | -0.0281   | -0.0338   | -0.0261   | -0.0290   |
|      | (0.515)   | (0.637)   | (0.602)   | (0.520)   | (0.620)   | (0.584)   |
| L3_executenure| 0.000252 | 0.000167  | 0.000184  | 0.000244  | 0.000185  | 0.000198  |
|      | (0.567)   | (0.720)   | (0.697)   | (0.595)   | (0.689)   | (0.668)   |
| L3_age2| 0.00182   | 0.00237   | 0.00346   | 0.00342   | 0.000592  | 0.000256  |
|      | (0.854)   | (0.801)   | (0.971)   | (0.720)   | (0.949)   | (0.784)   |
| L3_executenure2| -0.000255| -0.000212 | -0.000150 | -0.000223| -0.000176| -0.000203|
|      | (0.451)   | (0.507)   | (0.647)   | (0.495)   | (0.581)   | (0.526)   |
| L3_female| 0.0942    | 0.0224    | 0.0985    | 0.0689    | 0.0376    | 0.0343    |
|      | (0.689)   | (0.924)   | (0.676)   | (0.764)   | (0.872)   | (0.884)   |
| L3_InDelta| -0.0127   | -0.0151   | -0.000100 | -0.0116   | -0.0143   | -0.0109   |
|      | (0.637)   | (0.592)   | (0.997)   | (0.679)   | (0.616)   | (0.709)   |
| L3_InVega| 0.0244    | 0.0259    | 0.0315    | 0.0289    | 0.0214    | 0.0264    |
|      | (0.316)   | (0.319)   | (0.235)   | (0.259)   | (0.405)   | (0.309)   |
| L3_MA_score| 0.536*    | 0.662**   | 0.794***  | 0.708**   | 0.591**   | 0.734***  |
|      | (0.071)   | (0.023)   | (0.006)   | (0.014)   | (0.041)   | (0.010)   |
| L3_InSale| 0.0946*   | 0.102*    | 0.0741    | 0.0857    | 0.109**   | 0.0880*   |
|      | (0.076)   | (0.061)   | (0.164)   | (0.109)   | (0.036)   | (0.097)   |
| L3_InAsset| 0.318***  | 0.367***  | 0.345***  | 0.374***  | 0.343***  | 0.375***  |
|      | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   |
| L3_InFirmAge| 0.0744    | 0.00567   | 0.0151    | -0.00508  | 0.0336    | -0.00744  |
|      | (0.229)   | (0.923)   | (0.809)   | (0.932)   | (0.563)   | (0.901)   |
| L3_InReturn| 0.106**   | 0.108**   | 0.0808    | 0.0986*   | 0.111**   | 0.101**   |
|      | (0.047)   | (0.034)   | (0.148)   | (0.057)   | (0.027)   | (0.043)   |
| L3_InPPEEmp| -874.6*** | -894.9*** | -704.2**  | -899.5*** | -939.5*** | -865.6*** |
|      | (0.001)   | (0.002)   | (0.011)   | (0.001)   | (0.001)   | (0.002)   |
| L3_CSR| 0.399***  | 0.475***  | 0.522***  | 0.462***  | 0.458***  | 0.480***  |
|      | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   |
Table 6: Influence of CEO’s Big Five Traits on Innovation Outputs (Total Patents Held) (cont)

|                  | (1)      | (2)      | (3)      | (4)      | (5)      | (6)      |
|------------------|----------|----------|----------|----------|----------|----------|
|                  | TPAT_adj | TPAT_adj | TPAT_adj | TPAT_adj | TPAT_adj | TPAT_adj |
| L3_lnInstitution| 0.144    | 0.224    | 0.208    | 0.233    | 0.161    | 0.230    |
|                  | (0.646)  | (0.486)  | (0.531)  | (0.475)  | (0.612)  | (0.480)  |
| _cons            | -2.272   | -3.025*  | -1.465   | -2.685*  | -3.032** | -1.785   |
|                  | (0.169)  | (0.052)  | (0.351)  | (0.069)  | (0.040)  | (0.240)  |
| N                | 3789     | 3789     | 3789     | 3789     | 3789     | 3789     |
| F                | 59.53    | 67.01    | 65.82    | 68.41    | 69.28    | 66.76    |
| R2               | 0.263    | 0.246    | 0.245    | 0.247    | 0.250    | 0.245    |

p-values in parentheses  * p<0.10  ** p<0.05  *** p<0.01
Table 7: Influence of CEO’s Big Five Personalities on Innovation Output (New Patents)

|          | (1) NPAT_adj | (2) NPAT_adj | (3) NPAT_adj | (4) NPAT_adj | (5) NPAT_adj | (6) NPAT_adj |
|----------|--------------|--------------|--------------|--------------|--------------|--------------|
| openn    | 0.132        | 0.150*       |              |              |              |              |
|          | (0.317)      | (0.053)      |              |              |              |              |
| consc    | -0.356***    |              |              | -0.136*      |              |              |
|          | (0.000)      |              |              | (0.081)      |              |              |
| extra    | 0.0849       |              | 0.132**      |              |              |              |
|          | (0.176)      |              | (0.015)      |              |              |              |
| agree    | 0.200***     |              |              |              | 0.179***     | -0.118*      |
|          | (0.009)      |              |              |              | (0.002)      | (0.086)      |
| neuro    | -0.00467     |              |              |              |              | -0.118*      |
|          | (0.959)      |              |              |              |              | (0.086)      |
| L3_age   | -0.0328      | -0.0252      | -0.0281      | -0.0338      | -0.0261      | -0.0290      |
|          | (0.515)      | (0.637)      | (0.602)      | (0.520)      | (0.620)      | (0.584)      |
| L3_executenure | 0.000252     | 0.000167     | 0.000184     | 0.000244     | 0.000185     | 0.000198     |
|          | (0.567)      | (0.720)      | (0.697)      | (0.595)      | (0.689)      | (0.668)      |
| L3_age2  | 0.00182      | 0.00237      | 0.000346     | 0.000342     | 0.000592     | 0.00256      |
|          | (0.854)      | (0.801)      | (0.971)      | (0.720)      | (0.949)      | (0.784)      |
| L3_executenure2 | -0.000255     | -0.000212    | -0.000150    | -0.000223    | -0.000176    | -0.000203    |
|          | (0.451)      | (0.507)      | (0.647)      | (0.495)      | (0.581)      | (0.526)      |
| L3_female | 0.0942       | 0.0224       | 0.0985       | 0.0689       | 0.0376       | 0.0343       |
|          | (0.689)      | (0.924)      | (0.676)      | (0.764)      | (0.872)      | (0.884)      |
| L3_InDelta | -0.0127      | -0.0151      | -0.000100    | -0.0116      | -0.0143      | -0.0109      |
|          | (0.637)      | (0.592)      | (0.997)      | (0.679)      | (0.616)      | (0.709)      |
| L3_InVega | 0.0244       | 0.0259       | 0.0315       | 0.0289       | 0.0214       | 0.0264       |
|          | (0.316)      | (0.319)      | (0.235)      | (0.259)      | (0.405)      | (0.309)      |
| L3_MA_score | 0.536*       | 0.662**      | 0.794***     | 0.708**      | 0.591**      | 0.734***     |
|          | (0.071)      | (0.023)      | (0.006)      | (0.014)      | (0.041)      | (0.010)      |
| L3_InSale | 0.0946*      | 0.102*       | 0.0741       | 0.0857       | 0.109**      | 0.0880*      |
|          | (0.076)      | (0.061)      | (0.164)      | (0.109)      | (0.036)      | (0.097)      |
| L3_InAsset | 0.318***     | 0.367***     | 0.345***     | 0.374***     | 0.343***     | 0.375***     |
|          | (0.000)      | (0.000)      | (0.000)      | (0.000)      | (0.000)      | (0.000)      |
| L3_InFirmAge | 0.0744       | 0.00567      | 0.0151       | -0.00508     | 0.0336       | -0.00744     |
|          | (0.229)      | (0.923)      | (0.809)      | (0.932)      | (0.563)      | (0.901)      |
| L3_InReturn | 0.106**      | 0.108**      | 0.0808       | 0.0986*      | 0.111**      | 0.101**      |
|          | (0.047)      | (0.034)      | (0.148)      | (0.057)      | (0.027)      | (0.043)      |
| L3_InPPEEmp | -874.6***    | -894.9***    | -704.2**     | -899.5***    | -939.5***    | -865.6***    |
|          | (0.001)      | (0.002)      | (0.011)      | (0.001)      | (0.001)      | (0.002)      |
| L3_CSR | 0.399***     | 0.475***     | 0.522***     | 0.462***     | 0.458***     | 0.480***     |
|          | (0.000)      | (0.000)      | (0.000)      | (0.000)      | (0.000)      | (0.000)      |
Table 7: Influence of CEO’s Big Five Personalities on Innovation Output (New Patents) (cont)

|          | (1)       | (2)       | (3)       | (4)       | (5)       | (6)       |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|
|          | NPAT_adj  | NPAT_adj  | NPAT_adj  | NPAT_adj  | NPAT_adj  | NPAT_adj  |
| _cons    | (0.646)   | (0.486)   | (0.531)   | (0.475)   | (0.612)   | (0.480)   |
|          | -2.272    | -3.025*   | -1.465    | -2.685*   | -3.032**  | -1.785    |
|          | (0.169)   | (0.052)   | (0.351)   | (0.069)   | (0.040)   | (0.240)   |
| N        | 3789      | 3789      | 3789      | 3789      | 3789      | 3789      |
| F        | 59.53     | 67.01     | 65.82     | 68.41     | 69.28     | 66.76     |
| R2       | 0.263     | 0.246     | 0.245     | 0.247     | 0.250     | 0.245     |

p-values in parentheses * p<0.10  ** p<0.05  *** p<0.01
Table 8: Influence of CEO’s Big Five Traits on Innovation Quality (Total Citations Weighted)

|                | (1)       | (2)       | (3)       | (4)       | (5)       | (6)       |
|----------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                | TCW_adj   | TCW_adj   | TCW_adj   | TCW_adj   | TCW_adj   | TCW_adj   |
| openn          | 0.192     | 0.184**   |           |           |           |           |
|                | (0.212)   | (0.041)   |           |           |           |           |
| consc          | -0.453*** | -0.178**  |           |           |           |           |
|                | (0.000)   | (0.048)   |           |           |           |           |
| extra          | 0.0896    |           | 0.148**   |           |           |           |
|                | (0.225)   |           | (0.021)   |           |           |           |
| agree          | 0.241***  |           |           | 0.214***  |           |           |
|                | (0.007)   |           |           | (0.001)   |           |           |
| neuro          | 0.00512   |           |           |           | -0.133*  |
|                | (0.962)   |           |           |           | (0.100)  |           |
| L3_age         | -0.0440   | -0.0359   | -0.0396   | -0.0458   | -0.0370   | -0.0403   |
|                | (0.469)   | (0.577)   | (0.543)   | (0.470)   | (0.560)   | (0.528)   |
| L3_executenure | 0.000337  | 0.000242  | 0.000264  | 0.000329  | 0.000264  | 0.000278  |
|                | (0.529)   | (0.667)   | (0.644)   | (0.552)   | (0.636)   | (0.619)   |
| L3_age2        | 0.00268   | 0.00356   | 0.00101   | 0.00459   | 0.00138   | 0.00363   |
|                | (0.820)   | (0.750)   | (0.929)   | (0.684)   | (0.900)   | (0.744)   |
| L3_executenure2| -0.000384 | -0.000332 | -0.000256 | -0.000340 | -0.000288 | -0.000317 |
|                | (0.341)   | (0.381)   | (0.513)   | (0.383)   | (0.448)   | (0.406)   |
| L3_female      | 0.0528    | -0.0340   | 0.0626    | 0.0227    | -0.0144   | -0.0163   |
|                | (0.844)   | (0.899)   | (0.817)   | (0.931)   | (0.957)   | (0.952)   |
| L3_InDelta     | -0.00902  | -0.0121   | 0.00682   | -0.00723  | -0.0108   | -0.00645  |
|                | (0.783)   | (0.724)   | (0.853)   | (0.834)   | (0.756)   | (0.857)   |
| L3_InVega      | 0.0282    | 0.0300    | 0.0370    | 0.0336    | 0.0246    | 0.0308    |
|                | (0.333)   | (0.338)   | (0.244)   | (0.276)   | (0.426)   | (0.325)   |
| L3_MA_score    | 0.808***  | 0.966***  | 1.131***  | 1.027***  | 0.885***  | 1.057***  |
|                | (0.018)   | (0.004)   | (0.001)   | (0.002)   | (0.007)   | (0.001)   |
| L3_InSale      | 0.0750    | 0.0830    | 0.0477    | 0.0630    | 0.0906    | 0.0655    |
|                | (0.232)   | (0.196)   | (0.452)   | (0.318)   | (0.138)   | (0.294)   |
| L3_InAsset     | 0.352***  | 0.415***  | 0.386***  | 0.422***  | 0.385***  | 0.423***  |
|                | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   |
| L3_InFirmAge   | 0.0819    | -0.00561  | 0.00711   | -0.0182   | 0.0276    | -0.0209   |
|                | (0.267)   | (0.937)   | (0.924)   | (0.799)   | (0.692)   | (0.773)   |
| L3_InReturn    | 0.123*    | 0.125**   | 0.0908    | 0.113*    | 0.128**   | 0.116*    |
|                | (0.050)   | (0.038)   | (0.169)   | (0.067)   | (0.029)   | (0.052)   |
| L3_InPPEEmp    | -1243.5***| -1281.0***| -1038.7***| -1275.6***| -1330.7***| -1237.6***|
|                | (0.000)   | (0.000)   | (0.002)   | (0.000)   | (0.000)   | (0.000)   |
| L3_CSR         | 0.431***  | 0.521***  | 0.579***  | 0.511***  | 0.502***  | 0.531***  |
|                | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   | (0.000)   |
Table 8: Influence of CEO’s Big Five Traits on Innovation Quality (Total Citations Weighted) (cont)

|                  | (1)  | (2)  | (3)  | (4)  | (5)  | (6)  |
|------------------|------|------|------|------|------|------|
|                  | TCW_adj | TCW_adj | TCW_adj | TCW_adj | TCW_adj | TCW_adj |
| L3_inInstitution| 0.128 | 0.227 | 0.206 | 0.237 | 0.152 | 0.233 |
|                  | (0.726) | (0.545) | (0.595) | (0.535) | (0.683) | (0.540) |
| _cons            | -2.182 | -3.065* | -1.084 | -2.594 | -3.042* | -1.581 |
|                  | (0.261) | (0.098) | (0.559) | (0.141) | (0.086) | (0.380) |
| N                | 3789  | 3789  | 3789  | 3789  | 3789  | 3789  |
| F                | 57.85 | 63.92 | 62.52 | 65.13 | 66.55 | 63.48 |
| R2               | 0.245 | 0.227 | 0.227 | 0.227 | 0.231 | 0.226 |

p-values in parentheses  * p<0.10  ** p<0.05  *** p<0.01
Table 9: Influence of CEO’s Big Five Traits on Innovation Quality (Market Value of Patents)

|                  | (1)            | (2)            | (3)            | (4)            | (5)            | (6)            |
|------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                  | TSM_adj        | TSM_adj        | TSM_adj        | TSM_adj        | TSM_adj        | TSM_adj        |
| openn            | 0.225          | 0.243***       | 0.231          | 0.089          | 0.044          | 0.044          |
| consc            | -0.539***      | -0.196*        | 0.231          | 0.043          | 0.043          | 0.043          |
| extra            | 0.0670         | 0.169**        | 0.488          | 0.046          | 0.046          | 0.046          |
| agree            | 0.275***       | 0.263***       | 0.008          | -0.220**       | -0.220**       | -0.220**       |
| neuro            | -0.0896        | 0.609          | 0.521          | 0.047          | 0.047          | 0.047          |
| L3_age           | -0.0431        | -0.0334        | -0.0379        | -0.0451        | -0.0351        | -0.0401        |
| L3_executenenure | 0.000328       | 0.000216       | 0.000242       | 0.000318       | 0.000244       | 0.000273       |
| L3_age2          | -0.00265       | -0.00193       | -0.00511       | -0.00106       | -0.00476       | -0.00122       |
| L3_executenenure2| -0.000430      | -0.000362      | -0.000263      | -0.000358      | -0.000302      | -0.000360      |
| L3_age2          | -0.00265       | -0.00193       | -0.00511       | -0.00106       | -0.00476       | -0.00122       |
| L3_executenenure2| -0.000430      | -0.000362      | -0.000263      | -0.000358      | -0.000302      | -0.000360      |
| L3_age2          | -0.00265       | -0.00193       | -0.00511       | -0.00106       | -0.00476       | -0.00122       |
| L3_executenenure2| -0.000430      | -0.000362      | -0.000263      | -0.000358      | -0.000302      | -0.000360      |
| L3 Female        | 0.281          | 0.194          | 0.311          | 0.268          | 0.222          | 0.206          |
| L3 LnDelta       | 0.0374         | 0.0339         | 0.0572         | 0.0415         | 0.0366         | 0.0394         |
| L3 LnVega        | 0.0311         | 0.0341         | 0.0427         | 0.0390         | 0.0279         | 0.0353         |
| L3 LnMA_score    | 1.399***       | 1.564***       | 1.772***       | 1.655***       | 1.474***       | 1.674***       |
| L3 LnSale        | 0.121          | 0.133          | 0.0897         | 0.107          | 0.141*         | 0.111          |
| L3 LnAsset       | 0.539***       | 0.606***       | 0.573***       | 0.612***       | 0.569***       | 0.622***       |
| L3 LnFirmAge     | 0.182*         | 0.0862         | 0.0989         | 0.0708         | 0.127          | 0.0628         |
| L3 LnReturn      | 0.251***       | 0.251***       | 0.210**        | 0.234**        | 0.254***       | 0.244***       |
| L3 LnPPEEmp      | -1336.2***     | -1383.2***     | -1089.7**      | -1355.2***     | -1433.8***     | -1352.9***     |
| L3 CSR           | 0.510***       | 0.619***       | 0.693***       | 0.615***       | 0.599***       | 0.618***       |
Table 9: Influence of CEO’s Big Five Traits on Innovation Quality (Market Value of Patents) (cont)

|                  | (1) TSM_adj | (2) TSM_adj | (3) TSM_adj | (4) TSM_adj | (5) TSM_adj | (6) TSM_adj |
|------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| L3_Institution   | 0.0607      | 0.172       | 0.147       | 0.181       | 0.0779      | 0.184       |
|                  | (0.903)     | (0.736)     | (0.780)     | (0.727)     | (0.878)     | (0.721)     |
| _cons            | -4.148*     | -5.888***   | -3.482      | -5.166**    | -5.770***   | -3.774*     |
|                  | (0.080)     | (0.008)     | (0.126)     | (0.016)     | (0.008)     | (0.081)     |
| N                | 3789        | 3789        | 3789        | 3789        | 3789        | 3789        |
| F                | 90.33       | 101.3       | 98.72       | 102.9       | 105.3       | 101.2       |
| R2               | 0.330       | 0.317       | 0.316       | 0.317       | 0.320       | 0.317       |

p-values in parentheses  * p<0.10  ** p<0.05  *** p<0.01