Engineer CEOs and Corporate Innovation

Jialun Yang[1] and Frank Y. Feng*[2]

Abstract

One-in-three CEOs of Chinese manufacturing firms are engineers. Firms led by CEOs with professional certifications in engineering, are associated with greater innovation quality, indicating that on-the-job training in engineering produces human capital which fosters innovation. In addition, firms with Engineer CEOs don't spend more on R&D comparing to others, which argues against the "functionally biased perception theory". The result is more pronounced when CEOs have senior-level professional certifications in engineering. Our main finding still holds when we apply an instrumental variable approach. Finally, we also show that Engineer CEOs have opposite impacts on innovation quality in high- and low-leverage firms.

---

[1] School of Economics and Management, Tsinghua University.

[2] *Corresponding author. School of Finance, Shanghai Institute of International Finance and Economics, Shanghai University of Finance and Economics.

1. Introduction

Elon Musk, CEO of SpaceX and Tesla, is both an entrepreneur and an engineer. Mr. Musk emphasizes innovation and says that "The path to the CEO's office should not be through the CFO's office, and it should not be through the marketing department. It needs to be through engineering and design." Many other innovative companies, such as Huawei and Lenovo in China, LG Electronics in South Korea etc., are also led by engineers. Is it just a coincidence that corporate innovation goes hand in hand with a CEO's engineering background? In this paper, we take a closer look at whether, and if so how, the hands-on engineering trainings of CEOs influence innovation activities in manufacturing firms.

Existing studies have suggested that CEOs exhibit biases in decision making, reflecting the perspectives of the business functions in which they were trained (Dearborn and Simon, 1958). CEOs with engineering backgrounds commonly possess skills related to innovation, and their past experiences equip them with strong senses and solid understandings of innovation. Yet existing literature regarding the impact of CEOs with engineering backgrounds on corporate innovation are relatively scarce. Recently, Jung (2018) studied the benefits and costs of having CEOs with STEM (Science, Technology, Engineering and Math) degrees in high-tech firms, and found that these CEOs usually have preferences for innovation and adopt innovation-oriented corporate strategies. While for the effects of CEOs with on-the-job training in engineering, which can also produce human capital and thus foster innovation (see Becker, 1962; Stroombergen et al., 2002), Barker and Mueller (2002) focused on the determinants of firm R&D spending, and found that CEOs with career experiences in engineering invest more in R&D. However, little is known regarding the influence of CEOs with on-the-job training in engineering on corporate innovation outcomes measured by patents and citations. Considering that innovation activities, especially those with significant influences, i.e. those with greater citations, play an important role in generating economic growth, and according to Mr. Changyu Shen, Director of Chinese State Intellectual Property Office, patent-intensive industries, such as the manufacturing industry, contribute to approximately 15.7% of China's GDP growth in 2018[3]. Therefore, it is of great importance to identify how CEOs with engineering backgrounds impacts on firm innovation in manufacturing industry, and thus delivers benefits to society.

In this paper, we examine how CEOs with on-the-job trainings in engineering (Engineer CEOs hereafter), affect corporate innovation. Following Benmelech and Frydman (2015), we only consider firms in the manufacturing industry, where innovation is considered very important, and approximately 30% of CEOs in manufacturing firms are Engineer CEOs. Our results show that firms led by Engineer CEOs are associated with innovation of better quality but no significant changes in innovation quantity, which indicates that the rise of human capital embedded in the on-the-job training process to pursue professional certifications

---

[3] See http://news.cctv.com/2020/04/23/ARTI3EZNDxmFshLEHUiBCWIY200423.shtml (in Chinese)

enhances innovation quality. While these firms do not behave differently from other firms in terms of innovation input, measured by R&D expenditures, or innovation output quantity, measured by patents than firms without Engineer CEOs, thus argues against CEOs' functionally biases or preferences originated from past experience in engineering. Furthermore, we show that Engineering CEOs with senior-level professional certifications in engineering are more influential in innovation efficiency than Engineer CEOs with junior-level certifications, consistent with previous results that Engineer CEOs' influences are in increasing the quality of innovation, which requires more keen insights and deeper understanding of related theories and techniques, and senior-level engineers are more proficient in these.

We also implement an instrumental variable approach to address potential endogeneity issues, since firms chasing decent goals of innovation may deliberately select Engineer CEOs to help realize their ambition. Considering that CEOs are commonly elected from executives inside the company, or headhunted from executives (including CEOs) of other local companies, the (Engineering) executives in local manufacturing industry serve as the major supply of (Engineering) CEOs. We thus take the Local Engineering Executive Ratio, which is defined as the proportion of Engineer Executives, i.e. executives with professional certifications in engineering, of all the executives of local manufacturing firms, as an instrument and find that Engineer CEOs indeed enhance firm innovation. This instrumental variable is highly correlated with the variable of interest, Engineer CEO, from the supply side, taking into account that Engineer Executives are potential candidates to become Engineer CEOs, and should have little to do with a specific firm's innovation policies except through the channel of CEO certification.

Finally, we find that Engineer CEOs have opposite influences on innovation in firms of high- and low-leverages. Engineer CEOs have positive impacts on innovation quality in low-leverage firms. However, in high-leverage firms, Engineer CEOs need to focus more on shorter-term investments to increase current cash flows, thus the longer-term innovation activities are compromised. However, most Engineer CEOs in Chinese manufacturing industry may not be experts in investments as only 0.3% of the Engineer CEOs possess professional certifications in economics or management, such as Chartered Financial Analyst (CFA) or Human Resources Professional, etc., so Engineer CEOs tend to under-perform in high-leverage firms, bringing down innovation output efficiency.

Our paper contributes to three strands of literature. First, we contribute to literature that explores the correlation between human capital and economic development, dating back to Mincer (1958), Schultz (1961) and Romer (1990). Fleisher and Chen (1997) find that human capital has played a significant role in the Chinese economic miracle. Fleisher, Li and Zhao (2010) find that human capital also has an important effect on reducing regional inequality in China. In this paper, we consider how human capital rising from on-the-job training in engineering influences corporate innovation in Chinese manufacturing firms.

Our study also adds new insights to the growing literature studying the effects of

managers on corporate policies. Early research observed that CEOs with technical experience run firms with higher R&D expenditures (Daellenbach, McCarthy and Schoenecker, 1999). Later, it was found that the CEO's personal style and demographic characteristics influence corporate policies and performance (Bertrand and Schoar, 2003; Davidson, Dey and Smith, 2013; Lim and Lee, 2019). Malmendier and Tate (2009) show that superstar CEOs perform poorly. Recently, researchers have explored the impact of a variety of CEO traits and experiences including early-life experience, military experience, pilot experience, etc. (See Malmendier, Tate and Yan,2011; Benmelech and Frydman, 2015; Sunder, Sunder and Zhang, 2017). Also, a series of research look into the impact of CEOs with general and specific management abilities by constructing general ability indexes based on work experience, and show that generalist CEOs and specialist CEOs, financial expert CEOs, and inventor CEOs, have different impacts on firm performance, innovation and IPO. (Custódio and Metzger, 2013; Custódio and Metzger, 2014; Gounopoulos and Pham, 2018; Islam and Zein, 2018; Custódio and Metzger, 2019). Aktas, Louca and Petmezas (2019) and Leung, Tse and Westerholm (2019) find that CEO's personal trading behavior also reveals information about the firm performance. We try to answer the question of how some specific type of human capital stock of managers influences corporate innovation.

Third, we contribute to research that examines factors that influence innovation. Hirshleifer, Teoh and Low (2012) show overconfident CEOs do a better job at exploring opportunities to innovate. Atanassov (2013) finds that antitakeover laws, particularly business combination antitakeover laws, are associated with a decrease in both the number of patents filed by affected firms and the number of times these new patents are cited. Fang, Vivian, Tian, and Tice (2014) identify two possible mechanisms through which liquidity impedes innovation: increased exposure to hostile takeovers and higher presence of institutional investors who do not actively gather information or monitor. Cho, Halford, Hsu and Ng (2016) suggest that firm and manager characteristics explain a large portion of the variation in a firm's innovation productivity. Fang, Lerner and Wu (2017) empirically show how intellectual property rights (IPR) protection affected innovation in China in the years around the privatization of state-owned enterprises (SOEs). Feng (2019) find that industrial policy improves innovation efficiency of firms. Our findings provide a new human capital-based explanation for why some firms are more successful at innovation than others.

The remainder of the paper is organized as follows. Section 2 presents the data and summary statistics. Section 3 describes our empirical strategy and results. Section 4 concludes the paper.

2. Data and summary statistics

2.1   Sample construction

We construct a firm-year panel of listed Chinese companies in the manufacturing industry using data from China Stock Market & Accounting Research Database (CSMAR) over 2008-2016. We then match the panel with multiple innovation measures, including R&D expenditure from Wind Economic Database, and patent and citation records hand-collected from official website of Chinese State Intellectual Property Office. The dataset consists of 11,282 observations. The variable definitions are presented in Table 1.

Table 1: Variable Definitions

Variables	Descriptions
Dependent variables	
Patent	The natural logarithm of one plus the number of patents applied for during the year.
Successful Patent	The natural logarithm of one plus the number of patents granted during the year.
Patent Efficiency	The number of patents granted during the year, scaled by the number of patents applied for during the year.
Citation	The natural logarithm of one plus the number of citations.
Citation per Patent	The natural logarithm of one plus citation per patent.
Relative Citation Strength	The natural logarithm of one plus citation per patent corrected for industry and year fixed effects, using HJT(2001)'s fixed effect method.
R&D_TA	Research and development expenditures, scaled by total assets, multiplied by 100
Independent variables	
Engineer CEO	An indicator variable equal to 1 if the CEO has a professional certification in engineering, and 0 otherwise.
Junior_Engineer	An indicator variable equal to 1 if the CEO has a junior-level professional certification in engineering, and 0 otherwise.
Senior_Engineer	An indicator variable equal to 1 if the CEO has a senior-level professional certification in engineering, and 0 otherwise.
Age	CEO age in years.
Bachelor Degree	An indicator variable equal to 1 if the CEO has a bachelor's degree or above, and 0 otherwise.
Cash flow	Cash flow from operation, scaled by lagged firm size.
Tobin's Q	The market value of assets divided by the book value of assets.
Current	Current assets scaled by current liabilities.
Firm Size	The natural logarithm of total assets.
SOE	An indicator variable equal to 1 if the company is a state-owned enterprise, and 0 otherwise.
ROA	Return on assets.

2.2   Identifications of Engineer CEOs

Our main variable of interest is *Engineer_CEO*, a dummy variable equal to 1 if a CEO possesses professional certifications in engineering, such as "Mechanical Engineer" or "Electronic Engineer", and 0 otherwise. In China, the acquisition of such certifications requires practical experience, publications in SCI journals, and experience of leading research projects at province- or national-levels. Therefore,

the possession of professional certifications in engineering is a direct indicator that a CEO possesses specialized knowledge related to innovation activities in manufacturing industry.

In addition, the CSMAR database also provides detailed levels of professional certifications in engineering, including

(a) Assistant Engineer.

(b) Engineer.

(c) Senior Engineer.

(d) Professorate Senior Engineer.

Higher level certifications require stricter qualifications. Commonly, we refer to levels (a) and (b) as Junior-Level Engineers, and levels (c) and (d) as Senior-Level Engineers. For individuals with more than one certification, we classify them using the highest level. For example, for a CEO with both "Mechanical Engineer" and "Senior Electronic Engineer", we regard him/her as a level (c) engineer, and a "Senior-Level Engineer". Correspondingly, we refer to CEOs with junior- and senior-level certifications as *Junior-Level Engineer CEOs* and *Senior-Level Engineer CEOs,* respectively. Of all the 3,125 CEOs, approximately 30% are Engineer CEOs, including 9% of Junior-Level Engineer CEOs and 21% of Senior-Level Engineer CEOs.

2.3   Measuring innovation

We construct the measures of innovation from two perspectives.

First, we use three metrics related to patents to represent firms' innovation output quantity.

a) *Patent*, defined as the logarithm of one plus the number of patents, and it represents the quantity of innovation output (see Griliches, Pakes, and Hall, 1987).

b) *Successful Patent*, defined as the logarithm of one plus the number of patent applications filed in a given year that were granted by 2016.

c) *Patent Efficiency*, defined as the ratio of *Successful Patent* and *Patent*, and it measures the probability of patent application success.

Second, we also include three metrics related to citations to better quantify the efficiency of innovation outputs, and thus measure a patent's economic power.

a) *Citations*, defined as the logarithm of one plus the number of citations a listed firm's patents receive.

b) *Citation per Patent*, defined as the logarithm of one plus average number of citations for each patent.

c) *Relative Citation Strength*, defined as the number of citations-per-patent for each firm scaled by the mean of the number of citations-per-patent in the same year-industry cohort to which the patent belongs.

The measure is defined following Hall, Jaffe, and Trajtenberg (2001) in order to adjust for the potential truncation problems of citations as they are received many years after the patent is applied for and granted, and also to adjust for the differences

in citation intensities across industries.

2.4   Control variables

We also include control variables that describe time-varying firm characteristics, including
a) *Firm Size*, defined as the natural logarithm of total assets.
b) *Cash Flow*, defined as cash flow from operation scaled by lagged firm size.
c) *Tobin's Q*, defined as market value of assets divided by book value of assets.
d) *Current*, defined as Current assets scaled by current liabilities.
e) *SOE*, defined as a dummy variable indicating whether the company is a state-owned-enterprise.
f) *ROA*, defined as return on assets. We further include CEO's personal characteristics, including *Age*, *Bachelor Degree* (a dummy variable indicating whether the CEO achieves bachelor's degree or higher).

2.5   Summary statistics

Table 2 provides descriptive statistics of Engineer CEOs by year. We can see that both the number of CEOs and number of Engineer CEOs are increasing in most years, though the rate at which Engineer CEOs increase is slower than the increase rate of the number of firms, and causing the total ratio of Engineer CEOs relative to total CEOs to decrease over time. As for the period from 2012 to 2014, although the number of Engineer CEOs decreases during this period, the proportion of Engineer CEOs remains stable, and thus the decline in the number of Engineer CEOs is due to a slight fluctuation in the manufacturing industry as a whole, rather than in firms with Engineer CEOs only.

Table 2: Distribution of Engineer CEOs by Year

Year	No. of Engineer CEOs			No. of CEOs	Percentages of Engineer CEOs
	Junior-Level	Senior-Level	Total		
2008	92	227	319	798	40%
2009	94	226	320	850	38%
2010	110	272	382	1,097	35%
2011	127	313	440	1,271	35%
2012	121	328	449	1,367	33%
2013	117	321	438	1,352	32%
2014	118	306	424	1,370	31%
2015	125	300	425	1,447	29%
2016	124	302	426	1,498	28%
Total	1,028	2,595	3,623	11,050	33%

Table 3 presents descriptive statistics of firms with/without Engineer CEOs, and we use t-tests to compare the means of each innovation measure between the two groups. The results show that firms with Engineer CEOs tend to innovate more effectively, both in terms of quantity and quality, as measured by patents and citations. Taking a closer look at the differences between firms with/without Engineer CEOs, the innovation measures related to citations are more economically significant than those related to patents, though all patent and citation related measures are statistically significant based on t-test results. For *Citation* and *Citation per Patent*, and *Relative Citation Strength*, firms with Engineer CEOs are approximately 56%, 42%, and 38% stronger on average, respectively, than firms without Engineer CEOs, indicating economically significant differences in innovation quality. While no significant differences are observed in innovation input, measured by R&D expenditures, whether or not they have Engineer CEOs.

Table 3: Summary Statistics of Measures of Corporate Innovation

Variables	Non-Engineer CEO			Engineer CEO		
	N	Mean	Std. Dev.	N	Mean	Std. Dev.
Patent	7,427	2.517	1.626	3,623	2.748***	1.649
Successful Patent	7,427	2.256	1.588	3,623	2.480***	1.623
Patent Efficiency	7,427	0.639	0.368	3,623	0.670***	0.339
Citation	5,721	0.428	0.925	2,868	0.670***	1.161
Citation per Patent	5,721	0.092	0.251	2,868	0.131***	0.288
Relative Citation Strength	5,721	0.225	0.488	2,868	0.310***	0.535
R&D_TA	6,266	2.402	2.348	3,111	2.450	2.483

3. Main Results

3.1   Engineer CEOs and innovation outputs

In this section, we test the hypotheses that Engineer CEOs spur firm innovation outputs. Our model is described as follows:

$$Innovation_{it} = \beta_0 + \beta_1 \times Engineer\_CEO_{it} + \gamma \times Control + Industry + Year + \varepsilon_{it} \quad (1)$$

Where subscripts i and t refer to firm and year, respectively. *Innovation* stands for different measures of innovation outcomes, $Engineer\_CEO_{it}$ equals to 1 if $firm_i$ has an Engineer CEO in $year_t$, and 0 otherwise. *Control* represents all control variables. We also include industry and year fixed effects (labeled as "*Industry*" and "*Year*", respectively) to control for variations of innovation across industry and year. Finally, we cluster standard errors by firm.

Table 4 provides the results for baseline analysis of the relationship between Engineer CEOs and innovation. We include all 6 innovation measures illustrated before as dependent variables, and take *Engineer_CEO* as our variable of interest.

We control for the industry-year fixed effects in the analysis to control for innovation shocks across industry and year.

Table 4: Engineer CEOs and Innovation Outputs

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent	Successful Patent	Patent Efficiency	Citation	Citation per Patent	Relative Citation Strength
Engineer CEO	0.0228	0.0295	0.0165	0.0718**	0.0208***	0.0494***
	(0.57)	(0.73)	(1.63)	(2.00)	(2.66)	(3.24)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observation	10,094	10,094	10,094	7,794	7,794	7,794
R-squared	0.3626	0.3568	0.1546	0.3096	0.2136	0.1745

We can see from Table 4 that the influence of Engineer CEOs is more clearly manifested in the quality of innovation, measured by citations (Columns 4-6), rather than in the quantity of innovation, measured by patents (Columns 1-3). Therefore, the on-the-job training embedded in the process of achieving professional certifications in engineering increases the human capital levels of CEOs, and promotes the innovation qualities.

3.2   Engineer CEOs and R&D spending

Thus far, our results show that firms managed by Engineer CEOs are associated with higher innovation quality measured by various metrics of patent citations. In this section, we examine whether Engineer CEOs generate better-quality patents due to CEOs' functionally biases or preferences originated from past experience in engineering. If Engineer CEOs have biases or preferences towards risky investments, they are supposed to invest more (or less) in innovation projects. We make use of firms' R&D expenditures to measure innovation input. To avoid a size effect, we scale R&D expenses by total assets (multiplied by 100) and designate it as *R&D_TA*.

We repeat the regression in section 3.1, with dependent variable replaced by *R&D_TA*. Table 5 shows the regression result. The coefficient of R&D expenditure is negative and not statistically significant, indicating that the increase in innovation quality does not rise from excessive spending in R&D, which argues against the functionally biased perception theory that CEOs exhibit biases in decision making.

Table 5: Engineer CEOs and R&D spending

	(1)
	R&D_TA
Engineer CEO	-0.0725
	(-0.60)
Controls	Yes
Year F.E.	Yes
Industry F.E.	Yes
Observation	8,470
R-squared	0.0725

To sum up, we conclude from Sections 3.1 and 3.2 that Engineer CEOs, who possess specialized knowledge related to innovation, are able to grasp the innovation activities of greater technological and economic importance, and thus produce more citations rather than simply the number of patents. In addition, the enhancement in innovation outputs are not originated from excessive investments in innovation, which argues against the functional biases theory.

3.3 Layering effects of Engineer CEOs

We further compare the effects of Engineer CEOs on innovation by examining the layering effects, i.e. whether Junior- and Senior-Level Engineer CEOs have different impacts on innovation. We use two dummy variables, *Junior_Engineer* and *Senior_Engineer*, to discriminate between three types of CEOs. *Junior_Engineer* (*Senior_Engineer*) equal to 1 if the Engineer CEO possesses junior-level (senior-level) certifications in engineering, and 0 otherwise.

Table 6 presents the empirical results for testing layering effects. We can infer from the table that effects of Engineer CEOs on innovation quality (Columns 4-6) are more prominent for Senior-Level Engineer CEOs than Junior-Level Engineer CEOs judging from the significance levels of the citation measures. The results are consistent with previous results that Engineer CEOs' influences on innovation are on the quality rather than the quantity.

Table 6: Layering Effects of Engineer CEOs

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent	Successful Patent	Patent Efficiency	Citation	Citation per Patent	Relative Citation Strength
Junior-Engineer	-0.0326	-0.00610	0.0122	0.0597	0.0263**	0.0423*
	(-0.55)	(-0.10)	(0.77)	(1.45)	(2.04)	(1.85)
Senior-Engineer	0.0490	0.0463	0.0184	0.0772*	0.0184**	0.0525***
	(1.08)	(1.00)	(1.60)	(1.78)	(2.06)	(2.92)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,066	10,066	10,066	7,768	7,768	7,768
R-squared	0.362	0.357	0.155	0.310	0.214	0.174

3.4   Instrumental variable analysis

To deal with potential endogeneity issues, we also instrument *Engineer_CEO* with an instrumental variable *Local_Engineering_Executive_Ratio*, defined as the number of executives with professional certifications in engineering (Engineer Executives hereafter) divided by the total number of executives in the manufacturing firms in the city. Engineer Executives are potential future Engineer CEOs, and thus *Local_Engineering_Executive_Ratio* reflects the supply level of Engineer CEOs. The correlation between Engineer CEO dummy and *Local_Engineering_Executive_Ratio* is 26.49%. Also, this rato does not directly affect a specific firm's innovation performance, thus can be used as an instrumental variable.

We apply a 2SLS method in the analysis, with the results shown in Table 7. The coefficients of *Local_Engineering_Executive_Ratio* in the first stage are all significant, and the Kleibergen-Paap rk LM statistics and Kleibergen-Paap rk Wald F statistics in the second stage shows that the instrumental variable passes both the underidentification test and the weak instrument identification test, further comfirming the validity of our instrumental variable. The results in the second stage show that all measures related to citations, including number of citations, number of citations per patent, and relative citation strength, are all significant, indicating that Engineer CEOs can lead to better innovation, as is consistent with all previous results. We should notice that after dealing with endogeneity by instrument variable, the patent efficiency coefficient is also positively significant here, showing that firms with Engineer CEOs also have a higher probability of having their patent applications granted. This, combined with the fact that Engineer CEOs do not spur innovation quality by more R&D input, leads to the conclusion that Engineer CEOs innovate better because the rise of human capital from the training in engineering improves their innovation efficiency.

Table 7: Instrumental Variable Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent	Successful Patent	Patent Efficiency	Citation	Citation per Patent	Relative Citation Strength
First Stage	1.372***	1.372***	1.372***	1.386***	1.386***	1.386***
	(11.05)	(11.05)	(11.05)	(10.42)	(10.42)	(10.42)
Engineer CEO	0.379	0.437	0.225***	0.330**	0.0917**	0.120*
	(1.34)	(1.62)	(3.59)	(2.03)	(2.28)	(1.67)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,066	10,066	10,066	7,768	7,768	7,768
R-squared	1.807	2.666	14.31	4.266	5.501	2.817

3.5   Heterogeneity test

Finally, we conduct a heterogeneity test to examine whether Engineer CEOs' impact on innovation varies across firms with different leverage ratios. We add firm leverage ratio, and its interaction with *Engineer CEO* to the regression of model (1) in the analysis.

Table 8 provides the results of the heterogeneity test. We can see that Engineer CEOs still have positive effect on firm innovation measured by all citation measures for firms with lower leverage ratios. However, for firms with high leverage ratio, Engineer CEOs have the opposite effects on innovation, as the coefficients of the interaction term for all three citation measures are all negative. Innovation is a risky, long-term activity. However, Engineer CEOs of high-leverage firms would need to focus on shorter-term investments, at which they are not as proficient as they are at research and development. In this case, the extent to which they devote to improving the quality of innovation outcomes, as measured by citations, are compromised. Therefore, the influence of Engineer CEOs in high-leverage firms are negative, which is opposite to that in low-leverage firms.

Table 8: Heterogeneity Test for Engineer CEOs

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent	Successful Patent	Patent Efficiency	Citation	Citation per Patent	Relative Citation Strength
Engineer CEO	0.0919	0.130*	0.0736***	0.184***	0.0404***	0.0872***
	(1.20)	(1.68)	(3.79)	(3.32)	(3.09)	(3.24)
Engineer CEO	-0.153	-0.222	-0.130***	-0.266*	-0.0479*	-0.0917*
* Leverage	(-0.94)	(-1.36)	(-3.16)	(-1.94)	(-1.71)	(-1.68)
Leverage	0.0163***	0.0142***	0.00125	-0.0261*	-0.0146**	-0.0191*
	(3.74)	(3.60)	(0.41)	(-1.75)	(-2.28)	(-1.95)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observation	10,094	10,094	10,094	7,794	7,794	7,794
R-squared	0.364	0.358	0.157	0.311	0.215	0.176

4. Conclusions

Engineer CEOs account for nearly one-third of all CEOs in the manufacturing industry. They are important human capital carriers within firms as decision-makers for critical issues and projects. Yet the economic cootribution of a CEO being an engineer, especially from the view of technology growth and innovation, has not been explored thoroughly. By measuring innovation importance using a series of ajusted patent-citation metrics, we find that Engineer CEOs significantly improve the quality of corporate innovation outcomes, and this does not rise from the excessive spending in R&D. We argue that, the effect of Engineer CEOs on innovation quality reflects their enhancement of human capital stock from the trainings in engineering, rather than CEOs' functionally biases or preferences originated from past experience in engineering. We further find that the effects on innovation outputs are more prominent for Senior-Level Engineer CEOs, who possess more sophisticated engineering knowledge than Junior-Level Engineer CEOs. This again, adds more evidence to our human capital perspective. We then address potential endogenous matching problems using an instrumental variable approach, with the ratio of the executives with professional certifications in engineering of all executives in the local manufacturing industry as the instrument, and our main results are robust. The results confirm our findings that Engineer CEOs enhance firm innovation. Finally, we find that Engineer CEOs have opposite effects on firm innovation in firms of high- and low-leverages.

References

[1] Dearborn,D.C. and Simon,H.A.,1958. A Selective Perception: A Note of the Departmental Identification of Executives.*Sociometry,21*,pp.140-144.

[2] Jung, Y., 2018. Engineers vs. Business-People: Who Should Manage High-Tech Firms?. Harvard University Working Papers.

[3] Becker, G.S., 1962. Investment in human capital: A theoretical analysis. Journal of Political Economy, 70(5, Part 2), pp.9-49.

[4] Stroombergen, A., Rose, W.D. and Nana, G., 2002. Review of the statistical measurement of human capital. Statistics New Zealand working paper.

[5] Barker, V. , and G. Mueller., 2002. CEO Characteristics and Firm R&D Spending. Management Science, 48 (6), pp.782 – 801.

[6] Benmelech, E. and Frydman, C., 2015. Military CEOs. Journal of Financial Economics, 117(1), pp.43-59.

[7] Mincer, J., 1958. Investment in human capital and personal income distribution. Journal of Political Economy, 66(4), pp.281-302.

[8] Schultz, T.W., 1961. Investment in human capital. American Economic Review, pp.1-17.

[9] Romer, P.M., 1990. Endogenous technological change. Journal of Political Economy, 98(5, Part 2), pp.S71-S102.

[10] Fleisher, B.M. and Chen, J., 1997. The coast–noncoast income gap, productivity, and regional economic policy in China. Journal of Comparative Economics, 25(2), pp.220-236.

[11] Fleisher, B., Li, H. and Zhao, M.Q., 2010. Human capital, economic growth, and regional inequality in China. Journal of Development Economics, 92(2), pp.215-231.

[12] Daellenbach, U.S., McCarthy, A.M. and Schoenecker, T.S., 1999. Commitment to innovation: The impact of top management team characteristics. R&D Management, 29(3), pp.199-208.

[13] Bertrand, M. and Schoar, A., 2003. Managing with style: The effect of managers on firm policies. Quarterly Journal of Economics, 118(4), pp.1169-1208.

[14] Davidson, R., Dey, A. and Smith, A., 2015. Executives' "off-the-job" behavior, corporate culture, and financial reporting risk. Journal of Financial Economics, 117(1), pp.5-28.

[15] Lim and Lee., 2019. Relationship between the Characteristics of CEOs and Excess Cash Holdings of Firms. Emerging Markets Finance and Trade, 55(5), pp.1069-1090.

[16] Malmendier, U. and Tate, G., 2009. Superstar CEOs. Quarterly Journal of Economics, 124(4), pp. 1593-1638.

[17] Malmendier, U., Tate, G. and Yan, J., 2011. Overconfidence and early-life experiences: the effect of managerial traits on corporate financial policies. Journal of Finance, 66(5), pp.1687-1733.

[18] Sunder, J., Sunder, S.V. and Zhang, J., 2017. Pilot CEOs and corporate innovation. Journal of Financial Economics, 123(1), pp.209-224.

[19] Custódio, C. and Metzger, D., 2013. How do CEOs matter? The effect of industry expertise on acquisition returns. Review of Financial Studies, 26(8), pp.2008-2047.

[20] Custódio, C. and Metzger, D., 2014. Financial expert CEOs: CEO's work experience and firm's financial policies. Journal of Financial Economics, 114(1), pp.125-154.

[21] Gounopoulos, D. and Pham, H., 2018. Specialist CEOs and IPO survival. Journal of Corporate Finance, 48, pp.217-243.

[22] Islam, E. and Zein, J., 2019. Inventor CEOs. Journal of Financial Economics. Forthcoming.

[23] Custódio, C., Ferreira, M.A. and Matos, P., 2019. Do general managerial skills spur innovation?. Management Science, 65(2), pp.459-476.

[24] Aktas, N., Louca, C. and Petmezas, D., 2019. CEO overconfidence and the value of corporate cash holdings. Journal of Corporate Finance, 54, pp.85-106.

[25] Leung, H., Tse, J. and Westerholm, P.J., 2017. CEO traders and corporate acquisitions. Journal of Corporate Finance. 54, pp. 107-127.

[26] Hirshleifer, D., Low, A. and Teoh, S.H., 2012. Are overconfident CEOs better innovators?. Journal of Finance, 67(4), pp.1457-1498.

[27] Atanassov, J., 2013. Do hostile takeovers stifle innovation? Evidence from antitakeover legislation and corporate patenting. Journal of Finance, 68(3), pp.1097-1131.

[28] Fang, V.W., Tian, X. and Tice, S., 2014. Does stock liquidity enhance or impede firm innovation?. Journal of Finance, 69(5), pp.2085-2125.

[29] Cho, C., Halford, J.T., Hsu, S. and Ng, L., 2016. Do managers matter for corporate innovation?. Journal of Corporate Finance, 36, pp.206-229.

[30] Fang, L.H., Lerner, J. and Wu, C., 2017. Intellectual property rights protection, ownership, and innovation: Evidence from China. Review of Financial Studies, 30(7), pp.2446-2477.

[31] Feng, 2019. Does Industrial Policy Play an Important Role in Enterprise Innovation? Emerging Markets Finance and Trade, 55(15), pp.3490-3512.

[32] Griliches, Z., Pakes, A. and Hall, B., 1987. The value of patents as indicators of inventive activity sin P. Dasgupta and P. Stoneman, eds. Economic Policy and Technological Performance, Cambridge England: Cambridge University Press, 39.

[33] Hall, B.H., Jaffe, A.B. and Trajtenberg, M., 2001. The NBER patent citation data file: Lessons, insights and methodological tools. NBER Working Paper No. 8498.