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Innovation effects of academic executives: Evidence from China

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ABSTRACT

Since the 1980s, policy reforms have been undertaken in China to gradually promote entrepreneurship of academic researchers. Based on manually collected data on academic executives (defined as either chairperson of the board or CEO, who had an academic title), we investigate the effects of academic executives on corporate technological capabilities and innovation performance among Chinese listed manufacturing firms from 2001 to 2015. Our results demonstrate that firms with academic executives are more likely to implement technological advancement strategies by increasing firm basic research, collaborating with outside institutions, and providing incentives to knowledge workers. Consequently, they have enhanced technological capabilities, as well as a higher quantity and quality of innovation output. In addition, firms with academic executives are more likely to have better financial performance regarding sales and profitability and keep a higher proportion of profits inside the firm to reinvest. The identification of the causal effects of academic executives relies on top executive turnover within firms and the propensity score matching strategy. Further analysis demonstrates that the effects of academic executives are more pronounced when they have a higher academic title, administrative experience, and a specialization in sciences. Our findings suggest that promoting entrepreneurship of academic researchers is an effective way of diffusing and utilizing knowledge, and it provides an internal driving force for the enhancement of corporate technological capabilities, which is crucial for technological catch-up of firms in latecomer countries.

1. Introduction

Starting from the economic reforms in the late 1970s, China has experienced rapid economic growth and has gradually developed an innovation-driven growth strategy that is based on technological progress, and a number of firms have achieved technological catch-up (e.g., Joo et al., 2016; Mu and Lee, 2005; Xiao et al., 2013). In middle-income countries, capacity-building is essential for technological catch-up (Lee, 2019). A unique strategy for Chinese firms to enhance technological capabilities is "forward engineering," that is, the direct involvement of academia (Eun et al., 2006; Lee, 2013; Lee et al., 2011; Lu, 2000). However, there is evidence that the impacts of collaboration between industry and academia, such as joint research and development (R&D), on corporate innovation suffer from a lack of efficiency (Guan et al., 2005) and are constrained by firms' internal R&D capacity (Berchicci, 2013; Kafouros et al., 2015; Laursen and Salter, 2006).

In this study, we argue that the flow of researchers from universities and research institutions to firms' key decision-making positions is an important way to exert the influence of academia on corporate technological innovation. To promote the transformation of scientific and technological (S&T) achievements, China has issued a series of policies to gradually promote entrepreneurship of academic researchers. As a result, a growing number of them get involved in company management and bring their academic expertise to practice. By investigating the innovation effects of academic executives (defined as either chairperson of the board or CEO, who had an academic title), we show that having an academic executive is an effective way of diffusing and utilizing knowledge, and it provides an internal driving force for the enhancement of technological capabilities, which is crucial for technological catch-up of firms in latecomer countries.

Top executives (chairperson of the board and CEO) are the focus of our study because they are responsible for making key decisions about corporate development strategies and operations. According to the upper echelons theory, top executives' previous working experience plays an important role in determining their choices (Hambrick, 2007; Hambrick and Mason, 1984). However, findings of existing literature

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provide opposing predictions on the relationship between academic executives and corporate performance. On the one hand, academic executives have the potential to contribute to high performance of a firm through their advising and monitoring roles (Francis et al., 2015); advantage in facilitating entrepreneurial access to, and absorption of, external knowledge and expertise (Audretsch and Lehmann, 2006); experience and preference for R&D (Erev and Roth, 1998); access to academic networks (e.g., Fabrizio, 2006; Mindruta, 2013); intrinsic motivation for advancing knowledge (Lam, 2011); and understanding of the process of innovation due to its similarities to conducting research (Jiang and Murphy, 2007; Manso, 2011). On the other hand, the goal of earning tenure limits researchers' exposure to the business world (Bennis and O'Toole, 2005). An increased board heterogeneity in terms of the existence of academic executives may also lead to greater coordination costs (Knyazeva et al., 2013). Moreover, shareholders may cast doubt on the independence of the board due to potential conflicts of interest arising from academic executives' association with a certain university or research institution (Gillan and Martin, 2007). Overall, the majority of related studies support that the involvement of individuals with an academic background in corporate governance promotes innovation (e.g., Chemmanur et al., 2019; Protogerou et al., 2017). However, most of them are based on firms in developed countries, lacking evidence in developing countries. Investigating the role academic executives play in affecting corporate innovation has the potential to provide important implications for firms in developing countries to cultivate technological capabilities and achieve technological catch-up. More importantly, it provides a valuable perspective for understanding internal driving forces for technological catch-up that firms in developing countries generally lack. Nevertheless, whether and why top executives' research experience affects corporate technological capabilities and innovation performance remain unclear and are underexamined in the literature.

Built on the upper echelons theory and the literature on innovation and technological catch-up, we provide, to the best of our knowledge, the first analysis on whether, the extent to which, and why academic executives affect corporate innovation. We contribute to the literature in two major ways. First, by investigating the innovation effects of academic executives from corporate technological capabilities and innovation performance, our analysis uncovers that academic executives contribute to the intrinsic catch-up motivations of firms in latecomer countries. That is, we show that, compared to firms without academic executives, firms with these executives have enhanced technological capabilities and adopt innovation strategies in favor of indigenous innovation. They have a higher quantity and quality of innovation output and are more likely to turn patented knowledge into competitive advantages. They also have better financial performance in terms of higher sales and profitability and are inclined to keep a larger proportion of profits inside the firm to reinvest. We further document that the innovation effects of academic executives are more pronounced when they have a higher academic title, administrative experience in academia, and a specialization in sciences. Overall, our findings shed new light on the explanation of the driving forces of firms' adoption of catch-up strategies in latecomer countries despite their technological weakness and provide implications for transition economies that seek technological catch-up.

Second, motivated by the studies that examine the driving forces of innovation (e.g., Arora et al., 2018; Crossan and Apaydin, 2010; Guo et al., 2016; Rong et al., 2017), as well as the theoretical argument and empirical evidence supporting the positive relationship between academic executives and corporate innovation (e.g., Audretsch and Lehmann, 2006; Francis et al., 2015; Manso, 2011), we complement the literature by investigating the mechanisms underlying the effects of academic executives, and find that investing in firm basic research, collaborating with outside institutions, and motivating knowledge workers play important roles in explaining the innovation effects of academic executives.

Our empirical analysis is conducted using a sample of Chinese listed manufacturing firms from 2001 to 2015. To identify academic executives, we manually collected information on top executives' work experience (academic title, administrative experience, and academic specialization) in universities and research institutions. To address the issue of endogeneity that the appointment of top executives is not random (e.g., Boone et al., 2007; Francis et al., 2015; White et al., 2014), we apply the strategy proposed by Sunder et al. (2017) and examine the change in corporate performance around top executive turnover within the same firm. To further mitigate the concern of endogeneity, we utilize the propensity score matching (PSM) approach.

The remainder of this study is organized as follows. Section 2 introduces policy background, related literature, and hypotheses. Section 3 describes data and provides summary statistics. Section 4 specifies the empirical methods. Section 5 reports the innovation effects of academic executives. Section 6 investigates possible channels through which the innovation effects of academic executives operate. Section 7 presents the effects of academic executives' innovation strategies on corporate financial performance. Section 8 concludes.

2. Policy background, literature, and hypotheses

2.1. Policy background

Since the reforms and opening-up in the late 1970s, China has put great emphasis on the transformation of S&T achievements, successively issued a series of laws and regulations to reform the S&T system and strived to promote economic and social development using science and technology. However, the scientific research system, and the production system, have been separated for such a long time that scientific research institutions, in general, had difficulty understanding the actual needs of firms regarding scientific research. Likewise, the production system lacked innovation capabilities and was not able to precisely request the type of S&T research in need. Under these circumstances, in order to promote the integration of technology and production, an important method implemented by China was to relax the constraints on scientific and technical personnel (STP: individuals engaged in S&T research, management, and service in academia), and gradually promote their flow to corporate departments in the form of part-time or full-time entrepreneurship.

To illustrate, in the early stages of the reforms, firms in towns and villages developed rapidly, and a large number of them needed guidance from STP. In order to meet their needs, the Chinese government issued the first official regulation on part-time jobs for STP in 1981,[1] which relaxed the restrictions on their flow from scientific research institutions to industry, yet such flow was still highly restricted. With further reforms and opening-up, a large amount of foreign direct investment (FDI) flowed in. However, absorbing technological and management knowledge in FDI requires local firms to have certain levels of technological absorptive capacity. In this context, China promulgated a series of laws and regulations to further promote the flow of STP to firms and improved the efficiency of transformation of S&T achievements. After joining the World Trade Organization in 2001, China established new guidelines for S&T development with a focus on improving indigenous innovation capabilities. In 2006, the State Council issued the “National Medium- and Long-Term Science and Technology Development Plan Outline (2006–2020).” It proposed indigenous innovation as a key strategy for China's technological development for the first time and supported firms playing an important role in technological innovation. It also encouraged and guided STP toward innovation and starting a business. Since 2012, China has prioritized innovation as the nation's

[1] A list of related policies is summarized in Table A.1.

core development strategy and strived to transform the mode of economic growth from investment-driven to innovation-driven.[2] Correspondingly, China has revised a series of S&T innovation laws, provided support for the implementation of Outline, and improved policies to encourage innovation and entrepreneurship of STP. As a result, a growing number of STP have started their own businesses or were appointed as chairperson of the board or CEO, to directly decide the internal allocation of corporate resources and develop strategies.

2.2. Related literature

Strengthening the link between academia and industry is not only an important direction of China's technological policy reforms, but also attracts considerable attention in the innovation and catch-up literature. Lee et al. (2011) summarize three technological catch-up strategies employed by Chinese firms, with direct involvement of academia in industry being one of them. Researchers have documented that collaborations with universities and research institutions foster firm innovation performance (Caloghirou et al., 2021; Eom and Lee, 2010; Guan et al., 2005; Hu and Mathews, 2008; Kafouros et al., 2015; Mansfield, 1991; Mindruta, 2013; Ponds et al., 2009; Rosenberg and Nelson, 1994). In particular, relying on academic collaborations is an important innovation strategy for firms in emerging countries that lack strong internal R&D capabilities (Kafouros et al., 2015; Motohashi and Yun, 2007). However, researchers have also found an inverted U-shaped relationship between collaboration with universities and corporate innovation performance. Over relying on external sources of knowledge reduces firm innovation output, especially for firms that have a lower level of R&D capacity (Berchicci, 2013; Kafouros et al., 2015; Laursen and Salter, 2006). Therefore, despite great benefits associated with collaborating with universities and research institutions, the importance of cultivating firms' own absorptive and R&D capabilities should not be overlooked.

In the technological catch-up literature, learning advanced technological knowledge from developed countries is regarded as a shortcut to catch-up for less developed countries. However, absorbing and utilizing advanced technologies require the receiver to have certain technological capabilities. One important reason that firms in middle-income countries are rarely able to catch up is that they lack intrinsic motivation to build technological capabilities given strict global intellectual property rights protection and the increasing costs of using advanced technology from developed countries (Lee and Kim, 2009). Thus, motivating firms in latecomer countries to build technological capabilities has become increasingly crucial for them to achieve technological catch-up (Lee, 2019).

The upper echelons theory argues that corporate outcomes are affected by the characteristics of the executives (Hambrick, 2007; Hambrick and Mason, 1984). Empirically, a large number of studies have documented that previous experience of top executives greatly influences corporate outcomes (Anderson et al., 2011; Chemmanur et al., 2019; Cho et al., 2017; Fich, 2005; Güner et al., 2008; Hillman et al., 2000; Protogerou et al., 2017; Wiersema and Bantel, 1992). For example, CEOs' military service (Benmelech and Frydman, 2015) and early life experience with the Great Depression (Malmendier et al., 2011) are both associated with conservative corporate policies, and there is a non-monotonic relationship between CEOs' fatal disaster experience and corporate risk-taking (Bernile et al., 2017).

There is a growing number of studies examining the effects of managers' academic background on corporate performance. For example, top management teams with academic specialization in science and engineering are associated with changes in corporate strategy (Wiersema and Bantel, 1992); firms with professors on the board of directors are associated with higher corporate social responsibility performance ratings than firms without (Cho et al., 2017); founders' human capital, such as prior exposure to R&D, plays an important role in determining young firms' innovation performance (Protogerou et al., 2017); a higher quality of the top management (e.g., a higher fraction of management with MBAs or PhDs) of a firm leads to a higher quality of innovation (Chemmanur et al., 2019); CEOs' academic experience is positively associated with corporate patent applications (Shao et al., 2020); and senior managers' academic background positively affects R&D expenditures and patent application counts (Shen et al., 2020).

Our study is distinguishable from the existing literature in two major ways. First, we focus on academic executives, who are different from STP that are working part-time or full-time in firms as scientific workers or top management team members. Being the academic executive has the potential advantages of not only promoting the diffusion and utilization of knowledge, but also influencing and implementing corporate strategies regarding technological development and injecting intrinsic incentives to corporate indigenous innovation in a way that lower positions cannot. Second, this is the first study that is built on both the upper echelons theory and the technological catch-up literature and reveals positive relationships between academic executives and the technological catch-up behaviors of firms. Specifically, we focus on examining whether, the extent to which, and why academic executives affect corporate technological capabilities and innovation performance, and demonstrate that by increasing firms basic research, collaboration, and knowledge workers' incentives, academic executives provide an intrinsic driving force for firms to carry out technological catch-up strategies that emphasize the cultivation of technological capabilities, which is our unique contribution to the literature.

2.3. Hypotheses development

Based on the upper echelons theory (Hambrick, 2007; Hambrick and Mason, 1984) and related supporting empirical evidence (Audretsch and Lehmann, 2006; Fabrizio, 2006; Jiang and Murphy, 2007; Lam, 2011; Manso, 2011; Mindruta, 2013), we argue that given academic executives' knowledge, experience, and resources in research, they may transfer their preference for research and eagerness for solving problems (Horwitz et al., 2003; Lam, 2011) to corporate innovation strategies. Thus, when problems arise from the process of developing and producing new products, academic executives are willing and have the knowledge and resources to address these problems through strengthening internal R&D breadth and intensity, actively learning and absorbing external knowledge, and fostering interactions between R&D and production, which would increase the technological capabilities of firms. That is, academic executives tend to emphasize the growth of firms through the enhancement of technological capabilities. Technological capability is a key factor affecting the catch-up process of firms in latecomer countries, and firms that enter the catch-up stage through the improvement of technological capabilities will show higher quantity and quality of patents (Lee, 2013; Lee and Lim, 2001). Thus, we expect that academic executives contribute to corporate technological capabilities and innovation performance. Accordingly, our first hypothesis is stated as follows:

Hypothesis A. Academic executives improve corporate innovation, which is reflected in enhanced technological capabilities and innovation performance.

Based on the resource-based theory of firms (Penrose, 1959), Lee (2013, pp. 103) concludes that "one of the key ideas of this theory is that firm performance and growth depend on the kinds, and how much, of these diverse resources the firm commands and can utilize for its growth." Peteraf (1993) documents that resources and capabilities for production are heterogeneous, i.e., they have various levels of efficiency, which affect firm performance differently. For most firms in developing countries, S&T knowledge closely related to corporate

[2] See, for example, Guan and Yam (2015), Liu and White (2001), Liu et al. (2011), and Sun and Cao (2018) for related studies on China's innovation policies.

technological progress is a scarce resource that is generally difficult for them to obtain. Academic executives master different levels of S&T resources due to variations in their academic title, administrative experience, and academic specialization, which would affect corporate outcomes in different ways. Specifically, being awarded a senior academic title reveals strong academic capabilities as well as rich academic experience and resources. Top executives with administrative experience in universities and research institutions normally have good academic performance, management skills, and rich resources and networks, which are effective in integrating and utilizing outside resources and promoting collaboration with external units. Further, since top executives of various academic backgrounds are expected to play different roles (Jiang and Murphy, 2007; White et al., 2014), academic executives with different specializations may make diverse managerial decisions regarding S&T knowledge. In general, academic executives with a specialization in sciences,[3] such as physics, have richer training and experience in S&T research, as compared to those who are specialized in non-science fields such as finance and accounting. The accumulation of explicit and tacit S&T knowledge during the process of S&T research gives academic executives in sciences an advantage over other top executives in understanding the S&T knowledge and their applications and accumulating S&T social capital, such as S&T network. As a result, they may be better at facilitating the identification and absorption of outside S&T knowledge, establishing technological collaboration, and providing support for basic research. For example, a large number of Japanese corporate directors in the catch-up stage had knowledge and experience in production and R&D, which contributed to the country's rapid development (Odagiri and Gotō, 1996). Accordingly, we hypothesize that academic executives with different resources have heterogeneous innovation effects:

Hypothesis B. Corporate technological capabilities and innovation performance are positively related to academic executives' previous academic title, administrative experience in academia, and specialization in sciences.

There are three potential mechanisms underlying the innovation effects of academic executives. First, according to the literature on technological catch-up, an important reason that catch-up is difficult to achieve in developing countries is these countries' low level of technological capabilities, meaning they are unable to conduct in-house R&D (Lee, 2019). As an important form of in-house R&D, firm basic research focuses on the area between scientific knowledge and product development, and enables an effective use of scientific knowledge aimed at solving problems that exist in product development with visible application prospects. By enhancing firms' own basic research capabilities instead of outsourcing all research projects to universities and research institutions, firms are able to cultivate their own absorptive and technological capabilities and reduce the cost of collaboration due to information asymmetry, thus lowering the cost of product development, increasing R&D efficiency and quality, and ultimately improving corporate innovation performance and achieving long-term competitiveness (Arora et al., 2017; Cohen and Levinthal, 1990; Hsu et al., 2021; Rosenberg, 1990). Due to academic executives' knowledge, experience, and resources in research, they are likely to better understand and value the process of knowledge creation and capacity-building and provide resources to support corporate innovative activities. Thus, a potential mechanism of academic executives' innovation effects is that they attach greater emphasis on firm basic research than other top executives. Combining this with the empirical evidence that Chinese firms' collaboration with universities emphasizes basic research (Motohashi and Yun, 2007), we expect that an increased level of basic research activities brought about by academic executives would positively affect corporate technological capabilities and innovation performance. Thus, we hypothesize the following:

Hypothesis C1. Academic executives are positively associated with firm basic research, which contributes to corporate technological capabilities and innovation performance.

Second, although external collaborations are beneficial for firms' innovation performance, such collaborations may suffer from a lack of efficiency when patent protection and the market for intellectual property transactions are not mature, or when the coordination between them is costly. Moreover, as many firms do not have experience collaborating with outside units and the search cost for a suitable match is high, firms tend to underestimate the value of such collaborations (Howells et al., 2012). Collaborating with outside units is also a complex process with uncertainty that requires firms to have a certain level of capabilities to identify and assimilate outside knowledge (Zheng and Yang, 2015). Researchers have shown that managers with a high level of human capital, such as an advanced academic degree, increase firms' capacity for understanding, accessing, and absorbing external knowledge, thus enhancing their competitive advantage (Audretsch and Lehmann, 2006). Academic executives' research experience has the potential to improve firms' ability to identify and absorb external knowledge (Cohen and Levinthal, 1990), which is crucial for the enhancement of corporate innovation. The experience of handling professional risks in academic projects as well as in choosing research topics and collaborators further facilitates academic executives to make effective management decisions, such as recognizing opportunities and establishing collaborative innovation networks (Jiang and Murphy, 2007). Their social network to researchers in academia also enriches firms' sources of external knowledge (Subramanian et al., 2016). In addition, as argued earlier, academic executives are likely to attach more importance to firm basic research than other top executives, which further enhances firms' ability to collaborate with external institutions. Collectively, due to their knowledge, experience, and social capital, academic executives have the potential to improve firms' ability to identify and absorb advanced S&T knowledge from outside resources, build collaborative innovation networks that are beneficial to corporate development, and foster communication between industry and academia by reducing search cost and collaboration inefficiency (Guan et al., 2005). Correspondingly, we expect that an expanded cooperation network associated with academic executives contributes to corporate technological capabilities and innovation performance. Thus, our next hypothesis is put forward as:

Hypothesis C2. Academic executives are positively associated with a firm's cooperation network, which contributes to corporate technological capabilities and innovation performance.

Third, innovation is a long-term process that is carried out by individual knowledge workers, such as in-house scientific researchers and engineers. Providing incentives to keep employees engaged and motivated is essential for firms to achieve better innovation performance (Chang et al., 2015; Lazonick, 2010; Manso, 2011). A strand of literature on organizational culture addresses that top management shapes and reinforces corporate culture and affects employees' beliefs and behaviors (e.g., Bass and Avolio, 1993; Tsui et al., 2006). The existence of academic executives has the potential to promote a knowledge and research friendly environment that provides positive incentives to knowledge workers. They may also transfer profits to internal investment (Odagiri and Gotō, 1996) and provide monetary incentives to keep knowledge workers motivated. Empirical evidence further reveals that top management support is important in motivating knowledge workers (Horwitz et al., 2003). Thus, academic executives, especially those with a senior academic title and administrative experience, may have rich experience leading a team and understand the importance of staying

[3] Degrees awarded in China include the following fields: philosophy, economics, law, education, literature, history, sciences, engineering, agriculture, health, management, and arts. Sciences are defined in this study to include sciences, engineering, agriculture, and health.

motivated in research. In this context, we expect that academic executives tend to facilitate an incentive scheme that motivates knowledge workers, which positively affects corporate technological capabilities and innovation performance. Thus, we hypothesize as follows:

Hypothesis C3. Academic executives are positively associated with knowledge workers' incentives, which contribute to corporate technological capabilities and innovation performance.

Finally, the enhancement of technological capabilities has the potential to ultimately improve the financial performance of firms. Examining the technological development performance of Japanese and Korean firms in the catch-up stage, continuous R&D efforts have narrowed the technological gap between them and advanced firms, and corporate profitability has increased sharply as a result (Lee, 2013; Odagiri and Gotō, 1996). Given these firms' great emphasis on growth, they also tend to keep a large proportion of profits within firms for reinvestment in R&D. We argue that academic executives provide an internal driving force for corporate technological catch-up that emphasizes the cultivation of technological capabilities. Thus, we expect that firms with academic executives demonstrate similar characteristics in financial performance as Japanese and Korean firms in their catch-up stage. Accordingly, our last hypothesis is stated as follows:

Hypothesis D. Academic executives positively affect corporate financial performance in terms of sales and profitability, and for reinvestment in R&D, they are more likely to keep a larger proportion of profits within firms than other top executives.

3. Data

3.1. Data sources and sample construction

The data for this study come from multiple sources. Data on patents and citations of patents of Chinese listed manufacturing firms from 1985 to 2018 are provided by the Dawei Innojoy Patent Search Database. Data on R&D investment of these firms starting from 2007 are drawn from the Chinese Innovation Research Database.[4] Firm-related financial information is obtained from the China Stock Market & Accounting Research (CSMAR) database, Wind Economic database, and listed firms' annual reports. The number of industry and national standards established by each firm is provided by the Wanfang Standards Database. For each firm, we manually collected data on top executives' academic title, administrative experience, and academic specialization in universities and research institutions from the CSMAR database, Wind Economic database, listed firms' annual reports, and internet resources.

Target firms for our sample are all manufacturing firms listed on China's A-share Main Board, Small and Medium-Sized Enterprise Board, and Second Board markets. Our focus is on manufacturing firms for two reasons. The first is due to data availability. The second and more important reason is that technological innovation plays a fundamental role in upgrading the manufacturing industry in China's economy. Further, considering the fact that data on citations are limited before 2000 and it takes time for a patent to get granted and cited, referencing Chang et al. (2015), we delete data before 2001 or after 2015. We continue to delete Special Treatment (ST or *ST) firms and firms that only have one year of valid information. As a result, our sample includes 1645 manufacturing firms and 13,995 firm-year observations.

3.2. Measuring corporate innovation

We explore the innovation effects of academic executives from corporate technological capabilities and innovation performance. Specifically, our first set of variables mainly concerns corporate technological capabilities. To begin, the first measure is *R&D/sales*, which represents the intensity of R&D investment and is calculated by the percentage of R&D investment relative to a firm's sales in a year. It is used to denote the level of innovation input and the intensity of firm learning (Lee, 2013). The second measure is *Self-citations*, which reflects the extent to which a firm's innovation activities build upon its existing knowledge and is documented to be positively correlated with a firm's technological capabilities (Joo et al., 2016; Lee, 2013). To construct this measure, we first calculate the ratio of a patent's number of citations that are from a firm's own patents or non-patent literature to the patent's total number of citations, and the variable *Self-citations* is calculated as the average ratio of all patents in a year. Next, we calculate a patent's non-patent citations as a percentage of its all citations and use the average percentages of all patents in a year as our third measure, *Exploration*. A firm's innovation efforts based on non-patent knowledge reveal its basic research and absorptive capabilities to integrate and exploit generic knowledge (Breschi et al., 2000). According to Joo et al. (2016), drawing ideas from basic research is important for firms to develop different technologies from forerunners to achieve catch-up. Finally, we calculate the original score of a patent as the difference between one and the Herfindahl index of the technology class distribution of the patent's citations (Hall et al., 2001; Trajtenberg et al., 1997),[5] and define the average value of the original scores of all patents in a year as our fourth measure, *Originality*. It is constructed to represent the breadth of technological fields utilized in a firm's research. The larger the score of *Originality*, the broader the technological base of the research.

Our second set of variables is mainly related to corporate innovation performance. Information on patents and citations is widely used to construct measures for the quantity and quality of innovation output (Acharya and Subramanian, 2009; Balsmeier et al., 2017; Chang et al., 2015; Hall and Rosenberg, 2010; Hirshleifer et al., 2012; Lee, 2013). Following this strand of literature, our first measure is *Patents*, which is the number of invention patents and utility model patents granted in a firm in a specific year,[6] and is constructed to represent the scale of innovation output. Second, given the differences in the complexity of technology, difficulty in getting granted, and the market value between invention patents and utility model patents, we use the number of granted invention patents in a year, *Inventions*, to measure the quality of innovation output. Third, we rely on the number of forward citations of a patent to construct an alternative measure for the quality of innovation output. In constructing this measure, the concern of truncation bias arises since patents granted close to the last year of our panel data might be cited less than those that were granted earlier simply because they have less time to accumulate citations. To mitigate this concern, we adopt the method in Hall et al. (2005) and calculate the number of citations after adjustment,[7] *Citations*, as our third measure. Fourth, we construct a variable indicating the number of industry and national standards established by a firm in a year, *Standards*. In general, current leaders in the industry have an incentive to turn their leading

[4] Missing values are set to zero in our summary statistics and regression analysis. Our main conclusions remain the same after deleting the missing values.

[5] $Original\ Score_i = 1 - \sum_{k=1}^{N_i}(Ncite_{ik}/Ncite_i)^2$, where $Ncite_{ik}$ is patent i's number of citations from technology class k, $Ncite_i$ is the total number of citations of patent i.

[6] There are three types of patents in China: invention patents, utility model patents, and design patents. Since design patents are different from the other two types of patents in their requirement for technological innovation (He et al., 2018; Tong et al., 2018), they are not considered in our main analysis. In addition, we used the number of patent applications (instead of granted patents) to perform robustness checks and obtained consistent results.

[7] We start by calculating the average number of citations in the same technology class and year. We further calculate the average number of citations in the same technology class of all years in the sample. The adjustment factor of such a technology class in a year is then computed as the ratio of the average citation counts of the year to the average citation counts of all years.

technologies into industry standards to guide the development of technology in a direction that is beneficial to them (Lee, 2019). By developing standards, firms are able to build technological barriers, obtain competitive advantages, and achieve and maintain significant financial performance (Auriol and Benaim, 2000; Pohlmann et al., 2016). Thus, a larger number of *Standards* represents better innovation performance of a firm, it is also associated with considerable strategic and economic value.

In addition, to examine whether, and the extent to which, academic executives and their innovation strategies affect corporate financial performance, we use *Ln*(*Sales per employee*), the natural logarithm of the ratio of sales to the number of employees; *Profit margin*, the ratio of net income to revenue; *ROE*, the ratio of net income to shareholders' equity; *ROA*, the ratio of net income to total assets; and *Tobin's Q*, the ratio of the market value to total assets, to measure a firm's profitability and market value. We further investigate the role of academic executives in allocating profits within firms by constructing two additional variables: *Dividend payout ratio*, the ratio of total dividends paid to shareholders to net income; and *Cash holding ratio*, the ratio of cash and cash equivalents to total assets.

3.3. Measuring academic executives

We construct *Pre_academic*, the key independent variable of interest, to indicate academic executives. It is equal to one if at least one of the top executives has research experience, i.e. had an academic title, in universities or research institutions, and is equal to zero otherwise. To examine the heterogeneous effects, we separate academic executives by their academic title, administrative experience, and academic specialization. Specifically, *Pre_junior* indicates academic executives who were assistant professors/researchers. *Pre_senior* indicates academic executives who were associate professors/researchers or full professors/researchers. We further distinguish between academic executives who held an administrative leadership position in academia, such as dean or president (*Pre_administr*), and those without such a position (*Pre_noadministr*). Finally, *Pre_sciences* denotes academic executives who are specialized in sciences, and *Pre_nosciences* stands for academic executives who are specialized in other fields.

In our sample, 190 firms have academic executives. The top part of Table 1 reports the distribution of firms with academic executives by industry. Computers and telecommunications, pharmaceuticals, and electrical machinery are the three industries that have the top three largest number of firms with academic executives. To assess the possibility that this fact is due to the large number of firms in these industries, we also report the percentage of firms with academic executives in each industry. Results show that firms in high-tech industries, such as computers and telecommunications and pharmaceuticals, have more firms with academic executives in both absolute and relative values. However, firms in certain general industries, such as non-ferrous metal smelting and non-metallic mineral, also have a relatively high percentage of academic executives.

To demonstrate the stage of firm development at the time when academic executives started to appear, we report in the bottom of Table 1 the distribution of firm age (calculated as *Year of observation-Year of establishment* $+ 1$) when the firm started to have academic executives. To illustrate, there are nine firms with academic executives that are age three, meaning three years after establishment, nine firms started to have top executives with research experience. At age ten, we observe the highest number of firms with academic executives, and there is a decreasing trend in their prevalence for firms more than ten years old. Consequently, we can conclude that firms in their early stage of development are more likely to have academic executives. Given the evidence that younger firms perform better in innovation than firms with longer years of establishment in China (Guan et al., 2009), our statistics point to a potential link between academic executives and corporate innovation. To further explore the pattern of emergence of academic executives within firms, in Table A.2, we report the distribution of year when these executives first appeared within firms. Before 2006, less than ten firms had academic executives in each year. From 2007 onward, there was a noticeable change in this trend. For example, 24 firms started to have academic executives in 2010. Taken together, these statistics suggest that growing firms are more likely to have academic executives, and an increasing number of firms are having these executives as the regulations on the flow of STP to firms are relaxed.

3.4. Firm characteristics and summary statistics

A set of control variables are constructed to represent firm-specific characteristics that are potentially related to corporate innovation. *Ln* (*Assets*), the natural logarithm of a firm's total assets, is used to represent the firm's scale, which is found to be positively related to its innovation output (e.g., Hall and Ziedonis, 2001). *Ln*(*Firm age*), the natural logarithm of a firm's age, is constructed to control for the impact of a firm's life cycle since managerial and strategic decision-making varies with a firm's development phases according to the theory of firm life cycle. *Ln* (*PPE per employee*), the natural logarithm of net fixed assets (Property, Plant, and Equipment) per employee, is used as a proxy for a firm's capital intensity. *Sales growth*, the year-on-year growth of operating revenue, as well as the *Book to market ratio* are constructed to measure a firm's growth opportunities in the future. *Leverage*, the ratio of debt to equity, is created to control for the influence of corporate capital structure. *Stock return*, the annual rate of return during the stock holding period, is used to control for the impact of a firm's performance in the stock market (Fang et al., 2014). *Stock volatility*, the standard deviation of a firm's stock's daily rate of return, is used to control for a firm's stock return volatility, since the fluctuation of stock income is positively correlated with R&D investment (Chan et al., 2001). Further, given the inverted U-shaped relationship between corporate innovation and product market competition (Aghion et al., 2005), *Herfindahl* and *Herfindahl*^{2}, the Herfindahl index and its squared term that are based on a firm's proportion of operating income in the industry, are used to represent the industry's degree of competition. All these control variables are winsorized at the 1 % and 99 % quantiles to remove outliers.

Table 2 displays means and standard deviations of main variables used in this study. The last three columns report the mean values of these variables in subsamples without academic executives, with academic executives, and the results of the *t*-test for difference in the means of a specific variable between these two subsamples, respectively. In Panel A, we show that 6.3 % of our sample is firms with at least one of their top executives being an academic executive. Within these firms, 54.7 % of the executives had a senior academic title, 45.5 % had administrative experience, and 76.4 % are specialized in sciences. In Panel B, comparison of the average values of *Self-citations* suggests that firms with academic executives innovate through a technological path that relies more on its own knowledge accumulation compared to firms without these executives. Higher average numbers on *Exploration* and *Originality* demonstrate respectively that firms with academic executives are more likely than other firms to achieve technological progress through basic research and a wide technological knowledge base. In addition, firms with academic executives have significantly higher average numbers of *Patents*, *Inventions*, and *Citations*, suggesting they perform better in both the quantity and quality of innovation output than firms without these executives. Panel C shows that firms with academic executives also have

Table 1
Distribution of firms with academic executives by industry and year of establishment.

Industry	No. of firms with AE	Pct. in the industry	Industry	No. of firms with AE	Pct. in the industry
Computers and telecommunications	39	16.7	Wine, beverage, tea	4	11.1
Pharmaceuticals	25	15.7	Textile	3	9.1
Electrical machinery	23	13.3	Transportation	3	9.1
Special equipment	17	11.0	Rubber and plastic	3	6.7
Chemistry	17	10.6	Clothing	2	8.0
Non-ferrous metal smelting	10	17.2	Chemical fiber	1	4.8
Non-metallic mineral	10	15.6	Petroleum, coking, nuclear combustion	1	7.1
Agriculture related	8	14.5	Ferrous metal smelting	1	3.7
General equipment	6	6.3	Waste management	1	4.8
Metal production	5	10.9	Food	1	3.0
Instrumentation	4	12.1	Paper	1	4.2
Automobile	4	4.7	Other manufacturing	1	6.7

Firm age	No. of firms with AE	Pct.	Firm age	No. of firms with AE	Pct.
3	9	4.74	15	8	4.21
4	8	4.21	16	10	5.26
5	7	3.68	17	7	3.68
6	5	2.63	18	5	2.63
7	7	3.68	19	7	3.68
8	8	4.21	20	4	2.11
9	18	9.47	21	5	2.63
10	21	11.05	23	1	0.53
11	16	8.42	24	2	1.05
12	14	7.37	25	2	1.05
13	14	7.37	26	1	0.53
14	11	5.79	Total	190	100

Notes: "AE" stands for academic executives. "Pct. in the industry" indicates the percentage of firms with academic executives in a specific industry. "Firm age" is calculated as *Year of observation-Year of establishment* + *1*. "Pct." represents the percentage of firms with academic executives for a given firm age among all firms with academic executives.

better financial performance in terms of higher average *Profit margin*, *ROA*, and *Tobin's Q*. Statistics on the average values of *Ln*(*Assets*), *Ln* (*Firm age*), *Sales growth*, and other firm-specific variables in Panel D demonstrate that firms with academic executives are on average smaller, younger, and growing faster than those without. Collectively, our summary statistics reveal significant differences in corporate innovation and financial performance between firms with and without academic executives.[8]

4. Empirical methods

We specify the following baseline model to estimate the effects of academic executives on corporate performance:

$$Y_{i,t} = \alpha + \beta Pre_{academic_{i,t-1}} + \sum \gamma_k X_{k,i,t-1} + \theta Year_t + \delta Industry_j + \varepsilon_{i,t},$$

where $Y_{i,\ t}$ represents technological capabilities and innovation performance of firm *i* at time *t*, which are measured by *R&D/Sales*, *Self-citations*, *Exploration*, *Originality*, *Patents*, *Inventions*, *Citations*, and *Standards*. $Pre\_academic_{i,\ t-1}$ is equal to one if firm *i* at time *t-1* has at least one academic executive and is equal to zero otherwise. Referencing related studies (e.g., Chang et al., 2015; Cho et al., 2017), firm-specific characteristics described in Section 3.4, as well as financial indicators (*Ln* (*Sales per employee*), *ROA*, and *Cash holding ratio*) are included in $X_{k,\ i,\ t-1}$. $Year_t$ and $Industry_j$ are respectively year and industry fixed effects (dummies), and $\varepsilon_{i,\ t}$ is the error term. Since *Patents*, *Inventions*, *Citations*, and *Standards* are count variables, we use fixed-effect negative binomial (NB) regressions to estimate the effects of academic executives when the dependent variable is *Patents* or *Inventions*; use population-averaged NB regressions when the dependent variable is *Citations* or *Standards* due to non-convergence when fixed-effect NB regressions are used; and include an exposure variable in the controls of these regressions to represent the total number of years a firm is observed in our sample period.[9] Ordinary least squares (OLS) regressions are used for other outcome variables.

The parameter of interest is β, which represents the effect of academic executives on a specific measure of corporate technological capabilities and innovation performance. In order to interpret β as the causal effect, the endogeneity issue associated with academic executives has to be addressed. This issue arises from the possibility that firms that attach more importance to enhancing technological capabilities tend to hire top executives with a research background. In order to identify the causal effect, we employ two identification strategies. First, based on the approach used in Sunder et al. (2017), we rely on top executive turnover to examine changes in corporate performance and their relationships with the appointment of academic executives. By doing so, we are able to rule out potential confounding influences of time-invariant unobserved factors at the firm level. Specifically, denote $Y_{year\ h}$, ($h = 1,2,3$) as the outcome during each of the first three years when the new academic executive was in office (the year when the turnover happened is not considered), and Y_{year-1} as the outcome in the last year when the preceding top executive was in office. We then regress $Y_{year\ h} - Y_{year-1}$ on change from a non-academic executive to an academic executive ($\Delta New\_academic$) and changes in control variables (ΔX) from *year* − *1* to *year h*. To be more precise, $\Delta New\_academic$ is equal to one when the new

[8] Since innovation strategies vary by firm type (Guan et al., 2009; Whitley, 2000), we examine the possibility that the differences in technological achievement between firms with and without academic executives are attributable to differences between firms in high-tech industries and general (non-high-tech) industries in Table A.3. We find that significant differences in corporate performance between firms with and without academic executives exist in both industries.

[9] The fixed-effect NB regressions have the advantage of estimating the coefficients of time-invariant factors, so that firm fixed effects are accounted for. In addition, we used double-hurdle regressions and OLS regressions and obtained consistent findings on the relationships between academic executives and various measures of innovation output that are count variables.

Table 2
Summary statistics of main variables.

Variables	All firms (N = 13,995)		Firms without AE (N = 13,110)	Firms with AE (N = 885)	Difference in mean
	Mean	S.D.	Mean	Mean	
Panel A					
Pre_academic	0.063	0.243	0	1	1***
Pre_senior	0.035	0.183	0	0.547	0.547***
Pre_administr	0.029	0.167	0	0.455	0.455***
Pre_sciences	0.048	0.214	0	0.764	0.764***
Panel B					
R&D/sales	0.023	0.029	0.022	0.034	0.012***
Self-citations	0.001	0.018	0.001	0.003	0.002***
Exploration	0.146	0.280	0.142	0.196	0.054***
Originality	0.053	0.133	0.052	0.07	0.018***
Ln(1 + Patents)	1.210	1.450	1.201	1.341	0.140***
Ln(1 + Inventions)	0.727	1.084	0.714	0.928	0.214***
Ln(1 + Citations)	1.241	1.571	1.226	1.469	0.243***
Standards	0.553	1.535	0.549	0.615	0.066
Panel C					
Ln(Sales per employee)	6.438	0.840	6.439	6.415	−0.024
Profit margin	0.075	0.159	0.074	0.102	0.028***
ROE	0.058	0.139	0.057	0.065	0.007
ROA	0.046	0.055	0.046	0.051	0.005***
Tobin's Q	2.168	1.812	2.129	2.753	0.624***
Dividend payout ratio	30.696	34.271	30.72	30.302	−0.418
Cash holding ratio	0.235	0.151	0.233	0.261	0.028***
Panel D					
Ln(Assets)	7.743	1.131	7.764	7.428	−0.336***
Ln(Firm age)	2.008	0.683	2.019	1.852	−0.167***
Ln(PPE per employee)	5.449	0.9	5.452	5.402	−0.051
Sales growth	0.164	0.307	0.162	0.19	0.027**
Book to market ratio	0.824	0.685	0.837	0.63	−0.207***
Leverage	0.430	0.207	0.433	0.392	−0.040***
Stock return	0.289	0.758	0.289	0.291	0.002
Stock volatility	0.473	0.150	0.472	0.487	0.015***
Herfindahl	0.084	0.070	0.085	0.075	−0.009***

Notes: "AE" stands for academic executives. ** and *** indicate that difference in the mean is not equal to zero at the 5 % and 1 % level, respectively.

top executive has research experience and is equal to zero otherwise.

Since a relatively small proportion of our sample has changed top executives during the sample period,[10] we further address the endogeneity issue using the PSM approach (Rosenbaum and Rubin, 1983), and estimate the treatment effect of academic executives on corporate performance. The treatment variable is whether a firm has an academic executive, the outcome variables are various measures of corporate performance, and covariates include an array of firm-level characteristics. After calculating the conditional probability (propensity score) of a firm being randomly assigned to the treated group (firms with academic executives) or untreated group (firms without academic executives), we match firms in the treated group and untreated group based on the propensity scores. If the means of an outcome variable from the treated group and untreated group in the matched sample are significantly different, then the treatment variable has a significant effect on the outcome variable. In the context of this study, this means that academic executives have a significant impact on the specific measure of corporate performance.

In an alternative specification, we examine the effects of academic executives on a variety of financial indicators (*Ln*(*Sales per employee*), *Profit margin*, *ROE*, *ROA*, *Tobin's Q*, *Dividend payout ratio*, and *Cash holding ratio*). The corresponding control variables included in $X_{k,\ i,\ t-1}$ are *Ln*(*Assets*), *Ln*(*Firm age*), *Ln*(*PPE per employee*), and *Stock volatility*. We also include *Inventions* and *Non-inventions* (the number of granted utility model patents and design patents) measured at time *t* to account for the influences of innovation output on corporate financial performance. Year and industry fixed effects are also controlled for.

5. Innovation effects of academic executives

In this section, we estimate the effects of academic executives on corporate technological capabilities and innovation performance. We further examine the heterogeneous effects of academic executives by their academic title, administrative experience, and academic specialization. The identification of the innovation effects relies on top executive turnover and the PSM strategy. Finally, we perform a variety of checks to test the robustness of our findings.

5.1. Results from the baseline model

In Panel A of Table 3, we report the estimated effects of academic executives on various measures of corporate technological capabilities. Column (1) reveals a statistically significant and positive relationship between academic executives and R&D investment intensity, implying firms with these executives are more likely than firms without to support and invest in R&D, thus advancing the intensity of firm learning. This is in line with the empirical evidence that university-industry collaboration enhances firms' R&D effort (Maietta, 2015; Scandura, 2016). The estimate in Column (2) indicates that firms with academic executives have a higher value of *Self-citations*, implying these firms' innovation efforts have a relatively high degree of reliance on their own knowledge

Table 3
Estimated innovation effects of academic executives: baseline model.

Panel A	(1)	(2)	(3)	(4)
	OLS regressions			
	R&D/sales	*Self-citations*	*Exploration*	*Originality*
Pre_academic	0.010***	0.002*	0.059***	0.018***
	(0.001)	(0.001)	(0.010)	(0.005)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158
R-squared	0.493	0.012	0.244	0.130

Panel B	(5)	(6)	(7)	(8)
	Fixed-effect NB regressions		Population-averaged NB regressions	
	Patents	*Inventions*	*Citations*	*Standards*
Pre_academic	0.100*	0.155**	0.671***	1.327***
	(0.058)	(0.066)	(0.194)	(0.241)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	9553	9091	12,158	12,158

Notes: Robust standard errors are in parenthesis. Control variables include *Ln*(*Assets*), *Ln*(*Firm age*), *Ln*(*PPE per employee*), *Sales growth*, *Book to market ratio*, *Leverage*, *Stock return*, *Stock volatility*, *Herfindahl*, *Herfindahl*^{2}, *Ln*(*Sales per employee*), *ROA*, and *Cash holding ratio*. *Pre_academic* and control variables are measured at time *t-1*. Estimates of the control variables are presented in Table A.4.

* Significant at 10 %.
** Significant at 5 %.
*** Significant at 1 %.

[10] 16 % of firms have changed top executives in the sample period and there are 2973 top executive turnovers in total.

base compared to firms without these executives. An increase in self-citations is observed in the successful catch-up of firms in latecomer countries (e.g., Joo and Lee, 2010). Thus, we expect the increase in self-citations brought about by academic executives contributes to firms' catch-up performance in our sample. Column (3) shows that having academic executives is associated with a 0.059 (about 40 % of the mean value) increase in *Exploration*, indicating the patented knowledge of firms with academic executives tend to draw inferences from non-patent literature such as basic research papers. This positive estimated effect reveals these firms' endeavor to explore new technologies, which facilitates a technological advancement path that relies on the creation of new knowledge, rather than imitation of existing knowledge. Column (4) implies that firms with academic executives have more original patents, i.e., patents that use a wide range of technological knowledge compared to other firms. This suggests that these firms have a relatively low level of dependence on a particular type of existing technological knowledge, and that they intend to explore a broad set of knowledge bases to generate new ideas. In general, innovation involving marginal improvement of the existing knowledge and technologies is associated with low risks and costs. Innovation that depends on original exploration, which is consistent with the strategy of path-creating catch-up (Lee and Lim, 2001), is associated with high risks and costs. However, it has the potential to help firms establish a technological advancement path. Altogether, it can be inferred from Panel A that firms with academic executives undertake technological advancement strategies that not only rely on their own knowledge accumulation, but also draw new ideas and knowledge from non-patent knowledge and a wide range of knowledge sources.

The estimated effects of academic executives on corporate innovation performance are reported in Panel B of Table 3. Looking at Column (5), where the dependent variable is the number of patents, our result indicates that, compared to firms without academic executives, firms with these executives are associated with a statistically significant increase in the quantity of firms' innovation output. In the next two columns, the results demonstrate that academic executives exert an economically sizable and statistically significant influence on the quality of corporate innovation output, as measured by the number of inventions and citations. The last column reveals that firms with academic executives are associated with a substantial increase in the number of industry and national standards. Since it requires high-quality patents to establish such standards, this result implies that firms with academic executives have a relatively high level of innovation performance, which has the potential to contribute to their establishment of technological barriers and competitive advantages in the market.

Estimated coefficients of the control variables (reported in Table A.4) are in line with the existing empirical evidence. For example, *Ln*(*Assets*) is positively correlated with innovation output, implying that, all else equal, larger firms are more capable of tolerating the risks of innovation than smaller firms; *Ln*(*Firm age*) is negatively associated with innovation output, suggesting given all else equal, young firms are likely to have a high level of innovation output than firms with a longer years of establishment.

Taken together, our findings from Table 3 reveal that compared to their counterparts, firms with academic executives are more likely to adopt the strategy of relying on technological progress to promote corporate growth, which is reflected in the improvement of technological capabilities as well as the quantity and quality of innovation output. These findings provide additional evidence for the upper echelons theory that top executives' research experience facilitates firms' formulation of technological advancement strategies in latecomer countries. Thus, our findings support Hypothesis A. We also add to the literature on technological catch-up by showing that for firms that lack intrinsic motivation for catch-up due to their low technological capabilities and strict intellectual property rights protection, choosing top executives with research experience is beneficial for them to carry out technological innovation strategies.

In Table 4, we examine whether, and to what extent, the estimated effects of academic executives depend on their academic title, administrative experience in academia, and academic specialization. Results in Panel A show that top executives of both types of academic titles contribute significantly and positively to multiple measures of firm performance. However, in most cases, the effects of academic executives are more pronounced when their academic title is higher. For example, academic executives who had a senior academic title are associated with a 0.074 increase in *Exploration*, compared to a 0.04 increase for those who had a junior academic title. Results in Panel B reveal that academic executives with administrative experience in academia are associated with better corporate innovation performance than their counterparts without such an experience. Results in Panel C further illustrate that firms with academic executives who are specialized in sciences have higher technological capabilities and better innovation performance than firms with academic executives who are specialized in other fields, such as finance and accounting. Different from the large number of studies that examine the effects of fields of study on individual wages and career choice (e.g., Altonji et al., 2016), our results provide new evidence that top executives' academic specialization has an impact on innovation output at the firm level and are in line with the findings that academic background and R&D experience influence executives' corporate strategy (Hitt and Tyler, 1991; Protogerou et al., 2017; Wiersema and Bantel, 1992).

Overall, it can be concluded from Table 4 that academic executives with a higher academic title, administrative experience in academia, and a specialization in sciences exert more pronounced innovation effects as compared to their counterparts, which validates Hypothesis B. These results can hardly be explained by others reasons, thus providing further evidence for the existence of a causal relationship between top executives' research experience and corporate innovation. They also support the resource-based theory of firms that academic executives with diverse backgrounds bring various types and levels of resources that contribute differently to firm performance.

5.2. Identification

In order to rule out potential influences of time-invariant unobserved factors at the firm level on the innovation effects of academic executives, we start by exploiting top executive turnover to examine changes in innovation performance in the same firm. Results are displayed in Table 5 where the coefficients of Δ*New_academic* represent the estimated changes in outcome variables brought to the same firm by academic executives as compared to non-academic executives. We find that most outcomes have improved three years after the academic executive took office. For example, three years after the academic executive was in power, citation counts increase by 64.4 % ($e^{0.497}$-1). Overall, by ruling out firm-level time-invariant unobserved factors that may confound our findings, we show that academic executives, as compared to other top executives, lead to statistically significant and positive innovation effects. This is consistent with the findings from the baseline model. More generally, our results imply that appointing academic executives is an important strategic managerial decision that would generate large and positive innovation effects.

Next, to further address the issue of selection on observed factors, we employ the PSM strategy. We first estimate the propensity score, i.e., the probability of having an academic executive, conditional on an array of covariates using a logit regression model. Following the strand of literature on the determinants of academic directors and board composition (e.g., Boone et al., 2007; Francis et al., 2015; White et al., 2014), the covariates include firm general characteristics (*Ln*(*Assets*), *Ln*(*Firm age*), and *Ln*(*PPE per employee*)), financial indicators (*Ln*(*Sales per employee*), *ROA*, *Sales growth*, *Book to market ratio*, *Leverage*, *Cash holding ratio*, *Stock return*, and *Stock volatility*), governance factors (*Number of universities in a firm's province*, *Institutional ownership percentage*, *Number of directors on board*, *Number of executives*, and *At least one executive is an inventor*), and

Table 4
Estimated effects of academic executives by academic title, administrative experience, and academic specialization.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Panel A. Estimated effects by academic title								
Pre_senior	0.010***	0.003	0.074***	0.022***	0.196***	0.026	0.749***	0.932***
	(0.001)	(0.003)	(0.014)	(0.007)	(0.074)	(0.081)	(0.226)	(0.294)
Pre_junior	0.007***	0.002**	0.040***	0.013*	−0.017	0.409***	0.552*	2.111***
	(0.002)	(0.001)	(0.015)	(0.008)	(0.091)	(0.107)	(0.317)	(0.403)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.493	0.012	0.244	0.131				
Panel B. Estimated effects by administrative experience								
Pre_administr	0.012***	0.004	0.103***	0.029***	0.588***	0.572***	0.799***	2.137***
	(0.002)	(0.003)	(0.016)	(0.008)	(0.085)	(0.094)	(0.290)	(0.397)
Pre_noadministr	0.006***	0.001	0.022*	0.009	−0.213***	−0.177*	0.481**	0.847***
	(0.001)	(0.001)	(0.013)	(0.007)	(0.080)	(0.092)	(0.238)	(0.245)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.494	0.013	0.245	0.131				
Panel C. Estimated effects by academic specialization								
Pre_sciences	0.012***	0.003*	0.064***	0.021***	0.232***	0.332***	0.781***	1.974***
	(0.001)	(0.002)	(0.012)	(0.006)	(0.067)	(0.079)	(0.212)	(0.299)
Pre_nosciences	−0.001	0.000	0.0439**	0.009	−0.215*	−0.176	0.218	0.470
	(0.001)	(0.001)	(0.019)	(0.009)	(0.115)	(0.116)	(0.448)	(0.330)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.495	0.012	0.244	0.131				

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. Variables representing different types of academic executives and control variables are measured at time *t-1*.
* Significant at 10 %.
** Significant at 5 %.
*** Significant at 1 %.

industry structures (*Herfindahl* and *Herfindahl*^{2}). We then match firms in the treated group to the untreated group using various matching algorithms (Caliendo and Kopeinig, 2008) so that the matched firms have similar propensity scores. Results from the balance test (Table A.5) reveal that, conditional on the propensity score, the treated group and untreated group have a similar distribution of covariates. Table 6 reports PSM results, where ATT (Imbens, 2004) represents average treatment effect for firms that have academic executives. We obtain significant and positive relationships between academic executives and various outcome variables. For example, academic executives lead to a 0.006–0.009 increase in *R&D/sales* as shown in Panel A. Although this is slightly smaller than the result from the baseline model (0.01), it remains economically sizeable and statistically significant. Overall, PSM estimates further confirm our previous conclusion that academic executives exert important innovation effects.

5.3. Robustness checks

We perform a comprehensive set of robustness checks in Table A.6. In Panels A and B, we distinguish between chairperson of the board with research experience (*Chair_academic*) and CEO with research experience (*CEO_academic*) and separately examine their innovation effects. Our conclusion that top executives' research experience plays an important role in corporate innovation holds in both panels.

In previous estimations, we use a lag period of one year when measuring academic executives following the majority of related studies. However, some researchers argue that it normally takes more than one year from technological innovation to patent application (e.g., He and Tian, 2013). Thus, based on the baseline model, a lag period of three years for academic executives is used in Panel C. Results show that most estimated effects are positive and statistically significant and are similar in magnitude to our estimates from the baseline model. These illustrate that our results are not very sensitive to the lag period chosen.

Further, based on the baseline model, we eliminate firms with zero granted patents in Panel D to remove firms that are obviously lagging in their innovation output; eliminate firms in Beijing, Shanghai, Guangzhou, and Shenzhen in Panel E to prevent overestimating the innovation effects given the disproportionately high number of listed firms in these cities as well as the belief that they are generally leading in innovation within China; and eliminate firms that have participated in foreign mergers and acquisitions in the past two years in Panel F to ensure that academic executives have the potential to enhance innovation performance through improving firms' own technological capabilities instead of relying on acquiring innovation output from foreign firms. The corresponding results are consistent with our main conclusions.

Finally, doubts may remain on whether our estimates are driven by firms in high-tech industries, where the innovation level is high and a large proportion of firms have academic executives. To assess this possibility, we interact *Pre_academic* with the indicator for high-tech industries (*High-tech*) and include both this interaction term and *High-tech* in the baseline model to examine the interaction effects of academic executives and high-tech industries. Results in Table A.7 show that the impacts of academic executives on *R&D/sales*, *Originality*, and *Inventions* are more pronounced in high-tech industries. Alternatively, we re-examine the effects of academic executives in a subsample that excludes firms in high-tech industries in Table A.8. There is clear evidence that academic executives in general industries have statistically significant and positive impacts on corporate technological capabilities and

Table 5
Estimated innovation effects of academic executives: using top executive turnover.

Panel A	Year −1 to year 1	Year −1 to year 2	Year −1 to year 3	Year −1 to year 1	Year −1 to year 2	Year −1 to year 3
	ΔR&D/sales	*ΔR&D/sales*	*ΔR&D/sales*	*ΔExploration*	*ΔExploration*	*ΔExploration*
ΔNew_academic	0.004**	0.004	0.014***	0.024	0.064	0.225***
	(0.002)	(0.002)	(0.004)	(0.038)	(0.051)	(0.072)
ΔControl variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2567	1851	1332	2567	1851	1332
R-squared	0.025	0.020	0.031	0.032	0.013	0.017

Panel B	Year −1 to year 1	Year −1 to year 2	Year −1 to year 3	Year −1 to year 1	Year −1 to year 2	Year −1 to year 3
	ΔOriginality	*ΔOriginality*	*ΔOriginality*	*ΔLn(1 + Patens)*	*ΔLn(1 + Patens)*	*ΔLn(1 + Patens)*
ΔNew_academic	−0.003	0.013	0.131***	0.041	0.162	0.174
	(0.014)	(0.018)	(0.033)	(0.108)	(0.145)	(0.134)
ΔControl variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2567	1851	1332	2567	1851	1332
R-squared	0.011	0.008	0.023	0.009	0.011	0.006

Panel C	Year −1 to year 1	Year −1 to year 2	Year −1 to year 3	Year −1 to year 1	Year −1 to year 2	Year −1 to year 3
	ΔLn(1 + Inventions)	*ΔLn(1 + Inventions)*	*ΔLn(1 + Inventions)*	*ΔLn(1 + Citations)*	*ΔLn(1 + Citations)*	*ΔLn(1 + Citations)*
ΔNew_academic	0.104	0.153	0.319**	0.159	0.173	0.497**
	(0.086)	(0.136)	(0.160)	(0.124)	(0.188)	(0.201)
ΔControl variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2567	1851	1332	2567	1851	1332
R-squared	0.015	0.004	0.008	0.014	0.004	0.011

Notes: Robust standard errors are in parenthesis. OLS regressions are used. Δ*New_academic* is equal to one when the new top executive has research experience and is equal to zero otherwise. Control variables are the same as the ones in Table 3. Estimates using selected dependent variables are presented due to space limitation. Our main conclusions remain the same for other dependent variables.

** Significant at 5 %.
*** Significant at 1 %.

Table 6
Results from the PSM.

	Matching algorithms						
	One-to-one	Nearest neighbor	Caliper	Radius	Kernel	Local linear	Spline
Panel A. Dependent variable: *R&D/sales*							
ATT	0.006***	0.008***	0.008***	0.009***	0.009***	0.009***	0.009***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Panel B. Dependent variable: *Exploration*							
ATT	0.046***	0.058***	0.058***	0.057***	0.056***	0.060***	0.058***
	(0.018)	(0.013)	(0.015)	(0.011)	(0.011)	(0.012)	(0.011)
Panel C. Dependent variable: *Originality*							
ATT	0.026***	0.021***	0.021***	0.019***	0.019***	0.020***	0.019***
	(0.009)	(0.008)	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)
Panel D. Dependent variable: *Ln(1 + Patents)*							
ATT	0.244**	0.178**	0.178**	0.181***	0.203***	0.176***	0.176***
	(0.107)	(0.082)	(0.082)	(0.068)	(0.057)	(0.060)	(0.062)
Panel E. Dependent variable: *Ln(1 + Inventions)*							
ATT	0.320***	0.294***	0.297***	0.290***	0.296***	0.290***	0.289***
	(0.081)	(0.073)	(0.076)	(0.049)	(0.053)	(0.050)	(0.054)
Panel F. Dependent variable: *Ln(1 + Citations)*							
ATT	0.371***	0.307***	0.314***	0.290***	0.318***	0.281***	0.281***
	(0.116)	(0.103)	(0.103)	(0.076)	(0.076)	(0.071)	(0.068)

Notes: Robust standard errors are in parenthesis. Standard errors are obtained through bootstrap. Control variables are the same as the ones in Table 3. Industry and year fixed effects are included. Estimates using selected dependent variables are presented due to space limitation. Our main conclusions remain the same for other dependent variables.

** Significant at 5 %.
*** Significant at 1 %.

innovation performance as measured by *R&D/sales*, *Exploration*, *Patents*, *Inventions*, and *Standards*. Therefore, although academic executives exert larger influences in certain corporate outcomes in high-tech industries, our conclusion that academic executives are beneficial for enhancing corporate innovation holds for firms in general industries. Overall, after changing the measurement of variables and using different model specifications and samples, results from the robustness checks demonstrate that our findings are robust and reliable.

6. Mechanism analysis

6.1. Firm basic research

To investigate the mechanisms underlying the innovation effects of academic executives, we start by exploring whether, compared to other top executives, academic executives are more likely to invest in firm basic research and consequently enhance corporate technological capabilities and innovation performance.

Following the approach applied in related studies (Arora et al., 2018; Arora et al., 2021; Hsu et al., 2021; Simeth and Cincera, 2016), we use the natural logarithm of one plus the number of papers published by a firm in the fields of science and technology in core journals (*Ln(1 + Papers*), measured at time *t-1*) as a proxy for its level of basic research.[11] Information on these papers (written in either Chinese or English) was manually collected from the China National Knowledge Infrastructure Database and Elsevier's Scopus Database. Column (1) of Table 7 shows that firms with academic executives are associated with a 26.1 % ($e^{0.232}$-1) increase in the number of papers published, suggesting these firms have more basic research activities. Throughout the rest of the columns, the estimated effects of firm basic research are sizeable and statistically significant, implying firm basic research is a strong factor in fostering corporate technological capabilities and innovation performance. Compared to Table 3, we find that the estimated effects of academic executives decrease in most columns after controlling for firm basic research. For example, the estimated effect of *Pre_academic* on *Exploration* changes from 0.059 in Tables 3 to 0.049 in Table 7. Overall, we demonstrate that academic executives attach greater importance to basic research than other top executives, and such an original knowledge learning and exploring activity contributes to better corporate innovation performance. Thus, Hypothesis C1 is supported.

6.2. Collaboration

Next, we investigate whether increased collaboration brought about by academic executives is a potential mechanism underlying their innovation effects. Referencing related studies that rely on the number of R&D partners and joint publications to measure collaboration (e.g., Maietta, 2015; Subramanian et al., 2016), we add up the number of external collaborative units when applying for patents in each year for each firm (*Patent partner*) and use *Ln(1 + Patent partner*) (measured at time *t-1*) as a proxy for collaboration with external institutions. In Column (1) of Table 8, we find that firms with academic executives have about 4 % ($e^{0.04}$-1) more outside partners in patent applications than firms without these executives. This is in line with the expectation that academic executives enhance corporate collaboration with outside institutions. We further demonstrate that Hypothesis C2 is supported by showing that collaboration plays an important role in explaining the effects of academic executives in certain corporate outcomes. For example, compared to Table 7, after controlling for collaboration, the estimated coefficient of *Pre_academic* on *Inventions* decreases considerably and becomes insignificant in Column (7) of Table 8. Meanwhile, decreases in the estimated coefficients of *Ln(1 + Papers*) after the inclusion of *Ln(1 + Patent partner*) indicate that collaboration also has an indirect impact on the outcome variables through its positive correlation with firm basic research.

[11] Articles that are not in fields of science and technology, and articles that are promotional, introductory, or unrelated with technological knowledge, are not taken into account. Although the number of scientific papers published does not capture firms' entire basic research activities, it has the advantages of proxying for the link between corporate scientists to the scientific community, enhancing the technical reputation of the firm, attracting talented scientists, and signaling its scientific and technological capabilities (Cockburn and Henderson, 1998; Gambardella, 1992; Henderson and Cockburn, 1994; Hicks, 1995; Mindruta, 2013).

Table 7
Mechanism: Firm basic research.

	(1)	(2)	(3)	(4)
	OLS regressions			
	Ln(1 + Papers)	*R&D/sales*	*Self-citations*	*Exploration*
Pre_academic	0.232***	0.008***	0.002	0.049***
	(0.041)	(0.001)	(0.001)	(0.010)
Ln(1 + Papers)		0.002***	0.001***	0.045***
		(0.000)	0.000	(0.002)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158
R-squared	0.242	0.497	0.014	0.271

	(5)	(6)	(7)	(8)
	OLS regression	Fixed-effect NB regressions		Population-averaged NB regression
	Originality	*Patents*	*Inventions*	*Citations*
Pre_academic	0.015***	0.09	0.156**	0.631***
	(0.005)	(0.057)	(0.065)	(0.198)
Ln(1 + Papers)	0.014***	0.114***	0.153***	0.246***
	(0.001)	(0.012)	(0.013)	(0.048)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	9553	9091	12,158
R-squared	0.137			

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. *Pre_academic*, mechanism variable, and control variables are measured at time *t-1*. Estimates using selected dependent variables are presented due to space limitation.
** Significant at 5 %.
*** Significant at 1 %.

6.3. Knowledge workers' incentives

Finally, we examine the role of motivating knowledge workers in explaining the innovation effects of academic executives. Given the empirical evidence that providing employee stock options positively affects corporate innovation output (e.g., Chang et al., 2015; Lazonick, 2010; Manso, 2011), we measure knowledge workers' incentives using whether core scientific and technical employees are provided with stock options. Data on listing firms' stock options were manually collected from the CSMAR Database, and the variable *Stock options* (measured at time *t-1*) is constructed to be equal to one if core scientific and technical employees are provided with stock options and equal to zero otherwise. A probit model is used to estimate the effect of academic executives on the probability of receiving stock options among scientific and technical employees. Column (1) of Table 9 reveals a positive and statistically significant relationship, implying scientific and technical employees are more likely to receive stock options in firms with academic executives than in firms without. We further find that compared to Table 8, the estimated effects of academic executives continue to decrease after controlling for *Stock options*. In particular, the estimated coefficient of

Table 8
Mechanism: collaboration.

	(1)	(2)	(3)	(4)
	OLS regressions			
	Ln(1 + Patent partner)	*R&D/ sales*	*Self-citations*	*Exploration*
Pre_academic	0.040**	0.008***	0.002	0.045***
	(0.018)	(0.001)	(0.001)	(0.010)
Ln(1 + Papers)	0.107***	0.001***	0.001***	0.036***
	(0.005)	(0.000)	0.000	(0.002)
Ln(1 + Patent partner)		0.004***	0.001***	0.088***
		(0.001)	0.000	(0.006)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158
R-squared	0.219	0.499	0.015	0.288

	(5)	(6)	(7)	(8)
	OLS regression	Fixed-effect NB regressions		Population-averaged NB regression
	Originality	*Patents*	*Inventions*	*Citations*
Pre_academic	0.014***	0.016	0.087	0.784***
	(0.005)	(0.058)	(0.066)	(0.187)
Ln(1 + Papers)	0.011***	0.046***	0.074***	0.204***
	(0.001)	(0.012)	(0.014)	(0.046)
Ln(1 + Patent partner)	0.031***	0.667***	0.545***	0.802***
	(0.003)	(0.021)	(0.024)	(0.111)
Control variables	yes	yes	yes	yes
Fixed effects	year, firm	year, firm	year, ind.	year, ind.
Observations	12,158	9553	9091	12,158
R-squared	0.150			

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. *Pre_academic*, mechanism variables, and control variables are measured at time *t-1*. Estimates using selected dependent variables are presented due to space limitation.

** Significant at 5 %.

*** Significant at 1 %.

Table 9
Mechanism: knowledge workers' incentives.

	(1)	(2)	(3)	(4)
	Probit regression	OLS regressions		
	Stock options	*R&D/ sales*	*Self-citations*	*Exploration*
Pre_academic	0.420***	0.008***	0.002	0.041***
	(0.068)	(0.001)	(0.001)	(0.010)
Ln(1 + Papers)	(0.019)	0.001***	0.001***	0.036***
	(0.019)	(0.000)	(0.000)	(0.002)
Ln(1 + Patent partner)	0.187***	0.003***	0.001***	0.086***
	(0.037)	(0.001)	(0.000)	(0.006)
Stock options		0.007***	−0.001	0.045***
		(0.001)	(0.001)	(0.010)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.
Observations	9990	12,158	12,158	12,158
R-squared		0.503	0.015	0.289

	(5)	(6)	(7)	(8)
	OLS regression	Fixed-effect NB regressions		Population-averaged NB regression
	Originality	*Patents*	*Inventions*	*Citations*
Pre_academic	0.012**	−0.022	0.056	0.296*
	(0.005)	(0.058)	(0.066)	(0.155)
Ln(1 + Papers)	0.011***	0.061***	0.104***	0.209***
	(0.001)	(0.013)	(0.015)	(0.046)
Ln(1 + Patent partner)	0.030***	0.602***	0.515***	0.794***
	(0.003)	(0.023)	(0.025)	(0.098)
Stock options	0.025***	1.233***	1.049***	1.964***
	(0.006)	(0.043)	(0.046)	(0.153)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	9553	9091	12,158
R-squared	0.153			

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. *Pre_academic*, mechanism variables, and control variables are measured at time *t-1*. Estimates using selected dependent variables are presented due to space limitation.

* Significant at 10 %.

** Significant at 5 %.

*** Significant at 1 %.

Citations decreases by over 60 %. Overall, our findings suggest that providing incentives to knowledge workers in the form of stock options can partially explain the innovation effects of academic executives, which supports Hypothesis C3.

Note that our examination of the heterogeneous effects provides evidence that the impacts of academic executives vary by their academic title, administrative experience, and specialization. We explore whether our proposed mechanisms explain the heterogeneous effects in Table A.9. After controlling for the three mechanisms, we observe large decreases in the estimated effects of academic executives of different academic background, which further confirm the validity of our proposed mechanisms. Overall, the mechanism analysis demonstrates that enhanced basic research, expanded collaboration, and increased knowledge workers' incentives brought about by academic executives contribute to improved corporate technological capabilities and innovation performance.[12]

6.4. Other potential explanations

In this section, we investigate two other potential explanations that may illustrate the innovation effects of academic executives. First, firms with academic executives might be established and/or operated by universities (e.g., Eun et al., 2006). These firms have the advantage of commercializing new technologies, which may lead to better innovation performance than other types of firms. Thus, it may be the special corporate ownership structure, rather than the research experience of academic executives, that affects corporate innovation. To examine this possibility, we construct a variable, *University,* using data from the Wind Database to identify firms with the majority shareholder being a university. If *University* plays an important role in determining corporate innovation, the effects of academic executives would decrease and become insignificant after controlling for this variable. Panel A of Table A.10 presents that after controlling for *University*, the estimated effects of academic executives are similar to the ones from the baseline model. Overall, we find little evidence that having a university as the majority shareholder contributes largely to the innovation effects of academic executives. This result also suggests that, compared to having the majority shareholder being a university, having academic executives is more important in enhancing technological capabilities and fostering innovation performance among our sample firms.

Second, given the evidence that firms with more diversified boards tend to have a higher level of innovation (Bernile et al., 2018; Talke et al., 2010), we examine whether increased diversity of the board explains the innovation effects of academic executives. We combine five director characteristics (gender, service on outside boards, age,

[12] We altered the order of addition of the mechanisms to the baseline model and obtained similar findings.

bachelor's degree offered institutions, and financial expertise) and construct the variable *Diversity* describing the board diversity.[13] In Panel B of Table A.10, we do not observe decreases in estimated effects of academic executives in most columns after considering board diversity. As a result, we rule out board diversity as a potential explanation.

7. Effects of academic executives' innovation strategies on corporate financial performance

The literature on technological catch-up supports that an enhancement in technological capabilities has the potential to increase the profitability of firms (Lee, 2013; Odagiri and Gotō, 1996). Can academic executives' innovation strategies contribute to better corporate financial performance? In this section, we attempt to answer this question to present a more comprehensive assessment on the effects of academic executives and uncover how their innovation strategies affect corporate financial performance. In Panel A of Table 10, we examine the impacts of academic executives on corporate financial performance. On average, compared to their counterparts without academic executives, we find that firms with these executives have a better financial performance in *Ln*(*Sales per employee*), *Profit margin*, *ROA*, and *Tobin's Q*. This is in line with the empirical evidence that executives' academic background contributes to corporate productivity (Jiang and Murphy, 2007). Further, although it is less precisely estimated, the coefficient on *Dividend payout ratio* is negative and sizable, suggesting academic executives are not positively associated with distributing dividends. In the last column, we find that firms with academic executives have a higher *Cash holding ratio*.[14] By keeping a relatively large proportion of profits inside the firm, firms with academic executives show characteristics that are similar to firms that sought technological catch-up in Japan (Odagiri and Gotō, 1996). Combining this with the finding that firms with academic executives have a higher R&D investment intensity in Table 3, it can be inferred that these firms may be inclined to transfer profits to internal reinvestment, such as R&D, that benefits corporate development. Thus, Hypothesis D is supported.

To further examine how academic executives' innovation strategies affect corporate financial performance, based on the specification in Panel A, we include interaction terms of academic executives and the two types of innovation output (*Pre_academic* × *Inventions* and *Pre_academic* × *Non-inventions*, measured at time *t-1*) in Panel B. The statistically significant and positive estimated coefficients of *Pre_academic* × *Inventions* reveal that academic executives significantly improve *Ln*(*Sales per employee*), *Profit margin*, and *ROA* through the enhancement of the quality of innovation. By contrast, *Pre_academic* × *Non-inventions* does not have positive effects on corporate financial performance. Thus, our findings suggest that fostering innovation output of a good quality, rather than just quantity, brought about as a result of academic executives contribute to the improvement of firms' sales and profitability. These findings are consistent with the related empirical evidence in the technological catch-up literature (Lee, 2013; Odagiri and Gotō, 1996). Note that we demonstrate positive correlations between academic executives and various measures of corporate financial performance in this section. A rigorous establishment of a causal relationship is important and needs a more thorough examination, but is outside the scope of this study.

8. Conclusions

As China continues to relax its regulations on the flow of researchers from academia to firms, an increasing number of firms started to have top executives with research experience. However, empirical evidence on the effects of academic executives on corporate outcomes is rare. In this study, based on the upper echelons theory and related literature on corporate innovation and technological catch-up, we contribute to the literature by studying the innovation effects of academic executives and the underlying mechanisms, and revealing the significance of the flow of academic researchers to key corporate decision-making positions on technological innovation.

Our findings demonstrate that academic executives are likely to reshape firms' innovation strategies by relying more on R&D activities, existing knowledge pool, basic research, and a wide knowledge base. Moreover, firms with academic executives have a higher quantity and quality of innovation output, as well as greater competitive advantages in the market, as represented by a larger number of industry and national standards. Further analysis shows that the effects of academic executives are more pronounced when they have a higher academic title, administrative experience in academia, and a specialization in sciences. The endogeneity issue is addressed using top executive turnover and the PSM approach, and our main conclusions are robust to a variety of robustness checks. In addition, we investigate the mechanisms and find that increased firm basic research, collaboration with outside institutions, and knowledge workers' incentives brought about by academic executives contribute to the enhanced corporate technological capabilities and innovation performance. Finally, we show that academic executives and their quality-enhanced innovation strategies contribute to better financial performances of firms in terms of higher sales and profitability. They are also more likely to keep a relatively high proportion of profits inside the firms and invest more in R&D than other executives.

These findings support the upper echelons theory by demonstrating that top executives' research experience has important effects on corporate innovation. Academic executives, who understand and value the importance of R&D due to their knowledge, experience, and resources in research, have an advantage in building corporate technological catch-up awareness and enhancing technological capabilities. In the context of China, our results reveal that academic executives implement innovation strategies that emphasize the cultivation of indigenous technological capabilities. Thus, encouraging academic researchers to start their own businesses or engage in top executive management are effective "forward engineering" strategies to foster the diffusion and utilization of technological knowledge and facilitate technological catch-up among Chinese manufacturing firms.

More generally, our findings have implications for firms in transition economies aimed at achieving technological catch-up. With stricter intellectual property rights protection in the world, it is important for firms seeking catch-up to cultivate their own technological capabilities. Our empirical analysis shows that top executives' research experience positively enhances corporate technological capabilities. Thus, for latecomer economies, policies targeted at enhancing corporate technological capabilities and innovation performance are recommended to further reduce the barriers to the flow of researchers from academia to industry. For example, encouraging and supporting the part-time or full-time entrepreneurship of academic researchers, and clarifying the ownership of the property rights of patents invented on the job by academic researchers. In addition, many firms in latecomer countries lack intrinsic motivation for technological catch-up even though the government provides sufficient R&D subsidies (Lee, 2019). This study finds that for corporate managers, appointing academic executives is an

[13] Specifically, following Bernile et al. (2018), we calculate the percentage of females on the board (Pct_female), the average number of other boards on which the current board members serve (Num_boards), the standard deviation of directors' age (Std_age), the Herfindahl concentration indices for the institutions where the directors received their bachelor's degree (HHI_bachelor), and the Herfindahl concentration indices for directors' financial expertise (HHI_finance). We then normalize these variables and define the variable *Board diversity* as Pct_female + Num_boards + Std_age-HHI_bachelor-HHI_finance.

[14] As a robustness check, we report the estimated effects of academic executives on corporate financial performance in general industries in Table A.11. We find strong and positive relationships between academic executives and *Ln* (*Sales per employee*), *Tobin's Q*, and *Cash holding ratio*.

Table 10
Estimated effects of academic executives on financial performance.

Panel A	*Ln(Sales per employee)*	*Profit margin*	*ROE*	*ROA*	*Tobin's Q*	*Dividend payout ratio*	*Cash holding ratio*
Pre_academic	0.081***	0.014**	0.008	0.004**	0.238***	−0.883	0.016***
	(0.024)	(0.006)	(0.006)	(0.002)	(0.057)	(1.227)	(0.005)
Inventions	0.028***	0.005***	0.007***	0.003***	0.142***	1.033**	0.004***
	(0.007)	(0.001)	(0.002)	(0.001)	(0.016)	(0.402)	(0.002)
Non-inventions	−0.024***	−0.002	−0.001	0.0001	−0.049***	0.074	0.001
	(0.006)	(0.001)	(0.001)	(0.001)	(0.013)	(0.353)	(0.001)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	12,158	10,877	12,158
R-squared	0.407	0.114	0.060	0.092	0.442	0.059	0.192

Panel B	*Ln(Sales per employee)*	*Profit margin*	*ROE*	*ROA*	*Tobin's Q*
Pre_academic	0.03	0.006	0.001	−0.001	0.252***
	(0.034)	(0.010)	(0.009)	(0.003)	(0.077)
Inventions	0.0214***	0.0043***	0.007***	0.003***	0.136***
	(0.007)	(0.002)	(0.002)	(0.001)	(0.016)
Non-inventions	−0.021***	−0.002	−0.001	0.000	−0.042***
	(0.007)	(0.001)	(0.001)	(0.001)	(0.014)
Pre_academic × inventions	0.080***	0.010*	0.008	0.006***	0.086
	(0.025)	(0.006)	(0.005)	(0.002)	(0.057)
Pre_academic × non-inventions	−0.028	−0.001	0.0001	−0.0003	−0.106**
	(0.022)	(0.004)	(0.004)	(0.002)	(0.045)
Control variables	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	12,158
R-squared	0.407	0.114	0.060	0.093	0.442

Notes: Control variables include *Ln*(*Asset*), *Ln*(*Firm age*), *Ln*(*PPE per employee*), *and Stock volatility*. *Pre_academic*, *Inventions*, *Non-inventions*, and control variables are measured at time *t-1*. OLS regressions are used. Robust standard errors are in parenthesis.
* Significant at 10 %.
** Significant at 5 %.
*** Significant at 1 %.

important strategic managerial decision that is beneficial for providing an internal driving force for corporate technological progress. Particularly, in the appointment of top executives, it is advised that firms consider executives with research experience, especially those with a senior academic title, administrative experience, and a specialization in sciences if the goal is to enhance firms' ability to achieve technological catch-up.

Due to data limitation, the variables representing academic executives are categorical variables. Further investigation on the quality of top executives' research experience, such as examining academic executives by publication indices, is an avenue for future research. It is also worth investigating how the flow of researchers from academia to firms affect the technological capabilities of universities and research institutions. In addition, we have demonstrated the importance of encouraging the flow of academic researchers to corporate key decision-making positions in fostering corporate technological capabilities and innovation performance. Given data limitations, we are not able to control for the effects of employees in lower positions with academic background. A possible extension is to account for the effects of academic workers in a firm. Further, additional data, such as data on joint research projects between academic executives' previous academic institutions and current firms, are needed to examine in detail how, and to what extent, academic executives promote collaboration between industry, universities, and research institutions.

CRediT authorship contribution statement

Xiaosheng Ju: Conceptualization, Methodology, Software, Formal analysis, Funding acquisition. **Shengjun Jiang:** Methodology, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing, Funding acquisition. **Qifeng Zhao:** Resources, Data curation, Software.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

Table A.1
Selected related major policies on the management of STP.

Year	Selected related major policies	Summary of policies
1981	The General Office of the Communist Party of China (CPC) Central Committee and the General Office of the State Council (State Council) issued the "Trial Regulations on the Management of Scientific and Technical Cadres."	Science and technology leaders may accept temporary employment from outside units upon the completion of their own work and with the consent of their units.
1985	The CPC Central Committee issued the "Decision on the Reform of the Science and Technology System."	The waste of talents must be changed, and the rational flow of STP must be promoted. Upon the completion of their work, STP are allowed to accept part-time jobs to promote knowledge exchange and fully realize their potential.
1986	The State Council issued the "Notice on Promoting the Reasonable Flow of STP."	Encourage collaboration as well as technological and economic cooperation between firms and institutions, and allow STP to transfer, involve in secondment, and perform part-time jobs.
1993	The Standing Committee of the Eighth National People's Congress adopted the "Law of the People's Republic of China on Progress of Science and Technology."	Governments and firms and institutions shall provide conditions for the rational flow of STP, and encourage them to make full use of their expertise.
1996	The Standing Committee of the Eighth National People's Congress adopted the "Law of the People's Republic of China on Promoting the Transformation of S&T Achievements."	Encourage R&D institutions, higher education institutions, and other institutions to collaborate with firms to jointly implement the transformation of technological achievements.
1999	The State Council forwarded the "Regulations on Promoting the Transformation of S&T Achievements" formulated by the Ministry of Science and Technology and other departments.	STP may perform part-time research and transform scientific achievements in other units under the premise of completing their own work. Colleges and universities should establish rules to standardize and guarantee such activities.
2006	The State Council issued the "National Medium- and Long-Term Science and Technology Development Plan Outline (2006–2020)."	Encourage and guide STP from scientific research and higher education institutions to innovate and start businesses and allow them to work part-time in firms to carry out technological activities.
2015	The Standing Committee of the 12th National People's Congress amended the "Law of the People's Republic of China on Promoting the Transformation of S&T Achievements."	Encourage R&D institutions, higher education institutions, and firms and other organizations to carry out exchanges of STP and support them to enter firms and other organizations to engage in the transformation of S&T achievements.
2016	The General Office of the CPC Central Committee issued the "Opinions on Deepening the Reform of Institutional Mechanism for Talent Development."	Encourage and support innovation and entrepreneurship, and formulate policies on the leave of STP in universities and scientific research institutions.
2017	The Ministry of Human Resources and Social Security of China issued the "Guiding Opinions on Supporting and Encouraging Innovation and Entrepreneurship among Professional and Technical Personnel in Public Institutions."	Support and encourage professional and technical personnel in public institutions to innovate in part-time jobs or start a business while employed.

Table A.2
Distribution of year when academic executives appeared for the first time in a firm.

Year	Number of firms	Percent
2002	7	3.68
2003	9	4.74
2004	7	3.68
2005	7	3.68
2006	8	4.21
2007	12	6.32
2008	8	4.21
2009	15	7.89
2010	24	12.63
2011	13	6.84
2012	9	4.74
2013	4	2.11
2014	12	6.32
2015	21	11.05
Total	190	100

Note: Due to data limitation, we do not have information on the number of firms that started to have academic executives for the first time in 2001.

Table A.3
Comparisons between high-tech and general industries.

Variables	Firms in high-tech industries			Firms in general industries		
	Without AE ($N = 5691$)	With AE ($N = 501$)	Difference in mean	Without AE ($N = 7419$)	With AE ($N = 384$)	Difference in mean
	Mean	Mean		Mean	Mean	
R&D/sales	0.031	0.046	0.015***	0.015	0.018	0.003***
Self-citations	0.001	0.001	0	0.001	0.005	0.004***
Exploration	0.156	0.199	0.043***	0.132	0.193	0.061***
Originality	0.060	0.089	0.029***	0.046	0.045	−0.001
Ln(1 + Patents)	1.427	1.617	0.190***	1.028	0.981	−0.047
Ln(1 + Inventions)	0.870	1.079	0.209***	0.593	0.730	0.137***

(*continued on next page*)

Table A.3 (*continued*)

Variables	Firms in high-tech industries			Firms in general industries		
	Without AE ($N = 5691$)	With AE ($N = 501$)	Difference in mean	Without AE ($N = 7419$)	With AE ($N = 384$)	Difference in mean
	Mean	Mean		Mean	Mean	
Ln(1 + Citations)	1.474	1.731	0.257***	1.035	1.128	0.093
Standards	0.540	0.527	−0.013	0.555	0.729	0.174**
Ln(Sales per employee)	6.349	6.342	−0.008	6.508	6.511	0.003
Profit margin	0.090	0.132	0.042***	0.061	0.061	0.001
ROE	0.062	0.071	0.009	0.054	0.057	0.003
ROA	0.047	0.056	0.009***	0.045	0.045	0
Tobin's Q	2.508	3.104	0.596***	1.839	2.295	0.456***
Dividend payout ratio	29.955	33.962	4.007**	31.325	25.286	−6.039***
Cash holding ratio	0.263	0.292	0.029***	0.210	0.222	0.011

Notes: "AE" stands for academic executives. According to the classification of high-tech manufacturing industries in China, high-tech industries include pharmaceutical manufacturing, aerospace and equipment manufacturing, electronic and communication equipment manufacturing, computer and office equipment manufacturing, medical instrument equipment and instrumentation manufacturing, and information chemical manufacturing. The numbers of observations for *Originality* are 6903, 521, 3559, and 186, respectively. The numbers of observations for *Dividend payout ratio* are 11,817, 806, 6619, and 340, respectively. ** and *** indicate that difference in the mean is not equal to zero at the 5 % and 1 % level, respectively.

Table A.4
Estimates of control variables that are not reported in Table 3.

	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Ln(Assets)	0.0004	0.0001	0.0305***	0.0096***	0.3654***	0.4109***	1.7274***	1.4960***
	(0.000)	(0.000)	(0.003)	(0.002)	(0.021)	(0.025)	(0.090)	(0.058)
Ln(Firm age)	−0.0063***	−0.0001	−0.0288***	−0.0115***	−0.4011***	−0.1790***	−5.3675***	−3.1401***
	(0.000)	(0.000)	(0.004)	(0.002)	(0.033)	(0.039)	(0.099)	(0.115)
Ln(PPE per employee)	0.0019***	0.0002	−0.0100***	−0.0036**	−0.1164***	0.0145	−0.1789**	−0.6839***
	(0.000)	(0.000)	(0.004)	(0.002)	(0.025)	(0.028)	(0.073)	(0.075)
Sales growth	0.0008	−0.0003	0.0085	0.0063	−0.4580***	−0.3898***	−0.0246	−1.0015***
	(0.001)	(0.000)	(0.007)	(0.004)	(0.042)	(0.044)	(0.192)	(0.109)
Book to market ratio	−0.0028***	0.0007	−0.0122**	0.0002	0.0146	0.1376***	−0.7997***	−0.4846***
	(0.000)	(0.001)	(0.005)	(0.003)	(0.025)	(0.026)	(0.127)	(0.064)
Leverage	−0.0180***	−0.0013	−0.0612***	−0.0148**	−2.6120***	−2.7603***	−4.7337***	−5.1017***
	(0.002)	(0.001)	(0.016)	(0.008)	(0.110)	(0.125)	(0.346)	(0.369)
Stock return	0.0002	0.0001	−0.0174***	−0.0037	−0.0412***	−0.0168	0.6726***	0.0523
	(0.001)	(0.000)	(0.005)	(0.003)	(0.015)	(0.016)	(0.057)	(0.034)
Stock volatility	0.0013	−0.0001	−0.0179	0.0048	1.4061***	1.0256***	−2.1329***	−0.1837
	(0.003)	(0.002)	(0.030)	(0.015)	(0.084)	(0.090)	(0.342)	(0.270)
Herfindahl	−0.0681***	−0.0235***	−1.3743***	−0.1714**	−6.7747***	−3.8801***	0.6599	4.3836*
	(0.013)	(0.006)	(0.137)	(0.080)	(0.865)	(0.973)	(3.589)	(2.240)
Herfindahl^2	0.2340***	0.0495***	3.0855***	0.3374*	13.5027***	8.1137***	−24.1664**	−16.8135**
	(0.029)	(0.014)	(0.322)	(0.179)	(2.128)	(2.333)	(9.435)	(7.460)
Ln(Sales per employee)	−0.0042***	0.0000	0.0010	−0.0023	0.3895***	0.2103***	0.4785***	1.4590***
	(0.000)	(0.000)	(0.003)	(0.002)	(0.024)	(0.028)	(0.058)	(0.064)
ROA	−0.0073	−0.0001	0.0656	0.0544**	−0.5825**	0.6307**	−3.7956***	−5.8048***
	(0.005)	(0.003)	(0.046)	(0.023)	(0.275)	(0.314)	(0.906)	(0.677)
Cash holding ratio	0.0125***	−0.0001	−0.0082	0.0044	1.3313***	1.6804***	−2.6580***	−2.6647***
	(0.002)	(0.001)	(0.021)	(0.011)	(0.116)	(0.126)	(0.509)	(0.388)

Notes: Robust standard errors are in parenthesis. Control variables are measured at time *t-1*.
* Significant at 10 %.
** Significant at 5 %.
*** Significant at 1 %.

Table A.5
Balance test before and after the PSM.

Variable	Unmatched	Mean		% bias	%reduction	*t*-Test	
	Matched	Treated	Untreated		|bias|	t	p > |t|
Ln(Assets)	U	7.366	7.677	−30.1		−7.66	0
	M	7.366	7.315	4.9	83.6	1.02	0.308
Ln(Firm age)	U	1.819	1.991	−25.6		−6.7	0
	M	1.819	1.828	−1.4	94.3	−0.27	0.784
Ln(PPE per employee)	U	5.359	5.390	−3.7		−0.95	0.341
	M	5.359	5.369	−1.2	66.5	−0.24	0.81
Ln(Sales per employee)	U	6.384	6.402	−2.2		−0.55	0.582
	M	6.384	6.415	−3.7	−70.5	−0.72	0.473
ROA	U	0.052	0.048	9		2.36	0.018
	M	0.052	0.050	5.1	43.8	0.95	0.34
Sales growth	U	0.194	0.176	5.8		1.56	0.119
	M	0.194	0.184	3.2	45.1	0.62	0.539

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Table A.5 (*continued*)

Variable	Unmatched / Matched	Mean: Treated	Mean: Untreated	% bias	%reduction |bias|	t-Test: t	t-Test: p > |t|
Book to market ratio	U	0.660	0.842	−30.6		−7.45	0
	M	0.660	0.634	4.4	85.5	1.04	0.297
Leverage	U	0.394	0.432	−17.5		−4.81	0
	M	0.394	0.385	4.4	74.9	0.84	0.401
Cash holding ratio	U	0.268	0.239	17.9		4.92	0
	M	0.268	0.266	1.4	92.1	0.26	0.793
Stock return	U	0.237	0.232	0.7		0.18	0.858
	M	0.237	0.238	−0.1	86.2	−0.02	0.985
Stock volatility	U	0.458	0.446	10		2.62	0.009
	M	0.458	0.455	2.3	77.4	0.43	0.668
Herfindahl	U	0.077	0.082	−7.7		−2.03	0.042
	M	0.077	0.072	7.3	5.3	1.54	0.123
Number of universities in a firm's province	U	6.190	5.801	16.4		4.44	0
	M	6.190	6.176	0.6	96.4	0.11	0.913
Institutional ownership percentage	U	27.774	29.960	−9.2		−2.36	0.018
	M	27.774	26.227	6.5	29.2	1.29	0.196
Number of directors on board	U	8.910	8.983	−4.2		−1.06	0.291
	M	8.910	8.874	2.1	50	0.42	0.673
Number of executives	U	6.205	6.491	−12.5		−3.11	0.002
	M	6.205	6.114	4	68.1	0.84	0.403
At least one executive is an inventor	U	0.444	0.378	13.5		3.59	0
	M	0.444	0.416	5.7	57.4	1.1	0.272

Table A.6
Robustness checks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Panel A. Chairperson of the board with research experience								
Chair_academic	0.012***	0.003	0.046***	0.018***	0.061	0.187**	0.941***	1.804***
	(0.001)	(0.002)	(0.012)	(0.006)	(0.071)	(0.084)	(0.225)	(0.312)
Controls Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
Panel B. CEO with research experience								
CEO_academic	0.009***	0.002**	0.075***	0.020***	0.409***	0.418***	0.560**	1.447***
	(0.001)	(0.001)	(0.014)	(0.007)	(0.069)	(0.076)	(0.227)	(0.349)
Controls Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
Panel C: Lag period of three years for academic executives								
Pre_academic	0.009***	0.003	0.043***	0.016**	0.198***	0.261***	0.513***	0.900***
	(0.001)	(0.002)	(0.012)	(0.006)	(0.068)	(0.077)	(0.171)	(0.237)
Controls Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	9154	9154	9154	9154	7064	6650	9154	9154
Panel D. Eliminate firms with zero granted patents								
Pre_academic	0.010***	0.004*	0.083***	0.025***	0.125**	0.225***	0.671***	0.994***
	(0.001)	(0.002)	(0.013)	(0.008)	(0.056)	(0.067)	(0.203)	(0.262)
Controls Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	6534	6534	6534	6534	6379	6237	6534	6534
Panel E. Eliminate firms in Beijing, Shanghai, Guangzhou, and Shenzhen								
Pre_academic	0.008***	0.002	0.054***	0.010	0.030	−0.131	0.712***	1.400***
	(0.001)	(0.002)	(0.014)	(0.006)	(0.077)	(0.091)	(0.233)	(0.294)
Controls Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	9798	9798	9798	9798	7689	7295	9798	9798
Panel F. Eliminate firms that have participated in foreign mergers and acquisitions in the past two years								
Pre_academic	0.009***	0.003*	0.063***	0.022***	0.216***	0.324***	1.079***	1.068***
	(0.001)	(0.002)	(0.011)	(0.006)	(0.064)	(0.074)	(0.237)	(0.233)

(*continued on next page*)

Table A.6 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Controls Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	9973	9973	9973	9973	7569	7234	9973	9973

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. Variables representing academic executives and control variables are measured at time *t-1* (except that *Pre_academic* is measured at *t-3* in Panel C).

* Significant at 10 %.

** Significant at 5 %.

*** Significant at 1 %.

Table A.7

Estimated interaction effects of academic executives and high-tech industries.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Pre_academic	0.003***	0.005	0.079***	0.005	0.041	−0.089	0.488*	1.818***
	(0.001)	(0.003)	(0.017)	(0.007)	(0.099)	(0.105)	(0.272)	(0.386)
High-tech	0.012***	−0.001***	−0.019***	0.009***	0.298***	−0.536***	1.584***	0.376***
	(0.000)	(0.000)	(0.005)	(0.003)	(0.046)	(0.085)	(0.142)	(0.140)
Pre_academic × *High-tech*	0.010***	−0.005	−0.041*	0.024**	0.048	0.406***	0.037	−1.029**
	(0.002)	(0.003)	(0.021)	(0.011)	(0.122)	(0.134)	(0.370)	(0.485)
Controls variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.457	0.010	0.227	0.121				

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. *Pre_academic*, *High-tech*, and control variables are measured at time *t-1*.

* Significant at 10 %.

** Significant at 5 %.

*** Significant at 1 %.

Table A.8

Estimated innovation effects of academic executives: Excluding firms in high-tech industries.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Pre_academic	0.004***	0.005	0.080***	0.006	0.301***	0.297***	0.017	0.785***
	(0.001)	(0.003)	(0.017)	(0.007)	(0.103)	(0.114)	(0.239)	(0.299)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	6852	6852	6852	6852	5351	5056	6852	6852
R-squared	0.487	0.015	0.233	0.120				

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. *Pre_academic* and control variables are measured at time *t-1*.

*** Significant at 1 %.

Table A.9

Explaining the effects of academic executives by academic title, administrative experience, and academic specialization.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Panel A. Estimated effects by academic title after controlling for firm basic research, collaboration, and knowledge workers' incentives								
Pre_senior	0.009***	0.003	0.052***	0.015**	−0.163**	−0.124	0.259	0.628**
	(0.001)	(0.002)	(0.013)	(0.007)	(0.073)	(0.081)	(0.199)	(0.277)
Pre_junior	0.006***	0.002**	0.028*	0.008	0.230**	0.432***	0.344	1.407***
	(0.002)	(0.001)	(0.015)	(0.008)	(0.091)	(0.108)	(0.237)	(0.414)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.503	0.015	0.290	0.153				

(*continued on next page*)

Table A.9 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Panel B. Estimated effects by administrative experience after controlling for firm basic research, collaboration, and knowledge workers' incentives								
Pre_administr	0.011***	0.004	0.073***	0.020**	0.026	0.213**	0.476**	1.782***
	(0.002)	(0.003)	(0.015)	(0.008)	(0.081)	(0.093)	(0.209)	(0.363)
Pre_noadministr	0.005***	0.001	0.015	0.005	−0.068	−0.088	0.096	0.406
	(0.001)	(0.001)	(0.013)	(0.007)	(0.081)	(0.092)	(0.224)	(0.274)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.504	0.015	0.290	0.153				
Panel C. Estimated effects by academic specialization after controlling for firm basic research, collaboration, and knowledge workers' incentives								
Pre_sciences	0.011***	0.003	0.042***	0.014**	0.072	0.178**	0.348*	1.452***
	(0.001)	(0.002)	(0.012)	(0.006)	(0.068)	(0.079)	(0.191)	(0.279)
Pre_nosciences	−0.002*	0.000	0.039**	0.006	−0.236**	−0.191	0.007	0.004
	(0.001)	(0.001)	(0.018)	(0.009)	(0.107)	(0.117)	(0.302)	(0.437)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.505	0.015	0.289	0.153				

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. Variables representing different types of academic executives and control variables are measured at time *t-1*.

* Significant at 10 %.

** Significant at 5 %.

*** Significant at 1 %.

Table A.10
Other potential explanations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS regressions				Fixed-effect NB regressions		Population-averaged NB regressions	
	R&D/sales	*Self-citations*	*Exploration*	*Originality*	*Patents*	*Inventions*	*Citations*	*Standards*
Panel A. Majority shareholder is a university								
University	−0.0070***	−0.0011**	−0.0379*	0.0063	−0.8214***	−1.8665***	−1.5165***	−1.0170
	(0.002)	(0.001)	(0.021)	(0.012)	(0.184)	(0.198)	(0.469)	(0.717)
Pre_academic	0.0089***	0.0025*	0.0600***	0.0180***	0.0941	0.1368**	0.6993***	1.3325***
	(0.001)	(0.001)	(0.010)	(0.005)	(0.058)	(0.066)	(0.191)	(0.240)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.493	0.012	0.244	0.130				
Panel B. Board diversity								
Diversity	−0.0002***	0.0001	−0.0006	0.0002	0.1203***	0.1126***	0.1335***	0.1987***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.006)	(0.007)	(0.019)	(0.018)
Pre_academic	0.0087***	0.0024*	0.0591***	0.0181***	0.1388**	0.2190***	0.7754***	1.3209***
	(0.001)	(0.001)	(0.010)	(0.005)	(0.058)	(0.067)	(0.190)	(0.235)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, firm	Year, firm	Year, ind.	Year, ind.
Observations	12,158	12,158	12,158	12,158	9553	9091	12,158	12,158
R-squared	0.493	0.012	0.244	0.130				

Notes: Robust standard errors are in parenthesis. Control variables are the same as the ones in Table 3. *Pre_academic*, *University*, *Diversity*, and control variables are measured at time *t-1*.

* Significant at 10 %.

** Significant at 5 %.

*** Significant at 1 %.

Table A.11
Estimated effects of academic executives on financial performance: Excluding firms in high-tech industries.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Ln(Sales per employee)	*Profit margin*	*ROE*	*ROA*	*Tobin's Q*	*Dividend payout ratio*	*Cash holding ratio*
Pre_academic	0.227***	0.002	0.005	0.001	0.259***	−4.209**	0.023***
	(0.042)	(0.009)	(0.009)	(0.003)	(0.078)	(1.661)	(0.007)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, ind.	Year, ind.
Observations	6852	6852	6852	6852	6852	6060	6852
R-squared	0.986	0.093	0.063	0.088	0.415	0.457	0.136

Notes: Robust standard errors are in parenthesis. OLS regressions are used. Control variables are the same as the ones used in Table 10. *Pre_academic* and control variables are measured at time *t-1*.
** Significant at 5 %.
*** Significant at 1 %.

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