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ESSAYS ON INSTITUTIONS AND INNOVATION

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Introduction

Institutions and institutional changes play a pivotal role in the global economy and are a key determinant of innovation and innovation activities. This thesis examines the complex interplay between institutional environments and innovation, using China as a case study due to its unique and rapidly evolving economic landscape as well as global economic relevance. China's transformation into a major economic power has been significantly influenced by institutional changes, which in turn affect firm behaviors and innovation outcomes, both at the firm level and in terms of research output. Understanding these dynamics offers insights not only into China's economic development but also into broader implications for global economic practices and policies.

Chapter 1 delves into how weak formal institutional environments in China impact the market valuation of innovation inputs, such as research and development (R&D), and outputs, like patents. This chapter draws on the Resource-Based View (RBV) to argue that a positive market valuation of innovative assets is crucial for the firms' credibility as innovators and for facilitating future innovation activities financing, which are pivotal in attaining a sustainable competitive advantage, but can be hindered by institutional uncertainty. Using a dataset of publicly listed firms in China, we show that in weak institutional environments, both R&D and patents face a lower market valuation. As the signalling power of patents appears to be undermined by the weak institutional environment, this chapter shows that means with stronger signalling value, i.e. insider ownership, act as a signal for the value of innovative assets and increase their stock market valuation for firms located in weak institutional contexts.

Chapter 2 exploits the exogenous shock represented by Google's sudden withdrawal of its services from mainland China to assess the importance of access to information for the knowledge production function of scientific scholars in the field of economics. For economists, a type of scholar with a simple knowledge production function, results from difference-in-difference analyses, which compare their scientific output to scholars located in the neighbouring regions, show that the scientific productivity declines by about 28%

in volume and 30% in terms of citations. These results are consistent with the view that information accessibility is an important driver of scientific progress and highlight the importance of institutional changes in research output. Considering that the negative effect of the shock is stronger for top scholars located in China, Google's sudden exit bears the risk that researchers lose touch with the research frontier and persistently lag behind their foreign peers in this field.

In Chapter 3, I build on a growing body of literature which focuses on the connection between CEOs' pre-career experiences and firms' strategic choices and policies, and proposes that CEOs' set of values and beliefs, crucial factors in their own strategic choice-making processes, are imprinted by such experiences. I argue that CEOs who have been exposed to the pro-social, Confucian ideology during their childhood, i.e. the period of highest 'susceptibility', will reflect these social values into their firms, among others, when it comes to their firms' corporate science strategy. Recognizing their firms' potential to contribute positively to society by increasing the stock of publicly available knowledge, a metric that is directly related to innovation and social benefits, pro-social CEOs will tend to publish more of their firms' research through scientific publications, therefore, attaining their personal-life, Confucian goals. These pro-social predictions are supported by an analysis of Chinese listed firms between 2007 and 2021 and highlight the relevance of informal institutions on innovation strategies.

Throughout this thesis, the overarching narrative is that both formal and informal institutional factors as well as institutional changes critically shape innovation practices and outcomes, defined as the production of new knowledge which can also take the form of academic publications. By studying these phenomena within the context of China, a country at the intersection of traditional values and modern economic pressures, this research contributes to a deeper understanding of how institutions can either foster or hinder innovation and growth. The insights gleaned not only enhance academic discourse but also inform policymakers and business leaders aiming to cultivate environments that support innovative activities.

Chapter 1

Insider ownership and the value of innovation in weak institutional environments

Keywords: Innovation; Assets; Market valuation; Institutions; Insider ownership

This chapter is based on joint work with Katrin Hussinger.

1.1 Introduction

The resource-based view (hereafter, RBV) explains heterogeneity among firms as a result of their different resource endowment (Barney, 1986a, 1991). Whenever a firm is capable of obtaining and utilizing valuable and rare resources and capabilities, which are in addition difficult to imitate, it can extract value, gain and sustain a competitive advantage, and generate abnormal returns (Amit & Schoemaker, 1993; Collis & Montgomery, 1995; Peteraf, 1993; Teece, Pisano & Shuen, 1997; Wernerfelt, 1984). Innovative assets, including research and development (R&D) and patents, have been identified as those resources with the greatest potential for generating a competitive advantage (Barney & Arikan, 2001; Crook, Ketchen Jr, Combs & Todd, 2008; Kogut & Zander, 1992; McGrath, Tsai, Venkataraman & MacMillan, 1996) thanks to their uniqueness, novelty, tacitness, and firm specificity (Amit & Schoemaker, 1993; Grant, 1991; He & Wang, 2009).

Given these characteristics, innovative assets are often surrounded by a high degree of information asymmetry and uncertainty (Arrow, 1963; Czarnitzki & Toole, 2011; Gans, Hsu, & Stern, 2008; Hottenrott, Hall & Czarnitzki, 2016; Hussinger & Pacher, 2019; Maskus, Milani & Neumann, 2019; Nemlioglu & Mallick, 2020), which can compromise their value assessment by the market (Akerlof, 1970; Capron & Shen, 2007; Maskus, Milani & Neumann, 2019; Shen & Reuer, 2005).[1] A positive valuation of a firm's innovative assets by the market is, nonetheless, of utmost importance (Priem & Butler, 2001a) as it reduces asymmetric information between insiders and outsiders and improves the innovating firm's credibility and reputation (Arora, Fosfuri & Gambardella, 2001a; Helmers and Rogers, 2011; Long, 2002). In addition, the positive acknowledgment of the value of the firm's innovative assets by the stock market serves as an indication of the firm's ability to convert research investments into potentially valuable knowledge (Levitas & McFadyen, 2009), and it eases the process of securing funding for future R&D. This, in turn, results in

[1] When information relevant to evaluating a firm's assets is scarce or unreliable, investors lower the price that they are willing to pay as they discount their offer as compensation for purchasing more uncertain and riskier assets. In other words, to avoid overpaying for a firm's assets, under uncertainty, investors reduce the price they are willing to pay (Akerlof, 1970; Capron & Shen, 2007; Coff, 1999; Maskus, Milani & Neumann, 2019; Shen & Reuer, 2005).

lower capital costs, ultimately contributing to the generation of future profits and company growth (Hottenrott, Hall & Czarnitzki, 2016; Lev, Sarath & Sougiannis, 2005). In other words, a positive valuation of a firm's innovative assets by the market is an important step toward the firm's ability to create and sustain a competitive advantage from innovation (Priem & Butler, 2001a).

The literature on the market valuation of innovative assets has, so far, focused on developed institutional environments and demonstrates that stock markets' valuations reflect the value of investments in innovative assets positively (Bloom & Van Reenen, 2002; Griliches, 1981; Hall, Jaffe & Trajtenberg, 2005; Shleifer & Vishny, 1997; Toivanen, Stoneman & Bosworth, 2002). This means that markets acknowledge that these investments can lead to future profits. Still, these results cannot be taken for granted for institutional contexts that are relatively unstable and characterized by weak institutions including poor enforcement of property rights, investors' protection, and information disclosure laws, such is the case in the majority of the developing economies (Amankwah-Amoah, Boso & Kutsoati, 2022). Our first research question, therefore, reads: are innovative assets of firms operating in weak institutional environments valued positively by the market?

We expect that in a weak institutional environment, the higher degree of institutional uncertainty can lead to a reduced market valuation of innovative assets therefore weakening the firm's credibility as an innovator towards its investors and competitors, indicating that innovation activities are not generating the expected returns or are perceived as risky by the market, and raising the cost of capital for future innovation initiatives so that future innovation, profits, and growth are impacted (Hottenrott et al., 2016; Lev et al., 2005). Since firms' strategic choices are affected by the institutional framework in which they operate (Huang, Geng & Wang, 2017; Peng, Wang & Jiang, 2008), such an effect can perpetuate so that firms in weak institutional environments invest less in future innovation (Alam, Uddin & Yazdifar, 2019; Choi, Yoshikawa, Zahra & Han, 2014; Seitz & Watzinger, 2017). In other words, considering the circular connection between investment in R&D (stage 1), receiving a positive market valuation for that R&D investment (stage 2), and lower cost of capital and increased credibility as well as reputation from the positive market acknowledgement (stage 3), which then reconnects to the first stage of investment in R&D, if a firm does not observe a positive valuation of its R&D efforts from the market it might have to decrease its future investment in R&D, with all the well-established detrimental effects on its growth and future prospects.

Patents, instead, mark a successfully developed invention, i.e. the outcome of one or more R&D initiatives, which (1) have already been recognized by the firm as having enough market potential so as to choose to seek legal protection, and (2) are, compared to R&D, much less vulnerable to unfair misappropriation (Qian, Wang, Geng & Yu, 2017). In addition, as outlined by Long (2002), patents can be interpreted as a signal (see Spence, 1973) for the quality of the R&D activities of the firm indicating the success of an R&D initiative and its positive expected effect on future returns. Still, we expect that due to the weak institutional environment and the higher degree of institutional uncertainty as well as the low enforcement of IPR protection regulations, patents should also receive a reduced market valuation.

In this paper, we investigate the market value of innovative assets for firms operating in different institutional contexts by exploiting the variation in the level of institutional development of the 31 provinces, cities, and independent regions of China. Although China's formal institutions are weak in general (Huang et al., 2017; Zhao, 2006), regions in China are not equal in their degree of development (Huang et al., 2017). In fact, both scholarly research and anecdotal evidence suggest significant variations in, for example, the enforcement of IPR regulations across regional boundaries (Ang, Cheng & Wu, 2014; Dou, Ye, Ye & Pan, 2019; Liu, Lu, Peng & Wang, 2022; Ma, Tong & Fitza, 2013; Zhang, Crupi & Di Minin, 2020), which makes IPR *enforcement* dependent on local authorities' strategies and aims (Xiao, Han, Li, Ran, Zhou, & Tong, 2024).

We define innovative assets as R&D investment and patent applications (Christensen, 1995; Hussinger & Pacher, 2019). R&D investment can be seen as a measure of R&D input, but also a proxy for highly skilled employees and specialized equipment (Edworthy & Wallis, 2008; Koch & McGrath, 1996; Wright et al., 1994). The tacitness of the knowledge held by an R&D workforce (Polanyi, 1962; Polanyi, 1969) questions whether it is reflected appropriately in the market value of a firm when the institutional environment is weak and disclosure regulations are weakly enforced. In addition, due to weak IPR protection, investors might tend to discount the value of such R&D investments due to misappropriation concerns (Zhao, 2006), which might hinder the firm ability to benefit from the full returns of their investment. Patent applications, in contrast, serve as intellectual property protection means and contain codified knowledge. On the one hand, the downside of the codified knowledge contained in patents is that patented inventions are more easily imitable (Barney, 1991), especially in institutional environments with weak intellectual property protection, on the other hand, they still serve as a signal of the value of the invention they protect.

Our results show that both R&D investment and patents of firms operating in a weak institutional environment receive a reduced market valuation. The lower market valuation of patents belonging to firms in weak institutional contexts indicates that (1) there is a lack of confidence regarding the efficacy and reliability of the patent system's protective measures and (2) patents have a limited signalling value when institutions are weak.[2] For this reason, we consider insider ownership as an alternative, arguably stronger, means in weak institutional contexts that qualifies as a signalling device in the sense of Spence (1973). Insider ownership qualifies as a strong signal for the value of innovative assets because it is costly for the insiders who put their own wealth at risk, therefore, increased insider ownership signals strong confidence in the future value of the firm and its innovative assets. (Ahuja, Coff & Lee, 2005; Coff & Lee, 2003). More specifically, we inquire: can higher insider ownership signal the value of innovative assets therefore mitigating their reduced market valuation in weak institutional contexts?

Insider ownership or trading is a fiercely debated practice in developed institutional contexts (e.g. Bebchuk & Fershtman, 1994; Bhattacharya & Nicodano, 2001; Fischer, 1992; Leland, 1992; Manove, 1989; see also Bhattacharya, 2014 for a complete review of the debate on insider trading). Referring to the trading of shares by corporate officers, directors, and large stockholders of the traded company (Jaffe, 1974),[3] insider

[2] As discussed later, our within-country analysis allows us to rule out the hypothesis that the patented technology is simply not valuable. In fact, if this is true (and it is; see Prud'homme (2012)), it would equally affect both firms in weaker and stronger institutional contexts.

[3] Insider trading is a standard practice that becomes illegal only once it is proven that insiders have traded based on private information, still undisclosed to the public. Most insider trading, in fact, is “routine, legal, and far removed

trading can transmit credible signals to external investors because insiders risk their private wealth (Bagnoli & Khanna,1992; Coff & Lee, 2003; John & Lang, 1991; John & Mishra, 1990). Especially for innovative assets, investors can view increases in insider ownership as positive signals of the quality of the firm's resources and their future prospects (Coff & Lee, 2003). Our results confirm that increases in firm insiders' ownership are associated with higher market valuations of R&D therefore counteracting the R&D's lower market valuation in weak institutional contexts.

We make several contributions to the literature. First, a well-established stream of literature has found that investment in R&D is typically positively evaluated by the market (Bloom & Van Reenen, 2002; Griliches, 1981; Hall et al., 2005; Shleifer & Vishny, 1997; Toivanen et al., 2002) and therefore influences positively the value of the innovating firms as the expected future returns from innovation are positive. However, the vast majority of the studies investigate the effect of R&D on a firm market value in well-developed institutional contexts. Our study highlights that in weak institutional contexts, the market tends to allocate a lower market valuation to R&D due to the surrounding institutional uncertainty. Moreover, patenting in such contexts does not provide a signal for the value of the underlying R&D which is the case for well-developed institutional environments (Heger & Hussinger, 2017; Hsu & Ziedonis, 2013; Long, 2002).

Second, we add to the literature on the interplay between institutional contexts and innovation (see He & Tian, 2020, for a recent survey). This literature establishes that the institutional framework impacts firms' strategic choices and success (Huang et al., 2017; Peng, 2002; Peng, Sun, Pinkham & Chen, 2009), but it has mainly focused on the impact of institutions on the level of R&D investment. Our study extends to the effect of institutions on the *market value* of R&D and patents. In addition, the Chinese context, characterized by strong within-country heterogeneity in terms of legal and financial institutional development among regions that are relatively comparable to Western countries and regions that are lagging far behind, allows us to discern the effect of *local* institutions while keeping other socio-economic factors fixed as well as avoiding the standard issues arising from between-country comparisons. Furthermore, by

from headlines" (Coff & Lee, 2003, p. 183). For a current overview see Bainbridge (2021).

focusing on the case of China, our study answers the call put forth by Wickert, Potočnik, Prashantham, Shi & Snihur (2024) to embrace non-Western contexts in management research as they have the potential to unveil novel insights previously overlooked and to advance our understanding of management and organizations as a global phenomenon.

Third, we make a theoretical contribution to the RBV by clarifying an implicit, often overlooked assumption. Many studies, drawing from the RBV, fall short of acknowledging the importance of the recognition of the positive value of innovative assets by external parties to generate a sustainable competitive advantage from those assets (see Armstrong & Shimizu, 2007 for a review of empirical studies on the RBV). Priem & Butler (2001a) were the first to point out a potential "fallacy" in the RBV spanning from one of the main definitions in Barney (1991, p. 106) of 'valuable resources': "the RBV value definitions clearly show […] that it is the *market environment*, through opportunities and threats, that determines the degree of value held by each firm resource in the RBV." (Priem & Butler, 2001a, p. 29). They continue "RBV simplifies strategic analysis with an implicit assumption of homogeneous and immobile product markets (i.e., unchanging demand)[…]".[4] In this sense, not taking into consideration the market value of those assets might lead to erroneous conclusions. This point has been also recognized by Barney (2001, p. 42) who 'shifted the blame' to "resource-based theorists who have tried to examine the implications of resource-based logic without considering the market conditions under which a firm's resources will and will not be valuable". Our study emphasizes this theoretical point by showing that firms operating in a weak institutional environment receive a lower stock market value for their R&D.

Fourth, we propose preliminary evidence that certain strategies can be implemented by firms to signal the market value of R&D in weak institutional environments. The finding that outside investors interpret higher insider ownership (Dye, 1984; Leland, 1992; Levine, Lin & Wei, 2017; Manne, 1966; Merton, 1987) as well as company stock repurchases, i.e. yet another signalling action that can be undertaken by the firm

[4] As shown in their Figure 1, in fact, as the demand curve shifts also the value of the resource shifts indicating that the market demand is relevant to the definition of the 'valuable and rare resources and capabilities' that can lead to a competitive advantage.

(Bhattacharya, 1979; Lakonishok & Vermaelen, 1990; Vermaelen, 1981), as a positive signal concerning the firm's R&D value when institutions are weak, suggests stronger signals are needed in weak institutional environments.

1.2 Theory and Hypotheses

1.2.1 The resource-based view and the role of the market valuation of strategic assets

The RBV sees firms as bundles of assets and asserts that those resources that are valuable, rare, and costly to imitate are most likely to generate a sustainable competitive advantage (Barney, 1991; Wernerfelt, 1984). Innovative assets have been found to have the greatest potential for generating such an advantage and, hence, increasing future profits (Crook et al., 2008; Grant, 1996; Kogut & Zander, 1992). A long and well-established literature has built on the RBV and directed its focus toward the idea that firms can achieve and sustain a competitive advantage if they *possess* such strategic resources (Barney, 1991; Karadag & Poppo, 2023). In this paper, starting from the initial insights of Priem & Butler (1991a) and Barney (2001), we pose that this literature may have overlooked a crucial determinant of firm success derived from strategic resources, i.e. the market's perception and valuation of these strategic resources. The market value of a strategic asset (or any asset) is not solely determined by its inherent qualities or attributes but is also significantly influenced by the perceptions and beliefs that market participants hold regarding its value. In essence, the market's perception of the value of a strategic asset plays a pivotal role in shaping its market value as it drives its demand and the expectations regarding the future returns it will generate. If market participants perceive a strategic asset to be of low value or lacking in significance, they are likely to assign a lower or even negative valuation to it, irrespective of its actual potential to generate future returns. This phenomenon underscores the subjective, core nature of market valuation, where factors such as investor sentiment, prevailing market conditions, and informational asymmetries can profoundly impact perceptions of asset value. Consequently, firms must not only focus on developing and leveraging strategic assets but also actively manage and cultivate positive market perceptions to ensure that their assets are valued optimally in the marketplace. Failure to do so may result in the undervaluation of strategic assets, limiting their ability to contribute to firm performance and competitiveness. We argue, therefore, that it might not be sufficient for a firm to *possess* valuable and rare resources; rather, the market's positive assessment and recognition of these resources as sources of competitive advantage are equally essential. A positive acknowledgement of the value of innovative assets by the market is crucial in the process of generating a sustainable competitive advantage from innovative assets (Bowman & Ambrosini, 2001, Priem & Butler, 2001; Srivastava, Fahey & Christensen, 2001) because (1) it grants the firm credibility as an innovator which is associated with lower firm's risk (Helm, 2007) and higher sales and return on assets (Kotha, Rajgopal & Rindova, 2001; Roberts and Dowling, 2002), and can signal to competitors, customers, and stakeholders in general the firm's strength and capabilities, further bolstering its competitive position (Chauvin & Hirschey, 1993; Henard & Dacin, 2010), (2) it helps generating future profits from the innovative assets (Arora et al., 2001a; Long, 2002), and (3) it facilitates the financing of future R&D (Hottenrott et al., 2016; Lev et al., 2005). Therefore, to truly achieve a sustainable competitive advantage, firms must not only focus on acquiring and leveraging strategic resources but also actively manage and cultivate the market's perception and valuation of these resources.

1.2.2 Institutions and the market valuation of innovative assets

Prior studies examining the assessment of innovative assets' value by stock markets have focused on developed countries with stable institutional structures[5] (e.g. Bloom & Van Reenen, 2002; Chan, Lakonishok & Sougiannis, 2001; Griliches, 1981; Hall et al., 2005; Pindado, De Queiroz & De La Torre, 2010; Toivanen et al., 2002; see Czarnitzki, Hall & Oriani, 2006, for a survey), neglecting, or taking for granted, the influence of the institutional context. As Barney (2001, p.51), however, noted "the value of a firm's resources must be understood in the specific market context within which a firm is operating". Hence, particularly in emerging markets characterized by institutional changes and evolvements, it is crucial to

[5] To the best of our knowledge there exist only two exceptions which focus on India (Chadha & Oriani, 2010; Kanwar & Hall, 2015).

understand the role of the institutional framework as a key factor impacting the firms' ability to translate strategic resources into a sustainable competitive advantage (Oliver, 1997; Peng, Ahlstrom, Carraher & Shi, 2017a; Peng et al., 2008; Rodríguez-Pose and Zhang, 2020; Scott, 1995).

While institutional contexts are a complex bundle of different factors, such as policies, rules, and social structures, which may all affect firm-level innovation, the financial and legal dimensions of institutional development are widely accepted as the most relevant ones for innovation (Brown, Martinsson & Petersen, 2017; Maskus et al., 2019; Qian et al., 2017).[6] First, more developed equity markets improve firms' access to external sources of financing which are typically crucial to innovation activities (Hsu, Tian & Xu., 2014), and allow faster and more efficient information disclosures to investors providing timely and accurate securities' prices and assets' values (Moshirian, Tian, Zhang & Zhang, 2021). Second, more developed stock markets, as well as more developed and more strongly enforced IPR protection, increase investors' confidence in minimized unfair rent appropriation risk from firms' insiders or competitors which are prevalent in weaker institutional contexts (Qian et al., 2017) therefore improving market participation which then can lead to a fair assessment of firms' assets. Third, more efficient capital markets and credit allocation allow firms, especially smaller ones, to engage in innovation activities that are otherwise solely in the hands of incumbent firms who have the capital to invest in R&D, therefore the higher competition leads firms to disclose more information (Li, 2010) possibly resulting in, again, higher firms' market values. Fourth, more enforced property rights protection and investor protection, as well as more enforced contract regulations, reduce information asymmetries between insiders and outsiders, decrease the risk of rent misappropriation, and increase the market value of, especially, more opaque assets such as innovative ones (Himmelberg, Hubbard & Love, 2004). Fifth, more developed patent laws are crucial for firms to protect their returns; when properly enforced, patent laws improve investors' confidence that the firms can fairly appropriate the returns of their R&D (Cohen, Nelson & Walsh, 2000; Levin et al., 1987) which decreases the risk of

[6] We focus exclusively on formal institutions which include laws and regulations, while informal institutions are not the focus of this study (Peng et al., 2009; Qian et al., 2017).

investment in innovation hence increasing their market values.

Overall, whenever information relevant to properly evaluating a firm's assets is scarce or unreliable and the risk of economic rent misappropriation is higher, as is the case when the development of the institutional context is weak, investors lower the price that they are willing to pay as a compensation for investing in a riskier asset (Akerlof, 1970; Capron & Shen, 2007; Coff, 1999; Shen & Reuer, 2005). At the same time, while some investors might be willing to decrease their price to buy riskier assets, others may be completely discouraged by such investments and unwilling to invest. This directly affects the demand for a firm's assets and, again, is reflected in a lower market value (e.g. Akerlof, 1970; Capron & Shen, 2007). Hence, we hypothesize that in weak institutional contexts, the market valuation of innovative assets is lower.[7]

> **Hypothesis (H1)**. *Firms located in weak institutional environments experience a lower market valuation of their innovative assets as compared to comparable firms located in stronger institutional contexts.*

1.2.2.1 A closer look at innovative assets

Innovative assets exist in various forms. We focus on R&D investment and patent applications as the two most common types. R&D investment mainly reflects the salary of highly skilled employees (Edworthy & Wallis, 2009). High R&D expenses reflect a productive workforce and as Koch & McGrath (1996, p. 335) note "a highly productive workforce is likely to have attributes that make it a particularly valuable strategic asset" (see also Wright et al., 1994). A human capital advantage can be defined as the potential to capture a stock of exceptional human talent and the human process advantage as a function of causally ambiguous, socially complex, historically evolved processes such as learning, cooperation and innovation (Boxall, 1996). Human assets include 'invisible assets' such as skills, the ability to learn, and intangible assets (Teece, 1986). Therefore, human assets are a special form of strategic assets (Amit & Schoemaker, 1993).

[7] While we acknowledge the existence of an extensive literature on the effect of legal and financial institutions on the quantity of innovation (see He and Tian, 2020, for a review), our attention here is on how markets assess the *value* of innovative assets when firms are located in different institutional development regions.

They are often hard to imitate due to scarcity, specialization, and tacit knowledge (Lippman & Rumelt, 1982; Polanyi, 1962; Teece, 1982) reflecting Barney's (1991) definition of resources that can lead to a competitive advantage. In particular, the tacitness of knowledge held by an R&D workforce is a special attribute of human resources. Tacit knowledge can be an important source of a competitive advantage as it is, by definition, hardly transferable (Polanyi, 1962; Polanyi, 1969). Due to the specific attributes of human assets, they are referred to as the "key asset base" of a firm (Bapna, Langer, Mehra, Gopal & Gupta, 2013, p. 641) and their contribution to firm performance has been largely documented (e.g. Grant 1996; Henderson & Cockburn, 1994; Kogut & Zander, 1992; Toole & Czarnitzki, 2009). We argue that due to its tacitness, investors have difficulties finding reliable information to value R&D especially when the institutional context is weak and characterized by stronger information asymmetries. In addition, the higher risk of economic rent misappropriation increases the likelihood that R&D investments in weak institutional environments receive a lower market valuation than in well-developed institutional contexts.

Patent applications differ crucially from the innovative assets captured by R&D investments. In contrast, a patent application marks a successfully developed invention, i.e. the outcome of an R&D project, which has market potential. Other than human innovative assets, patent applications cover explicit knowledge as the invention needs to be detailed in the patent application documents. Therewith, these innovative assets do not have the attractive attributes of tacitness and are, hence, more likely to be imitable (Barney, 1991), especially in institutional environments with weak intellectual property protection. The upside of the explicitness of these innovative assets include that they are tradable on the market for ideas (Arora et al., 2001a; Arora & Gambardella, 2010) and reduce information asymmetries between the patenting firm and outside investors (Long, 2002).

Long (2002) distinguishes between patents as a tool for IP protection and patents as a vehicle for credibly conveying information about the underlying invention. The latter view of patents portrays them as a signal for the quality of the R&D activities of the firm (Heger & Hussinger, 2017; Hsu & Ziedonis, 2013). Patents qualify as signals according to Spence (1973) because, first, they are costly to obtain. The costs of patenting include administrative fees such as application costs and renewal fees (De Rassenfosse & Jaffe, 2018), and potential infringement costs (Somaya, 2012). Second, as patent documents are publicly available and detailed enough for a person skilled in the art to understand the protected technology, patents can be verified by outsiders (Myers & Majluf, 1984). In addition, there are penalties for intentionally misrepresenting information in patent applications which further increases their credibility (Long, 2002). We argue that the signalling value of patents is limited when the institutional context is weak and where property rights and information disclosure laws are poorly defined and enforced. This is why we expect that patent applications in weak environments receive a lower market valuation than patent applications in well-developed institutional contexts.

1.2.3 Insider ownership, institutional development, and the market valuation of innovative assets

When insiders purchase shares of their own firms, they aim to increase their private wealth (e.g. De La Brunière, Haye & Mazza, 2020). At the same time, their purchase conveys private information about positive future expectations regarding the firm to outsiders and, therewith, reduces information asymmetries between the firm and outside investors (Carlton & Fischel, 1982; Glosten, 1989; John & Mishra, 1990; Leland, 1992).

Insider ownership or trading qualifies as a signalling device in the sense of Spence (1973). First, insider trading is costly. Insiders put their personal wealth at risk when purchasing shares of their own firms. Second, insider purchases can be verified by outsiders. Legal insider trading, which accounts for the vast majority of insider trades (see Mazza & Wang, 2021, for China), respects the country-specific regulations and is reported to the market authorities (see Mazza & Wang, 2021, and Huang, 2020, for a discussion of the insider trading regulations in China).

We argue, that, especially for firms located in a weak institutional environment characterized by strong information asymmetries, outside investors can interpret insider purchases as a signal that they can profit by increasing their shareholdings. Two important arguments are to be made. First, the greater the information gap between insiders and external investors, the greater the expected gap between the fundamental value of the stock and the price of the stock so that a gain for external investors based on insider signals is larger. A small information advantage, in contrast, limits potential profits (Brunnermeier, 2005). We argue that the information gap is larger for firms located in a weak institutional environment as there are many uncertainties that well-developed institutional contexts pre-empt. In consequence, external investors expect to make larger profits when following signals to invest in firms in weak institutional environments. Second, insider purchases reflect sufficient confidence of the managers in their foresight about the value of their firms' assets so that they invest their private wealth. It has been shown that, on the one hand, insiders do have managerial foresight about innovative assets, and that, on the other hand, external investors rely on insiders' managerial foresight about the value of their innovative assets and follow their purchasing signals (Ahuja, Coff & Lee, 2005; Coff & Lee, 2003). In addition, in weak institutional environments, characterized by a high degree of asymmetric information, credible signals of managerial confidence in the form of insider purchases are of greater importance than in well-developed institutional contexts where outside investors have easier access to high-quality information about firms. In summary, we argue, that in a weak institutional environment characterized by information asymmetries, insider trading can provide valuable information about the value of innovative assets.

Hypothesis (H2). *In weak institutional environments, higher insider ownership is associated with higher market valuation of innovative assets.*

1.3 Data and Methodology

1.3.1 Empirical context: China

Our empirical analysis focuses on China which offers unique features for testing our hypotheses. Since the start of the "reform and opening-up" process in the early 1980s, which marked the shift from a centrally planned economy to a market system (Prasad & Rajan, 2006), China has recognized the importance of technology as the driver for turning the economy from a production-oriented state into a knowledge-based economy (Liang & Xue, 2010). The aim was to move to a market economy based on "innovation" rather than on "imitation" (Dang & Motohashi, 2015). The increase in foreign direct investment has, further, put pressure on China to adapt to international standards (Hu & Jefferson, 2009). Together with the rapid economic growth, these factors have led to a fast modernization of the institutional environment which generated *de facto* systematic differences across regions in the development of the legal and financial system and appreciation of formal laws (Huang et al., 2017). For example, provinces like Guizhou, Qinghai, Shaanxi, and Yunnan have poor formal institutions for IPR protection and enforcement (Fan et al. 2010), and the IPR courts and legal systems in these regions are often influenced by local administrative agencies (Huang et al., 2017) which leaves space for more informal institutional factors to have a stronger influence.[8] What makes China especially interesting for our empirical setting is, in fact, that the laws and regulations covering accounting standards, investors protection, and transfer of information, and especially their enforcement are enacted and enforced locally, at the provincial, regional, and/or city level (Krug & Hendrischke, 2003) and that the central and provincial governments as well as individual ministries within governments have competing and overlapping areas of authority as well as interests (Brander, Cui & Vertinsky, 2017). When it comes to IPR enforcement, for example, some provincial governments' priorities are "designed to satisfy local consumers' demands for cheap products, with little concern about copyright violation, patent infringement, or counterfeiting (Mertha, 2007). Provincial governments are reluctant to spend scarce resources on IP protection when local residents have no ownership of relevant intellectual property and little interest in its protection" (Brander et al., 2017, p. 915). Therefore, China represents a highly variegate and fragmented institutional environment that varies from province to province (Fan & Wang, 2006; Wang, Wong & Xia, 2008), and, by exploiting the significant variation in the level of regional, institutional development, we are able to study the market value of innovative assets in different, within-

[8] See, for example, Huang et al. (2017) for an overview of how greater institutional embeddedness can promote innovation in such contexts and effectively replace the role of formal institutions in the protection of innovation.

country institutional contexts.

Regarding insider ownership, like most jurisdictions, China allows legal insider trading (Bhattacharya, 2014). Illegal insider trading was prohibited in China by the Company Law of 1994, the Criminal Law of 1997, and the Securities Law of 1998 (Mazza & Wang, 2021). The Chinese Securities Law of 2006 and the implementation of stricter regulations let Mazza & Wang (2021) conclude that the incentives to engage in illegal insider trading in China are low. Strict insider trading laws and enforcement are important prerequisites for our empirical test because in the case of unregulated insider trading, stock market prices would show no reaction to events as Bhattacharya, Daouk, Jorgenson & Kehr (2000) demonstrate for the case of Mexico. In a recent comparative study, Huang (2020) concludes that based on the type, magnitude, and frequency of sanctions, the intensity of insider trading enforcement in China is at a comparable level to overseas jurisdictions such as the U.S., the U.K., Australia, Singapore, and Hong Kong. Also, Miller, Li, Eden & Hitt (2008) consider the period from 2001 onwards as a period of strong insider trading regulations for China (see also Mazza & Wang, 2021).

In addition, our empirical model (detailed in the next section) requires that stock markets are efficient enough to reflect the future expected return of investments. Carpenter, Lu & Whitelaw (2021) show that, since the reforms of the early 2000s, stock prices in China have become as informative about firm future profits as they are in the U.S. and they have become much more efficient since (Chong, Lam & Yam, 2012). Adding to these general findings, recent evidence shows a positive association between the market value of Chinese firms and patents (Hsu, Wang & Wu, 2013; Hsu, Hsu & Zhao, 2021).

1.3.2 Empirical specification

Since we are interested in the market value of innovative assets, we employ Griliches' (1981) market value model. Challenging the at-that-time prevalent assumption that the market value of a firm reflects R&D investments only after they are converted into actual sales, Griliches (1981) shows that R&D investments directly affect a firm market valuation because R&D investments create a stock of intangible assets which generates future cash flow.[9] Aside from the forward-looking character of Tobin's Q as its dependent variable, this model allows us to empirically identify the value of specific assets separately. Drawing from the hedonic pricing model, the market value model views firms as bundles of assets whose value is defined as the present discounted value of the expected future cash flows (Czarnitzki et al., 2006). The model has been frequently applied to assess the value of innovative assets (e.g. Czarnitzki, Hussinger & Leten, 2020; Hall et al., 2005; Hall, 2007).

The market value model describes the value of a firm (V_{it}) as a function of its physical (A_{it}) and knowledge (K_{it}) assets:

$$V_{it} = q_t \left(A_{it} + \gamma K_{it}\right)^{\sigma} \tag{1}$$

Under the assumption of constant returns to scale ($\sigma = 1$), Equation (1) can be written as:

$$\log Q_{it} = \log \frac{V_{it}}{A_{it}} = \log q_t + \log \left(1 + \gamma \frac{K_{it}}{A_{it}}\right) \tag{2}$$

Equation 2 can be estimated directly using nonlinear least squares (NLLS) (e.g. Czarnitzki et al., 2020). The disadvantage of NLLS is that it becomes difficult to interpret the estimated effects of interaction terms, which are necessary to test our hypotheses. This is why we turn to ordinary least squares (OLS) regression models. OLS models can be applied to the linear approximation of the model: $log(1 + x) \sim x$. The linear approximation is valid if the difference between $log(1 + x)$ and x is small. This holds for the innovative assets' variables in our sample.[10] The linear approximation has the advantage of allowing for a straightforward interpretation of interaction terms and an easy inclusion of firm fixed effects.

We use R&D investments and patent applications to capture the knowledge assets K of a firm. This follows directly from Griliches (1981) who noted that patented inventions may be associated with a premium above

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[9] The link between the market value of the firm and investments that create intangible capital has also been documented for human resource management and information technology (Youndt, Subramaniam & Snell, 2004), investments in R&D alliances (Caner, Bruyaka & Prescott, 2018), and corporate social responsibility (Hannah, Sayari, Harris & Cain, 2021).

[10] Note that this approximation is, whenever appropriate, standard practice (see, for example, Simeth and Cincera, 2016). The measure for R&D investment over assets in our sample has a mean of 0.018 and a maximum value of 0.07. The measure of patent application stock over R&D has a mean of 0.35.

mere R&D investments. Including time (δ_t) and firm (λ_i) fixed effects, this leads to the following empirical specification:

$$\log Q_{it} = \lambda_i + \delta_t + \beta_1 \frac{R\&D_{it}}{\text{total assets}_{it}} + \beta_2 \frac{\text{application stock}_{it}}{R\&D_{it}} + \varepsilon_{it} \tag{3}$$

This model structure is referred to as "cascading indicators of the value of innovations, each adding further information on top of what could be predicted on the basis of the previous indicator" (Hall et al., 2005, p.27). Note that some form of normalization of the knowledge variables is needed for any empirical specification because by definition they are highly correlated. To test Hypothesis 1, we introduce interaction terms of the innovative assets variables and the variable that captures the level of institutional development (Eq. 4). For our empirical test of Hypothesis 2, we introduce triple interactions with the insider ownership variable (Eq. 5).

$$\begin{aligned} \log Q_{it} = {} & \lambda_i + \delta_t + \beta_1 \frac{R\&D_{it}}{\text{total assets}_{it}} + \beta_2 \frac{\text{application stock}_{it}}{R\&D_{it}} + \beta_3 \,\text{institutional development}_{it} + \\ & \beta_4 \frac{R\&D_{it}}{\text{total assets}_{it}} \times \text{institutional development}_{it} + \\ & \beta_5 \frac{\text{application stock}_{it}}{R\&D_{it}} \times \text{institutional development}_{it} + X_{it} + \varepsilon_{it} \end{aligned} \tag{4}$$

$$\begin{aligned} \log Q_{it} = {} & \lambda_i + \delta_t + \beta_1 \frac{R\&D_{it}}{\text{total assets}_{it}} + \beta_2 \frac{\text{application stock}_{it}}{R\&D_{it}} + \beta_3 \,\text{institutional development}_{it} + \\ & \beta_4 \text{insider ownership}_{it} + \beta_5 \frac{R\&D_{it}}{\text{total assets}_{it}} \times \text{institutional development}_{it} + \\ & \beta_6 \frac{\text{application stock}_{it}}{R\&D_{it}} \times \text{institutional development}_{it} + \\ & \beta_7 \frac{R\&D_{it}}{\text{total assets}_{it}} \times \text{insider ownership}_{it} + \beta_8 \frac{\text{application stock}_{it}}{R\&D_{it}} \times \text{insider ownership}_{it} + \\ & \beta_9 \text{institutional development}_{it} \times \text{insider ownership}_{it} + \\ & \beta_{10} \frac{R\&D_{it}}{\text{total assets}_{it}} \times \text{institutional development}_{it} \times \text{insider ownership}_{it} \\ & + \beta_{11} \frac{\text{application stock}_{it}}{R\&D_{it}} \times \text{institutional development}_{it} \times \text{insider ownership}_{it} + X_{it} + \varepsilon_{it} \end{aligned} \tag{5}$$

1.3.3 Matched sample

We use a matched sample to ensure that firms in weak and strong institutional settings are comparable (see, for example, Xu, Yuan & Zheng, 2021). For each firm located in a weak environment, we choose a comparable firm in a well-developed institutional context. Our treated firms are those in the first quartile of the distribution of institutional development while possible control firms are located in the fourth quartile. We do not take the middle range of the distribution into account because we want to capture the effect of a low or high institutional environment. The middle ranges reflect neither a high nor a low level of institutional development, but rather an average one. In addition, we use an index to capture the institutional development, the National Economic Research Institute (NERI) Index of Marketization (Fan & Wang, 2006), which changes yearly and, while the top and bottom locations of the distribution are relatively stable over time, regions in the middle of the distribution change more frequently.

We use a coarsened exact matching (CEM) to match treated and control firms. Our list of matching criteria consists of firm-level characteristics that may impact the dependent variable (Xu et al., 2021): industry and year dummies, R&D over assets, insider ownership volume and dummy, return on assets (ROA), top 10 shareholders concentration, earnings per share (EPS) growth rate, patent application stock over R&D, and total assets.[11]

T-tests, reported in Table 1.1, show that, after the matching, firms in weak and well-developed institutional contexts do not differ in terms of their R&D/assets (*p-value* = 0.7487), in their patent application stock/ R&D (*p-value* = 0.4622), nor with regard to the control variables. Given that our matched sample is balanced, we can safely proceed to our analysis.

1.3.4 Data sources

Our main data source is the China Stock Market and Accounting Research (CSMAR) database, which

[11] See Table 1.A1 in the Appendix for a detailed description of the variables. Our results are robust if different sets of matching criteria are used.

provides yearly information about publicly listed firms in China. It includes R&D expenditure, total assets, patent applications, outstanding shares, legal insider trading activity, and firms' headquarters location.[12] The dataset is supplemented with the provincial-level National Economic Research Institute (NERI) Index of Marketization (Fan & Wang, 2006), which captures the development of marketization of all 31 Chinese provinces, municipalities, and autonomous regions, and provides a measure of institutional development (e.g. Qian et al., 2017). The index is divided into five broad fields (government and market relations, development of the nonstate enterprise sectors, development of the commodity market, credit market development, and development of legal environment) composed of a total of 23 basic indicators. To test Hypothesis 1, we employ two of the main indicators: credit market development and development of legal institutions (Qian et al., 2017). These two indicators capture the degree of development of the institutions that are most closely related to innovation and technological development. The credit market development index measures the degree of competition in the financial markets (ratio of deposits taken by non-state-owned financial institutions to that of all financial institutions), the presence (in terms of market share) of non-state-owned financial institutions, and the efficiency of capital allocation (ratio of financial resources allocated to state-owned enterprises (SOEs) to that of all enterprises). The legal environment development index measures the conditions of service of market intermediaries such as lawyers and accountants and the extent to which industry associations help businesses.[13] Also, it measures the legal environment faced by businesses through an assessment of the level of law enforcement and the efficiency of local judicial and administrative law enforcement agencies. The final ingredient is a measure of IPR enforcement.

Our sample consists of Chinese firms that (1) are publicly listed on the Shanghai Stock Exchange (SSE) or the Shenzhen Stock Exchange (SZSE), (2) belong to the manufacturing sector because innovation differs substantially in service industries where firms spend less on R&D and apply for fewer patents (Hipp &

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[12] For a few firms, information on the location of the firms' headquarters is missing for individual years. We assume that the location of firms did not change if the information is missing in a particular year or several consecutive years, but it is the same for the previous and the first next year in which the information is not missing.

[13] This data is gathered through corporate surveys asking questions such as: "How are the conditions of market services such as local lawyers, accountants, etc." and "The extent to which local industry associations help the enterprises".

Grupp, 2005), (3) have no direct state-ownership because these firms have been shown to differ systematically from other publicly listed firms (e.g. Phi, Taghizadeh-Hesary, Tu, Yoshino & Kim, 2021; Ruan, Cullen, Ma & Xiang, 2014; Shleifer & Vishny, 1994; Tong, Junarsin & Li, 2015), and (4) are not listed as ST (Special Treatment) and PT (Particular Transfer) firms.[14] Our dataset covers the period 2008-2017.[15] Our matched sample consists of 1,582 observations for 837 publicly listed firms.[16]

1.3.5 Dependent variable

Our dependent variable is the natural logarithm of Tobin's Q. It is defined as the ratio of the firm's market value, i.e. the total number of shares outstanding multiplied by the price per share, to the book value of the firm's tangible assets (Dowell, Hart & Yeung, 2000; Morck & Yeung, 1991). Thanks to its forward-looking character, Tobin's Q incorporates future expected profits, i.e. the aggregate market expectations on the returns to current investments, and is therefore able to measure the market expected cash flows derived by R&D and patents (e.g. Griliches, 1981; Hall, 2000; Hall et al., 2005).

1.3.6 Independent variables

1.3.6.1 Innovative assets

Innovative assets are defined as R&D investment and the firms' patent application stock. R&D investment is measured by the amount of capitalized and expensed R&D divided by the book value of total assets (Hall et al., 2005; Hillier, Pindado, De Queiroz & De La Torre, 2011; Pindado et al., 2010).

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[14] "The special treatment means, for example, that the stocks are traded with a 5% price change limit each day vs. 10% for normal stocks. Its midterm reports must be audited. Also, if an ST firm continues to suffer losses for one more year, it will be designated a particular transfer (PT) firm. PT stocks can only be traded on Friday, with a maximum 5% upside limit to last Friday's close, but no restriction on the downside. PT firms will be de-listed if they cannot become profitable within one year" (Liu and Lu, 2007, p.886).

[15] These years have been chosen due to data availability. Information on R&D is only available as of 2008. Patent information is only available until 2017.

[16] Excluding the middle range of the NERI distribution (see section 3.3) leads to a drop of 5,499 observations. We also exclude one firm as it relocated its headquarter's province during our timeframe.

We calculate the firms' patent application stock as:

$$\text{application stock}_{it} = \text{number of applications}_{it} + (1\text{-}\delta)\ \text{application stock}_{it\text{-}1} \quad (6)$$

where δ is a depreciation rate of 15% (e.g. Hall & Mairesse, 1995; Hall, 2007).[17] We divide the patent application stock by R&D investment.[18]

1.3.6.2 Degree of institutional development

We rely on the NERI index of marketization (Wang, Fan & Zhu, 2007). This index comes in the form of a score and a ranking: a province that is ranked first (according to its score) has the highest level of institutional development. Our measure of provincial-year-level institutional development is the mean of the ranking of the province for credit market development and legal environment development (Qian et al., 2017). We chose the ranking over the score because the scores increase over time.[19]

1.3.6.3 Insider ownership

To test Hypothesis 2, we define insider ownership as the total value of shares purchased multiplied by the shares' closing price of the day, and use the logarithm to account for the skewness of the insider ownership volume (Ahuja et al., 2005):

$$\text{insider ownership}_{it} = \log\left(1\text{+total insider purchase value}_{it}\right) \quad (7)$$

Insider purchases, rather than sales, are perceived by outsiders as informative about future expected positive events (Cohen, Malloy & Pomorski, 2012; Marin & Olivier, 2008; Scott & Xu, 2004).[20] Corporate insiders

[17] Our results are qualitatively unchanged if a depreciation rate of 5% or 25% is used. The results are available upon request.
[18] Normalizing the patent application stock is necessary because of the naturally high correlation of R&D and the patent stock. Normalizing the patent application stock by R&D is a straightforward choice because the coefficient of patent application stock/ R&D can be interpreted as a premium (or discount) that patents constitute on top of R&D (see e.g. Czarnitzki et al., 2006; Hall et al., 2005). Our results hold when patent application stock is normalized by the number of employees. Results are available upon request.
[19] Virtually identical results are obtained when using the average of the scores.
[20] According to Lakonishok & Lee (2001, p.109), "insiders have many reasons to sell shares but the main reason to buy shares is to make money", therefore only insider purchases can be interpreted as signals for the presence of information asymmetries and the existence of positive, not-yet-disclosed information.

are defined as members of the board of directors, board of supervisors, and executives.

1.3.6.4 Control variables

A set of control variables is used, including working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, and ROA. These variables are chosen to control for potential firm-specific differences such as firm size, growth prospect, financial health, risks, past performance, and corporate governance, among others, and to avoid an omitted variables' bias. Table 1.A1 in the Appendix provides the variable definitions. We also employ firm- and time-fixed effects.

1.4 Results

1.4.1 Descriptive statistics

Table 1.1 shows the descriptive statistics and t-tests for our unmatched and matched sample divided into weak and strong institutional environments. A correlation matrix is presented in the Online Appendix (see Table 1.OA2) which shows low correlations between the key variables.

After the matching, the means of all variables are similar between the two groups. R&D investment over total assets is on average slightly over 1.05%, in line with previous studies (Qian et al., 2017).

1.4.2 Empirical results

1.4.2.1 Main results

Table 1.2 presents the main results starting with a lean specification which only includes our measures for innovative assets and the control variables (Model 1). Insider ownership and the degree of institutional development are added in Model 2 and the interaction terms between the innovative assets' variables and the degree of institutional development for testing Hypothesis 1 in Model 3. Model 4 includes interaction terms between the innovative assets' variables and insider ownership and tests whether insider ownership increases the market valuation of innovative assets for firms located in any institutional development level

Table 1.1: Balancedness of the matched sample

	Variable	Pre-matching weak	Pre-matching strong	P-value	Post-matching weak	Post-matching strong	P-value
1	Assets over liabilities ratio	0.40897	0.34859	0.00000	0.38975	0.37724	0.19896
2	EPS growth rate	-0.97476	-0.23861	0.00720	0.02696	-0.01469	0.83036
3	Financial leverage	1.81543	1.43493	0.00000	1.81128	1.61433	0.18512
4	Industry code	5.18777	5.31587	0.05405	5.21198	5.21198	1.00000
5	Insider ownership dummy	0.28566	0.37669	0.00000	0.22275	0.22275	1.00000
6	Insider ownership	3.69910	5.01802	0.00000	2.93996	2.98123	0.88324
7	Total assets	10.39724	10.06718	0.00000	10.24311	10.16588	0.12519
8	Profits	5.49569	3.60052	0.31615	4.98036	4.46615	0.45790
9	Operating leverage	1.88671	5.36041	0.33649	1.85091	1.76479	0.49731
10	Operating liabilities ratio	0.55651	0.62325	0.00000	0.57535	0.58179	0.60421
11	Operating profit growth rate	-1.29992	-81.51811	0.31485	0.52377	0.47147	0.97854
12	Operating profit margin	0.06318	0.08718	0.00004	0.07505	0.07896	0.54392
13	Owners equity ratio	0.59106	0.65228	0.00000	0.61037	0.62537	0.13650
14	Application stock over R&D	1.30878	0.52626	0.37910	0.38134	0.33808	0.46229
15	R&D over total assets	0.01733	0.02199	0.00000	0.01783	0.01800	0.74870
16	ROA	0.05372	0.06367	0.00000	0.05364	0.05553	0.41695
17	ROE	0.00733	0.06726	0.00549	0.05599	0.05922	0.50206
18	ROE growth rate	-2.88368	-0.47643	0.23472	-0.41649	0.34294	0.56494
19	Top shareholder concentration	0.13945	0.14378	0.16459	0.11098	0.11379	0.49813
20	Top 10 shareholder concentration	0.15739	0.16782	0.00063	0.13128	0.13711	0.15947
21	Top 3 shareholder concentration	0.15493	0.16474	0.00147	0.12842	0.13402	0.18128
22	Top 5 shareholder concentration	0.15654	0.16685	0.00075	0.13032	0.13612	0.16280
23	Working capital	6057.85231	8009.62741	0.06799	7962.13624	7088.89987	0.54507
24	Working capital to current assets ratio	0.29488	0.43887	0.00000	0.36450	0.36988	0.81954
25	Year	2014.12625	2013.77831	0.00000	2014.16766	2014.16766	1.00000

Notes: The table here divides firm-level information into four groups: before and after the matching process is applied and for firms located in weak and strong institutional environments. Number of observations in weak environment group pre-match: 2,503. Number of observations in strong environment group pre-match: 2,729. Pairs of matched observations: 835. Number of firms in weak environment group pre-match: 639. Number of firms in strong environment group pre-match: 907. Number of firms in weak environment group post-match: 405. Number of firms in strong environment group post-match: 432. Some of the variables included in this table are not present in our analysis as control variables nor as matching covariates. We include them here to show that even though they were not explicitly used in our matching procedure there is balance for a number of observable characteristics far larger than the few, key matching covariates we used.

province. Model 5 adds triple interaction terms between the innovative assets' variables, the degree of institutional development, and insider ownership to test Hypothesis 2.

The coefficients for R&D investment and patent application stock are both significant and positive, with the former having a larger magnitude than the latter due to the cascading structure of the model (Hall et al., 2005), for all models. In Model 2, our measures of institutional development and insider ownership are not significant at the 5% level, indicating that both measures do not affect the market value of the firm per se. In Model 3, the coefficients of the interaction terms between R&D investment and patent application stock and institutional development are both negative and significant ($p < 0.10$ and $p < 0.05$, respectively) providing support for Hypothesis 1. Model 4 includes an interaction term between the innovative assets' variables and insider ownership and shows that both interaction terms are not significant at the 5% level suggesting that insider ownership does not act as a signal for the value of innovative assets for the average institutional development. Model 5 includes a full set of interaction terms. We find support for Hypothesis 1 through the negative and significant coefficients of the interaction terms between R&D investment and patent application stock and institutional development ($p < 0.05$). The positive and significant ($p < 0.05$) coefficient for the triple interaction term of R&D, institutional development, and insider ownership provides support for Hypothesis 2 indicating that in weak institutional environments, a higher level of insider ownership is associated with a lower downward shift of the market value of R&D. Hypothesis 2 is only partially supported as we do not find the same effect of insider ownership on the valuation of the patent application stock.

We calculate the marginal effects at the 31 ranks of institutional development when insider ownership is at its minimum, mean, and maximum. At the highest institutional development level, the marginal effect of R&D investment decreases (from -1.20 to -1.36) as insider ownership increases, but the differences are not statistically significant. At the lowest institutional development level, as insider ownership increases, we find a statistically significant increase in the marginal effect of R&D investment (from -0.41 to 0.40).

Table 1.2: Market value regression with institutional development and insider ownership on matched sample
(Coarsened exact matching on total assets, insider ownership volume and dummy, ROA, top 10 shareholders concentration, EPS growth rate, patent applications stock over R&D, R&D over assets, and industry and year dummies)

Dependent Variable:	Log Tobin's Q							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:			*full sample*				*small firms sample*	
Variables								
R&D/Total Assets	12.10***	11.76***	18.09***	13.21***	20.37***	26.70***	15.27***	27.69***
	(3.555)	(3.576)	(5.132)	(3.509)	(4.760)	(5.769)	(4.068)	(5.909)
Application Stock/R&D	0.3998***	0.3838***	0.5512***	0.3868***	0.5607***	0.7376***	0.5248***	0.7756***
	(0.0905)	(0.0903)	(0.1357)	(0.0936)	(0.1455)	(0.1558)	(0.1045)	(0.1644)
Institutional Dev. Rank		0.0259*	0.0448***		0.0471***	0.0557***		0.0593***
		(0.0136)	(0.0166)		(0.0163)	(0.0202)		(0.0191)
Insider Ownership		0.0022		0.0116	0.0236*		0.0162*	0.0470**
		(0.0027)		(0.0072)	(0.0123)		(0.0083)	(0.0182)
R&D/Total Assets × Institutional Dev. Rank			-0.6624*		-0.7284**	-1.246***		-1.235***
			(0.3536)		(0.3510)	(0.4101)		(0.4146)
Institutional Dev. Rank × Application Stock/R&D			-0.0194**		-0.0206**	-0.0279***		-0.0290***
			(0.0089)		(0.0091)	(0.0103)		(0.0106)
R&D/Total Assets × Insider Ownership				-0.6237*	-1.472**		-0.2357	-1.678**
				(0.3609)	(0.5793)		(0.3928)	(0.7640)
Insider Ownership × Application Stock/R&D				0.0055	-0.0109		-0.0127	-0.0230
				(0.0080)	(0.0108)		(0.0126)	(0.0203)
Institutional Dev. Rank × Insider Ownership					-0.0013			-0.0023*
					(0.0008)			(0.0012)
R&D/Total Assets × Institutional Dev. Rank × Insider Ownership					0.0923**			0.1114**
					(0.0427)			(0.0533)
Institutional Dev.Rank × Insider Ownership × Application Stock/R&D					0.0019			0.0007
					(0.0013)			(0.0018)
Fixed-effects								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	1,582	1,582	1,582	1,582	1,582	791	791	791
R^2	0.88349	0.88449	0.88571	0.88429	0.88837	0.92676	0.92485	0.92894
Within R^2	0.17080	0.17793	0.18663	0.17649	0.20554	0.25057	0.23100	0.27288

Clustered (Firm) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: OLS regressions with standard errors clustered at the firm level, and firm and year fixed effects. Control variables: working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, ROA, and shareholders concentration for top 1, 3, 5, and 10 shareholders.

1.4.2.2 Subsample of smaller firms

Models 6, 7, and 8 of Table 1.2 show a robustness check in which we re-run Models 3, 4, and 5 for the firms in our sample with an asset size below the sample median. This subsample analysis accounts for the fact that the level of transparency increases with firm size so that we expect to find stronger effects for smaller firms about which less information is available.

Model 6 shows that the effect of a stronger institutional environment for the market valuation of both R&D and patents is stronger compared to the results for the full sample ($p < 0.01$). Model 8 shows support for Hypothesis 1 through the negative and significant ($p < 0.01$) coefficients of the interaction terms between R&D investment and patent application stock and institutional development, and partial support for Hypothesis 2 through the positive and significant ($p < 0.05$) coefficient of the triple interaction term between R&D investment, institutional development, and insider ownership.

1.4.3 Additional robustness checks

1.4.3.1 Placebo test for the development indicator

One might wonder whether the legal and financial institutional development are leading our results or whether different aspects of the institutional development would lead to similar findings. To address this concern, we re-run our regressions using the NERI index which depicts the "development of the commodity market". In line with our argument, i.e. the financial and legal environments should matter for the valuation of innovative assets, the results do not show an association of the development of the commodity market with the market valuation of innovative assets at the 5% level of statistical significance. The results are presented in Table 1.OA3 of the Online Appendix.

1.4.3.2 Placebo test for insider sales

A second placebo test uses insider sales instead of insider purchases. As insider sales should not carry a signalling value, we expect an insignificant effect of insider sales on the market valuation of innovative assets. Table 1.OA4 in the Online Appendix shows that this is the case.

1.4.3.3 Different definitions of insider ownership

We employ different definitions of the insider ownership measure and show the results in Tables 1.OA5 and 1.OA6 of the Online Appendix. The first measure uses the inverse hyperbolic sine (IHS) transformation which is a useful measure as it also defines zero values (Burbidge, Magee & Robb, 1988; Nyberg, Fulmer, Gerhart & Carpenter, 2010). The results are qualitatively the same.

The second measure is the total value of insider purchases minus the total value of insider sales. Here, the results are robust for the smaller firms' matched sample, while we do not find support for Hypothesis 2 for the full matched sample. A likely explanation is that the trading volume for larger firms is higher and that insiders sell the stock of their firms for a number of reasons other than negative private information, such as liquidity and diversification needs (Jin, 2002; Kahl, Liu & Longstaff, 2003) or personal tax management (Jin & Kothari, 2008). This implies that insider sales blur our measure, especially for large firms with a higher trading volume.

1.4.3.4 Corporate stock purchases as an alternative signal

We use corporate stock repurchases as an alternative signal for the value of innovative assets (e.g. Bhattacharya, 1979; Comment & Jarrell, 1991; Constantinides & Grundy, 1989; Dann, 1981; Lakonishok & Vermaelen, 1990; Vermaelen, 1981).

Table 1.3 below shows the robustness of our results using the ratio of the total number of shares repurchased to the total number of shares outstanding (e.g. Grullon & Michaely, 2004).[21] Table 1.OA7 of the Online Appendix shows robust results for the aggregate amount invested by the firm in shares repurchased scaled

[21] Note that we use different matched samples which also use the corporate stock repurchased as a matching criterion.

by the firm's net income to account for the available cash as a further robustness check.

1.5 Discussion

1.5.1 General discussion

Within the RBV framework, an often-overlooked assumption in the process of generating or sustaining a competitive advantage is that the market needs to acknowledge the value of strategic assets and their expected economic rents. A positive market valuation of a firm's innovative assets is essential for the next steps in which they are turned into profits because it increases the firm's reputation as an innovator and facilitates the financing of future R&D (Hottenrott et al., 2016; Lev et al., 2005).

Our study shows that, when institutions are weak, the market valuation of innovative assets is lower than for comparable firms in more developed institutional contexts. More specifically, R&D investment as well as patent applications receive a lower market evaluation in environments with weak institutions. This result is more pronounced for the smaller firms in our sample as firm size is correlated with the amount and the quality of information that outsiders receive. The smaller the firm, the less likely it is that it enters into contracts that are publicly visible or widely reported by the press, and the less well-known are its labor force, suppliers, and customers (Berger & Udell, 1998). This explains why the layer of uncertainty introduced by the weakness of the institutional environment affects the value of the innovative assets of smaller firms more strongly.

While uncertainty is highest for R&D investment as it constitutes an investment in uncertain projects (Arrow, 1963), patent applications certify a successfully finished R&D project with market potential. As patent applications are costly and verifiable by external investors they qualify as signals in the sense of Spence (1973). With these characteristics, patents reduce asymmetric information between insiders and outsiders so that their value is more correctly reflected in their market valuation.

Table 1.3: Robustness check - Share repurchase

(Coarsened exact matching on total assets, **share repurchased over total shares outstanding**, ROA, shareholders concentration, EPS growth rate, R&D over assets, patent application stock over R&D, and industry and year dummies)

Dependent Variable:	Log Tobin's Q							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	*full sample*					*small firms sample*		
Variables								
R&D/Total Assets	12.50***	12.77***	24.03***	12.40***	23.53***	17.08**	7.902*	16.89**
	(3.836)	(3.830)	(5.404)	(3.887)	(5.528)	(6.814)	(4.221)	(6.854)
Application Stock/R&D	0.3292***	0.3388***	0.6087***	0.3248***	0.5972***	0.7226***	0.2593*	0.7236***
	(0.1069)	(0.1054)	(0.2030)	(0.1085)	(0.2083)	(0.1666)	(0.1359)	(0.1676)
Institutional Dev. Rank		0.0250**	0.0450***		0.0455***	0.0461***		0.0456***
		(0.0126)	(0.0134)		(0.0135)	(0.0149)		(0.0150)
Share Repurchase		-12.90		-3.756	45.38		-13.44	127.6***
		(8.153)		(21.52)	(30.33)		(32.19)	(48.74)
R&D/Total Assets × Institutional Dev. Rank			-0.9997***		-0.9891***	-0.6501*		-0.6305*
			(0.3656)		(0.3709)	(0.3639)		(0.3606)
Institutional Dev. Rank × Application Stock/R&D			-0.0209*		-0.0209*	-0.0312***		-0.0316***
			(0.0120)		(0.0121)	(0.0107)		(0.0107)
R&D/Total Assets × Share Repurchase				-433.6	-3,439.8**		-5,483.0**	-12,260.8***
				(988.1)	(1,607.0)		(2,133.0)	(2,096.6)
Share Repurchase × Application Stock/R&D				-17.75	-95.68		375.4***	35.20
				(52.03)	(96.93)		(106.1)	(219.4)
Institutional Dev. Rank × Share Repurchase					-8.908**			-14.20***
					(3.492)			(5.250)
R&D/Total Assets × Institutional Dev. Rank × Share Repurchase					363.6***			677.7***
					(122.6)			(259.1)
Institutional Dev. Rank × Share Repurchase × Application Stock/R&D					23.94**			24.84*
					(12.03)			(14.83)
Fixed-effects								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	1,309	1,309	1,309	1,309	1,309	906	906	906
R^2	0.88206	0.88328	0.88537	0.88238	0.88641	0.91517	0.91394	0.91739
Within R^2	0.10153	0.11082	0.12673	0.10401	0.13473	0.14822	0.13585	0.17050

Clustered (Firm) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: OLS regressions with standard errors clustered at the firm level, and firm and year fixed effects. Control variables: working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, ROA, and shareholders concentration for top 1, 3, 5, and 10 shareholders.

Our results suggest, however, that patent applications cannot create full trust in the firms' innovation activities and their ability to create future profits in weak institutional environments because the market value of patents is lower than in stronger institutional contexts. Their signalling power is limited.

Our results for insider ownership as a stronger signal illustrate that it mitigates the downward shift of the market valuation of R&D investment for firms in weak institutional environments. As compared to patents, insider ownership is costlier and therefore more credible as a signal because it directly affects insiders' personal wealth. As China's insider regulations and reporting requirements are comparable to overseas jurisdictions such as the U.S. (Huang, 2020, Mazza & Wang, 2021), insiders increasing their stakes in their own firms in weak environments are considered 'good news' and incentivize outside investors to purchase stocks as the regulations do not allow insiders to capture the entire rent (Bhattacharya et al., 2000; Miller et al., 2008).

Our results show that the signalling effect of insider ownership is particularly strong for R&D investments of firms in institutionally weak environments because R&D is surrounded by a high degree of asymmetric information (Arrow, 1963; Czarnitzki & Toole, 2011; Hussinger & Pacher, 2019; Nemlioglu & Mallick, 2020). It is worthwhile to emphasize that insider ownership does not increase the market value of patent applications. This is likely due to the signalling value that patent applications feature themselves. Insider ownership does not add information beyond what the public can learn from the detailed description available in patent documents.

1.5.2 Contributions to the literature

The existing literature combining institutions and innovation has mainly focused on the effect of financial and/or legal institutions on the *quantity* of R&D investments and patents (see He & Tian, 2020, for a recent review). Our paper, instead, focuses on the effect of institutions on the *market valuation* of such innovative assets as an important determinant of the firm's ability to create and sustain a competitive advantage. To this end, we make a theoretical contribution to the RBV by clarifying an implicit, often overlooked assumption, i.e. the importance of a positive acknowledgement of innovative assets by external parties to generate a sustainable competitive advantage from those assets (see Armstrong & Shimizu, 2007 for a review of empirical studies on the RBV). This point was first highlighted by Priem & Butler (2001a) and later acknowledged by Barney (2001, p.51) who clearly pose that "the value of a firm's resources must be understood in the specific market context within which a firm is operating". In this sense, not taking into consideration the market value of those assets might lead to erroneous conclusions.

Moreover, most of the empirical evidence on innovative assets value focuses on the U.S. or, in general, on developed economies (e.g. Bloom & Van Reenen, 2002; Griliches, 1981; Hall et al., 2005; Toivanen et al., 2002; see Czarnitzki et al., 2006, for a survey). Our findings elucidate the situation of innovative firms in emerging economies characterized by poor enforcement of property rights, investors' protection, and information disclosure laws. In doing so, our study answers the call put forth by Wickert et al. (2024) to embrace non-Western contexts in management research as they have the potential to unveil novel insights previously overlooked and to advance our understanding of management and organizations as a global phenomenon. In fact, our results point to the possible presence of a vicious circle in such contexts. In a first step, firms in weak institutional settings have fewer incentives to invest in R&D (Alam et al., 2019; Amore, Schneider & Žaldokas, 2013; Brown & Martinsson, 2019; Choi et al., 2014; Fang, Lenrner & Wu, 2017; Li, Wu & Lu, 2019; Seitz & Watzinger, 2017; Zhong, 2018). And, in a second step, their innovative assets are valued less by the market which then leads to a lack of recognition as innovators and to higher costs of capital for the firms limiting their ability to grow and to finance future innovation. With this evidence, we close the gap to prior literature that shows that firms in weak institutional settings experience innovation and performance shortfalls (Qian et al., 2017).

We further add to the literature at the intersection of institutions and innovation (see He & Tian, 2020 for a recent survey) by highlighting the importance of analyzing the *local* quality of the institutional environment where firms operate as a key determinant of their innovation activities (Barasa, Knoben, Vermeulen, Kimuyu & Kinyanjui, 2017; Rodríguez-Pose and Zhang, 2020) vis-à-vis the national ones.

Furthermore, the literature on the effect of institutions on innovation shows that the institutional framework impacts firms' strategic choices and success (Peng, 2002; Peng et al., 2009). Focusing on the example of insider ownership (Carlton & Fischel, 1982; Dye, 1984; Glosten, 1989; Leland, 1992; Levine et al., 2017; Manne, 1966; Merton, 1987), we show that managerial actions can have a different effect in environments of different levels of institutional development. Outside investors in weak environments (with proper insider trading regulations) interpret insider purchases as a positive signal concerning a firm's innovative assets.

This finding touches upon the classic debate of the pros and cons of insider trading. Some scholars believe in the value-enhancing of insider trading thanks to the improved speed at which information reaches the market, therefore improving the informativeness of prices and allocation of resources (Carlton & Fischel, 1983; Glosten, 1989; Leland, 1992), and by motivating insiders to innovate, so they can profit through insider trades (Dye, 1984; Manne, 1966). Others, instead, suggest that policies aimed at restricting insider trading increase the valuation of innovative assets as they improve incentives for outside investors to acquire information on such assets (which are usually difficult to evaluate), lower the cost of capital, and therefore increase investments in innovative assets (Levin et al., 2017; Merton, 1987). Our results are in line with John & Mishra (1990) who argue that in environments in which information asymmetries are strong, corporate insiders have information superior to the market about the future prospects of the firm, and their trading activity is one of the most direct signals to communicate their private information to the market. In this sense, insider trading rebalances the information asymmetries generated by the poor enforcement of rules and regulations, especially on information disclosure, leading to a more efficient market.

1.5.3 Implications for practitioners

Our findings have important managerial implications. First, managers evaluating the returns of their innovation investments need to consider the specific institutional environment they operate in. In strong institutional environments, investments in innovative assets are acknowledged by the market leading to favorable conditions for the firm's access to finance, reducing the costs of capital, and paving the way for future investments in R&D and profitability increases (Hottenrott, Hall & Czarnitzki, 2016; Lev, Sarath & Sougiannis, 2005). In weak institutional environments, such a positive acknowledgment of investments is uncertain so that it is questionable whether the above-described positive conditions for developing innovations realize.

Ignoring the moderating effect of the institutional environment may, hence, lead managers to inaccurate conclusions regarding the resources available for the next steps in the innovation process and regarding the expected future returns of their investments in innovative assets. Managers should, hence, not make strategic decisions without considering the strength of their institutional environment. In other words, investments in innovative assets in weak institutional environments may require more patience and more internal resources. Our study further shows that managers can take actions such as insider trading or corporate stock repurchases to send strong signals about the value of innovative assets to the market (Coff & Lee, 2003).

A second managerial implication follows from the above. As we show that the value of innovative assets differs depending on the strength of the institutional environment, we can pinpoint the strong interrelatedness of a firm's strategy, and its innovation strategy in particular, and the institutional environment in which it operates (Peng, 2002; Peng et al., 2009). A straightforward practical implication is that the investment in innovative assets should follow a corporate strategy that considers the additional layer of uncertainty for innovation induced by a weak institutional context.

1.5.4 Limitations and future research

Our study invites future research at the intersection between the institutional context and innovation (He & Tian, 2020). This literature documents that the institutional framework impacts firms' strategic choices and success (Peng, 2002; Peng et al., 2009). We believe that there is room to investigate the implications for the innovative process further and to identify strategies for firms in weak institutional contexts.

As any, our study is not free of limitations. As we focus on the market value of innovative assets, we are restricted to publicly listed firms. We would expect that the innovative assets of privately held firms are more seriously affected, but this needs to be shown by future research. Furthermore, it would be interesting to replicate our results for other developing countries.

1.6 Conclusion

By exploiting inter-provincial institutional development differences in China, we show that innovative assets of firms located in weak institutional environments receive a significantly lower market valuation compared to firms located in stronger institutional contexts. This negative effect can be counterbalanced by managerial actions though. We find that insider purchases are associated with a higher market valuation of innovative assets in weak institutional contexts. Therefore, even when located in an institutionally adverse environment, firms can take strategic actions to signal the value of their innovative assets to the market.

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1.8 Appendix

Table 1.A1 Variable definitions

Variable	Definition
Tobin's Q	Number of A shares multiplied by the year-end price per share divided by total assets' book value
Total assets	Total assets are first divided by 100,000 and then log-transformed
R&D	Capitalized and expensed R&D divided by 100,000
Patent stock	Number of patent applications in the current year plus the number of patent applications in the previous years, discounted by 15% (see Eq.6)
Shares repurchase	1. Investment in the actual share repurchase plan over its net income multiplied by 1,000 2. Actual share repurchased over the total number of outstanding shares multiplied by 1,000
Shares repurchase dummy	Equals 1 if firms have re-purchased their shares in the current year; 0 otherwise.
Insider ownership	1. Logarithm of the value of shares purchased by insiders plus 1 2. Logarithm of the value of shares sold by insiders for our placebo test
Insider ownership dummy	1. Equals 1 if insiders purchased shares of their own firm in the current year; 0 otherwise 2. Equals 1 if insiders sold shares of their own firm in the current year; 0 otherwise (placebo test)
Legal env. development	Rank of legal environment development according to the NERI index. Takes values from 1, best rank, to 31, worst rank
Credit market env. Development	Rank of capital market environment development according to the NERI index. Takes values from 1, best rank, to 31, worst rank
Institutional development rank	Mean of the provincial ranking for credit market development and legal environment development
Development of the commodity market	Rank of commodity market development according to the NERI index. Takes values from 1, best rank, to 31, worst rank
ROA	Return on assets
ROE	Return on equity
EPS growth rate	(Earnings per share for the current period - earnings per share for the same period of the previous year)/(earnings per share for the same period of the previous year).
Working capital	Total current assets - total current liabilities.
Working capital over current assets	(Total current assets-total current liabilities)/(total current assets).
Assets over liabilities ratio	Total liabilities/total assets.
Operating liabilities ratio	(Total current liabilities - short-term borrowings - non-current liabilities due within one year - financial liabilities held for trading - derivative financial liabilities) / (total liabilities).
Financial leverage	(Net profit + income tax expenses + finance expenses)/(net profit + income tax expenses).
Profits	(Operating income - operating cost)/total profit.
Operating leverage	(Net profit + income tax expenses + financial expenses + depreciation of fixed assets, depreciation of oil and gas assets, depreciation of productive biological assets + amortization of intangible assets + amortization of long-term deferred expenses) / (net profit + income tax expenses + finance expenses).
Operating profit growth rate	(Amount of operating profit in the current period of the current year - amount of operating profit in the same period of the previous year)/(amount of operating profit in the same period of the previous year).
Operating profit margin	(Operating income - operating cost) / operating income
Owners' equity ratio	Total shareholders' equity/total assets.
ROE growth rate	(Net profit/total owner's equity at the end of the current period - net profit in the same period of the previous year/total owner's equity at the end of the previous year)/(net profit amount in the same period of the previous year / owner's equity total amount at the end of the same period last year).
Top shareholder concentration	Percentage of shares held by top 1, 3, 5, and 10 shareholders.
Industry code	3 digits industry codes grouped into 10 categories

1.9 Online Appendix

This online appendix provides additional descriptive evidence for the Chinese provinces. In addition, we comment on firm relocation, present a correlation matrix, and further robustness checks.

1.9.1 Sample descriptive

This section provides evidence of the provincial-level differences for our sample.

1.9.1.1 Persistency of institutional ranks over time

Figures 1.OA1 and 1.OA2 below show the degree of institutional development at the provincial level for the years 2008 and 2017 respectively. We show the measure of institutional development used in our analysis: the mean of the ranking for credit market development and legal environment development. A province that has a higher rank in terms of institutional development appears in a lighter color. The ranking is given by the bar at the bottom of the figures.

It appears that there is persistence over time regarding the level of institutional development of the provinces: the eastern provinces are overall enjoying a higher level of institutional development.

Figure 1.OA1 Institutional development by province in 2008

Figure 1.OA2 Institutional development by province in 2017

1.9.1.2 Correlation of the credit market development and the legal environment development index

Figures 1.OA3 and 1.OA4 below show the mean of the ranking for credit market development and legal environment development separately for the year 2017, which is the last year of our sample.
The comparison of Figure 1.OA3 and Figure 1.OA4 shows that most of the provinces that enjoy a higher level of institutional development in terms of their legal environment also enjoy a higher level of credit market development.

Figure 1.OA3 Institutional development as measured by credit market development

Figure 1.OA4 Institutional development as measured by legal environment development

1.9.1.3 Time trends on the province level

Time trends for R&D investment, patenting, insider ownership, and firms' market value may differ between firms in different provinces. Below we show graphs reporting the time trends divided in provinces with a strong institutional environment and weak institutional environment for the unmatched and matched sample.

As shown in Figure 1.OA5, there are substantial differences between firms in weak and strong institutional environments in terms of R&D investments and patent applications. For this reason, we resort to a matched sample for our analysis. Figure 1.OA6 shows that the time trends for the matched sample are very comparable.

Figure 1.OA5 Time trends for key variables – unmatched sample

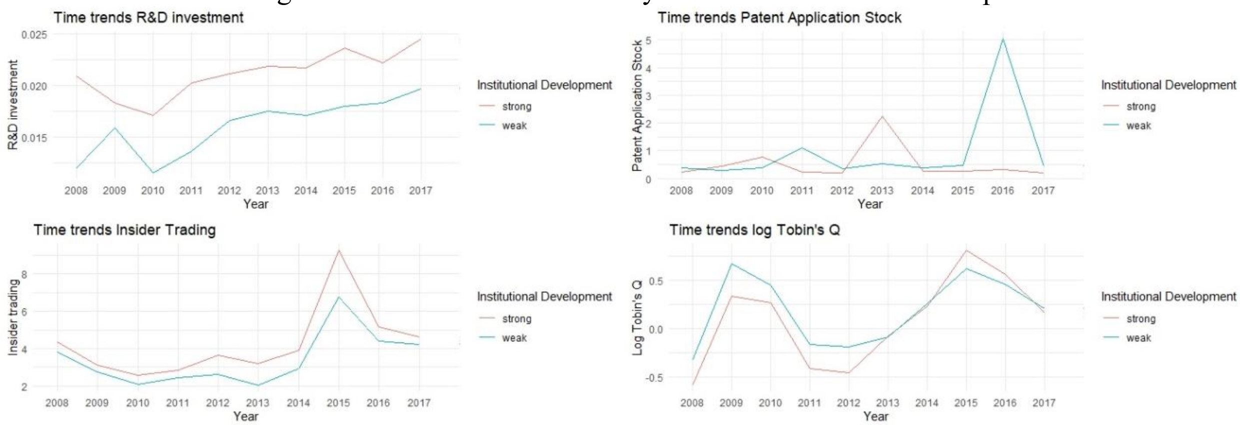
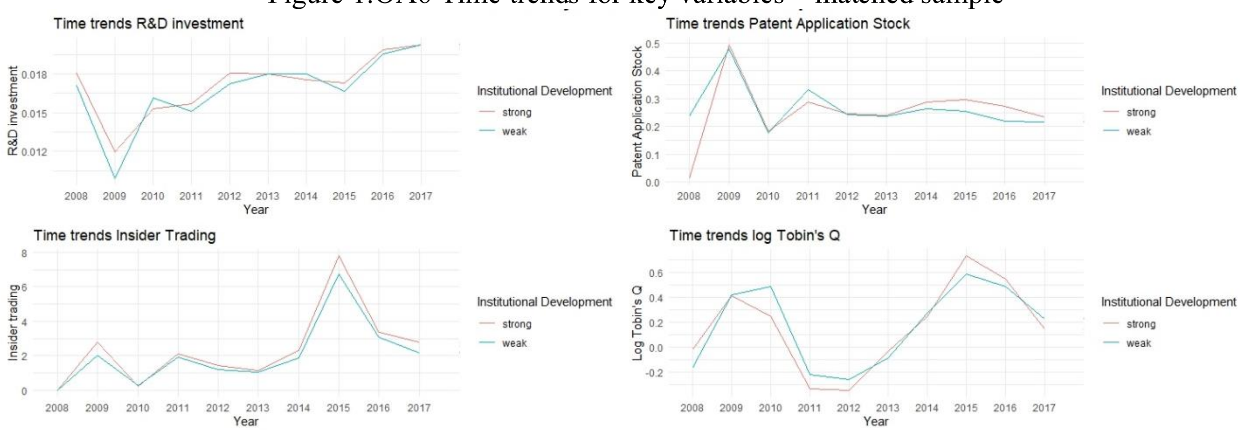


Figure 1.OA6 Time trends for key variables – matched sample



1.9.2 Firm relocation

We find that in the raw data, which includes all firm-year observations for the whole universe of Chinese listed firms, 188 listed firms changed their headquarters' province. Once accounting for missing values, restricting to our target years, accounting for ST (Special Treatment) and PT (Particular Transfer) firms, and restricting to firms located in the 1st and 4th quartile of the institutional development distribution, we end up directly excluding from our final unmatched sample, only one firm (ticker 600699) with 4 observations. In Table 1.OA1 below, we report also the number of firms per province in both pre- and post-matching samples.

Table 1.OA1: Number of firms in each province pre- and post-match

	Province	Number of firms pre-match	Number of firms post-match
1	Anhui	66	41
2	Fujian	63	27
3	Gansu	18	11
4	Guangdong	227	48
5	Guangxi	18	8
6	Guizhou	17	14
7	Hainan	8	5
8	Hebei	40	26
9	Heilongjiang	22	15
10	Henan	62	46
11	Hubei	58	47
12	Hunan	65	42
13	Inner Mongolia	16	7
14	Jiangsu	198	121
15	Jiangxi	25	15
16	Jilin	24	20
17	Liaoning	36	19
18	Ningxia	8	6
19	Qinghai	8	3
20	Shaanxi	26	22
21	Shanghai	102	48
22	Shanxi	19	15
23	Sichuan	60	29
24	Tibet	6	4
25	Xinjiang	18	11
26	Yunnan	19	13
27	Zhejiang	318	202

Notes: In the top quartile of the distribution of the institutional development index (strong institutional environment) we have 907 unique firms pre-match and 446 post-match; in the bottom quartile of the distribution of the institutional development index (weak institutional environment) we have 639 unique firms pre-match and 419 post-match. Notice that there are only 27 provinces represented in both pre- and post-match samples: Beijing, Shandong, Chongqing, and Tianjin are missing due to the fact that within our sample period, they never fall in either the 1st or the 4th quartile of the distribution of our measure of institutional development.

1.9.3 Correlation matrix

Table 1.OA2 below reports the correlation matrix and shows no worryingly high correlation levels between the key variables in our models.

Table 1.OA2: Correlation matrix Between key variables in our main model

	Application Stock/ R&D	Application Stock/n. employees	R&D investment	Total Assets	R&D/Total Assets	n. employees
Application Stock/ R&D						
Application Stock/n. employees	0.16****					
R&D investment	-0.06*	0.02				
Total Assets	-0.02	-0.01	0.81****			
R&D/Total Assets	-0.20****	0.07**	0.26****	-0.02		
n. employees	-0.03	-0.07**	0.77****	0.78****	0.09***	
Application Stock	0.02	0.15****	0.68****	0.49****	0.11****	0.56****

*Notes: Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

1.9.4 Additional robustness checks

1.9.4.1 Placebo test – Commodity market development

One might wonder whether the legal and financial institutional developments are leading our results or whether different aspects of institutional development would lead to similar findings. To address this concern, we re-run our regressions using the NERI index which depicts the "development of the commodity market". In line with our argument, that the financial and legal environment should matter for the valuation of innovative assets, the results do not show an association of the development of the commodity market with the market valuation of innovative assets at the 5% level of statistical significance. The results are presented in Table 1.OA3.

1.9.4.2 Placebo test – Insider sales

This placebo test uses insider sales instead of insider purchases. As insider sales should not carry a signalling value, we expect an insignificant effect of insider sales on the market valuation of innovative assets. Table 1.OA4 shows that this is the case.[22]

[22] Note that we use a matched sample that uses insider sales volume and a dummy instead of insider purchases volume and a dummy as matching criteria.

1.9.4.3 Different definitions of insider ownership

In section 4.3.3 of the main manuscript, we discuss different measures for insider ownership. The first measure uses the inverse hyperbolic sine (IHS) transformation as it also defines zero values (Burbidge et al., 1988; Nyberg et al., 2010). This is important in the context of insider ownership where many firm-year observations have a zero value. The IHS transformation is defined as follows:

$$\mathrm{ihs}(\mathrm{Y_{ijt}}) = \ln\left(\mathrm{Y_{ijt}} + \left(\mathrm{Y_{ijt}}^2 + 1\right)^{\frac{1}{2}}\right) \tag{8}$$

The results are qualitatively the same and are presented in Table 1.OA5.

The second alternative measure is the total value of insider purchases minus the total value of insider sales. Table 1.OA6 shows that the results are robust for the smaller firms matched sample (Model 8), while we do not find support for Hypothesis 2 for the full matched sample (Model 5). A likely explanation is that the trading volume for larger firms is higher and that insiders sell the stock of their firms for a number of reasons other than negative private information, such as liquidity and diversification needs (Jin, 2002; Kahl et al., 2003) or personal tax management (Jin & Kothari, 2008). This implies that insider sales blur our measure, especially for large firms with a higher trading volume.[23]

1.9.4.4 Share repurchases

In section 4.3.4 of the main manuscript, we introduce a robustness check that includes share repurchase instead of insider ownership. A second measure of share repurchase is used in Table 1.OA7 below to show robustness. As an additional robustness check, we calculated both corporate share repurchasing measures, the one used in the manuscript and the one used here, based on the year in which the share repurchase was announced for the first time as reference year. However, the vast majority of the shares repurchase actions

[23] We, further, conducted a placebo test where we used insider ownership from an earlier year. The results show that past insider ownership has no effect on our dependent variable which confirms that insider ownership in year *t* acts as a signal for the value of innovative assets. The results are available upon request.

are completed within the year of the first announcement so that the measures are very similar to the first ones.

Table 1.OA3: Placebo test - Commodity market development rank

(Coarsened exact matching on total assets, insider ownership volume and dummy, ROA, top 10 shareholders concentration, EPS growth rate, patent applications stock over R&D, R&D over assets, and industry and year dummies)

Dependent Variable:	Log Tobin's Q							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	*full sample*					*small firms sample*		
Variables								
R&D/Total Assets	8.624	9.958	17.97	12.45*	24.95	47.80	12.79	58.48*
	(7.536)	(7.127)	(18.36)	(7.402)	(19.12)	(29.17)	(11.32)	(33.07)
Application Stock/R&D	0.1184	0.1082	0.1399	0.1581	0.2447	-0.4759	0.0449	-0.7096
	(0.2212)	(0.2293)	(0.6317)	(0.2250)	(0.6247)	(0.5858)	(0.2779)	(0.4909)
Commodity Mkt. Dev. Rank		-0.0262	-0.0059		-0.0162	0.0409		0.0229
		(0.0237)	(0.0344)		(0.0335)	(0.0418)		(0.0451)
Insider Ownership		0.0147**		0.0422***	0.1065***		0.0923***	0.1494**
		(0.0058)		(0.0134)	(0.0353)		(0.0154)	(0.0682)
R&D/Total Assets × Commodity Mkt. Dev. Rank			-0.5943		-0.6535	-3.226*		-3.178
			(0.9368)		(0.9968)	(1.770)		(1.966)
Commodity Mkt. Dev. Rank × Application Stock/R&D			-0.0026		-0.0032	0.0096		0.0285
			(0.0271)		(0.0271)	(0.0281)		(0.0245)
R&D/Total Assets × Insider Ownership				-0.8748	-3.275**		-3.106***	-4.324*
				(0.6873)	(1.352)		(0.6921)	(2.202)
Insider Ownership × Application Stock/R&D				-0.0601***	-0.0638		-0.0911**	-0.0834
				(0.0223)	(0.0490)		(0.0450)	(0.1092)
Commodity Mkt. Dev. Rank × Insider Ownership					-0.0025			-0.0015
					(0.0015)			(0.0042)
R&D/Total Assets × Commodity Mkt. Dev. Rank × Insider Ownership					0.1056			0.0050
					(0.0761)			(0.2091)
Commodity Mkt. Dev. Rank × Insider Ownership × Application Stock/R&D					-0.0029			-0.0042
					(0.0035)			(0.0060)
Fixed-effects								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	480	480	480	480	480	239	239	239
R^2	0.96319	0.96525	0.96350	0.96597	0.96786	0.96212	0.96358	0.96951
Within R^2	0.19702	0.24204	0.20379	0.25784	0.29902	0.31938	0.34566	0.45226

Clustered (Firm) standard-errors in parentheses

Signif. Codes: ***: 0.01, **: 0.05, *: 0.1

Notes: OLS regressions with standard errors clustered at the firm level, and firm and year fixed effects. Control variables: working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, ROA, and shareholders concentration for top 1, 3, 5, and 10 shareholders.

Table 1.OA4: Placebo test - Insider sales

(Coarsened exact matching on total assets, insider ownership volume and dummy, ROA, top 10 shareholders concentration, EPS growth rate, patent applications stock over R&D, R&D over assets, and industry and year dummies)

Dependent Variable:	Log Tobin's Q							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	*full sample*					*small firms sample*		
Variables								
R&D/Total Assets	12.60**	12.17**	23.90***	11.88**	26.72***	30.80***	12.57**	31.88***
	(5.312)	(5.028)	(8.297)	(5.280)	(7.802)	(9.896)	(5.871)	(9.928)
Application Stock/R&D	0.2717**	0.2720**	0.2909*	0.2704**	0.2795*	0.5246**	0.3941**	0.5410**
	(0.1149)	(0.1173)	(0.1649)	(0.1188)	(0.1628)	(0.2602)	(0.1824)	(0.2513)
Institutional Dev. Rank		0.0219	0.0356*		0.0410**	0.0652***		0.0691***
		(0.0145)	(0.0185)		(0.0175)	(0.0245)		(0.0222)
Insider Ownership		0.0169***		0.0150*	0.0280**		0.0338***	0.0319*
		(0.0033)		(0.0085)	(0.0117)		(0.0107)	(0.0191)
R&D/Total Assets × Institutional Dev. Rank			-0.9839*		-1.175**	-1.392**		-1.349**
			(0.5710)		(0.5534)	(0.6082)		(0.6227)
Institutional Dev. Rank × Application Stock/R&D			-0.0022		-0.0014	-0.0126		-0.0132
			(0.0121)		(0.0125)	(0.0161)		(0.0159)
R&D/Total Assets × Insider Ownership				0.1281	-0.3103		-0.4325	-0.3731
				(0.3721)	(0.4904)		(0.4964)	(0.8942)
Insider Ownership × Application Stock/R&D				-0.0038	0.0023		-0.0278***	-0.0135
				(0.0097)	(0.0133)		(0.0107)	(0.0126)
Institutional Dev. Rank × Insider Ownership					-0.0007			0.0012
					(0.0009)			(0.0016)
R&D/Total Assets × Institutional Dev. Rank × Insider Ownership					0.0174			-0.0449
					(0.0444)			(0.0759)
Institutional Dev. Rank × Insider Ownership × Application Stock/R&D					-0.0013			-0.0027
					(0.0016)			(0.0023)
Fixed-effects								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	1,003	1,003	1,003	1,003	1,003	503	503	503
R^2	0.90976	0.91605	0.91138	0.91552	0.91823	0.95331	0.95602	0.95962
Within R^2	0.15234	0.21150	0.16761	0.20652	0.23191	0.30315	0.34356	0.39723

Clustered (Firm) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: OLS regressions with standard errors clustered at the firm level, and firm and year fixed effects. Control variables: working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, ROA, and shareholders concentration for top 1, 3, 5, and 10 shareholders.

Table 1.OA5: Robustness check - Inverse Hyperbolic Sine (IHS) transformation

(Coarsened exact matching on total assets, insider ownership volume and dummy, ROA, top 10 shareholders concentration, EPS growth rate, patent applications stock over R&D, R&D over assets, and industry and year dummies)

Dependent Variable:	Log Tobin's Q							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:			*full sample*				*small firms sample*	
Variables								
R&D/Total Assets	11.46***	11.36***	17.65***	12.81***	19.78***	26.35***	14.97***	27.23***
	(3.562)	(3.566)	(5.175)	(3.488)	(4.807)	(5.745)	(4.066)	(5.871)
Application Stock/R&D	0.3890***	0.3773***	0.5482***	0.3798***	0.5529***	0.7314***	0.5137***	0.7615***
	(0.0924)	(0.0900)	(0.1377)	(0.0930)	(0.1471)	(0.1545)	(0.1033)	(0.1635)
Institutional Dev. Rank		0.0240*	0.0433***		0.0460***	0.0538***		0.0586***
		(0.0130)	(0.0163)		(0.0161)	(0.0197)		(0.0193)
Insider Ownership		0.0013		0.0112	0.0197*		0.0144*	0.0402**
		(0.0025)		(0.0068)	(0.0115)		(0.0080)	(0.0169)
R&D/Total Assets × Institutional Dev. Rank			-0.6756*		-0.7286**	-1.235***		-1.205***
			(0.3520)		(0.3500)	(0.4076)		(0.4156)
Institutional Dev. Rank × Application Stock/R&D			-0.0201**		-0.0209**	-0.0277***		-0.0287***
			(0.0091)		(0.0093)	(0.0102)		(0.0106)
R&D/Total Assets × Insider Ownership				-0.6375*	-1.317**		-0.2481	-1.509**
				(0.3380)	(0.5479)		(0.3730)	(0.7278)
Insider Ownership × Application Stock/R&D				0.0043	-0.0082		-0.0098	-0.0187
				(0.0076)	(0.0104)		(0.0128)	(0.0185)
Institutional Dev. Rank × Insider Ownership					-0.0010			-0.0019*
					(0.0008)			(0.0011)
R&D/Total Assets × Institutional Dev. Rank × Insider Ownership					0.0813**			0.0994*
					(0.0399)			(0.0517)
Institutional Dev.Rank ×Insider Ownership × Application Stock/R&D					0.0017			0.0007
					(0.0014)			(0.0018)
Fixed-effects								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	1,582	1,582	1,582	1,582	1,582	791	791	791
R^2	0.88374	0.88488	0.88592	0.88487	0.88835	0.92726	0.92512	0.92902
Within R^2	0.16909	0.17726	0.18465	0.17719	0.20204	0.24789	0.22575	0.26604

Clustered (Firm) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Ordinary Least Squares (OLS) regression with standard errors clustered at the firm level, and firm and year fixed effects. Small refers to firms with total assets below the sample median. Insider ownership is calculated with the IHS transformation of insiders purchase value. Control variables: working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, ROA, and shareholders concentration for top 1, 3, 5, and 10 shareholders. Total assets, used as one of the matching covariates, is log-transformed.

Table 1.OA6: Second measure for Insider Ownership

(Coarsened exact matching on total assets, insider ownership volume and insider ownership categories, ROA, top 10 shareholders concentration, EPS growth rate, patent applications stock over R&D, R&D over assets, and industry and year dummies)

Dependent Variable:	Log Tobin's Q							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	*full sample*					*small firms sample*		
Variables								
R&D/Total Assets	14.71***	15.32***	22.09***	15.10***	22.71***	40.27***	21.21***	37.27***
	(4.913)	(4.985)	(7.501)	(4.928)	(7.499)	(10.79)	(7.728)	(10.67)
Application Stock/R&D	0.1890*	0.1906*	0.3984**	0.1927*	0.3999**	0.7662***	0.2662**	0.7397***
	(0.1122)	(0.1100)	(0.1737)	(0.1130)	(0.1755)	(0.1869)	(0.1179)	(0.1801)
Institutional Dev. Rank		0.0019	0.0226		0.0228	0.0233		0.0175
		(0.0144)	(0.0184)		(0.0188)	(0.0277)		(0.0280)
Insider Ownership		-0.0259		-0.2863	-0.3559		-0.0850	0.8273*
		(0.0440)		(0.2101)	(0.3002)		(0.3620)	(0.4729)
R&D/Total Assets × Institutional Dev. Rank			-0.8865*		-0.9379*	-1.753**		-1.506*
			(0.5152)		(0.5198)	(0.8225)		(0.8163)
Institutional Dev. Rank × Application Stock/R&D			-0.0248**		-0.0241**	-0.0428***		-0.0402***
			(0.0108)		(0.0109)	(0.0112)		(0.0110)
R&D/Total Assets × Insider Ownership				10.29	14.19		-9.279	-48.36***
				(7.985)	(11.23)		(15.60)	(18.43)
Insider Ownership × Application Stock/R&D				0.0601	-0.1065		0.1939	-0.1442
				(0.1245)	(0.2215)		(0.1468)	(0.2189)
Institutional Dev. Rank × Insider Ownership					0.0065			-0.1289***
					(0.0267)			(0.0438)
R&D/Total Assets × Institutional Dev. Rank × Insider Ownership					-1.372			6.761**
					(1.752)			(2.732)
Institutional Dev. Rank × Insider Ownership × Application Stock/R&D					0.1706			0.0876
					(0.1580)			(0.1153)
Fixed-effects								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	1,039	1,039	1,039	1,039	1,039	517	517	517
R^2	0.90749	0.90774	0.90940	0.90791	0.91003	0.95502	0.95135	0.95772
Within R^2	0.20133	0.20355	0.21786	0.20499	0.22332	0.39724	0.34811	0.43348

Clustered (Firm) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: OLS regressions with standard errors clustered at the firm level, and firm and year fixed effects. Control variables: working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, ROA, and shareholders concentration for top 1, 3, 5, and 10 shareholders.

Table 1.OA7: Robustness check - Share repurchase

(Coarsened exact matching on total assets, **share repurchased over net income**, ROA, shareholders concentration, EPS growth rate, R&D over assets, patent application stock over R&D, and industry and year dummies)

Dependent Variable:	Log Tobin's Q							
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	*full sample*					*small firms sample*		
Variables								
R&D/Total Assets	13.16***	13.58***	24.18***	12.89***	23.87***	17.96***	8.217*	17.33**
	(3.878)	(3.870)	(5.417)	(3.901)	(5.488)	(6.875)	(4.290)	(6.957)
Application Stock/R&D	0.2956***	0.3091***	0.6161***	0.2920***	0.6227***	0.7328***	0.2437*	0.7307***
	(0.1045)	(0.1029)	(0.2052)	(0.1049)	(0.2084)	(0.1664)	(0.1350)	(0.1675)
Institutional Dev. Rank		0.0263**	0.0463***		0.0462***	0.0453***		0.0459***
		(0.0128)	(0.0135)		(0.0136)	(0.0150)		(0.0151)
Share Repurchase		-0.0886		4.195	11.75***		-12.52*	4.109
		(0.6241)		(2.623)	(3.563)		(6.694)	(3.874)
R&D/Total Assets × Institutional Dev. Rank			-0.9468***		-0.9280**	-0.6469*		-0.6227*
			(0.3613)		(0.3665)	(0.3643)		(0.3666)
Institutional Dev. Rank × Application Stock/R&D			-0.0244**		-0.0247**	-0.0332***		-0.0334***
			(0.0118)		(0.0119)	(0.0107)		(0.0108)
R&D/Total Assets × Share Repurchase				-173.2	-365.8**		66.14	-771.1***
				(118.5)	(151.8)		(420.5)	(193.2)
Share Repurchase × Application Stock/R&D				-16.63	-43.96**		39.13**	0.2512
				(11.13)	(18.53)		(18.17)	(18.97)
Institutional Dev. Rank × Share Repurchase					-6.569***			-4.617***
					(1.451)			(0.7586)
R&D/Total Assets × Institutional Dev. Rank × Share Repurchase					141.9***			141.2***
					(34.06)			(26.27)
Institutional Dev. Rank × Share Repurchase × Application Stock/R&D					26.94***			19.33**
					(8.791)			(8.149)
Fixed-effects								
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics								
Observations	1,290	1,290	1,290	1,290	1,290	894	894	894
R^2	0.88293	0.88392	0.88648	0.88316	0.88731	0.91618	0.91355	0.91765
Within R^2	0.09988	0.10749	0.12719	0.10169	0.13354	0.14683	0.12004	0.16178

Clustered (Firm) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Notes: Ordinary Least Squares (OLS) regression with standard errors clustered at the firm level, and firm and year fixed effects. Small refers to firms with total assets below the sample mean. Share repurchase is measured as the ratio of the firm monetary investment in the actual share repurchase plan over its net income; if there are no share repurchases in a year, it takes a value of 0. Control variables: working capital, asset-to-liability ratio, EPS growth rate, operating liabilities ratio, and ROA. Total assets, used as one of the matching covariates, is log-transformed.

1.10 References to the online appendix

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Chapter 2

Information accessibility and knowledge creation: The impact of Google's withdrawal from China on scientific research

Keywords: information accessibility; academic publications; knowledge production; Google; China.

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2.1 Introduction

Since Google entered mainland China in 2006, its share of the search engine market of mainland China[1] rapidly increased to 40.08% by the end of 2009.[2] Together with the Chinese firm Baidu, which offers a similar service portfolio and held a market share of 58.47%,[3] Google effectively became part of a duopoly (Kong, Lin, Wei, & Zhang, 2022). Google was, hence, a main source of information in China, especially of information from foreign countries (Kong et al., 2022; Wang, Yu & Zhang, 2020). Like any search engine provider operating in China, Google was obliged to follow the strict censorship guidelines imposed by the Chinese government, but, in January 2010, Google decided to discontinue the censoring of search results on its China search page (Google.cn).[4] This decision rapidly escalated in a sudden and unannounced withdrawal of some Google services from China, leaving millions of users without access to the world's top search engine overnight. From the 30th of June 2010 onwards, users in China could not access some of the main Google services anymore (Roberts, 2014; Quinn, 2012; The Official Google Search Blog, 2012; Xu, Xuan & Zheng, 2021; Kong et al., 2022).[5]

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[1] Hereafter, we refer to mainland China simply as 'China'.

[2] https://gs.statcounter.com/search-engine-market-share/all/china/#quarterly-200901-201601

[3] https://gs.statcounter.com/search-engine-market-share/all/china/#quarterly-200901-201601

[4] In January 2010, following a major cyber-attack on Google, originating from China, it has been uncovered that accounts of dozens of human rights activists connected with China were being routinely hacked. This, "combined with attempts over the last year to further limit free speech on the web in China including the persistent blocking of websites such as Facebook, Twitter, YouTube, Google Docs and Blogger" (Drummond, 2010), led Google to discontinue its censoring activities on search results from Google.cn.

[5] Towards the end of March 2010, frictions between the Chinese Communist Party (CCP) and Google's executives due to censorship issues and hacking attempts led Google to withdraw its search engine from China, meaning that Google.cn was not working anymore. Google users' search requests, after the 23rd of March 2010, were redirected to Google's Hong Kong servers, but, as Kong et al. (2022, p. 5) points out: "[t]he Chinese government criticized Google's withdrawal as unfriendly and irresponsible and blocked Google's Hong Kong search website and its search websites in all other languages on March 30, 2010. Google then stopped redirecting visits to its Chinese search website to its Hong Kong website starting from June 30, 2010 (Cheng, 2010). From there on, accessing search results via Google has become excessively difficult from mainland China". The initial redirection to the Hong Kong servers was applied only to Google Search, Google News, and Google Images, while other specialized services of Google, such as Google Maps, Google Music, and Google Shopping, remained available in China and were shut down from 2012 onward. While scholars like Zheng and Wang (2020) focus on 2014 as the year of the 'shock' since this is the date in which all of the services offered by Google were unavailable in China, we, in the spirit of Kong et al. (2022) and Xu et al. (2021), use the year 2010 as the relevant year of the 'shock', i.e., when Google's search engine became unavailable in China. We do so because at that time Google search engine was the essential service to access information about science as Google Scholar was still underdeveloped and underfeatured as compared to its current version.

In this paper, we investigate the effect of Google's[6] sudden exit from China on the scientific research output of scholars in the field of economics located in China. Access to information in the form of books and research material has been shown to be crucial for the generation of new knowledge (Furman & Stern, 2011; McCabe & Snyder, 2015; Waldinger, 2016; Berkes & Nencka, 2019; Mueller-Langer, Scheufen & Waelbroeck, 2020; Furman, Jensen & Murray, 2012; Biasi & Moser, 2021; European Commission, 2012). A lack of access or high accessibility costs can, hence, be a key barrier to new discoveries and knowledge creation. Not surprisingly, information and communication technologies have been shown to enhance science production by increasing the availability of information and, hence, reducing search costs (Agrawal & Goldfarb, 2008; Ding, Levin, Stephan & Winkler, 2010; Winkler, Levin & Stephan, 2010; Kim, Morse & Zingales, 2009). While the withdrawal of Google's services from China does not completely shut down access to information for academic scholars, it surely leads to an increase in their search costs.[7] Affected scholars are, therefore, still able to access information, but the lengthier research process generates a slowdown of their knowledge production and, hence, their short-term publication outcome.[8] Google's sudden exit from China, therefore, bears the risk that researchers located in China lose touch with the research frontier and persistently lag behind their foreign peers.

Using Google's exit from China to assess the effect of barriers to information accessibility on scientific research has several advantages that address common challenges for causal estimation. First, Google's exit was exogenous to science production and unexpected as it was the result of a rapid escalation of political tensions between the Chinese leadership and Google (Zheng & Wang, 2020; Xu et al., 2021; Kong et al., 2022). Second, Google was, at the time of the sudden withdrawal of its services, one of the main sources

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[6] Note that we do not specifically refer to Google scholar.

[7] In fact, for quite some time "there is growing evidence that both novice and experienced searchers are increasingly using simple single text box search interfaces such as those provided by search engines like Google (http://google.com)" (Hemminger, Lu, Vaughan & Adams, 2007, p. 2214).

[8] A scholar affected by the withdrawal of Google can still have access to specific websites. Without a centralized platform such as Google search, however, the researcher would either need to know the exact source of the piece of information she is looking for or would have to invest a significantly larger amount of time to look for it (compared to accessing it through Google search). This would lead to a delay of her publications.

of knowledge for China (Kong et al., 2022; Wang, Yu & Zhang, 2020) and its scientists (Qiu, 2010).

Our empirical analysis focuses on the field of economics following prior studies such as Kim et al. (2009), McCabe & Snyder (2015), Liang, Gu & Nyland (2022), and Piracha, Tani, Zimmerman & Zhang (2022). Economics is a research field with a simple knowledge production function as it does not rely on material and expensive specialized equipment (Stephan & Levin, 1992). In addition, new insights are published almost exclusively in scientific journals rather than in books and conference proceedings which are often not well covered in bibliometric databases (e.g., Michels & Fu, 2014). Hence, an estimated effect of the sudden decrease in information accessibility on scientific output is less likely to be confounded by other effects resulting from the knowledge generating process or the publication strategy of the field.

To derive causal results, we use a Difference-in-Difference (DiD) approach employing a control group of researchers located in Taiwan and Hong Kong following Zheng & Wang (2020) who argue for a control group that is culturally, economically, and geographically closely related to China. Our results show that researchers in the field of economics affiliated with Chinese institutions experience a significant decline in both their research output quantity and impact as measured by citations received by the future literature. The magnitude is about 28% for co-author weighted publications and 30% for co-author weighted citations.

We explore the proposed underlying mechanism of information accessibility further and show that the productivity and impact of those scholars located in China who work with foreign co-authors are less affected by Google's exit. These scholars can use their interpersonal networks as a channel for knowledge access (Singh, 2005; Mohnen, 2022). The publication output and impact of these scholars decrease by smaller shares of 20% and 22%, respectively, supporting that the mechanism of knowledge accessibility is responsible for the decline in publication output after Google's withdrawal.

In further analysis, we find that the effect in terms of quantity and impact is stronger for those scholars with the highest impact as measured by their citation stock over publication stock before Google's withdrawal. The publication output and impact of the top 25% scholars decrease by 39.5% and 37.5%, respectively, while the publication output of the scholars at the bottom of the impact distribution decreases by 20%. There is no significant effect for the scholars at the bottom of the impact distribution in terms of impact. The large effects on the top scholars raise concerns about the ability of China to stay in touch with the research frontier in the medium and long run with potentially harmful implications for economic growth (Griliches, 1992; Jaffe, 1989). Also, we find no significant differences in the negative effect of the shock on treated scholars affiliated with both top and less renowned universities.

While our study is limited to the field of economic research, we make several contributions to the literature. First, our work adds to our understanding of the determinants of knowledge creation (Stephan & Levin, 1992; Stephan, 1996, for an overview) and more specifically of the role of information and communication technology in knowledge creation (Agrawal & Goldfarb, 2008; Ding et al., 2010). Prior studies have shown that access to network technology (Agrawal & Goldfarb, 2008; Ding et al., 2010, for the case of BITNET) eases information accessibility and facilitates the knowledge production of scientists. Here, we focus on Google as a general search engine and complement prior findings for different technologies. Second, we contribute to recent literature that focuses on positive information shocks such as the availability of access to libraries (Berkes & Nencka, 2019; Furman et al., 2012; Biasi & Moser, 2021), of research resources (Furman & Stern, 2011) and of online access to scientific journals (McCabe & Snyder, 2015; Mueller-Langer et al., 2020), and their impact on knowledge creation. We differ from these studies in two ways. First, these studies focus on the access to prior scientific knowledge available in the form of books, journals, and research resources while we focus on the access to a search engine that covers a much broader scope of information. Second, we explore a negative shock to information availability to assess the effects on science production while prior studies focus on positive shocks to information availability. We cannot assume that positive and negative shocks have a symmetric effect since this is rarely the case in reality (see, for instance, the large literature on asymmetric investor reactions in financial markets, e.g., Kuhnen, 2015; Kluger & Wyatt, 2005, or, a very different example, the asymmetric responses of individuals to positive and negative feedback about their intelligence and beauty, Eil & Rao, 2011).

Third, our finding that scholars can use their interpersonal networks as a channel for knowledge access (Singh, 2005; Mohnen, 2022) contributes to the large literature on academic networks (e.g. Beaver & Rosen, 1978; Wuchty, Jones & Uzzi, 2007; Greene, 2007; Fanelli & Lariviere, 2016) and, in particular, to the smaller literature on informal links between researchers (Laband & Tollison, 2000; Brown, 2005; Oettl, 2012; Rose & George, 2021). Prior studies define informal links between researchers as providing feedback visible in the acknowledgment of the paper (Laband & Tollison, 2000; Rose & George, 2021) or through presentations (Laband & Tollison, 2000; Oettl, 2012; Brown, 2005) and show that these informal collaborations increase citations. We provide suggestive evidence for co-author networks facilitating access to knowledge beyond joined projects which leads to a lower drop in scientific productivity and citations in the presence of an information shock.

Lastly, we add to the developing literature that focuses on the implications of Google's withdrawal from China. These include a higher stock crash risk for firms (Xu, Xuan & Zheng, 2021) and a decrease in corporate innovation (Kong et al., 2022; Zheng & Wang, 2020). Differently from these prior studies, our focus is on the scientific rather than on the corporate sector.

2.2 Background

The well-known cumulative nature of science requires research to evolve along specific lines where scientists build on and advance prior insights (Merton, 1973; Mokyr, 2002; Azoulay, Furman & Murray, 2015). Having access to the most recent worldwide developments in the respective research field is, hence, crucial for the generation of new state-of-the-art knowledge (Berkes & Nencka, 2019; Furman et al., 2012; European Commission, 2012). Further, the nature of competition in science is a winner-takes-all game that promises high reputation gains, lucrative jobs, and research opportunities for the winner, i.e., the first to make a discovery, while the second to finish the race often leaves empty-handed (Merton, 1973). This implies that the distribution of publications and citations at the individual level is extremely skewed (Lotka, 1926; Price, 1963) and only a minority of scientists are able to contribute to the advancement of science (Cole & Cole, 1972; Partha & David, 1994). The nature of competition in science emphasizes the crucial importance of speedy access to recent information.

As scientific research becomes increasingly complex and multidisciplinary over time (Jones, 2009; Wuchty et al., 2007), scientists' costs of staying up to date with the latest discoveries in their research field increased tremendously over the past decades. Information and communication technologies have been shown to be crucial factors in today's knowledge production function as they increase the availability of information and reduce search costs (Agrawal & Goldfarb, 2008; Ding et al., 2010; Winkler et al., 2010; Kim et al., 2009). Agrawal & Goldfarb (2008) and Ding et al. (2010), for instance, show how access to BITNET facilitated collaboration between scientists and enhanced knowledge production. McCabe & Snyder (2015) and Mueller-Langer et al. (2020) show how online access to scientific journals improves citation rates and the creation of new scientific results in both developed and developing countries.

Here, we focus on Google and its search engine as an alternative technology that facilitates information access and reduces search costs (Zheng & Wang, 2020; Xu et al., 2021; Kong et al., 2022). Google's services have been shown to be crucial for corporate China by facilitating the development of novel technologies (Zheng & Wang, 2020; Kong et al., 2022) and preventing investor overreactions leading to stock crashes in Chinese businesses (Xu et al., 2021). The importance of Google was not less significant for the academic sector. After Google's exit, visits to Wiley Online Library from Google dropped by around 30%, and from Google Scholar by around 15% (Eassom, 2016). According to a survey of almost 800 Chinese researchers conducted by Nature just before Google's withdrawal, more than 80% of the respondents used Google's search engine to find academic papers, close to 60% to get information about scientific discoveries or other scientists' research programs, and one-third of the survey respondents made use of Google's products to find science-policy and funding news (Qiu, 2010). This evidence highlights how important information is at all stages of the research process, from searching for input and defining a research project to access to funding. Google's withdrawal from China, hence, significantly increased the barriers to access information for scientists located in China and they could hardly find alternatives, such as Virtual Private Networks (VPNs) [9] or mirror platforms [10], to overcome the search hurdle (Lu et al., 2017).[11]

In this article, we, therefore, ask the question of whether and to what extent the scientific output of scholars located in China is negatively affected by Google's withdrawal of its services. We expect a negative effect since access to information and prior knowledge is one key ingredient of the knowledge production function (Stephan & Levin, 1992; Ding et al., 2010). The limited accessibility of information is expected to affect both publication outcome and impact. The underlying mechanisms are different though. Regarding publications, treated scholars may publish less due to a more difficult access to information and higher search costs. Regarding citations, treated scholars may receive fewer citations per publication due to a lower "quality" of their work. Not having readily access to the most recent scientific advances implies that their research is not as close to the knowledge frontier as other articles. The resulting restricted novelty of the publications leads to fewer citations. Overall, difficulties to stay in touch with the research frontier delay the scientists and make them less likely to win the race for priority. This should be directly reflected in a lower publication output. In addition, Google's search engine was especially important in China for accessing foreign information (Kong et al., 2022). Baidu's search engine, in contrast, ranks local search results, i.e. search results in Chinese language, with higher priority than foreign information (Yi, 2014). Google has therefore a comparative advantage in nonlocal information search and its exit enforced a tendency to source more local information (Zheng & Wang, 2020). While local search can be more efficient

[9] As noted by Jennings (2010), "[t]he rise of VPNs comes as China defends its curbs on the internet after the world's biggest search engine provider, Google Inc., threatened to shut down its Chinese Google.cn site over censorship and a severe hacking attack". This means that VPNs in China back in 2010 were not a main instrument to circumvent the GFC. In addition, there is evidence that the Chinese government was strongly against VPNs already back in 2011 with users reporting unstable connections when trying to access foreign websites. All the above evidence points to the fact that VPNs back in 2010 were not able to provide scholars with stable access to information.
[10] Mirror platforms, such as 'scholar.glgoo', aim at mirroring existing but inaccessible websites due to the Chinese internet censorship. Such platforms were not available around the 2010 shock year (https://web.archive.org/web/20230000000000*/https://scholar.glgoo.org/).
[11] Lu et al. (2017) surveyed 371 faculty members and students at Tsinghua University, one of the top academic institutions in China, in 2015, on whether and how they can bypass the Great Firewall of China (GFC). Even though 26% of the respondents claimed that they can regularly bypass the Great Firewall through VPNs, none of the commonly adopted solutions have provided satisfactory user experiences.

for some topics, it may lead to a 'local search trap' resulting in rather incremental improvements to the state of the art (Laursen, 2012; Wagner, Hoisl & Thoma, 2014; Zheng & Wang, 2020).[12] Distant search, in contrast, tends to be explorative in nature and stimulates the arrival of novel ideas so that it increases the chances of breakthrough inventions (Arts & Fleming, 2018). The difficulties in engaging in distant searches and the resulting decrease in novelty should be reflected in a decline in the impact of the scientific publications that scholars located in China publish after Google's withdrawal. Chinese publications after Google's exit are expected to be used to a lesser extent as building blocks for future research. In summary, we expect that the publication volume and impact of scholars located in China drops after Google's exit from China.

2.3 Method

To analyze the effect of the sudden withdrawal of Google from China on the publication volume and impact of scholars located in China, we employ DiD methods. Our treatment group consists of authors who were only affiliated with one or more universities in China before and after Google's withdrawal.[13] The control group consists of scholars that were affiliated with one or more universities in Hong Kong or Taiwan before and after 2010 following Zheng & Wang (2020) who recommend using a control group that is culturally, economically, and geographically closely related to China. We believe that scholars affiliated in Hong Kong and Taiwan are a suitable control group for the following reasons: (1) in China, Hong Kong, and Taiwan, scholars are influenced by Chinese culture, history, and politics and they all face similar political and

[12] In addition, (1) Baidu mixes and prioritizes a large proportion of advertisements in its search results (Yi, 2014) while Google displays paid search results separately leading to a low overlap and little ranking similarity in the search results between the two search engines (Jiang 2014a, b); (2) the quality of search results in Baidu was even poorer back in the years around 2010 (CNNIC, 2011), in fact 44% of the respondents to the Annual national survey on search engines in China conducted by the China Internet Network Information Center (CNNIC) criticized Baidu for 'garbage information and bad links' (Kong et al., 2022, p.5); and (3) Google appeared to continue providing uncensored search results from foreign websites despite the agreement with the Chinese government (Thompson, 2006; Xu et al., 2021; Wilson, Ramos & Harvey, 2007; Lau, 2010; Kong et al., 2022), hence providing higher-quality search results to users' requests.

[13] To obtain a clean setup for this study, we do not allow scholars in the treated group to be affiliated with institutions outside of China. That is, if a scholar is affiliated both in China and outside of China, she is not included in our treated group as we would not have information on her physical location. In fact, when analyzing the impact of the shock on scholars with double affiliations, we do not find any significant effect.

cultural pressures; (2) scholars in China, Hong Kong, and Taiwan had limited access to research funding and resources as compared to scholars in the U.S. and Europe (back in the years around the shock); (3) scholars in China, Hong Kong, and Taiwan are more likely to engage between themselves due to geographical proximity which is likely to affect their research visions and approaches; and (4) researchers in China, Hong Kong, and Taiwan speak the same language.

We estimate an equation of the form:

$$\mathrm{Publications_{it}} = \mathrm{f}(\beta_1 \mathrm{Treat_i} * \mathrm{Post_t} + \delta\Gamma_\mathrm{i} + \varphi_\mathrm{t}) + \varepsilon_{\mathrm{it}} \quad (1)$$

where $Publications_{it}$ represents different dependent variables that capture the publication output and impact of author i in year t. Those are the publication count, the fractional publication count, the citation count, the fractional citation count, and citations divided by publications in year t. As the dependent variables tend to follow a count distribution, we estimate the model as a Poisson model.

The variable $Treat_i$ is a binary variable that indicates whether a scholar belongs to the treatment group or the control group. Note that the affiliation with the treatment or control group ($Treat_i$) is time-invariant and, hence, included in the author's fixed effect (Γ_i). Γ_i controls for inherent differences between researchers caused by unobservable factors such as talent or ability in the form of researcher fixed effects. To show the robustness of our results, we also present specifications without fixed effects where we estimate a potential effect for the systematic difference between treatment and control groups and allow for control variables in the Appendix. The variable $Post_t$ is a binary variable that takes the value one from the year after Google's withdrawal from China, 2011, onwards. φ_t captures common time trends through a set of year dummies.

The main result of the model is provided by the coefficient β_1, which captures the average difference in the change of publication output between treatment and control observations after Google's withdrawal. If scientists in the treatment group experience a decline in publications after having a more restricted access to information, while scientists in the control group do not, β_1 shows a negative and significant effect.

2.4 Data, Variables, and Descriptive Statistics

2.4.1 Data

To investigate the effect of Google's withdrawal of its services from China on scientific productivity, we retrieve scholarly publications from English language journals and citation data for researchers in China, Taiwan, and Hong Kong for the time period 1995-2019 from Scopus. Scopus has been found to outperform its competitor World of Science in terms of coverage (Aksnes & Sivertsen, 2019), especially in the field of economics research (Bosman, Mourik, Rasch, Sieverts & Verhoeff, 2006). With our choice of research field, we follow prior studies such as Kim et al. (2009), McCabe & Snyder (2015), Liang et al. (2022), and Piracha et al. (2022) which also based their empirical analyses on data for scholars in the field of economics. Studying economics has two important advantages. First, the science production function is relatively simple as it does not rely on material and expensive equipment so that the input factors reduce to effort, skills, and knowledge (Stephan & Levin, 1992; Ding et al., 2010). Second, insights in the field of economics are published almost exclusively in scientific journals rather than in books and conference proceedings which are typically not well covered by publication databases. Hence, an estimated effect of the sudden decrease of information accessibility on scientific output in economics is less likely to be confounded by other effects resulting from the knowledge generating process or the publication strategy of the field.

To arrive at the author level, we aggregate our publication data at the author-year level relying on the Scopus author identifiers (Kawashima & Tomizawa, 2015).[14] This leads to an unbalanced panel that includes the complete publication record of each author from 1995 onwards. Each author enters the database with her first publication and leaves the dataset with the last publication observed in Scopus. Years in which an author has not published are treated as years of zero publications. After some data inspection at the author level, we exclude the earliest and latest years leading to a time window for the analysis of the years 2007-

[14] According to Kawashima and Tomizawa (2015) Scopus authors' identifiers are reliable, reaching about 98% in terms of recall and 99% in terms of precision (see also Baas, Schotten, Plume, Côté & Karimi, 2020).

2017.

After excluding authors with missing country information[15] and some further data cleaning[16], we drop authors with double affiliations in China and elsewhere as we cannot be sure about their country of residency. This is crucial because an author with an affiliation in China and the U.S. could be working in the U.S. and, hence, not be affected by the exit of Google from China. In total, we excluded 1,644 authors with affiliations both in China and the rest of the world (7,680 observations) and 725 authors with affiliations both in China and Hong Kong or Taiwan (5,509 observations).

Further, we include only authors who did not change their country of affiliation during our time period of interest. This reflects a conservative approach because we only focus on authors with one affiliation region, i.e. China, HK, and Taiwan, or rest of the world, and, implicitly, we also account for authors that did not change their affiliation before and after 2010, potentially motivated by the restrictions faced in China. At this point, 1,249 authors are excluded. We also only keep authors that have at least one publication before and after 2010 to assure that the treated scholar is part of the same regime in the pre-and post-treatment period so that the performance before and after the shock can be meaningfully compared. In other words, we exclude scholars who might have left or joined Chinese academia for reasons potentially related to the treatment. Here, 39,508 authors are removed.

After cutting some outliers, i.e. the top 1% of the distribution of each dependent variable, our final dataset comprises 16,750 observations at the author-year level which corresponds to 8,653 observations for 1,141 treated authors and 8,097 observations for 1,004 control authors. For a later investigation of the proposed mechanism of information accessibility, we further distinguish between treated authors who collaborated with foreign authors over our sample period and those who did not. 6,188 observations on 769 authors in

[15] This affected 1,189 observations of 237 authors.

[16] For example, we found that the International Journal of Biological Macromolecules was wrongly assigned to the field of economics and dropped all the misclassified authors (15,942 authors with 24,844 observations) that published in the respective research discipline.

the treatment group collaborated with foreign scholars.

2.4.2 Variables

We use five dependent variables to measure the scientific output of our scholars in terms of quantity and impact. Specifically, we use the number of publications and the co-author weighted number of publications, i.e. fractional publications, as simple output indicators. To account for publication impact, we weigh the publications by the citations they receive by future research. We therefore use the number of citations, the fractional citations, and the citations divided by publications per year. The citations are counted as aggregate citations in the publication year (see also Hussinger & Pellens, 2019). Citations are a widely used indicator of the importance of scientists and their scientific findings, showing the extent to which results and insights are used as building blocks for future research.

While our main results employ a lean specification without control variables, we show robustness checks that control for scientists' career age and funding in a regression setting without fixed effects. Career age accounts for the fact that scholars change their level of commitment to publishing as their career progresses (e.g. Stephan & Levin, 1992). The age effect is found to be non-linear showing that scientists' productivity peaks at a certain point in time. Our regressions account for this. Career age is measured as the number of years since the first publication. Access to funding is a means to facilitate productivity (e.g. Salter & Martin, 2001; Hottenrott & Lawson, 2017; Hussinger & Carvalho, 2022). We use information provided by Scopus on whether a publication received any type of funding to generate a dummy that depicts whether a researcher received funding in the year of publication. As funding may influence productivity beyond the funding period (Hussinger & Carvalho, 2022), we use the funding stock as our control variable:

$$\text{Funding stock}_{it} = \text{Number of articles that received funding}_{it} + (1\text{-}\delta)\ \text{Funding stock}_{it-1} \quad (2)$$

where δ is a depreciation rate of 15%. In order to have a meaningful stock measure, we use information from our initial dataset going back until 1995 and assume that *funding stock*$_{1994}$ is equal to 0.

Furthermore, we show the robustness of our results on a sample in which we match treated and control scholars on their citations stock, co-author weighted citations stock, publications stock, co-author weighted publications stock, and funding stock as of 2010. As for the funding stock above, these stocks are a function of the scholars current and previous performances and are calculated according to Eq. 2. Some of these stocks as well as a measure of citations over publications stock (again calculated as in Eq. 2) are used in further robustness checks where we use a synthetic DiD method (Arkhangelsky et al., 2021) and an entropy balancing approach (Hainmueller, 2012).

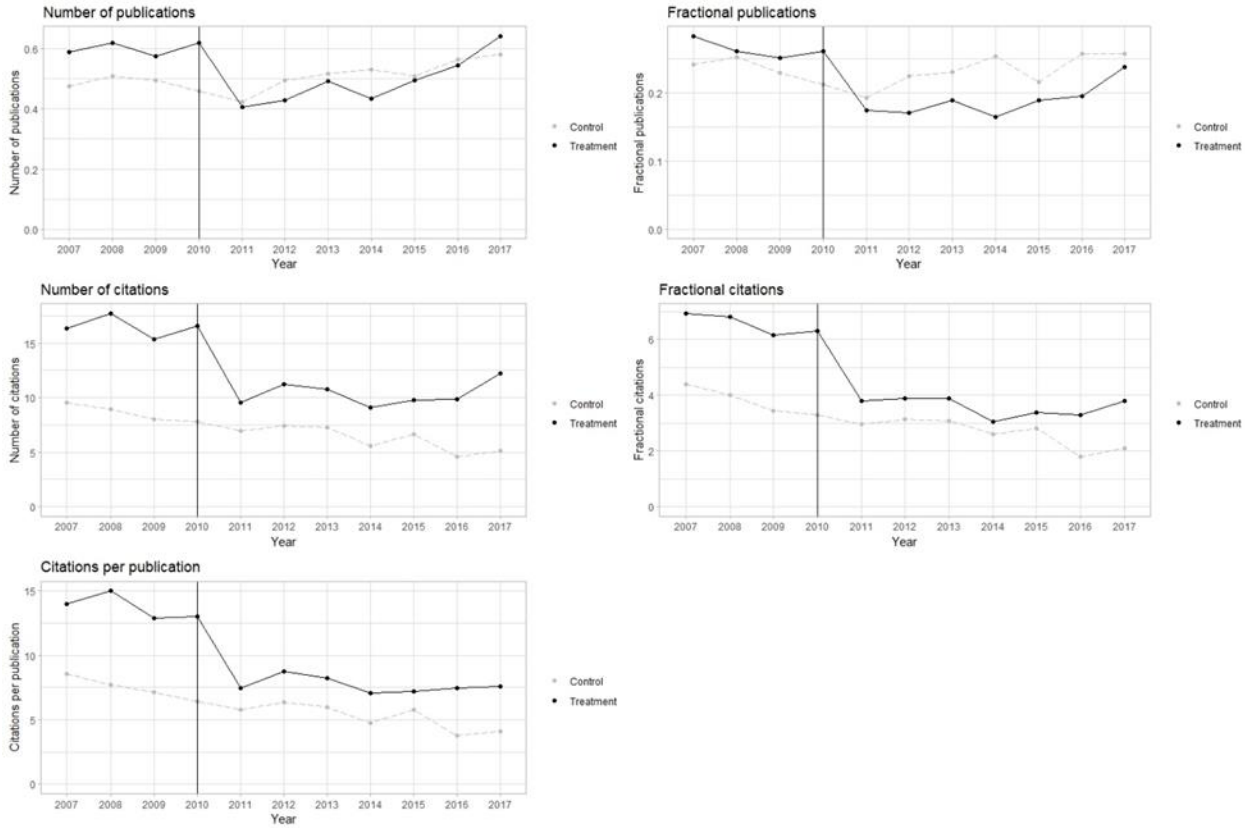
2.4.3 Descriptive evidence and statistics

To allow a first graphical inspection of the sample, Figure 2.1 shows the effect of Google's exit on our five dependent variables for the treated and control groups. We observe a reduction for all our output measures after Google's withdrawal for the treatment group, while the timeline for the control group seems to be unaffected. This simple descriptive evidence suggests a strong and immediate effect of Google's exit on the scientific output of scholars located in China which then fades out over time.

Table 2.1 shows some before-after comparisons of the means of the dependent variables for the treated and control groups. We observe that the treated scholars experience a drop in their co-author weighted publications of 27% and their co-author weighted citation impact of 44%. The control group, in contrast, sees no change regarding their co-author weighted publications before and after Google's exit from China and a significantly smaller decline of their co-author weighted citation impact of 25%. The changes are statistically significant at the 1% level as t-tests show.

Also the control group suffers a decline in impact of about 25%. This is perfectly in line with the literature which documents a strong increase in the competition among scholars to publish due to significantly lower acceptance rates and number of published articles as well as higher submission rates (see, for example, Larivière, Gingras & Archambault, 2009 or Card & DellaVigna (2013) for top journals in the field of economics). This provides some evidence that even though our sample had to be significantly restricted to a small portion of the population of treated scholars, we still find that the general population trends hold for our sample.

Figure 2.1: Descriptive evidence



2.5 Results

2.5.1 Parallel trends

One of the requirements for deriving causal effects from a DiD analysis is a parallel movement of the dependent variable in the pre-treatment period. Table 2.2 reports our results from a regression investigating the existence of pre-treatment parallel trends. The specification extends equation (1) in that we interact the year dummies (φ_t) with the treatment indicator ($Treat_i$).

Table 2.2 shows that all our dependent variables moved in parallel for the treated and control groups before 2010. Only after Google's exit from China, the interaction terms of the year dummies and the treatment group become significant showing different trajectories for the treatment and control group.

Table 2.1: Descriptive statistics

			Treated scholars						Control scholars					
	Time	Variable	n	mean	sd	median	min	max	n	mean	sd	median	min	max
1	Pre-2010	number of publications	2789	0.60	0.72	0.00	0.00	5.00	3069	0.48	0.67	0.00	0.00	4.00
2	Pre-2010	fractional publications	2789	0.26	0.35	0.00	0.00	2.00	3069	0.23	0.36	0.00	0.00	2.00
3	Pre-2010	number of citations	2789	16.42	33.34	0.00	0.00	274.00	3069	8.42	21.57	0.00	0.00	203.00
4	Pre-2010	fractional citations	2789	6.44	13.49	0.00	0.00	106.00	3069	3.68	9.50	0.00	0.00	103.00
5	Pre-2010	citations per publication	2789	13.47	26.30	0.00	0.00	177.00	3069	7.29	19.00	0.00	0.00	177.00
6	Post-2010	number of publications	5864	0.48	0.76	0.00	0.00	5.00	5028	0.50	0.72	0.00	0.00	5.00
7	Post-2010	fractional publications	5864	0.19	0.32	0.00	0.00	2.00	5028	0.23	0.36	0.00	0.00	2.00
8	Post-2010	number of citations	5864	10.30	26.00	0.00	0.00	265.00	5028	6.46	18.02	0.00	0.00	213.00
9	Post-2010	fractional citations	5864	3.61	9.29	0.00	0.00	97.00	5028	2.75	7.89	0.00	0.00	97.00
10	Post-2010	citations per publication	5864	7.72	18.66	0.00	0.00	170.00	5028	5.43	15.37	0.00	0.00	177.00

Notes: Number of treated scholars: 1,141; number of control scholars: 1,004. Treated scholars refers to scholars only affiliated in China.

Table 2.2: Parallel trends

Dependent Variables:	number of publications	fractional publications	number of citations	fractional citations	citations per publication
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
treat × 2007	0.0817	0.1026	-0.1085	-0.1186	-0.1012
	(0.1074)	(0.1178)	(0.1818)	(0.1902)	(0.1785)
treat × 2008	0.0370	-0.0149	0.0199	-0.0093	0.0587
	(0.0922)	(0.1016)	(0.1675)	(0.1684)	(0.1685)
treat × 2009	-0.0784	-0.0398	-0.0732	-0.0373	-0.0508
	(0.0820)	(0.0928)	(0.1505)	(0.1506)	(0.1475)
treat × 2011	-0.3425***	-0.3113***	-0.4618***	-0.4344***	-0.4680***
	(0.0817)	(0.0907)	(0.1429)	(0.1476)	(0.1445)
treat × 2012	-0.3858***	-0.4217***	-0.3192**	-0.4343***	-0.3692**
	(0.0867)	(0.0948)	(0.1505)	(0.1500)	(0.1511)
treat × 2013	-0.2481***	-0.2895***	-0.3265**	-0.3918**	-0.3535**
	(0.0907)	(0.0988)	(0.1541)	(0.1586)	(0.1550)
treat × 2014	-0.4082***	-0.5284***	-0.2537	-0.4975***	-0.3062*
	(0.0970)	(0.1050)	(0.1823)	(0.1844)	(0.1822)
treat × 2015	-0.2086**	-0.2041*	-0.3531**	-0.4597**	-0.4845***
	(0.0961)	(0.1058)	(0.1730)	(0.1795)	(0.1733)
treat × 2016	-0.2090**	-0.3234***	-0.0135	-0.0693	-0.0848
	(0.1002)	(0.1085)	(0.1876)	(0.1843)	(0.1799)
treat × 2017	-0.1083	-0.1467	0.0249	-0.1194	-0.1766
	(0.1049)	(0.1142)	(0.2147)	(0.2081)	(0.1969)
Fixed-effects					
Author	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Observations	16,444	16,444	16,159	16,159	16,159
Squared Correlation	0.25931	0.26549	0.27743	0.26888	0.27172
Pseudo R^2	0.12860	0.11977	0.35738	0.33675	0.33729
BIC	47,842.0	36,031.8	373,062.6	170,670.2	309,882.0

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level. Treated scholars refers to scholars only affiliated in China

At first glance, it may seem surprising that the effect of the restricted access to information is visible immediately, i.e., in the first year after Google's withdrawal of its services. For a discipline like economics with a lengthy peer-review process, one might expect that the effect would be visible only in later years after the treatment. Recent evidence, however, shows that when considering the globality of the available journals in this field, i.e., top as well as less-renowned ones, the average length of the review process in economics can be less than a year. Huisman & Smits (2017) report an average of 25 weeks from the submission to the acceptance and Björk & Solomon (2013) report an average of 18 months. In addition, it needs to be considered that the peer review process in economics typically takes several rounds (2.16 according to Huisman & Smits, 2017). The nature of the reviewer comments changes over the different stages of the peer review process though. The first round of comments is the most important one for authors, as it defines how much time is lost in case of a rejection, as well as for academic journals for which the duration of the first-round review stage is an important indicator for journal management quality (Huisman & Smits, 2017; Azar, 2007; Solomon & Bjoerk, 2021). The most important comments are, hence, typically made in the first round. They relate to the core literature of the paper, raise technical issues or suggestions about the data and methods, and request further robustness checks (Allen et al., 2019). Once these key comments are addressed, in later rounds, reviewers tend to make more minor and more general comments which often span beyond the scope of the paper and target issues such as the broader implications of the study (Allen et al., 2019). Therefore, while robustness checks and comments targeting the core literature that authors receive during the first round of the peer review process can be addressed with limited new information, the papers that are close to publication tend to need more additional information dealing with the comments of a second or third round of the review process. This is reflected in the observed sudden drop in publications right after the shock which to a large extent may present a delay in the revision of second or third-round papers.[17]

[17] To investigate the immediateness of the effect further, we check the parallel trend only for the top journals in economics, i.e., authors that published in the top journals in economics before 2010. Those journals include: Econometrica, American Economic Review, Journal of Political Economy, Quarterly Journal of Economics, Journal

2.5.2 Main results

Table 2.3 reports the results of the Poisson regressions for equation (1). It appears that, in line with the descriptive evidence, all our dependent variables are affected by the shock significantly at the 1% significance level. The average treated researcher loses 28% of her co-author weighted publications and 30% of her co-author weighted citations which corresponds to an average decrease of about 0.08 and 2 in fractional publications and citations, respectively. These results are robust if a synthetic difference-in-difference approach (Arkhangelsky et al., 2021) or an entropy balancing approach (Hainmueller, 2012) is used. The results are presented in Tables 2.8 and 2.9 in the Appendix.

2.5.3 Foreign co-authors as a channel to access information

Above, we report that the publication volume and impact of scholars located in China dropped after Google's withdrawal. The proposed mechanism is a decline in information accessibility. To investigate further whether this mechanism is at work, we distinguish between scholars located in China with and without foreign co-authors during our sample period. Interpersonal networks have been shown to be an important channel for knowledge diffusion (Singh, 2005; Mohnen, 2022) so that we expect that scholars located in China leverage their foreign co-author network to access information in the aftermath of the Google exit.

The regressions presented in Table 2.4 show the effect for the subsample of the treatment group which consists of scholars located in China with foreign co-authors versus the control group. We find that those

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of Finance, Review of Economic Studies, Journal of Financial Economics, Journal of Economic Literature, Review of Financial Studies, Journal of Economic Perspectives, American Economic Journal: Macroeconomics, Journal of Accounting and Economics, American Economic Journal: Applied Economics, Review of Economics and Statistics, American Economic Journal: Economic Policy, Journal of Marketing, Journal of Management, Review of Corporate Finance Studies, Journal of Consumer Research, Annual Review of Economics, NBER Macroeconomics Annual, Marketing Science, Journal of Accounting Research, American Economic Journal: Microeconomics. This leaves us with a sample of 309 or 299 observations respectively. Note that all of the authors that publish in top journals have foreign co-authors. We find no effect, which provides some validity to our explanation of the immediateness of the effect which is most likely due to the significantly shorter review process in less-renowned economics journals. The results are available upon request.

Table 2.3: Main results

Dependent Variables:	number of publications	fractional publications	number of citations	fractional citations	citations per publication
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
treat × post	-0.2868***	-0.3306***	-0.2670***	-0.3570***	-0.3422***
	(0.0494)	(0.0536)	(0.0880)	(0.0885)	(0.0892)
Fixed-effects					
Author	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Observations	16,444	16,444	16,159	16,159	16,159
Squared Correlation	0.25799	0.26416	0.27542	0.26762	0.27007
Pseudo R^2	0.12815	0.11933	0.35654	0.33611	0.33669
BIC	47,768.6	35,952.2	373,439.7	170,730.2	310,057.0

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level. Treated scholars refers to scholars only affiliated in China.

scholars who still can access information through their coauthors' network are affected less by Google's exit supporting our proposed mechanism of information accessibility. The regressions presented in Table 2.4 show the effect for the subsample of the treatment group which consists of scholars located in China with foreign co-authors versus the control group. We find that those scholars who still can access information through their coauthors' network are affected less by Google's exit supporting our proposed mechanism of information accessibility. The average treated researcher with foreign co-authors loses 20% of her co-author weighted publications and 22% of her co-author weighted citations.[18]

2.5.4 A look at the top scholars and top institutions

The decline in publications would be more worrisome if top scholars were affected because only a small fraction of scientists is able to contribute to the advancement of science and because the top scholars are those who are likely to repeat their top performances (Cole & Cole, 1972; Partha & David, 1994; Merton, 1973). Should the top scholars' performance, hence, decline, the threat for China to lose touch with the research frontier would be more severe.

Table 2.5 shows regressions for the subsamples of scholars with the highest and lowest impact in our sample, i.e., in the treated and control groups. The distinction is based on the citation stock divided by the publication stock in the year 2010. We chose the highest and lowest 25% percentile to have enough observations in each subsample for a credible regression analysis. The subsamples of the top and less impactful scholars contain an almost equal number of observations for scholars in the treatment and control groups which makes us confident that we are showing a meaningful comparison.[19]

The results show that the top scholars are more affected by the restricted access to information than the average researchers (compared to results in Table 2.4). When focusing on the bottom of the impact distribution, we find a smaller decline in co-author weighted publication outcome and no significant effect

[18] The parallel assumption holds for this subsample. Results are available upon request.
[19] There are 281 treated scholars and 180 control scholars in the group of the top 25%. The group of the less impactful 25% includes 293 treated and 303 control scholars.

on the (already small) impact. More specifically we find that the average treated top researcher loses 39.5% of her co-author weighted publications and 37.5% of her co-author weighted citations. On the other hand, the average treated scholar in the lowest impact group only loses 20% of her co-author weighted publications and experiences no significant decline in her co-author weighted citations.[20]

University' s status may also play a role. It is expectable that top institutions might benefit from legalized access to Google services. We, therefore, identify treated scholars affiliated with the 39 universities within "Project 985" and the 112 universities within "Project 211", which are both nationwide projects aiming at creating elite universities, especially in terms of research output (Zhang, Patton & Kenney, 2013). We study whether these scholars, who might be expected to enjoy superior access to Google services through VPNs with the approval of the central government, are still negatively affected by the shock. As reported in Figures 2.A1 and 2.A2 in the Appendix, we find that both groups of treated scholars are equally negatively affected.

2.5.5 Robustness checks

Our results are robust to an estimation without fixed effects and to an estimation that includes control variables (see Tables 2.A1 and 2.A2 which show robustness for the full sample (Table 2.A1) and the subsample of those that have foreign co-authors (Table 2.A2)). Furthermore, we present matched sample regressions that account for differences in scientists' productivity before Google's exit from China (see Table 2.A3). The results are presented in the Appendix.

We, further, investigated whether the additional local internet restrictions in the form of local web filters at the level of the province matter (Kong et al., 2022; Xu et al., 2011). One could imagine that scientists in provinces with local filtering devices have more difficulty circumventing the GFC to access Google to search for information after 2010.

[20] The parallel assumption holds for this subsample. Results are available upon request.

Table 2.4: Scholars located in China with foreign co-authors versus the control group

Dependent Variables:	number of publications	fractional publications	number of citations	fractional citations	citations per publication
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
treat × post	-0.1796***	-0.2244***	-0.1671*	-0.2503***	-0.2653***
	(0.0528)	(0.0581)	(0.0931)	(0.0945)	(0.0934)
Fixed-effects					
Author	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Observations	14,057	14,057	13,834	13,834	13,834
Squared Correlation	0.25920	0.26454	0.26883	0.25192	0.26434
Pseudo R^2	0.12726	0.11747	0.35050	0.32541	0.33081
BIC	40,437.8	29,979.5	326,050.9	145,757.4	268,703.7

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level. Treated scholars refers to scholars only affiliated in China with foreign co-authors.

Table 2.5: Top scholars and less impactful scholars

	top 25% scholars					less impactful 25% scholars				
Dependent Variables:	number of publications	fractional publications	number of citations	fractional citations	citations per publication	number of publications	fractional publications	number of citations	fractional citations	citations per publication
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variables										
treat × post	-0.4205***	-0.5033***	-0.3273**	-0.4677***	-0.3399**	-0.1121	-0.2225**	0.3489*	0.2346	0.0902
	(0.1131)	(0.1279)	(0.1535)	(0.1571)	(0.1557)	(0.0953)	(0.1051)	(0.1886)	(0.1866)	(0.1872)
Fixed-effects										
Author	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics										
Observations	3,439	3,439	3,439	3,439	3,439	4,599	4,599	4,430	4,430	4,430
Squared Correlation	0.28520	0.27909	0.25743	0.26856	0.25702	0.23239	0.23708	0.30331	0.25639	0.28599
Pseudo R^2	0.13515	0.11943	0.28715	0.29228	0.27304	0.11335	0.10786	0.37725	0.31569	0.33782
BIC	9,199.2	6,579.4	142,229	58,733.1	121,426.3	12,442.2	9,462.1	47,370.0	24,679.0	40,250.8

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level. Treated scholars refers to scholars only affiliated in China. Number of top 25% treated scholars: 281. Number of top 25% control scholars: 180. Number of less impactful 25% treated scholars: 293. Number of less impactful 25% control scholars: 303.

We did not find a different impact of the withdrawal of Google's services in provinces with local filtering, which affects 22% of our observations, and without local filtering. This result may be explained by the fact that only a minority of scientists try to circumvent the GFC (Lu et al., 2017) perhaps also due to the high risk of penalties.[21] The results are available upon request.

2.6 Discussion

2.6.1 Summary

Knowledge and information are indispensable inputs for the knowledge production function (Stephan & Levin, 1992; Ding et al., 2010). With the increasing complexity and multidisciplinarity of science over time (Jones, 2009; Wuchty et al., 2007), access to information is of utmost importance for scientists aiming to contribute to the research frontier (Furman & Stern, 2011; McCabe & Snyder, 2015; Waldinger, 2016; Berkes & Nencka, 2019; Mueller-Langer et al., 2020; Furman et al., 2012; Biasi & Moser, 2021; European Commission, 2012).

In this paper, we employ Google's withdrawal from China in 2010 as an event that allows testing the impact of increased barriers to access information on scientists' publication output and impact. Google's search engine was a major channel for scholars located in China to obtain foreign information so that its sudden withdrawal severely hampered the ability of scientists to access the knowledge frontier (Qiu, 2010). Our results from DiD analyses that compare scholars in the field of economics located in China to a culturally, economically, and geographically close control group show that publication output dropped by 25% and by 28% if weighted by co-authors. In addition, publication impact measured through co-author weighted citations dropped by 30% and citations per publication dropped by 29%. These results contribute to our understanding of the determinants of knowledge creation (Stephan and Levin, 1992; Stephan, 1996, for an overview) and more specifically of the role of information and communication technology in knowledge

[21] Penalties for VPN usage start from as low as 100 CNY fines but can go up to 5 years in jail (see, for example, Hawkins, 2023, or Haas, 2017).

creation (Agrawal & Goldfarb, 2008; Ding et al., 2010). While prior studies have shown that access to network technology eases information accessibility and facilitates the knowledge production of scientists (Agrawal & Goldfarb, 2008; Ding et al., 2010), we complement prior findings and provide evidence for the importance of Google's services for science production in economics.

By providing evidence for the effect of a negative shock of information availability to assess the effects on science production in economics, we contribute to recent literature that focuses on the knowledge creation effect of positive information shocks such as the availability of access to libraries (Berkes & Nencka, 2019; Furman et al., 2012; Biasi & Moser, 2021), of research resources (Furman & Stern, 2011) and of online access to scientific journals (McCabe & Snyder, 2015; Mueller-Langer et al., 2020). Our findings confirm that reactions to a positive and negative shock are not symmetric. For a positive shock, it takes time for the knowledge production function of the majority of the scientists to adjust (e.g. Panel A and B of Figure 8 in Furman, Nagler & Watzinger (2021), for the effect of increased knowledge access through the United States Patent and Trademark Library systems on local patenting: it takes some time until the full benefits for local patenting realize). The effect of a negative shock, on the contrary, is expected to occur immediately as an existing knowledge production process is suddenly interrupted as observed in our analysis: the effect of the negative shock kicks in immediately, and fades out over time, in stark contrast to the delayed reactions to a positive shock.

We propose that the underlying mechanism of this decline is information accessibility and test this hypothesis further by showing that the productivity decline is smaller for scientists who can leverage their foreign network to access information. Here, the number of publications decreases by 16.5% and co-author weighted publications by 20%. In terms of quality, co-author weighted citations dropped by 22% and citations per publication dropped by 23%. The finding that scholars can use their interpersonal networks as a channel for knowledge access (Singh, 2005; Mohnen, 2022) contributes to the large literature on the positive effects of academic networks (e.g. Beaver & Rosen, 1978; Wuchty et al., 2007; Greene, 2007; Fanelli & Lariviere, 2016) and, in particular, on informal collaboration between researchers (Laband &

Tollison, 2000; Brown, 2005; Rose & George, 2021). We add by providing suggestive evidence that co-author networks facilitate access to knowledge beyond joined projects which leads to a lower drop in scientific productivity and citations in the presence of an information shock. Further results show that especially the top scholars located in China are affected in terms of their output and impact. The decline in top scholars' citations likely reflects a lack of novelty caused by access barriers to the novel frontier.[22,23] Losing touch with the research frontier can lead to a persistent lag behind foreign peers with potentially harmful implications for economic growth (Griliches, 1992; Jaffe, 1989) because the more novel discoveries have a higher chance to have an impact on technology development (Veugelers & Wang, 2019). It is worth mentioning the extreme relevance that citations have with respect to labor market outcomes (Hamermesh & Pfann, 2012; Ellison, 2013), especially for low-ranked departments (Gibson, Anderson & Tressler, 2017). Leveraging the recent finding by Koffi (2021), who shows that fewer citations have a negative effect on authors' future work, our results, especially for top researchers, are even more relevant for the future of scientists in China.

2.6.2 Broader implications

Our results also draw attention to the current influence of big tech firms, way beyond their commercial power (Khan, 2018; Petit & Teece, 2021; Igna & Venturini, 2023). While large companies existed before and despite the fact that societies developed regulations to protect consumers, competition, and the environment, big tech firms are powerful in new ways that derive from their control over digital technology that can grant or limit access to information, the most crucial resource of our fast-moving world (e.g. Yu,

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[22] The number of backward citations that are less than three years old drops for both treated and control groups from the pre- to the post-shock period, but the drop for the treated group is statistically larger than for the control group. Similar results are found when comparing the number of backward citations that are less than two, four, and five years old. In addition, when comparing the number of backward citations that are more than two, three, four, and five years old, we find that these increases are stronger and more significant for the treated group.

[23] The decline in citations to the treated scholars' work might be also explained by a decrease in the articles' visibility from the standpoint of other treated Chinese economists, i.e., the higher barriers to access information restrict the visibility of the treated articles such that the decline in citations might not be due to a decrease in quality, but, instead, to a decrease in visibility from a specific sample of scholars' point of view. Nevertheless, we argue that if this is true, the decreased visibility is likely to be negatively affecting both control and treated scholars' work alike.

Liang & Wu, 2021; Rikap & Lundvall, 2022; Igna & Venturini, 2023). In this position, big tech firms can also have a not neglectable influence on the creation of science, as we show using the example of economics.

The fact that Google's withdrawal from China affected researchers affiliated to both top and less prestigious universities alike (see Figures 2.A1 and 2.A2 in the Appendix) demands a deeper reflection on the impact of big tech firms on a much wider variety of elements of our society including science and research.

2.6.3 Limitations and future research

A limitation of the paper is that our results might not be generalizable to other fields of science. Economics is a scholarly discipline with a simple production function. For hard sciences, where next to information about the state of the art in the field, also specialized equipment is often essential, we could imagine that the effect of limited access to information has even larger effects on science production since also information about the latest advances in specialized equipment can be missing. In addition, due to a lack of information on the location of authors with multiple affiliations, we needed to drop these scientists. Similarly, due to a lack of information about the reasons for mobility of individual scientists, we also needed to drop those scientists who changed their affiliation from one country to another from our sample. Ideally, we would have access to this information as our results might be biased toward the less successful scientists.

We also acknowledge the limitations related to our measure of funding. Bibliometric data on funding relies heavily on the authors' funding acknowledgments (Sugimoto & Larivière, 2023) and databases like Scopus and Web of Science are not able to present complete information (Liu, 2020). Nonetheless, we are encouraged by the fact that policies regarding grant acknowledgment vary significantly by country, and China, for example, has extremely strict policies in this regard (Sugimoto & Larivière, 2023, p. 96), alleviating, therefore, some of our concerns. This is also one of the main reasons we decide to study the field of economics.

We also acknowledge that our results may be specific to the context of China. Access to information is only one factor in the scientific production function and the entire academic and political environments are likely to matter as well. We expect that in an advanced academic environment, which is rich in material resources, the effects of limited access to knowledge may be somewhat smaller, while it matters more in less developed environments (Mueller-Langer et al., 2020).

Furthermore, we acknowledge that Google's withdrawal from China cannot be entirely separated from coincident incremental policy changes that may have had an additional effect on publications in economics. To the best of our knowledge, no major policy change with implications for publications has taken place during our time frame of study such as the new evaluation policy of 2020 that requires Chinese scholars to publish at least one-third of their research in Chinese journals (Liang et al., 2022). Nevertheless, we acknowledge that the Chinese research landscape is in constant development (Piracha et al., 2022) with potential implications for our estimated effects.

Lastly, we acknowledge that our difference-in-difference setting with a country-wide shock can only rely on a "second best" type of control group. While in an ideal setting, we would observe treated and control scholars in the exact same conditions, this is by definition not possible for a country-wide shock. This is why we use a "second best" control group following Zheng & Wang (2020).

The extension of our analysis to other science fields and other political and academic contexts is hence a straightforward avenue for future research. In addition, future research could explore the effect of governmental initiatives to censor access to information for scientific productivity (Ritchie, Driscoll & Maron, 2017).

2.7 References

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2.8 Appendix

We present several robustness checks in this Appendix. The tables below show robustness checks for alternative specifications of equation (1). Tables 2.A1 and 2.A2 show regression models without fixed effects and including control variables when the treated group of scholars does and does not have foreign co-authors, respectively. It appears that our main effect is robust against these different specifications of our model.

A surprising effect is that we find a U-shaped effect of career age, while typically an inverse U-shape is found. This is driven by the first publication year of our authors in which they have a high publication rate. If the first year of publication is excluded, we find the typical pattern of an increase in publications which at some age peaks and declines.

Table 2.A3 shows robustness for a matched sample. We use nearest neighbor matching on authors' citations stock, co-author weighted citations stock, publications stock, co-author weighted publications stock, and funding stock as of 2010. We have matched 665 treated scholars to their most comparable peers in the control group. The 665 treated scholars and their matched controls are observed on average in 7.62 years which leads to a total sample of 10,131 scientist-year observations. The matched sample is balanced in terms of the matching criteria and the results are in line with the main findings of Table 2.3. The average treated researcher, in fact, loses 31% and 36.5% of her co-author weighted publications and citations, respectively.[24]

Tables 2.A4 and 2.A5 report the results when using a synthetic DiD (Arkhangelsky et al., 2021) and an entropy balancing approach (Hainmueller, 2012), respectively. We use career age, funding stock, publication stock, and citations over publications stock to define the balancing.

The Figures below show similarity in the effect of the shock on treated scholars affiliated with both top and less renowned universities.

[24] The parallel trend assumption holds for the matched sample. Results are available upon request.

Table 2.A1: Robustness checks I – Full sample

Dependent Variables:	number of publications		fractional publications		number of citations		fractional citations		citations per publication	
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variables										
(Intercept)	-0.7280***	-0.3617***	-1.465***	-1.079***	2.131***	2.697***	1.303***	1.885***	1.987***	2.640***
	(0.0260)	(0.0364)	(0.0376)	(0.0535)	(0.0062)	(0.0083)	(0.0094)	(0.0128)	(0.0067)	(0.0089)
treat	0.2223***	-0.0016	0.1214**	-0.1077**	0.6676***	0.3733***	0.5590***	0.2580***	0.6133***	0.3145***
	(0.0356)	(0.0365)	(0.0528)	(0.0541)	(0.0078)	(0.0079)	(0.0120)	(0.0123)	(0.0084)	(0.0086)
post	0.0443	0.1344***	-0.0110	0.1052**	-0.2652***	-0.0499***	-0.2911***	-0.0520***	-0.2953***	-0.0176*
	(0.0327)	(0.0357)	(0.0478)	(0.0525)	(0.0083)	(0.0091)	(0.0127)	(0.0139)	(0.0090)	(0.0099)
treat × post	-0.2764***	-0.3173***	-0.3320***	-0.3705***	-0.2011***	-0.2453***	-0.2878***	-0.3392***	-0.2616***	-0.2483***
	(0.0449)	(0.0461)	(0.0677)	(0.0693)	(0.0104)	(0.0107)	(0.0162)	(0.0167)	(0.0114)	(0.0117)
funding stock		0.2323***		0.2275***		0.2518***		0.2522***		0.2242***
		(0.0038)		(0.0062)		(0.0008)		(0.0013)		(0.0010)
career age		-0.1465***		-0.1499***		-0.2136***		-0.2162***		-0.2407***
		(0.0089)		(0.0135)		(0.0021)		(0.0033)		(0.0023)
career age square		0.0068***		0.0067***		0.0093***		0.0091***		0.0103***
		(0.0005)		(0.0007)		(0.0001)		(0.0002)		(0.0001)
Fit statistics										
Observations	16,750	16,749	16,750	16,749	16,750	16,749	16,750	16,749	16,750	16,749
Squared Correlation	0.00366	0.04209	0.00625	0.03209	0.01801	0.02889	0.01547	0.02353	0.01856	0.02831
Pseudo R^2	0.00195	0.06820	0.00328	0.04751	0.03144	0.13730	0.02548	0.11974	0.03037	0.10373
BIC	31,420.1	29,365.3	17,516.2	16,769.3	543,145.3	483,797.9	225,449.7	203,668.6	432,936.5	400,198.8

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level. Treated scholars refers to scholars only affiliated in China.

Table 2.A2: Robustness checks II – Treated scholars with foreign co-authors

Dependent Variables:	number of publications		fractional publications		number of citations		fractional citations		citations per publication	
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variables										
(Intercept)	-0.7280***	-0.3897***	-1.465***	-1.118***	2.131***	2.692***	1.303***	1.864***	1.987***	2.628***
	(0.0260)	(0.0376)	(0.0376)	(0.0557)	(0.0062)	(0.0086)	(0.0094)	(0.0133)	(0.0067)	(0.0092)
treat	0.2001***	0.0081	0.0295	-0.1676***	0.7011***	0.4446***	0.5243***	0.2639***	0.6452***	0.3873***
	(0.0393)	(0.0399)	(0.0597)	(0.0607)	(0.0083)	(0.0084)	(0.0131)	(0.0133)	(0.0090)	(0.0092)
post	0.0443	0.1295***	-0.0110	0.0923*	-0.2652***	-0.0408***	-0.2911***	-0.0551***	-0.2953***	-0.0132
	(0.0327)	(0.0359)	(0.0478)	(0.0529)	(0.0083)	(0.0091)	(0.0127)	(0.0140)	(0.0090)	(0.0100)
treat × post	-0.1304***	-0.2283***	-0.1810**	-0.2848***	-0.0724***	-0.1647***	-0.1421***	-0.2477***	-0.1632***	-0.1931***
	(0.0487)	(0.0499)	(0.0751)	(0.0769)	(0.0109)	(0.0112)	(0.0174)	(0.0179)	(0.0120)	(0.0123)
funding stock		0.2225***		0.2227***		0.2373***		0.2402***		0.2099***
		(0.0040)		(0.0066)		(0.0008)		(0.0014)		(0.0011)
career age		-0.1349***		-0.1355***		-0.2085***		-0.2065***		-0.2334***
		(0.0094)		(0.0144)		(0.0022)		(0.0036)		(0.0025)
career age square		0.0062***		0.0060***		0.0089***		0.0086***		0.0099***
		(0.0005)		(0.0007)		(0.0001)		(0.0002)		(0.0001)
Fit statistics										
Observations	14,285	14,285	14,285	14,285	14,285	14,285	14,285	14,285	14,285	14,285
Squared Correlation	0.00212	0.04159	0.00217	0.02904	0.02031	0.03209	0.01272	0.02310	0.01896	0.02995
Pseudo R^2	0.00116	0.06412	0.00114	0.04476	0.03631	0.13435	0.02152	0.11062	0.03167	0.09926
BIC	27,309.5	25,619.2	15,034.7	14,408.6	468,123.7	420,532.1	190,901.5	173,551.7	372,032.2	346,094.3

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level. Treated scholars refers to scholars only affiliated in China with foreign co-authors.

Table 2.A3: Matched sample

Dependent Variables:	number of publications	fractional publications	number of citations	fractional citations	citations per publication
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
treat × post	-0.3079***	-0.3714***	-0.3053**	-0.4558***	-0.3497***
	(0.0685)	(0.0755)	(0.1307)	(0.1313)	(0.1318)
Fixed-effects					
Author	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Observations	10,131	10,131	9,912	9,912	9,912
Squared Correlation	0.24099	0.24957	0.23580	0.24758	0.24018
Pseudo R^2	0.11937	0.11694	0.33497	0.32342	0.32148
BIC	27,709.5	21,011.3	203,283.4	94,016.7	175,067.2

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level. Treated scholars refers to scholars only affiliated in China. 665 pairs of matched scholars.

Table 2.A4: synthetic DiD results

Dependent variable	**ATT**	**se**	**t**	**P > |t|**	**95% confidence interval**	
Number of publications	-0.10412	0.01536	-6.78	0.000	-0.13423	-0.07401
Fractional publications	-0.03706	0.00836	-4.44	0.000	-0.05343	-0.02068
Number of citations	-1.98438	0.65555	-3.03	0.002	-3.26923	-0.69953
Fractional citations	-0.77467	0.27070	-2.86	0.004	-1.30523	-0.24411
Citations per publication	-1.26016	0.57935	-2.18	0.030	-2.39567	-0.12465

Table 2.A5: Entropy-balancing results

Dependent Variables	number of publications	fractional publications	number of citations	fractional citations	citations per publication
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
treat × post	-0.299***	-0.270**	-0.426***	-0.440***	-0.283***
	(0.090)	(0.132)	(0.020)	(0.030)	(0.022)
Fixed-effects					
Author	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Observations	16174	16174	15890	15890	15890
Log likelihood	-3041.337	-1582.674	-49486.628	-21196.999	-40383.314
Prob>chi^2	0.000	0.000	0.000	0.000	0.000

Notes: Clustered standard errors at the author level in parentheses. Significance levels: ***: 0.01, **: 0.05, *: 0.1. Poisson regression with standard errors clustered at the author level.

Figure 2.A1: Parallel trends for top universities' scholars vs control group

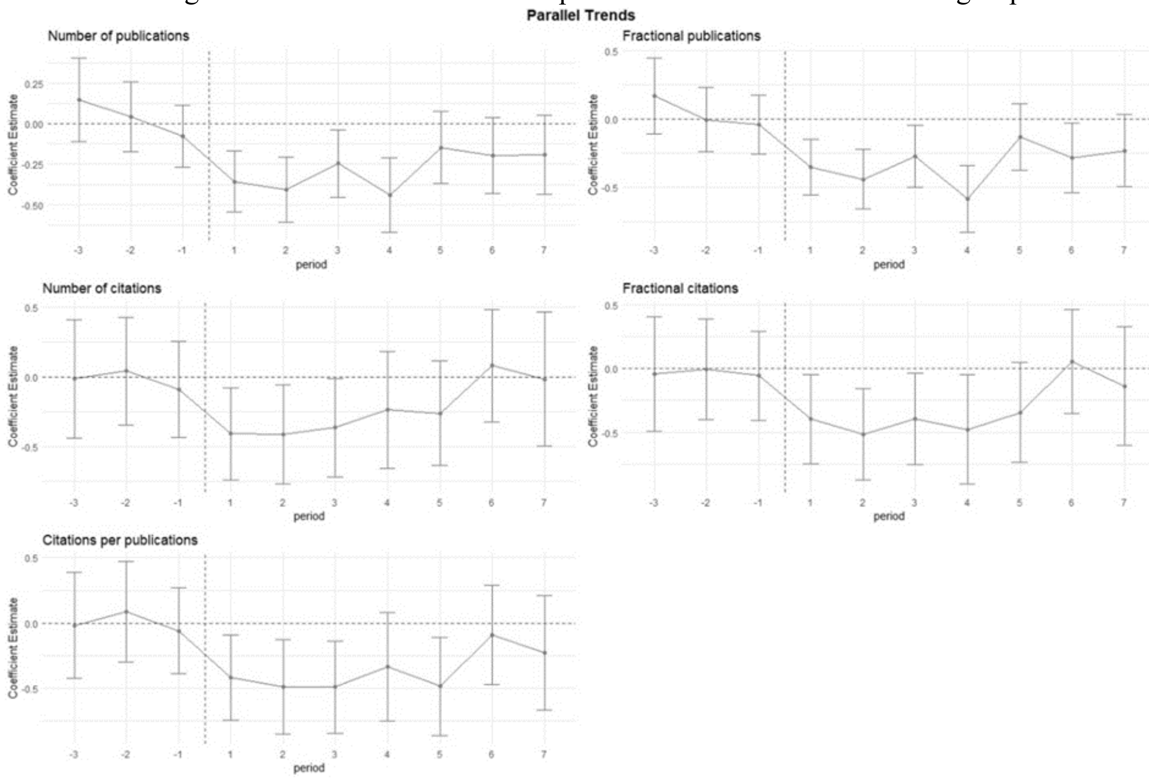
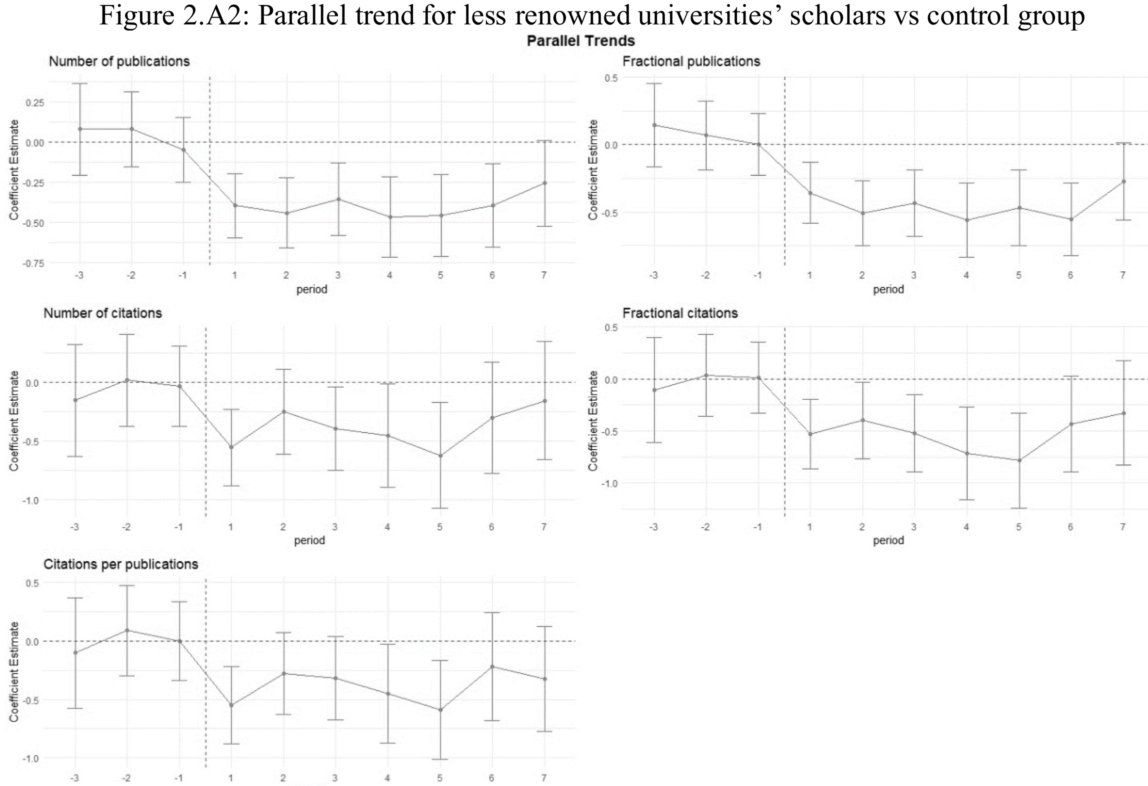


Figure 2.A2: Parallel trend for less renowned universities' scholars vs control group



Chapter 3

Corporate open science and CEOs' pre-career exposure to Confucian values

Keywords: Upper echelons theory; Imprinting theory; Open science; Corporate science; Pre-career exposure; Social view

3.1 Introduction

The upper echelon theory states that "organizational outcomes - both strategies and effectiveness - are […] reflections of the values and cognitive bases of powerful actors in the organizations" (Hambrick & Mason, 1984, p. 193), such as firms' CEOs. Such psychological traits and cognitive frameworks, following the imprinting theory (Marquis & Tilcsik, 2013), are the results of a process whereby, during certain periods of 'susceptibility', such as childhood (Liu, He & Wang, 2023; Marquis & Qiao, 2020) or the formative years of youth (Barnett, 1995; Levinson, 1986; Chen, Luo, Tang & Tong, 2023), CEOs develop characteristics, personal traits, values, and preferences that reflect prominent features of the external environment in which they live, and these characteristics continue to persist through the years despite significant environmental changes (Marquis & Tilcsik, 2013).[1]

Adding to the emerging stream of literature suggesting that CEOs' pre-career experiences impact their personalities, values, and cognitive bases (see, for example, Bernile, Bhagwat & Rau, 2017; Chen et al., 2023; Chen, Fu, Tang & Zhao, 2024; Choi & Jung, 2021; Koch-Bayram & Wernicke, 2018; O'Sullivan, Zolotoy & Fan, 2021), which then directly enter their decision-making processes and therefore affect their firms' choices, this article combines both theories and proposes that the cultural context in which firms' CEOs are born, and therefore most likely lived at least a part of their childhood, shape CEOs' values, norms, and beliefs, which then are reflected in the strategic choices of the firms they direct (Chen et al., 2023). More specifically, in this paper, I investigate the impact of CEOs' early-life exposure to pro-social, Confucian values on their firms' adoption of an open science strategy. The rationale behind this inquiry lies in the fundamental tenets of the Confucian ideology, which pose that individuals should prioritize and strive for the betterment of society (Li & Liang, 2015). I hypothesize that CEOs who have been exposed to these values during the main period of susceptibility, i.e. their childhood (Kish-Gephart & Campbell, 2015; Tian, Jiang & Yang, 2023), are more inclined to embrace open science practices, recognizing their potential to contribute positively to society by increasing the stock of knowledge publicly available and, therefore,

[1] Similar arguments can be made for firms in their founding stage (Marquis & Tilcsik, 2013).

attaining their personal-life, Confucian goals. This study, therefore, proposes a "social" perspective (see also the ‘Confucian social model’ proposed by Li & Liang, 2015), that has to be understood as *complementary* to the more conventional economic viewpoint, to understand the rationale behind corporate open science (see Rotolo, Camerani, Grassano & Martin (2022) for an outline of the five main economic incentives firms have to engage in open science) and deepens our understanding of the mechanisms and balance between CEOs profit making obligations and perceived social duties (Chen et al., 2024; Recendes, Chandler, Huang & Hill, 2023).

For more than two millennia, Confucianism or Confucian ideology has been an almost constant presence in China and “a latent cultural and psychological trait” of Chinese people (Du, 2015, p.664) which has recently been reinforced by the ‘Confucian revival’ movement (Billioud & Thoraval, 2015). As described by Han & Altman (2010, p. 38), “Confucian moral standards […] regulate Chinese behavior since Confucian doctrine and tradition are deeply rooted in their minds. […] There is no doubt that Confucianism serves as one main source of moral standards in China”.

Confucian culture, though, is in stark contrast with the individualistic cultures present in many Western countries (Hofstede, 1991) as it revolves around the concept of collectivism and places the greatest importance on collective values and interests above individual ones (Farh, Earley & Lin, 1997; Zhu & Yao, 2008). According to the Confucian ideology, one needs to be concerned with social issues and contribute to society (Li & Liang, 2015) as individual success is defined as serving and improving society as a whole. In this paper, I focus on firms’ corporate science and specifically firms’ open science policies, i.e. disclosing the results of their R&D efforts through scientific publications, as a tool that firms’ CEOs can use to contribute to society, therefore fulfilling their personal goal to be aligned with their Confucian values. In fact, by sharing their firms’ R&D findings in peer-reviewed journals, firms not only foster an environment characterized by collaboration and dialogue among researchers, academics, and industry professionals which then provides the firm access to more external knowledge (Cockburn & Henderson, 1998; Hicks, 1995; Zucker, Darby & Armstrong, 2002), but also advance the stock of public knowledge that is fully available to society at large which is directly related to innovation and social benefits. This transparent approach not only enhances the credibility and reputation of the firm (Arora, Belenzon & Patacconi, 2018; Nelson, 1990), but also promotes the dissemination of valuable insights and discoveries that can ultimately lead to practical applications, technological advancements, and societal progress. Furthermore, by engaging with the broader scientific community, firms can receive feedback, validation, and new perspectives that can further enhance the quality and impact of their research efforts, ultimately driving positive outcomes for society (Nosek et al., 2015). Openly sharing the outcomes of corporate science has therefore the potential to directly benefit society and it is a relevant source of public knowledge as the contribution of some firms to publicly available science has been shown to be comparable and at times significantly larger than that of world-renowned Universities (Pellens & Della Malva, 2018; Rosenberg, 1990).

As Confucian values, to which some CEOs are exposed during their childhoods, advocate for and prioritize social benefits over private gains, and bind individuals to contribute to society, I hypothesize that firms led by CEOs exposed to Confucian values during their childhood, *exposed CEOs*, are associated with a higher number of scientific publications as CEOs aim to attain their pro-social, Confucian aspirations. To test this hypothesis, I use a dataset of publicly listed firms in China between 2007 and 2021 and identify CEOs with higher exposure to Confucian values via their places of birth's proximity to one of the nine nationally famous Confucian centers spread across China and located in Qufu in Shandong province, Chengdu in Sichuan province, Luoyang in Henan province, Sanming and Longyan in Fujian province, Dongtai in Jiangsu province, Ningbo and Shaoxing in Zhejiang province, and Linchuan in Jiangxi province (Chen, Xiao & Zhao, 2021).[2] As these sites exercise a large influence on their surrounding environment and the individuals within it, following prior studies (Chen et al., 2021; Du, 2013a; Du, 2015; Huang, Liu & Yang, 2023; Huang, Li, Xia & Li, 2024; Kung & Ma, 2014), I assume that individuals who are born in these

[2] Note here that while Confucianism is a relatively widely spread ideology across China, there are still locations, such as the ones just mentioned, in which the presence of this ideology is stronger due to the presence of these nationally famous centers (Chow, 1996; Huang et al., 2023; Ji, Huang & Li, 2021; Kung and Ma, 2014). That is why I argue for a *higher* exposure.

regions have been exposed to Confucian values at least to a larger degree compared to individuals born in other areas. This assumption is supported by research available in developmental psychology, which suggests that people's value systems are shaped especially during the earlier stages of life and therefore shape people's cognition and behavior (see Elder (1998) or Jenks (1996) for the initial insights on which a burgeoning literature in this field rest on).

My prediction is supported through different methodologies including matching and difference-in-difference (DiD) as well as several robustness checks.

This paper contributes to the literature in several ways.

First, I contribute to the work in the field of behavioral strategy and more specifically to the literature on how CEOs' psychological traits and values affect firms' policies and strategic choices (Gow, Kaplan, Larcker & Zakolyukina, 2016; Hanlon, Yeung & Zuo, 2022; Malhotra, Reus, Zhu & Roelofsen, 2018). While extant literature has focused on the effect of CEOs' gender (Faccio, Marchica & Mura, 2016), age (Serfling, 2014), education (Bai, Tsang & Xia, 2020), personal traits (Cragun, Olsen & Wright 2020; Wales, Patel & Lumpkin, 2013), and marital status (Roussanov & Savor, 2014), among others, on firms' choices, I focus on CEOs early-life exposure to a particular social and cultural environment that is characterized by pro-social values. As firm's policies are also shaped by their top managers' values (Adams, Licht & Sagiv, 2011; Hambrick & Mason, 1984; Hambrick & Brandon, 1988), that is, their beliefs about abstract desirable goals, which guide their actions (Schwartz, 2009), this paper adds to the growing literature on the effects of CEOs pre-career exposure on firms' strategic choices and decisions. Being born and having lived in an environment characterized by strong pro-social, Confucian values, especially during a sensitive period, i.e. early youth, when individuals are more likely to develop or reinforce certain values and cognitions, it is plausible that the pro-social values of the Confucian ideology directly enter into the CEOs' strategic choice making processes. This paper, therefore, builds upon research in developmental psychology and imprinting theory to understand the implications of CEOs' exposure to the Confucian ideology and thus extends the existing research into the effect of executives' values on firms' policies as well as broaden our understanding of the effect of CEOs' social obligations and decision-making (Chen et al., 2024). As discussed later, it is crucial to note that I do not presume to be able to measure the degree of the private beliefs of the CEOs involved in the study, i.e. something that could potentially be achieved through surveys and questionnaires; instead, this paper leverages the CEOs' pre-career *exposure* to a specific pro-social ideology and how that might have an imprinting effect on the CEOs' decision-making processes (Chen et al., 2021). As implemented by other papers on the effect of pre-career experiences, my arguments are based on *exposure* rather than direct beliefs (Chen et al., 2021).

Second, corporate open science consists of firms disclosing the results of their R&D efforts, i.e. one of the key sources of competitive advantage for innovative companies (Amit & Schoemaker, 1993; Grant, 1991; Kogut & Zander, 1992), in peer-reviewed scientific journals. Disclosing such information through scientific publications has the potential to generate knowledge spillovers and hinder firms' ability to fully capture the returns from their R&D (Arrow, 1962; Nelson, 1959). Despite the clear tension between the ability of a firm to profit from its R&D investment and the potential restrictions and risks to rent appropriation due to the firm disclosing its findings through scientific journals, firms do disclose the results of their research in scientific journals (Pellens & Della Malva, 2018; Rosenberg, 1990). To disentangle this seemingly irrational choice, an extensive body of literature has focused on the question: why do firms disclose through scientific publications? To answer this question, Rotolo et al. (2022) provide a comprehensive conceptual framework that outlines five main sets of incentives that firms may have to disclose the outcomes of their R&D efforts through scientific publications: (1) accessing external knowledge and resources, (2) attracting and retaining researchers, (3) supporting IP strategies, (4) building the firm's reputation, and (5) supporting commercialization strategies. I argue that considering the social benefits generated when a firm engages in open science, there is the possibility that a pro-social incentive might play a *complementary* role to the incentives mentioned above. Such pro-social incentives might have not been found in a Western context characterized by a focus on private gains and benefits, but it is indeed observable in the Chinese context which is characterized by collectivistic ideals.[3] In fact, while, starting from the seminal work by Hicks (1995), all the incentives mentioned above have received ample support in both qualitative and quantitative research, a striking fact is that the vast majority of the studies on this topic have focused their attention on developed countries, e.g., the US and Europe, and tried to answer the initial question through a set of assumptions that might not hold in countries, such as China, or other developing economies, which are fundamentally different and for which other incentives and/or mechanisms might play a role when it comes to firms' strategic choices (Peng, Wang & Jiang, 2008). Indeed, in the management literature, the vast majority of empirical investigations and theoretical explanations of "management, managers, and those being managed are based on research that predominantly originates from Western contexts, particularly the USA and the larger European countries" (Wickert, Potočnik, Prashantham, Shi and Snihur, 2024, p. 1). Nevertheless, non-Western contexts are of interest to management scholars given the always-increasing relevance of countries like China, India, Brazil, and others in the global landscape and the increasing data quality generated from these countries which provides the opportunity to realize universal as well as generalizable claims just like when using Western data (Wickert et al., 2024).

In fact, the third contribution of this paper lies in responding to the call put forth by Wickert et al. (2024), among others, advocating for an increased emphasis on non-Western contexts, i.e. regions outside of North America, Europe and Australia, within management studies as this approach offers the potential to unveil novel insights previously overlooked and to advance our understanding of management and organizations as a global phenomenon.

To conclude, from a policy perspective, considering that the Chinese Communist Party (CCP) has recently underlined the importance of Confucianism in the Chinese social fabric and acknowledged that the communist ideology present in China overlaps extensively with the basic Confucian values (Du, 2015), the results of this paper speak to the positive impact that the recent support of the Confucian values coming

[3] Surely also in a context characterized by collectivistic ideals, economic benefits are still a priority, but perceived social duties are more likely to play a more significant role.

from the CCP can have on innovation and society as a whole.

3.2 Literature review

3.2.1 CEOs values and firms' policies: Upper echelons and imprinting theories

Starting from Hambrick and Mason's (1984) seminal work tracing firm strategic choices back to the characteristics of the managers making those decisions, a large literature has successfully linked managers' demographics and background characteristics, as well as their psychological traits and set of values to firms' choices and policies. While CEOs' characteristics such as age, gender, education, and previous professional experiences (Bai et al., 2020; Crossland, Zyung, Hiller & Hambrick, 2014; Faccio et al., 2016; Serfling, 2014), among other observable characteristics, are easily measurable and provided initial empirical support for the validity of the upper echelon theory (Hambrick and Mason, 1984), the set of values, i.e. that set of abstract desirable goals that serve as guiding principles in an individual life (Adams et al., 2011; Kluckhohn, 1951; Schwartz, 1992), of firms' CEOs is a significantly more challenging metric to measure, but at the same time a much more relevant one to the CEOs' strategic decision-making process. Drawing from psychological literature (Schwartz, 1992), in fact, extant research has highlighted the significant impact of personal values on strategic decision-making within organizations (Connor & Becker, 2003) and found that personal values act as guiding principles that shape individuals' behaviors, priorities, and actions, ultimately influencing their strategic choices and their organizations' policies. A crucial question is therefore: how and when do individuals develop such a set of values? What factors influence them?

The imprinting theory provides some insights. Stinchcombe (1965) introduced the concept of imprinting to organizational research, describing how organizations take on elements of their founding environment and how these elements persist well beyond the founding phase. More recently, scholars have transposed the concept of imprinting to the individual level and described how early experiences in a career or organizational tenure exert a lasting effect on individuals' behaviors and decision-making in the long run (Higgins, 2005; Schoar & Zuo, 2017). Even more recently, some scholars have focused on CEOs' pre-career experiences; for example, to mention a few, Chen et al. (2023) found that CEOs' exposure to religion during their university studies affects their firms' risk-taking and subsequent innovation performance while Chen et al. (2024) found that the same exposure makes CEOs less likely to avoid paying taxes; Koch-Bayram & Wernicke (2018) found that CEOs who served in the military are less inclined to be involved in financial misconduct and, in a similar fashion, Benmelech & Frydman (2015) observed that CEOs who served in the military before climbing the corporate ladder were more likely to pursue conservative financial policies and less likely to commit business fraud; Li, Shi, Connelly, Yi & Xin (2022) found that award-winning CEOs are more likely to commit financial misconduct in the post-award period than in the pre-award period. A natural extension of these studies is the analysis of CEOs' early youth exposure to certain social and cultural environments and informal institutions as individuals typically develop their values and beliefs before starting their professional careers. Some studies point exactly in this direction: for instance, Kish-Gephart & Campbell (2015) found that social class in childhood affects a CEO's risk-taking propensity; Campbell, Jeong & Graffin (2019) building on evolutionary theory found that earlier-born CEOs will take less risk than later-born CEOs; O'Sullivan et al. (2021) found that CEOs who experienced trauma early in their lives are positively associated with corporate social performance, while similarly Choi, Shin & Kim (2023) found that CEO's childhood experience of natural disaster is useful to explain a substantial portion in the variations in firms' CSR; Tang, Guo, Zha & Zheng (2024) found that CEOs who have been exposed to environmental pollution in early-life promote green innovation significantly more. Advancing this line of research, I focus on the characteristics of the place of birth following the vast research available in developmental psychology which suggests that people's value systems are shaped especially during the earlier stages of life and therefore shape people's cognition and behavior (Elder, 1998; Jenks, 1996). In this paper, I, therefore, aim to study whether early childhood *exposure* to an external, cultural environment that is strongly influenced by the pro-social, Confucian ideology has an impact on future CEOs' decisions and policies.

3.2.2 Confucianism

Confucianism is widely recognized as the core of the Chinese cultural system (Chen et al., 2021; Chen, Ma & Sinclair, 2022). Since 500 B.C., Confucianism or Confucian ideology has been an almost constant presence in China, "a latent cultural and psychological trait" of Chinese people (Du, 2015, p.664), and greatly shapes people's moral values (Ii et al., 2021; Ralston, Egri, Stewart, Terpstra & Kaicheng, 1999). According to Jiang (2018, p. 156), "it is no exaggeration to say that premodern China was basically a Confucian state […]".

Confucius (551–479 BC) was a philosopher, teacher, and politician in the Spring and Autumn periods of Chinese history whose ideas are summarized in the *Analects*, one, if not, the most important book of traditional Chinese studies. Confucius describes life as a four-step personal transformation from an "inner-focused sage" to an "outer-focused king" (Fung, 1948), which reflects a phase-wise switch of one's focus from himself to society (Li & Liang, 2015). While during the first three phases an individual builds himself through knowledge and self-reflection ("self-cultivation" stage), focuses on the most private social interactions in the Chinese culture, i.e. family and marriage ("regulation of the family" stage), and fulfills his ambitions through his work and career ("bringing order to the state" stage), in the fourth and last stage ("preserving world peace" stage), according to the Confucian ideology, one needs to be concerned with social issues and contribute to society (Li & Liang, 2015). This transformation is a crucial element in the Confucian ideology and shapes an individual's definition and understanding of achievement and success (Yu, 1994). The ultimate success is therefore to serve the larger community (Tu, 1985).

While some might argue that such an old cultural system can hardly have an impact on an individual's values and behaviors today, it is worth mentioning that Confucian values do persist, despite decades of political movements clamping down on these values (Gu, Sun & Zhou, 2024) and Confucianism has recently re-emerged and re-established itself in China.[4] And, while it might be straightforward to assume

[4] "Although Confucianism was officially discredited by Mao, the cultural values espoused by Confucius left a permanent mark on the psyche of the Chinese people" (Rarick, 2007, p.23).

that the "Confucian revival" movement (Billioud & Thoraval, 2015) in China has been promoted through a top-down approach originating from the government imposing on its citizens to embrace Confucian values, there is strong evidence supporting the idea that such a movement originated from the bottom (i.e. citizens and scholars) and found its way up without being "affiliated to the Party nor the state nor receiving direct financial/material assistance" (Payette, 2016, p. 3). This provides evidence that Chinese people, in general, are close to such values and they have not been imposed on them by their political leadership; this is crucial because to enter an individual's set of values, certain ideas cannot be imposed but instead, must be freely embraced. Only later, the CCP underlined the importance of Confucianism in the Chinese social fabric and acknowledged that the communist ideology present in China overlaps extensively with basic Confucian values (Du, 2015). In 2004, for example, the concept of "harmonious society", one of the key values of Confucianism, was formally announced by President Hu Jintao and was officially endorsed by the CCP. In the same year, the worldwide Confucius Institutes program was also initiated. In addition, since President Xi Jinping came to power, the Chinese government's endorsement of Confucianism has been unprecedentedly strong. In 2013, for example, Xi visited the birthplace of Confucius in Shandong and publicly praised Confucius's teachings. In 2014, Xi gave a keynote speech at the international conference in memory of Confucius's 2,565th birthday where he explicitly highlighted why the CCP acknowledges Confucius and how he thinks the Chinese people can learn from Confucian philosophy.[5]

All this is generally perceived as the CCP moving closer and promoting Confucianism (Qiou, 2016), an ideology that provides a set of values strongly rooted in the Chinese culture and internalized by Chinese people.

[5] In his speech, President Xi mentioned that Confucianism is an essential part of Chinese culture and that Confucianism "recorded the Chinese nation's spiritual activities, rational thinking and cultural achievements in building their homeland, reflected spiritual pursuits of the Chinese nation, and provided a key source of nutrition for the survival and continuous growth of our nation." He then maintained that Confucian values contain the answer to the many serious problems that mankind and China is currently facing, such as "widening wealth gaps, endless greed for materialistic satisfaction and luxury, unrestrained extreme individualism, continuous decline of social credit, ever-degrading ethics, and increasing tension between man and nature." (Jiang, 2018, p. 170).

3.2.3 The 'Confucian businessman'

Recently there has been a return to the so-called "Confucian businessman" (*rushang* or 儒商) which is a term used to characterize a group of entrepreneurs and managers eager to apply Confucian ethics to their businesses and in the management of their companies (Billioud, 2010). In fact, aside from the fact that the Confucian ideology still enters the Chinese way of life and directly influences the values of its people (Chen, Chen and He, 2019; Huang et al., 2023), "Confucianism profoundly influences managerial practices in China" (Huang et al., 2023, p.2170).

The main arenas for meetings and discussions between Confucian businessmen and managers are forums (Fu, 2022). According to Fu (2022, p.42), "the organisation of many forums with the name *rushang* in recent years shows that enthusiasm for Confucianism amongst entrepreneurs continues to grow. Already present in the 2000s, the organization of *rushang* forums is not a new phenomenon. Between 2008 and 2010, the Qingdao National Entrepreneur Forum (*Qingdao quanguo qiyejia luntan* 青島全國企業家論壇) in Shandong Province attracted a wide audience every year. Amongst the most recent forums, one can note the Bo'ao Confucian entrepreneur forum (*Bo'ao rushang luntan* 博鰲儒商論壇). Since 2016, on the initiative of Professor Li Honglei, a philosophy professor at Sun Yat-sen University, this forum has organized an annual conference at Bo'ao, Hainan Island, that attracts not only entrepreneurs but also academics and officials. The 2019 conference drew an attendance of 2,000 people. Alongside their participation in the promotion of "traditional values" in these various contexts, these "Confucian" company directors also try to build a "corporate culture," drawing inspiration not only from "traditional" values in the management of their businesses but also by setting up real *jiaohua* policies for their employees".[6] Attention to the implementation of Confucian values within companies has not gone unnoticed also by large corporations; in fact, while I cannot gather direct evidence on firms' CEOs proximity to the Confucian

[6] *Jiaohua* refers to actual classes that employees are given with the aim to spread the Confucian moral education (Brindley, 2021).

values[7], it is noticeable that many of the CEOs of some of the largest firms who are born close to a Confucian center in China have been nominated for the prize of "outstanding Confucian figure" by the Bo'ao Confucian entrepreneur forum. This list includes:

- Liu Chuanzhi, founder of Lenovo, born in Zhenjiang, about 100 km away from the nationally famous Confucian center of Dongtai. Chuanzhi showed his closeness to the Confucian ideology and his strong determination to adapt his company to follow Confucian values when he stated that "we'll need the resource of traditional Chinese culture to build a new business civilization" in his keynote speech at the 2017 Bo'ao Confucian Entrepreneur Summit, which he was invited to give following his public embracement of Confucian values.
- Li Ka-shing, founder, CEO, and chairman of Cheung Kong (Holdings) Limited and CK Hutchison Holdings, born in Chao'an, 180 km away from the nationally famous Confucian center of Longyan and a mere 15 km away from Chaozhou, the city where Han Yu (韩愈)[8] spent most of his life writing essays and spreading Confucian teachings. Li has been mentioned in the 2009 book by Kessler and Wong-Mingji, Cultural Mythology and Global Leadership, as the exemplification of Confucian values (McDonald, 2012).
- Zhang Ruimin, founder and CEO of Haier Group, born in Laizhou in Shandong Province which is the center of the Confucian revival as Qufu, the hometown of Confucius, is at its center. As described by the China Daily, Zhang believes that a successful entrepreneur should also be a philosopher and, given his familiarity with Chinese classics such as the Analects, he clearly proposes that Confucian values can and should be included in business management practices (McDonald, 2012).
- Ren Zhengfei, president of Huawei, born in Zhenning but educated in Chongqin, close to the

[7] An optimal strategy would focus on disentangling the CEOs' ideology, but as the greatest majority of CEOs in both state-owned and non-state-owned enterprises are Chinese communist party members and/or quasi-government officials, they might be reluctant to reveal their ideology or beliefs rendering a measure of personal beliefs either impossible to gather or difficult to trust (Du, 2015).

[8] A Confucian scholar who significantly influenced the development of Neo-Confucianism and who was described as "comparable in stature to Dante, Shakespeare or Goethe" for his influence on the Chinese culture and traditions (Nienhauser, W. H. (1986). The Indiana companion to traditional Chinese literature. Indiana University Press.)

Confucian center of Chengdu, who in an interview stated that both the work of Confucius and Mencius[9] inspired him.[10]

- Jack Ma, born in Hangzhou, 50 kms away from the Confucian center of Shaoxing and 130 from the one in Ningbo. Mr. Ma "believes that Chinese enterprises can gain fundamental strengths from traditional Chinese culture. He once said that a company, which has developed to a considerably large scale but still knows nothing about the ideological system of Confucianism, will have no chance to last in the market".[11]

Spanning outside the circle of CEOs who have been nominated for the prize of "outstanding Confucian figure", there are also many other individuals who are born in the proximity of a Confucian center and have been recognized as implementing Confucian values in their businesses.

- Zhong Shanshan, founder and chairman of the Nongfu Spring beverage company and the majority owner of Beijing Wantai Biological Pharmacy Enterprise, as well as the richest man in China, born also in Hangzhou, 50 km away from the Confucian center of Shaoxing and 130 from the one in Ningbo. He is known to have been brought up in a "traditional intellectual family influenced by Chinese Confucianism, [which] he applied to business and brought to the extreme".[12]
- The chairman of Tencent, Ma Huateng, and the CEO of Sina.com, Cao Guowei, constantly introduce and combine some concepts and ideas from Confucianism in their management (McDonald, 2011). The former was born in Chaoyang extremely close to the above-mentioned city of Chaozhou and, the latter was born in Shanghai, close to the temples of Shaoxing, Dongtai, and Ningbo.
- Wu Nianbo, founder and Chairman of Good-Ark, a firm listed on the Shenzhen Stock Exchange, who publicly stated that the global perspective of Good-Ark is to make a "Confucian contribution". [13]

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[9] Mencius is a Confucian philosopher who has often been described as the "second Sage", that is, second to Confucius himself.
[10] See https://www-file.huawei.com/-/media/corp/facts/pdf/in-his-own-words-dialogues-with-ren-volume-ii.pdf?la=en page 124.
[11] https://markets.businessinsider.com/news/stocks/confucianism-still-relevant-in-today-s-world-1027574827
[12] https://baijiahao.baidu.com/s?id=1683664024934073627&wfr=spider&for=pc and https://www.sohu.com/a/737487916_121161331.
[13] Other noticeable examples, among many others, are Chen Feng, founder of business conglomerate HNA Group and

Overall, many businessmen and CEOs have recognized their alignment with Confucian values; coincidentally, many of them were born in the proximity of at least one of China's nine nationally renowned Confucian centers. While it is challenging, if not impossible, to assert a causal relationship between birthplaces' proximity to a Confucian center and the adoption of Confucian values, this correlation provides preliminary evidence of a potential association, at the very least.

To conclude this excursus on Confucianism and the Confucian businessman, it is worthwhile mentioning that there is already evidence on how exposure to Confucianism and Confucian values are affecting firms' choices and policies. For example, among many others, Chen et al. (2021) find that Confucianism has a deep influence on the successor choice of family firms in China; Yan, Xu & Lai (2021) find that firms headquartered in provinces with stronger Confucian culture are more likely to invest in R&D; Chen, Jin, Ma & Xu (2018) find that Confucianism improves investment efficiency of Chinese listed firms; Jin, Li & Liang (2023) find that Confucianism is associated with less CEO compensation, a smaller CEO pay gap, and a larger gender pay gap in China; Huang et al. (2024) find that firms that have been exposed to Confucianism are more likely to participate in poverty alleviation programs because Confucianism emphasizes common social welfare and that this positive relationship is stronger for firms with CEOs born in regions characterized by a strong presence of Confucian ideas.[14]

For all the above, Confucian ideology is a crucial aspect of Chinese culture and today is experiencing a strong revival that is very much embraced by Chinese people and supported by the political class.

Since the Confucian ideology defines individual success as serving and improving society, and considering the benefits to society when a firm engages in open science (Nosek et al., 2015), a firm led by a CEO who

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Hainan Airlines, born in Huozhou, 215 kms away from the Confucian center of Luoyang, who also gave a keynote speech at the 2017 Bo'ao Confucian Entrepreneur Summit (https://www.bloomberg.com/news/articles/2020-03-04/how-coronavirus-claimed-hna-one-of-china-s-biggest-companies?embedded-checkout=true); and Liu Changle, founder and chairman of Phoenix TV, born in Shanghai, close to the Confucian centers of Shaoxing, Dongtai, and Ningbo.

[14] Aside from these studies, which link Confucianism to firms' strategic choices, many others point to the effect of Confucianism on firms in general. See for example Ma & Tsui (2015) on Confucianism and leadership in modern Chinese firms. Moreover, Liang (2010) proposes even a model to explain the East Asian countries' economic growth and finds Confucianism to have a strong explanatory power.

has been exposed to the Confucian values, especially during the period of highest 'susceptibility', i.e. her youth, might tend to embrace an open science policy and therefore have more scientific publications, which is directly related with social benefits. Therefore, I hypothesize that a CEO's early-life *exposure* to Confucian ideology is positively associated with her firm's propensity to adopt an open science policy and will tend to have a higher number of scientific publications.

3.3 Methodology

In this paper, I hypothesize that firms with CEOs who have been exposed to the pro-social, Confucian ideology tend to adopt an open science policy therefore publishing more in peer-reviewed, scientific journals as a result of the Confucian value that binds individuals to contribute to society. I identify CEOs' exposure to Confucianism through their places of birth. Borrowing from Du (2015), Chen et al. (2021), Chen, Chen & Jebran (2021), among others, who identify CEOs with higher exposure to Confucianism via their proximity to a Confucian center, I identify 'exposed CEOs' through the geographical location of the CEO's place of birth. If a CEO was born in an area in which a Confucian center is located, I assume she has been exposed to the Confucian values (at least to a larger extent compared to a CEO who was born in another region), leveraging the fact that the ideological atmosphere and the set of values surrounding an individual during her youth are reflected in her personal characteristics, traits, values, and preferences which then have an impact on her choices, which, in the case of a CEO, are then reflected in the firms' choices (Chen et al., 2021; Du, 2013a, b; El Ghoul, Guedhami, Ni, Pittman & Saadi, 2012; Marquis & Tilcsik, 2013). This assumption is supported by the anecdotal evidence proposed above on the birthplaces of CEOs and their public statements concerning Confucian values in their businesses and lives. In addition, Huang et al. (2023, p. 2175) argue that "this measurement is premised on the reasoning that Confucianism promotes the construction of Confucius temples, which in turn makes Confucianism more prevalent in the region (Chow, 1996; Kung & Ma, 2014). Research shows that there are indeed more Confucian temples in areas where Confucianism flourishes (Kung & Ma, 2014), and the culture remains stable for a long time and is passed down from generation to generation (Tang, Gu, Weng & Ho, 2022). People may visit the

Confucius temple, and in some places, Confucian-related activities will be held in the Confucius temples. Local news would report on the Confucius temple and Confucian activities. In local schools, teachers also mention local Confucius temples and Confucian culture to their students. Even many remnants of Confucius temple buildings are preserved on local school campuses. The influences of Confucianism on the values of local people are subtle and unconscious (Chen et al., 2019). Furthermore, research claims that the more Confucius temples a place has, the more local people embrace the core values of Confucianism (Wan, Cheng, Chan & Gao, 2021) and choose Confucianism as their ethical philosophy (Du, 2015)". For all the above, measuring exposure to Confucianism through the geographical locations of the main Confucian centers seems to be a fair assumption, supported and widely used in the literature, and backed by anecdotal evidence.

I therefore start my analysis from the whole sample of Chinese listed firms between 2000 and 2021 and gather the information, including the place of birth, of 4,731 CEOs in the 1,433 firms included in this study following the selection strategy implemented in Hsu, Hsu & Zhao (2021). After identifying CEOs who are born in a city or a province[15] with one of the nine main Confucian centers, I match firm-level characteristics of the firms with at least one exposed CEO to the characteristics of three firms that never had an exposed CEO using nearest neighbor matching. The matching criteria are selected as of the year in which the exposed CEO is appointed in the firm. This process allows me to implement a Difference-in-Difference (DiD) approach on a sample of treated (firms with an exposed CEO) and control (firms without an exposed CEO) firms with similar firm-level characteristics and estimate an equation of the form:

$$\text{Number of Publications}_{\text{it}} = \text{f}(\beta_1 \text{Treat}_{\text{i}} * \text{Post}_{\text{t}} + \gamma \text{X}_{\text{it}} + \delta_{\text{i}} + \varphi_{\text{t}}) + \varepsilon_{\text{it}} \quad (1)$$

where *Number of Publications*$_{it}$ represents the number of scientific publications made by firm i in year t. As the dependent variable tends to follow a count distribution, I estimate the model as a Poisson model. The variable *treat*$_i$ is a binary variable that indicates whether a firm belongs to the treatment group or the

[15] For the majority of the CEOs, only the province of birth is available, therefore when identifying the CEOs who have been exposed to the Confucian values, I also select the ones born in the provinces of Shandong, Sichuan, Henan, Fujian, Jiangsu, Zhejiang, and Jiangxi. These are 7 of the 31 provinces, cities, and independent regions in China.

control group. The latter refers to the group of firms that appointed an exposed CEO at some point during the period of study and the former refers to the group of firms that did not. Note that the affiliation with the treatment or control group ($treat_i$) is time-invariant and, hence, included in the firm's fixed effect (δ_i). δ_i controls for the time-invariant, unobservable characteristics of the firm. The variable $post_{it}$ is a binary variable that takes the value one from the year an exposed CEO is appointed in firm i onwards.[16] For the control group, this variable also takes value one from the year a Confucian CEO is appointed in the matched treated firm onwards. φ_t captures common time trends through a set of year dummies. X_{it} is a wide set of control variables including firm- as well as province-level characteristics. The main result of the model is provided by the coefficient β_1, which captures the average difference in the change of publication output between treated and control observations after an exposed CEO is appointed. If firms in the treatment group experience an increase in publications after appointing a CEO previously exposed to the pro-social, Confucian values, while firms in the control group do not, β_1 shows a positive and significant effect.

3.4 Data, variables, descriptive statistics and preliminary evidence

3.4.1 Data

Yearly firm-level characteristics are gathered from the China Stock Market and Accounting Research (CSMAR) database. Key variables include R&D investment, number of patents applied for and granted, firm market value, governance structure, balance sheet and income statement items, profitability, risk, growth, and efficiency ratios, manager-level information (including gender, age, education, position, and experience in current position), *CEOs' places of birth* and education, as well as firms' donations. Through the CEOs places of birth I identify the exposed CEOs and leveraging the panel structure of my dataset I can identify the year in which the new CEO was appointed. In addition, I manually gather information on yearly scientific publications made by scientists affiliated with Chinese-listed firms from the China National Knowledge Infrastructure (CNKI or "中国知网"). CNKI is a key national information database that is by

[16] Below, I discuss the possible endogeneity coming from the selection bias in CEOs' appointments.

far the most complete database on scientific publications in the Chinese language.[17] Following Hsu et al. (2021), I focus on manufacturing firms with industry codes between C13 and C43 according to the China Securities Regulatory Commission (this step decreases the number of firms in my sample from 4,371 to 3,059). I then include only firms that have at least one observation after 2006 because firms are required to disclose their R&D information only from 2007 onwards; 17 firms are excluded at this point. I then exclude firms that have been delisted (98 firms) and firms that have been listed after 2017. 2,363 firms are still in the sample so far. I then exclude firms that at any point in time have been in financial distress; these firms are listed as ST (Special Treatment) and PT (Particular Transfer) firms.[18] At this point, 1,922 firms are in my sample. To conclude, given the panel structure of my dataset, I only include firms with at least 3 years of observations before 2017 (due to patent data availability) so that I can take full advantage of the firm-level fixed effects and control for firms unobservable, time-invariant characteristics. 1,433 firms are in the sample. Among these 1,419 have at least one publication. Figure 3.A1, Panel A, in the Appendix, provides the distribution of the publication count for this initial sample.

To conclude, I also leverage the National Economic Research Institute (NERI) of China index which provides measures for formal institutional development at the provincial level for the 31 provinces, cities, and independent regions in which China is divided (Fan & Wang, 2006). The index is divided into five broad fields (government and market relations, development of the nonstate enterprise sectors, development of the commodity market, credit market development, and development of legal environment) composed of a total of 23 basic indicators and it provides a measure of the formal institutional environment

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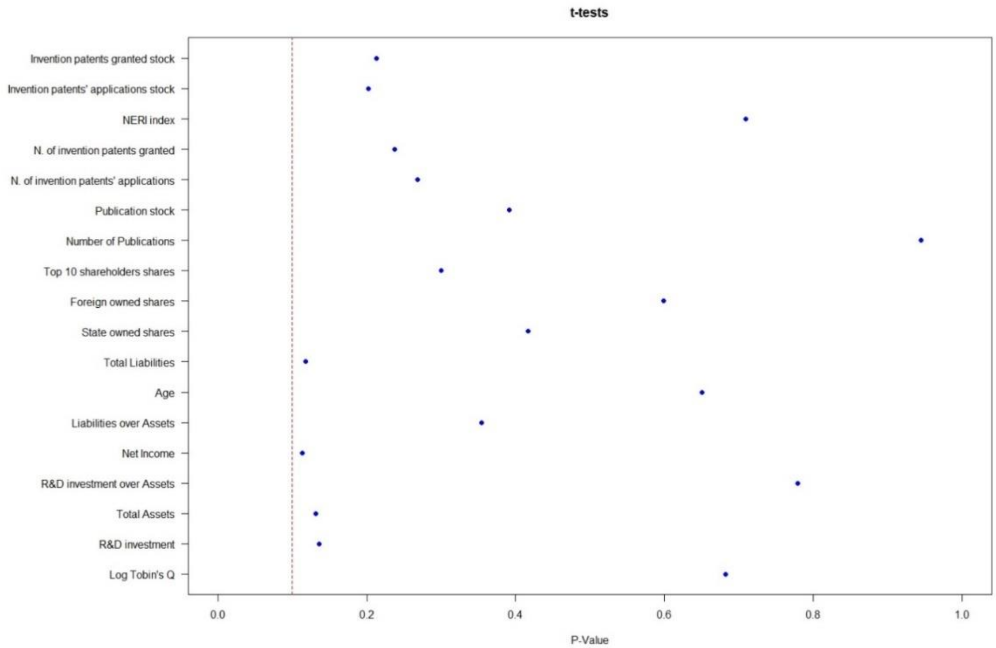
[17] While Scopus is one of the largest bibliometric databases for peer-reviewed literature in scientific journals, it has been shown that it lacks a sufficient coverage of articles that are not written in English (Mongeon & Paul-Hus, 2016; Visser, van Eck & Waltman, 2021). The same limitations are found for other popular bibliometric databases such as Web of Science (WoS), PubMed, and Microsoft Academic (Rotolo et al., 2022), therefore here, assuming also that in line with my expectations Chinese firms might be interested in generating benefit for their society, I focus only on publication available in CNKI.

[18] "The special treatment means, for example, that the stocks are traded with a 5% price change limit each day vs. 10% for normal stocks. Its midterm reports must be audited. Also, if an ST firm continues to suffer losses for one more year, it will be designated a particular transfer (PT) firm. PT stocks can only be traded on Friday, with a maximum 5% upside limit to last Friday's close, but no restriction on the downside. PT firms will be de-listed if they cannot become profitable within one year" (Liu and Lu, 2007, p.886).

development.

Once the datasets are combined, 322 firms are in the treated group, i.e. have at least one exposed CEO at some point. Among these, data for the exact year in which the exposed CEO was appointed, i.e. the treatment year, is available for 276 firms as some exposed CEOs were appointed before 2006 which does not allow me to observe the firms before the shock. After accounting for missing values in all the variables, 133 firms are still in the treatment group. To ensure that the treated firms are comparable to the control firms, I use nearest neighbor matching techniques in which I match, as of the year in which the Confucian CEO is appointed in the treated firm, each treated firm to the three most comparable firms in the pool of plausible control firms according to their R&D investment, number of publications, net income, percentage of state-owned shares, age, liabilities and assets, and shares owned by the top 10 shareholders; in addition, I require an exact matching on the year of the treatment and the 3-digit industry code. These variables are chosen to control for potential firm-specific differences such as firm size, experience, ownership, financial health, risks, performance, and corporate governance. The matching yields 130 and 319 treated and control firms, respectively (all matched control firms are kept in the sample). To ensure that the number of publications can be meaningfully compared, I exclude firms that are not observed at least once before and after the appointment of the exposed CEO and I restrict my analysis to the 4 years before and the 5 years after the treatment. 64 treated and 167 control firms, respectively, are left in the sample. The sample counts 2,053 observations divided between 492 and 1,561 observations in the treated and control groups, respectively. T-tests, reported in Figure 3.1, show that, after the matching, firms in the treatment and control groups do not differ in terms of their observable characteristics.

Figure 3.1. T-tests on treatment year between treated and control firms



3.4.2 Variables

The dependent variable, *number of publications*$_{it}$, is the number of scientific publications published by firm i in year t. The treatment dummy, *treat*$_i$, is defined in two stages. First, I identify the CEOs who have been exposed to Confucian values in their early life and define a dummy variable, *exposed CEO*$_k$, which is equal to one if CEO k is born in the proximity of one of the nine main Confucian centers, and zero otherwise. Second, I construct the dummy *treat*$_i$ to take the value of one if in my period of analysis, firm i has had at least an exposed CEO, and zero otherwise. Note that if the first year in which the exposed CEO is appointed is outside of my observation period, i.e., she was appointed before 2006, that firm is outside of my sample as I would not be able to observe the pre-exposed CEO-appointment trends in publications.

The variable *post*$_{it}$ takes value of one from the first year the exposed CEO is appointed; for the control firms, it also takes value of one from the exact same year as for the matched treated firm. I include a set of control variables to control for firms' observable characteristics. They include: *R&D investment*$_{it}$, which comprises both R&D investments and expenses and accounts for the innovation efforts and inputs of the firms which are directly related to innovation outputs, among which, scientific publications; *net income*$_{it}$ and *net income growth*$_{it}$, which account for the profitability and financial health of the company as well as its growth prospects and past performance; *percentage of state-owned shares*$_{it}$, which controls for the systematic differences that have been found between state-owned firms and other publicly listed firms (e.g. Phi, Taghizadeh-Hesary, Tu, Yoshino & Kim, 2021); *percentage of foreign-owned share*$_{it}$ together with the *shares held by the top 10 shareholders*$_{it}$, which controls for the governance structure of the firms; *total assets*$_{it}$ and *total liabilities*$_{it}$, which control for firm size and risk; the *age*$_{it}$ of the firm; and a measure of the formal institutional environment development, *NERI index*$_{it}$. The NERI index of marketization (Fan, Wang and Zhu, 2007) developed by the National Economic Research Institute of China is an index measuring the level of devopment of the 31 provinces, cities and independent regions in which China is divided. It considers the level of activity and intervention of the government in the markets, the level of development of state-owned firms, as well as the development of the legal and financial environment. This index comes in the form of a score and a ranking: a province that is ranked first (according to its score) has the highest level of institutional development. My measure of provincial-year-level institutional development is the mean of the five rankings given to each province in each of the 5 subindices. I chose the ranking over the score because the scores increase over time. Ranks take values between one and thirty-one, i.e. the total number of provinces, cities, and independent regions, with thirty-one being the region with the lowest level of institutional development.

In addition, when matching the treated firms to the most similar control firms, I require firms to be in the exact same industry. *Industry*$_{it}$ is defined by the three-digit industry code. To conclude, as shown in Figure 3.1, I check for the balancedness of my sample on more observable, firm-level characteristics, including the *stock of publications*$_{it}$, *stock of granted invention patents*$_{it}$, and *stock of invention patent applications*$_{it}$. For example, the stock of publications is calculated as:

$$\text{stock of publications}_{it} = \text{number of publications}_{it} + (1\text{-}\delta)\ \text{stock of publications}_{it\text{-}1} \qquad (2)$$

where δ is a depreciation rate of 15% (e.g. Hall & Mairesse, 1995; Hall, 2007). The same approach is used for the other stock measures. For the patent measures, I only include the invention patents as on average they are the most valuable ones. In the end, I also calculate the ratios of the total liabilities to the total assets of the firm (*liabilities over assets*$_{it}$) and R&D investment to total assets (*R&D investment over assets*$_{it}$), as well as the logarithm of Tobin's Q (*log Tobin's* Q_{it}). The natural logarithm of Tobin's Q is defined as the ratio of the firm's market value, i.e. the total number of shares outstanding multiplied by the price per share, over the book value of the firm's tangible assets (Dowell, Hart & Yeung, 2000; Morck & Yeung, 1991) and controls for the market value of the firm.

To avoid overfitting the model and/or having too high correlations between the dependent variables not all matching covariates have been included in the model as controls.

Table 3.A1 in the Appendix provides more detailed information and a summary of the variables used.

3.4.3 Descriptive statistics and preliminary evidence

3.4.3.1 Descriptive statistics

Table 3.1 presents the correlation matrix for the variables used in the regression models for all the firms included in the main sample.

Table 3.2 reports the descriptive statistics for the main variables divided by treated and control group, before (pre) and after (post) the CEO exposed to Confucian values in early life has been appointed as CEO in the treated firm. For the firms in the control group, the periods before and after are defined in the same fashion but according to the treated firm year of appointment of the exposed CEO. It is worth noticing that the number of publications remains virtually constant over time for the firms in the control group and it increases by almost 70% on average for the firms in the treated group (the standard deviation also increases though).

Table 3.1 Correlation matrix

	R&D Investment	Total Assets	Net Income	Age	% Foreign shares	Top 10 shareholders	N. of publications	Neri index	% State shares	Total Liabilities
Total Assets	0.78****									
Net Income	0.66****	0.77****								
Age	0.32****	0.36****	0.23****							
% Foreign shares	-0.03	-0.01	-0.01	-0.09****						
Top 10 shareholders	0.11****	0.18****	0.14****	-0.22****	0.12****					
N. of publications	0.42****	0.41****	0.28****	0.31****	0.01	0.15****				
Neri index	0.02	0.06**	0.01	0.22****	-0.04	0.03	0.12****			
% State shares	0.09****	0.12****	0.09****	0.04	0.05*	0.14****	0.10****	0.13****		
Total Liabilities	0.72****	0.98****	0.70****	0.33****	-0.01	0.18****	0.41****	0.06**	0.12****	
Net Income Growth	0.01	0.02	0.05*	0.01	0.01	0.06**	0.01	0.01	0.06**	0.02

Notes: Signif. codes:****: 0.001, ***: 0.01, **: 0.05, *: 0.1.

Table 3.2 Descriptive statistics

		Pre					Post				
Group	Variable	mean	Sd	Median	min	max	mean	sd	median	min	max
Treated	Year	2013	2.730	2014	2008	2020	2016	3.069	2017	2008	2021
	R&D Investment	17.856	36.020	4.693	0.016	201.200	36.337	78.655	8.017	0.092	592.133
	Total Assets	989.300	1,393.780	375.157	44.321	6,968.735	1,750.900	3,465.075	518.871	71.533	31,863.320
	Net Income	30.331	82.300	11.344	-290.502	751.798	77.417	325.511	19.421	-349.594	3,498.963
	Age	8.185	5.436	7.000	0.000	23.000	11.294	5.799	10.000	1.000	25.000
	% Foreign shares	0.006	0.030	0.000	0.000	0.257	0.002	0.021	0.000	0.000	0.257
	Top 10 shareholders	57.749	15.740	59.394	25.369	88.505	55.600	15.241	54.990	19.932	88.372
	N. of publications	14.035	29.800	3.000	0.000	219.000	24.287	53.116	4.000	0.000	324.000
	Neri index	9.633	6.094	6.800	3.000	29.200	9.651	6.173	6.800	2.400	30.800
	% State shares	0.026	0.104	0.000	0.000	0.739	0.011	0.053	0.000	0.000	0.513
	Total Liabilities	562.227	935.654	155.773	4.488	4,423.194	976.373	2,064.837	208.069	5.492	18,551.690
	Net Income Growth	-0.193	4.187	0.043	-38.061	18.519	-2.937	43.136	0.032	-680.162	150.532
Control	Year	2014	2.764	2014	2008	2020	2016	3.173	2016	2008	2021
	R&D Investment	12.670	25.246	5.190	0.000	229.627	16.787	38.070	7.263	0.037	497.500
	Total Assets	741.125	1,494.220	280.464	35.537	15,888.396	836.090	1,892.644	356.049	53.800	28,505.980
	Net Income	32.110	75.404	11.486	-245.692	705.799	35.696	103.762	12.306	-298.619	1,492.224
	Age	8.772	5.895	8.000	0.000	26.000	10.422	6.438	9.000	1.000	27.000
	% Foreign shares	0.008	0.052	0.000	0.000	0.638	0.004	0.038	0.000	0.000	0.626
	Top 10 shareholders	57.471	13.942	57.255	13.984	91.697	55.357	14.792	54.916	8.779	92.552
	N. of publications	17.464	44.755	3.000	0.000	291.000	16.122	40.486	3.000	0.000	297.000
	Neri index	9.362	5.684	7.000	2.400	28.000	9.313	6.119	6.800	2.400	28.000
	% State shares	0.030	0.101	0.000	0.000	0.725	0.025	0.091	0.000	0.000	0.877
	Total Liabilities	380.021	963.165	95.412	4.673	10,648.098	426.895	1,264.899	131.230	4.673	19,373.990
	Net Income Growth	-0.318	4.308	0.053	-45.637	17.797	-0.384	11.348	0.053	-189.288	213.336

Figure 3.2 provides information on the geographical locations of treated and control firms, the 9 main Confucian centers, and the places of birth of the exposed CEOs. As mentioned before, an exposed CEO is an individual who is more likely to have been exposed to the Confucian ideology during her childhood given the proximity between her place of birth and at least one of the nine main Confucian Centers.

Figure 3.2 Geographical locations of Confucian centers, CEOs' places of birth, treated and control firms

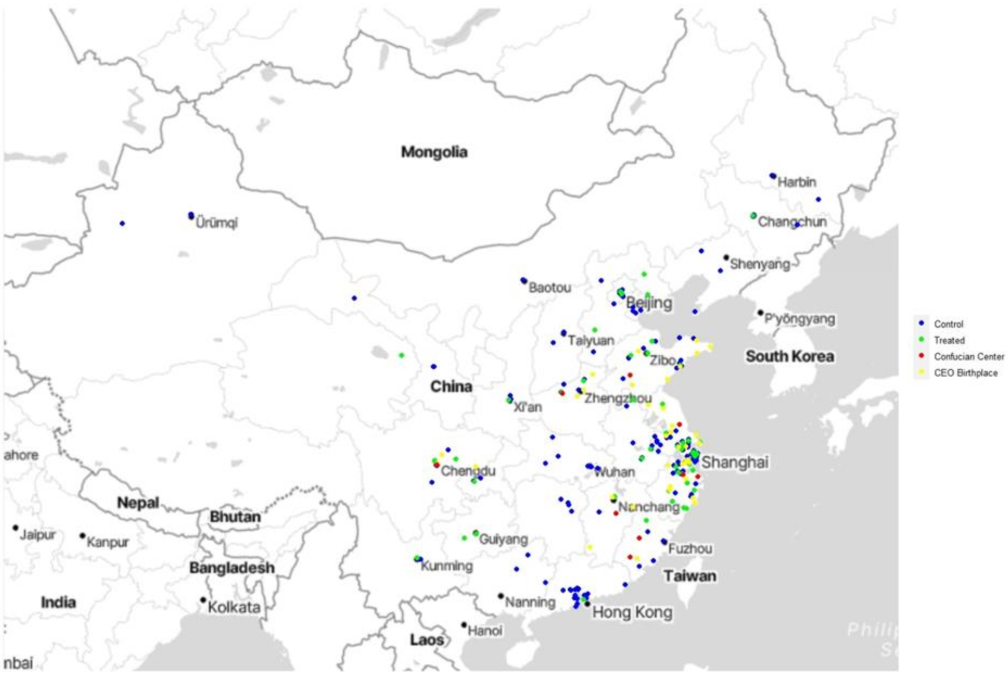
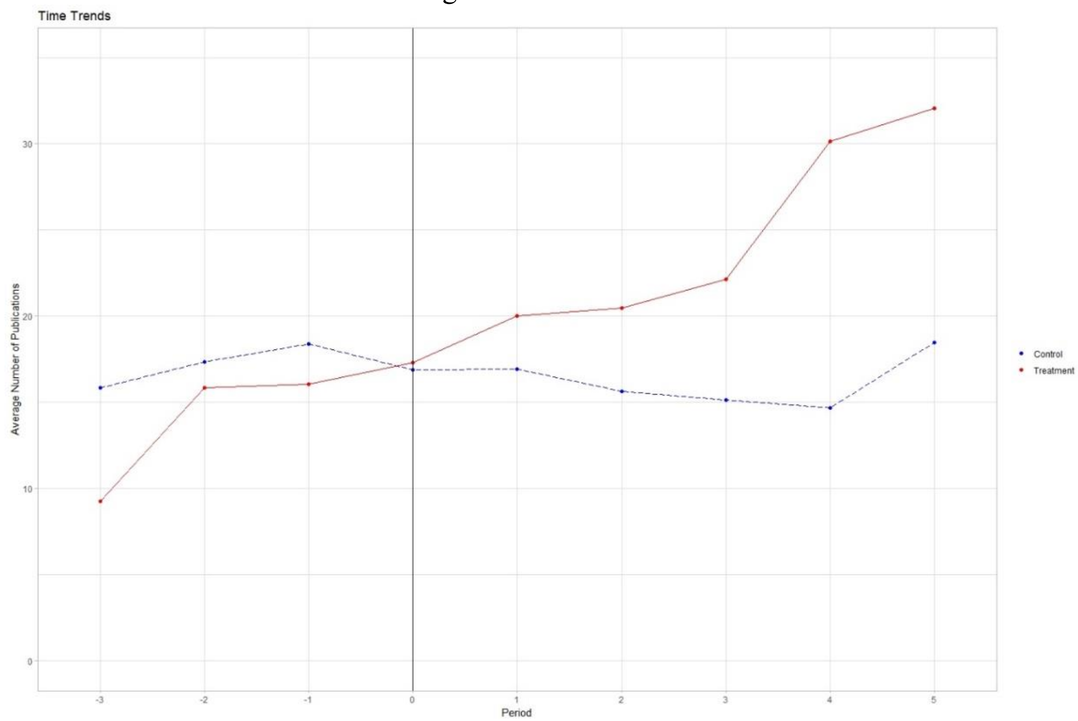


Figure 3.A1, Panel B, in the Appendix, shows the distribution of the dependent variable in the final dataset.

3.4.3.2 Preliminary evidence

Figure 3.3 presents the time trends. Following the initial evidence provided in Table 3.2 on the mean changes between pre- and post-periods for both groups, there seems to be a relatively stable number of publications over time for the control group and a steady increase in the number of publications for the treated group especially after the treatment.

Figure 3.3 Time trends



The main analysis of this paper relies on a matching sample as described above. While matching techniques are widely employed in the literature to identify a comparable group of control observations, they also run the risk of including a selection bias in the estimations (Rosenbaum and Rubin, 1985). To this end, in Table 3.3 below, I report some preliminary evidence in support of my hypothesis derived by the use of the full, unmatched sample.

I estimate an equation of the form:

$$\text{Number of Publications}_{it} = f(\beta_1 \text{Treat}_{it} + \gamma X_{it} + \delta_i + \varphi_t) + \varepsilon_{it} \quad (3)$$

where I regress the number of yearly publications on a treatment dummy, $treat_{it}$, which is equal to 1 for the firm-year observations where firm *i* has an exposed CEO and 0 otherwise. Columns 1 and 2 report the results when defining the treatment dummy through the city or province of birth of the CEO, while columns 3 and 4 report the results when defining the treatment dummy only through the city of birth of the CEO. As mentioned above, for the majority of the CEOs, only the province of birth is available, therefore when identifying the CEOs who have been exposed to the Confucian values, I also select the ones born in the provinces of Shandong, Sichuan, Henan, Fujian, Jiangsu, Zhejiang, and Jiangxi. These are 7 of the 31 provinces, cities, and independent regions in China. When considering both the city and province of birth, 302 CEOs over a total of 3,305 are included in the treatment group (in 254 firms covering 1459 observations); when considering only the city of birth, 30 CEOs are included in the treatment group (in 25 firms with covering 182 observations). Columns 2 and 4 show that there is a positive association between the treatment dummy and the number of publications also when controlling for several firm and provincial-level characteristics as described in the section above.

Table 3.3 Preliminary Evidence

Dependent Variable	Number of Publications			
Model	(1)	(2)	(3)	(4)
Variables				
treat (1)	0.1226***	0.1183***		
	(0.0242)	(0.0257)		
treat (2)			0.1363*	0.1364*
			(0.0799)	(0.0731)
Controls	No	Yes	No	Yes
Fixed-Effects:				
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Fit Statistics				
S.E. type	Drisco.-Kra. (L=1)	Drisco.-Kra. (L=1)	Dris.-Kra. (L=1)	Dris.-Kra. (L=1)
Observations	13,318	13,318	12,037	12,037
Squared Cor.	0.90034	0.90226	0.90143	0.90347
Pseudo R^2	0.81389	0.81467	0.81488	0.81557
BIC	87,009.0	86,794.3	77,892.1	77,741.0

Notes: Signif. codes: ***: 0.01, **: 0.05, *: 0.1.

3.5 Results

One of the necessary conditions for deriving causal effects from a DiD analysis is a parallel movement of the dependent variable in the pre-treatment period. Table 3.4, Column 1, reports the results from a regression investigating the existence of pre-treatment parallel trends. The results show no significant difference between the treated and control groups in terms of the number of scientific publications for the years immediately before the shock. The effect of the treatment kicks in mildly in the first and second post-treatment years and then to a larger extent in the years after. This is in line with my expectations as an immediate strong effect might have been indicative of other parallel changes or shocks that might affect my results. To the best of my knowledge, no parallel policies were implemented in China during this period that might affect the propensity of firms to publish more in scientific journals. To further alleviate the possible problem that my analysis might be picking up other simultaneous shocks, there is evidence from Hsu et al., (2021) who carried out an extensive literature review and news media search which pointed to no policy changes to firms' incentives to disclose their R&D findings through scientific publications within their study time period (2006 – 2015), which is virtually the same as the period I study here.[19] In addition, the authors also find no evidence of firms using the number of corporate publications as a performance indicator for local government officers, but they do find some municipal policies that seem to encourage academic publications from both universities and corporations. Nevertheless, the authors pose that it is unclear how effective these policies were (see also Hsu et al., 2021, footnote 14).

A further plausible issue derives from the likely endogeneity in the firms' choices of appointing an exposed CEO perhaps because more in line with their own firm's pro-social values. This problem is to a large extent alleviated by the use of the matching techniques mentioned above. In addition, if this was the case then I should observe a significant difference in terms of pre-treatment pro-social behaviors between treated and control firms. To this end, I compare the pre-treatment periods' amount of yearly social donations. If there is an endogenous choice of CEO due to alignment of pro-social values, then the treated firms should show more pro-social behaviors in their pre-treatment years compared to control firms. As there are no significant differences between the treated and control firms also in terms of the amount of donations (*p-value 0.6128*), this does not seem to be the case.

Column 2 reports the Poisson regression analysis testing my hypothesis. Here I only include the $treat_i$ and $post_{it}$ dummies, as well as their interaction. The coefficient of interest ($treat_i \ x \ post_{it}$) is positive and significant at the 5% significance level. In column 3, I run a similar model with the addition of all the control variables mentioned above. The results hold. In columns 4 and 5, I add the year and firm fixed effects without and with the control variables, respectively. The coefficient of interest remains positive and significant (p-value 1%). The average treated firm therefore tends to publish about 29% more after the appointment of the exposed CEO. As the average pre-treatment number of publications is about 16.5, this

[19] Please refer to Hsu et al. (2021) footnote 13 for a more in-depth explanation.

consists of an increase of about 5 publications.

Table 3.4 Main results

Dependent Variable:	Number of Publications				
Model	(1)	(2)	(3)	(4)	(5)
Variables					
treat x period -4	-0.4368**				
	(0.2015)				
treat x period -3	-0.1150				
	(0.1418)				
treat x period -2	-0.0372				
	(0.1367)				
treat x period 0	0.0705				
	(0.1199)				
treat x period 1	0.1550*				
	(0.0848)				
treat x period 2	0.1204*				
	(0.0728)				
treat x period 3	0.2741***				
	(0.0943)				
treat x period 4	0.4673***				
	(0.1247)				
treat x period 5	0.2998**				
	(0.1446)				
Constant		2.860***	0.0432		
		(0.0687)	(0.2800)		
treat		-0.2186	-0.1975		
		(0.2113)	(0.2069)		
post		-0.0800	-0.2812*	-0.0643	-0.0404
		(0.1207)	(0.1454)	(0.0391)	(0.0380)
treat x post		0.6283**	0.5263*	0.2640***	0.2555***
		(0.2591)	(0.2868)	(0.0726)	(0.0536)
Controls	Yes	No	Yes	No	Yes
Fixed-Effects:					
Firm	Yes	No	No	Yes	Yes
Year	Yes	No	No	Yes	Yes
Fit Statistics					
S.E. type	Drisco.-Kra. (L=1)	Drisc.-Kra. (L=1)	Drisc.-Kra. (L=1)	Drisco.-Kra. (L=1)	Drisco.-Kra. (L=1)
Observations	2,053	2,053	2,053	2,053	2,053
Squared Cor.	0.95694	0.00443	0.13838	0.94224	0.95292
Pseudo R^2	0.89694	0.00848	0.32215	0.89330	0.89571
BIC	12,869.4	103,956.1	71,154.6	13,060.3	12,876.1

Notes: Signif. codes: ***: 0.01, **: 0.05, *: 0.1.

3.6 Endogeneity discussion

The main threat to the validity of this analysis and its causal interpretation derives from the endogeneity generated by measurement error. While measuring CEOs' exposure to Confucian values through the CEOs' places of birth is an approach that is well supported by imprinting theory and the developmental psychology literature, and has been widely used in the literature, it is still empirically challenging to believe its validity.[20] In the context of this study, there is one main question that needs to be discussed: is it enough for an individual to be born in the proximity of a Confucian center and therefore be exposed at least to a larger extent to the Confucian values compared to other individuals born in other regions, to assume that those values have entered the individual's value system? In other words, do these nine nationally famous Confucian centers exercise such a strong influence on their surrounding environment to assume that individuals born in these regions are to some extent influenced by the Confucian ideology?

As mentioned above, examples from renowned CEOs as well as research put forth in different fields support this statement, still, the optimal strategy to alleviate this potential endogeneity concern would require me to disentangle each CEO's ideology. Unfortunately, as discussed by Du (2015), the greatest majority of CEOs in both state-owned and non-state-owned enterprises are Chinese communist party members and/or quasi-government officials, hence, even considering the more recent support of the CCP to the Confucian ideology, they might be reluctant to reveal their ideology or beliefs rendering a measure of personal beliefs either impossible to gather or difficult to trust. Taking this as a starting point, many studies have relied on the proximity to one of the nine Confucian centers to measure the exposure of Chinese firms to the Confucian ideology and therefore, its effect on the firms' choices and policies.[21]

As mentioned above another source of endogeneity for my analysis may derive from the plausible selection bias in the firm choice of CEO. It is possible that more pro-social firms choose to hire CEOs who have been exposed to Confucian values as they also have a set of strongly pro-social values. If this was the case, then I should observe a significant difference in terms of pre-treatment, pro-social behaviors between treated and control firms. To this end, I compare the pre-treatment periods' amount of yearly social donations. If there is an endogenous choice of CEO due to alignment of pro-social values, then the treated firms should show pro-social behaviors in their pre-treatment years. As there are no significant differences between the

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[20] Still, as mentioned above and later in the limitation section, my arguments leverage exposure to the Confucian ideology rather than direct belief in Confucian values.

[21] As shown in Table 3.A2 in the Appendix, when I define the variable $treat_i$ through the firm proximity to the Confucian centers without accounting for the CEO background, results hold.

treated and control firms also in terms of the amount of donations (*p-value 0.6128*), this does not seem to be the case.

Moreover, and this also further alleviates the measurement error issue mentioned above, I run my DiD analysis with the amount of donations as the dependent variable to test whether the appointment of an exposed CEO with strong pro-social values due to their exposure to the pro-social, Confucian ideology has an effect not only on the firm intellectual contribution to society but also on its economic contribution. As shown in Table 3.5 below, this seems to be the case.[22] This result further alleviates the endogeneity concern as the exposed CEOs' firms really seem to engage in pro-social activities in different ways in line with the Confucian ideology. In addition, this result further validates the mechanism proposed here, i.e. the CEOs' exposure to Confucian pro-social values change the direction of firms' policies towards a more pro-social trajectory.

Table 3.5 Effect on Donation

Dependent Variable:	Donation Amount
Model	(1)
Variables	
post	0.0008
	(0.0023)
treat x post	0.0050***
	(0.0016)
Controls	Yes
Fixed-Effects:	
Firm	Yes
Year	Yes
Fit Statistics	
S.E. type	Drisco.-Kra. (L=1)
Observations	2,038
R^2	0.41406
Within R^2	0.08492

Notes: Signif. codes: ***: 0.01, **: 0.05, *: 0.1.

In addition, there is yet another plausible source of endogeneity in the location of the Confucian centers. First, there could be some underlying, unobserved reasons explaining why these centers are exactly located in these cities. Second, there could be some unobserved similarities between people born in the proximity of all of these centers different from being exposed to Confucian values. Likely, the determinant of the

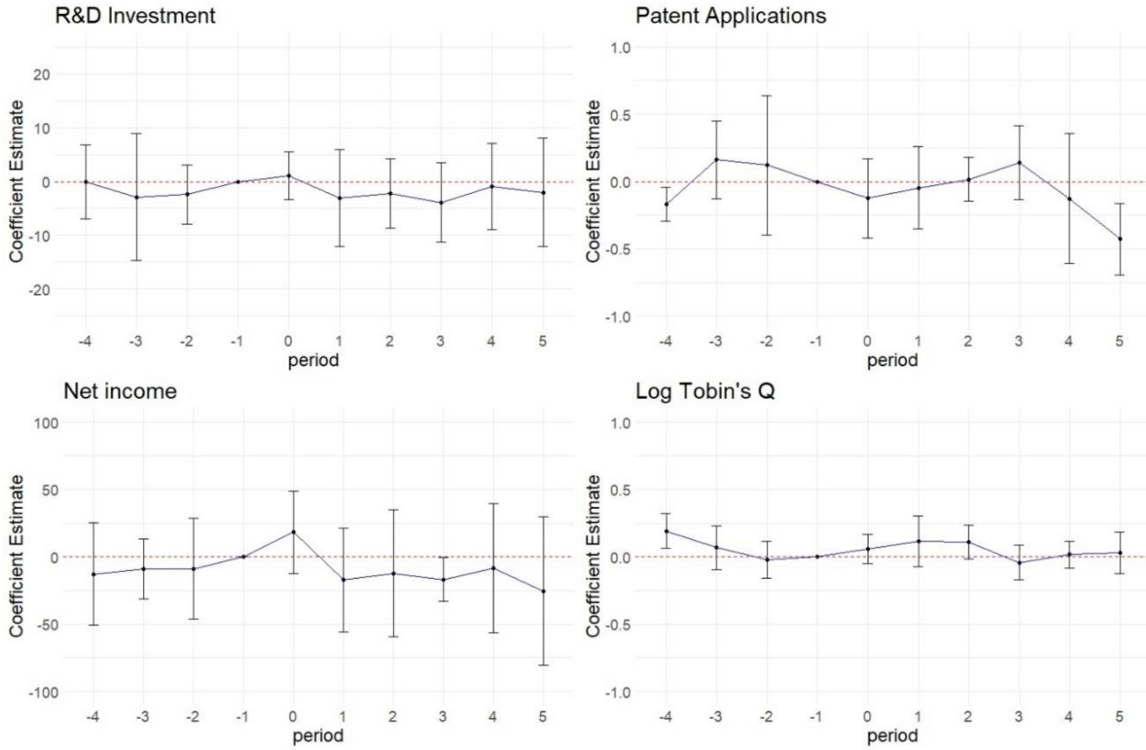
22 Parallel trends hold.

location of a Confucian center is Confucius' living places thousands of years ago (Chen et al., 2021), hence their location is hardly endogenous. This minimizes the endogeneity concerns from the first point. In addition, as shown in Figure 3.2, exposed CEOs are born in different places close to the Confucian centers around China. The exposed CEOs' birthplaces are both large cities and smaller villages spreading mostly in the east and center areas of China. These places are located in both well-developed regions and not-so-well-developed regions in China therefore it is hard to believe that such locations have anything in common that might create an issue to the validity of my analysis, which is still, only claiming an association between CEOs' exposure to Confucian values and corporate science strategies, rather than causality.

3.7 Further analysis

Supposedly firms either patent or disclose (a third way would be secrecy, but due to its nature, it is unobservable) hence, according to my argument I should observe a lower number of patents for treated firms after their appointment of an exposed CEO. This does not seem to be the case. As shown in Figure 3.4 below, firms' patenting behavior does not change after an exposed CEO is appointed. In the same fashion, also the amount of R&D investment does not change. This is useful for the validity of my results as an increase in the number of scientific publications after the exposed CEO's appointment might have been a mechanical response to the increased investment in R&D. As shown in Figure 3.4, this is not the case. At the same time, I also do not find a change in the firm's profitability as shown in the panels plotting the parallel trends for net income and Tobin's Q, showing that embracing a pro-social open science strategy does not harm the firms' economic returns.

Figure 3.4 Parallel trends



3.8 Discussion

3.8.1 General discussion

The cornerstone of the upper-echelons theory states that firms' choices, strategies, and policies are reflections of the values and cognitive bases of their managers (Hambrick & Mason, 1984). Ample support has been provided for the validity of this statement. Still, much of this effort has understandably been spent on exploring relations between CEOs' observable characteristics, such as age, education, and gender, and firms' outcomes. While these observable characteristics are easily measurable and provided initial empirical support for the validity of the upper echelons theory (Hambrick & Mason, 1984), the set of values, i.e. that set of abstract desirable goals that serve as guiding principles in an individual life (Adams, Licht & Sagiv, 2011; Kluckhohn, 1951; Schwartz, 1992), of firms' CEOs is a significantly more challenging metric to measure as it is not directly observable. Still, CEOs' values are a much more relevant characteristic as they directly enter the CEOs' strategic decision-making process and hence firms' choices. A crucial question is:

how and when do individuals, and CEOs in particular, develop such a set of values? Vast research in the field of developmental psychology suggests that people's value systems are shaped especially during the earlier stages of life (Elder, 1998; Jenks, 1996), thus it is straightforward to examine the early life experiences of CEOs to gain insights into the formation of their personal values. More recently, some of the insights from the psychology field have been transposed to the management field with the imprinting theory (Marquis & Tilcsik, 2013). The imprinting theory states that individuals' values reflect prominent features of the external environment in which individuals live especially during periods of susceptibility such as their childhood. Drawing on these bodies of literature, it appears that there is a connection between the characteristics of the environment of the CEOs' birthplaces, their personal values, and the strategic decisions made by their respective companies. In this paper, therefore, I focus on the exposure of CEOs during their childhood to specific socio-cultural contexts and highlight how the characteristics of the surrounding environment seem to be correlated with the choices of the firms in which CEOs are later appointed. More specifically, in this study, I highlight a positive relation between CEOs' exposure to the pro-social, Confucian values during their childhood and their tendency to implement pro-social policies in their firm, more specifically to embrace an open science policy which then results in a higher number of scientific publications.

This paper advances the line of research on CEOs' pre-career experiences (Chen et al., 2023) and posits that a natural extension, especially given the insights provided by the development psychology literature, is the analysis of CEOs' early youth exposure to certain social and cultural environments and informal institutions as individuals typically develop their values and beliefs before starting their professional careers (see, for example, Benmelech & Frydman, 2015; Gephart & Campbell, 2015).

3.8.2 Research implications

My results have implications for the literature on behavioral strategy and more specifically for the literature on how CEOs' psychological traits and values affect firms' policies and strategic choices (Aabo, Pantzalis, Park, Trigeorgis & Wulff, 2024; Benischke, Martin & Glaser, 2019; Gentry, Harrison, Quigley & Boivie, 2021). I demonstrate that CEOs' exposure to pro-social Confucian values influences firms' open science policy. By building on the imprinting theory, upper echelon theory, and insights from development psychology, I highlight the relevance of CEOs' value systems on the firms' strategic choices. More specifically I add to the relatively more recent body of literature focusing on CEOs' pre-career experiences (Benmelech & Frydman, 2015; Bernile et al., 2017; Chen et al., 2021; Malmendier, Tate & Yan, 2011).

In addition, I add to the debate on the firms' incentives to engage in corporate open science.

Corporate open science consists of firms disclosing the results of their R&D efforts in peer-reviewed scientific journals. R&D outcomes are nevertheless one of the key sources of competitive advantage for innovative companies (Amit & Schoemaker, 1993; Grant, 1991; Kogut & Zander, 1992) and their free distribution to the public is puzzling. Rotolo et al. (2022) provide a comprehensive conceptual framework that outlines five main sets of incentives that firms may have to disclose the outcomes of their R&D efforts through scientific publications: (1) accessing external knowledge and resources, (2) attracting and retaining researchers, (3) supporting IP strategies, (4) building the firm's reputation, and (5) supporting commercialization strategies. I argue that considering the social benefits generated when a firm engages in open science, there is the possibility that a pro-social incentive might play a *complementary* role to the incentives mentioned above, especially in the Chinese context which strongly revolves around the concept of collectivism and places the greatest importance on collective values and interests.

The plausible existence of such incentive is also supported by recent studies that found a declining trend in scientific publications made by firms in the U.S. and other developed countries (see, for example, Arora et al., 2018 and Tijssen, 2004) while data gathered from Hsu et al. (2021) suggests "a fairly stable growth in [corporate] academic publications" in China.[23]

[23] Similar, but not as striking, evidence on the trends of scientific publications of China and US shows that China has overtaken the United States as the number one ranked country for contributions to research (see, for example, Baker, 2023).

The plausible existence of such a pro-social, complementary incentive is supported in my analysis.

This finding, which has either not yet been studied or perhaps not been found in the usual empirical contexts of analysis, i.e. the U.S. and Europe, highlights the need in the management field to focus also on non-Western contexts, such as the Chinese one (Wickert et al., 2024, p. 1). Non-Western contexts are of interest to management scholars given the always-increasing relevance of countries like China, India, Brazil, and others in the global landscape. In addition, an increased emphasis on non-Western contexts within management studies may offer the potential to unveil novel insights previously overlooked as the set of assumptions applied to Western countries might not hold in countries, such as China, or other developing economies, which are fundamentally different and for which other incentives and/or mechanism might play a role when it comes to firms' strategic choices (Peng et al., 2008).

3.8.3 Limitations

This study has the following limitations. First of all, my identification strategy relies on CEOs' places of birth and their proximity to at least one of the nine main Confucian centers in Mainland China. This approach does not allow me to measure directly the CEOs' beliefs in the Confucian ideology. Nevertheless, following the arguments proposed by Chen et al. (2022), it is important to highlight that my focus here is *not* on CEOs' current beliefs but instead on their exposure during childhood to the Confucian ideology which affects their value system in a period of strong susceptibility. How the exposure affects the CEOs' firms' strategic choices and policies is the focus of this paper. Still, future research may focus on disentangling the current ideological beliefs of CEOs through a survey but keeping in mind the possibility that such an approach may not be valid because, as mentioned by Du (2015), the greatest majority of CEOs in China are Chinese communist party members and/or quasi-government officials, thus they might be reluctant to reveal their ideology or beliefs rendering a measure of personal beliefs either impossible to gather or difficult to trust. In addition, measuring an individual exposure to the Confucian ideology through her place of birth is a restrictive approach. During an individual life, there are multiple phases in which an individual value system changes and adapts to the current external environment. Still, childhood is arguably the most crucial of such phases and therefore the most important (Gephart & Campbell, 2015). Furthermore, it is possible that individuals born in places more distant from the Confucian centers have been still exposed to the Confucian ideology during childhood and therefore might be applying Confucian values to their managerial practices. Nevertheless, it would be virtually impossible to consider all the possible experiences in a CEO's life that might bring her to embrace the Confucian ideology. A proxy, like the place of birth's proximity to a Confucian center, while imperfect, is arguably a good starting point.

Second, I focus in this paper on the Confucian ideology. Still, other ideologies or religions, such as Buddhism, Taoism, and Christianity are also followed by a significant portion of the Chinese population and do propose pro-social values. Nevertheless, religious activity is strictly controlled by the CCP and needs to be authorized. On the other hand, the Confucian ideology is significantly more rooted in the value system of Chinese people and publicly embraced by the CCP.

Third, despite the use of matching and DiD, on top of a long list of control variables, I cannot completely rule out the potential endogeneity issues generated by the measurement error and the potential match between firms' and CEOs' characteristics. Therefore, while my conclusions should only be interpreted as associations rather than causations, I believe they still offer an interesting advance in the research on CEOs' exposure to certain ideologies and firms' policies.

3.9 References

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3.10 Appendix

Figure 3.A1 Distribution of publication count

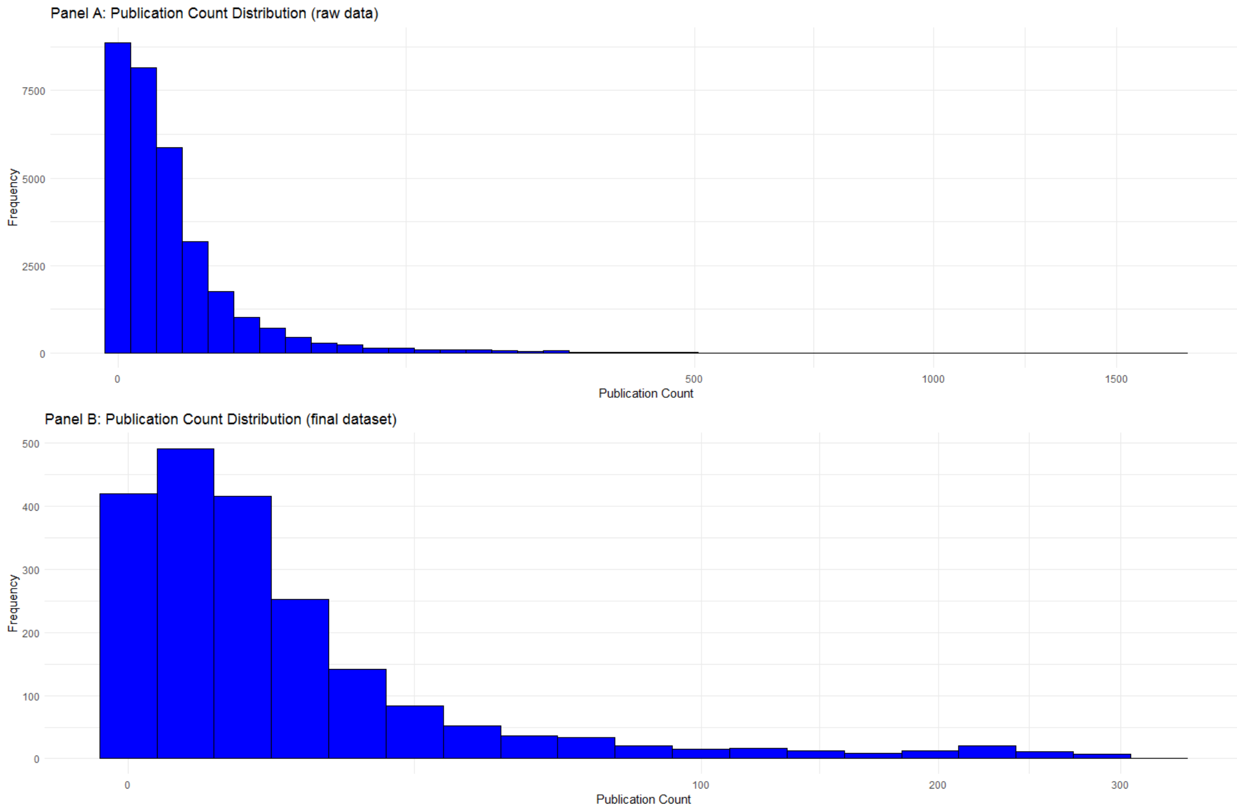

Table 3.A1 Variable Definition

Variable	Definition
Dependent Variables	
Number of publications	Number of yearly scientific publications
Donation amount	Economic value of firms' yearly donations divided by 10,000 CNY
Independent Variables	
Treat dummy	1. In the context of equation 3, $treat_{it}$ is equal to 1 for the firm-year observations where firm i has an exposed CEO and 0 otherwise 2. In the context of equation 1, $treat_i$ takes the value of one if in my period of analysis, firm i has had at least an exposed CEO, and zero otherwise
Treat IV	Dummy variables equal to 1 when the mean of the age of the CEOs during my period of analysis is above the sample mean (48.75), and zero otherwise.
Post dummy	Dummy variable that takes the value 1 from the year an exposed CEO is appointed in firm i onwards
Control Variables	
Total assets	Total assets' book value divided by 10,000,000 in CNY
Total liabilities	Total liabilities' book value divided by 10,000,000 in CNY
R&D investment	Capitalized and expensed R&D divided by 10,000,000 in CNY
Net income	Net income divided by 10,000,000 in CNY
Net income growth	Net income for the current period – net income for the same period of the previous year
Top 10 shareholder shares	Percentage of shares held by top 10 shareholders.
Percentage of state-owned shares	Percentage of shares that are state-owned
Percentage of foreign-owned shares	Percentage of shares that are owned by foreign entities
Age	Number of years since the firms has been listed
NERI Index	Mean of the provincial rankings of formal institutional development of the 5 sub-indices of the NERI index
Industry code	3 digits industry code
Other Variables	
Number of patent applications	Number of invention patent applications in the current year
Number of patents granted	Number of invention patent granted in the current year
Invention patent application stock	Number of patent applications in the current year plus the number of patent applications in the previous years, discounted by 15% (see Eq.2)
Invention patent grant stock	Number of patents granted in the current year plus the number of patents granted in the previous years, discounted by 15% (see Eq.2)
Publication stock	Number of publications in the current year plus the number of publications in the previous years, discounted by 15% (see Eq.2)
Liabilities over assets	Total liabilities over total assets
Log Tobin's Q	Number of A shares multiplied by the year-end price per share divided by total assets' book value and log-transformed
R&D investment over assets	R&D investment over total assets

Table 3.A2 Firm level results

Dependent Variable:	Number of Publications				
Model	(1)	(2)	(3)	(4)	(5)
Variables					
Treat firm (1)	0.7256*** (0.1625)				
Treat firm (2)		0.2043*** (0.0439)			
Treat firm (3)			0.1787*** (0.0386)		
Treat firm (4)				0.2520*** (0.0541)	0.1687** (0.0599)
Controls	Yes	Yes	Yes	Yes	Yes
Fixed-Effects:					
Firm	Yes	No	No	No	No
Year	Yes	Yes	Yes	Yes	Yes
Industry	No	Yes	Yes	Yes	Yes
Province	No	Yes	Yes	Yes	Yes
Establishment year	No	Yes	Yes	Yes	Yes
Fit statistics					
S.E. type	Drisco.-Kra. (L=1)	Drisco.-Kra. (L=1)	Drisco.-Kra. (L=1)	Drisco.-Kra. (L=1)	Drisc.-Kra. (L=1)
Observations	13,326	13,375	13,375	13,375	2,232
Squared Cor.	0.90299	0.38101	0.38138	0.38206	0.74609
Pseudo R^2	0.81527	0.42575	0.42565	0.42591	0.65924
BIC	86,897.4	227,733.2	227,772.6	227,669.5	23,943.2

Notes: Signif. codes: ***: 0.01, **: 0.05, *: 0.1.

Conclusion

This thesis aims to understand how institutional frameworks, both formal and informal, influence innovation and innovation activities within emerging markets, particularly focusing on China. This focus is driven by China's unique position in the global economy as a rapidly developing market that has seen significant institutional transformations over recent decades.

Chapter 1 provided an in-depth analysis of how weak institutional settings impact the valuation of innovative assets, such as R&D investments and patent applications, in China. The findings highlighted that in weaker institutional environments, these assets receive a lower valuation compared to similar assets in more developed institutional contexts. This valuation discrepancy is more pronounced in smaller firms, which lack the visibility and informational transparency of larger corporations. The chapter also identified insider ownership as a significant moderator of innovative assets valuation in weak institutional contexts, suggesting that insiders increasing ownership of their own firms' shares can serve as a powerful signal to the market, counterbalancing the negative effects of institutional weaknesses and uncertainties.

Chapter 2 examined the impact of an exogenous shock, i.e. Google's unexpected exit from the Chinese market, on the academic output of scholars. This event significantly decreased access to a primary information resource, affecting the productivity and impact of researchers within China. The sharp decline in publication output and citation impact documented in this chapter underscores the essential role of information accessibility in academic productivity and contributes to the broader discussion on how sudden institutional changes can disrupt knowledge economies.

Chapter 3 explored the relationship between CEOs' early life exposures to pro-social, Confucian values and their subsequent strategic decisions, particularly regarding open science policies. The findings suggest that CEOs with early exposure to pro-social values are more likely to embrace strategies that promote the dissemination of scientific knowledge, reflecting a broader pro-social orientation in their leadership approach.

Given the findings from these chapters, a few policy implications follow.

1. Enhanced regulatory frameworks: the results from Chapter 1 underscore the need for stronger institutional frameworks that can effectively recognize and appropriately value innovative assets. Policies aimed at improving the regulatory environment can help mitigate the uncertainty that plagues markets in weak institutional settings.

2. Ensuring access to information: the findings in Chapter 2 highlight the critical importance of maintaining and securing uninterrupted access to global information networks for the academic and research communities. Policies should focus on creating strong and stable infrastructures that support continuous access to crucial research resources, even in the face of geopolitical or corporate changes that could disrupt these flows.

This thesis contributes to several theoretical frameworks:

- Resource-based view: by focusing on the valuation of innovative assets, this thesis extends the RBV by incorporating the market's perception and valuation of these assets as a critical element leading to the generation of a sustainable competitive advantage. To this end, we clarify an implicit, often overlooked assumption, i.e. the importance of a positive acknowledgement of innovative assets by external parties to generate a sustainable competitive advantage from those assets. This point was first highlighted by Priem & Butler (2001a) and later acknowledged by Barney (2001, p.51) who clearly pose that "the value of a firm's resources must be understood in the specific market context within which a firm is operating". In this sense, not taking into consideration the market value of those assets might lead to erroneous conclusions.

- Upper echelons and imprinting theory: The findings from Chapter 3 provide insights into the role of CEOs' pre-career experiences on firm's strategic choices. Traditionally, the upper echelons theory suggests that organizational outcomes, both strategic choices and performance, are reflections of the values and cognitive bases of the decision makers. Chapter 3 extends this theory by highlighting the profound influence of non-observable traits such as personal values shaped during early life. This chapter leverages imprinting theory to demonstrate how socio-cultural environments during formative years can leave a lasting imprint on individuals, influencing their future behaviors and decisions in significant ways. By linking these imprints to strategic corporate decisions in the context of open science policies, the findings offer a deeper understanding of how early-life cultural contexts can dictate the strategic orientation of leaders towards more open, collaborative, and socially responsible business practices.

These chapters are also not free from limitations

Chapter 1 acknowledges that while it sheds light on the impact of institutional quality on the valuation of innovative assets, it is confined to publicly listed firms. This focus limits the generalizability to privately held firms, which may experience even more pronounced effects due to typically having less visibility and weaker governance structures compared to their public counterparts. Additionally, replicating these findings in other developing countries would enhance the robustness and applicability of the results, providing a clearer picture of how different institutional frameworks influence market valuations globally. Future research should explore the innovative processes within privately held firms and in various institutional contexts to ascertain whether the observed effects hold or if different dynamics emerge. Moreover, there is significant potential to investigate how firms can strategically navigate weak institutional environments to protect and enhance the valuation of their innovations.

Chapter 2, while providing useful observations on the impact of reduced information access on academic productivity, faces limitations regarding the generalizability of its findings across different scientific disciplines. The focus on economics may not fully capture the complexities and requirements of fields that rely heavily on specialized equipment and up-to-date technical knowledge. Additionally, the exclusion of researchers with multiple affiliations or those who have changed their affiliations introduces potential biases towards less mobile and possibly less successful scientists. Future studies should extend the analysis to include hard sciences and other fields to determine if the impact of information access disruptions is even more significant. Research should also consider the effects of governmental policies on information access and their direct and indirect impacts on scientific productivity. This would provide a more comprehensive understanding of the barriers to knowledge creation in different academic and political contexts.

In Chapter 3, the reliance on CEOs' places of birth as proxies for their exposure to Confucian values presents a methodological limitation. This approach does not account for the potential evolution of personal values over time or the influence of other ideologies that CEOs may encounter throughout their lives. Additionally, the study's focus on Confucian values may overlook the impact of other significant cultural or religious ideologies prevalent within China. Future research should aim to directly measure CEOs' current beliefs and values, despite the challenges associated with such data collection, especially in a context where political affiliations might influence self-reporting. Expanding the scope to include other ideologies and examining their influence on strategic decision-making could provide a more nuanced understanding of the interplay between culture and corporate strategy. Furthermore, addressing the potential endogeneity issues through more refined methodologies would strengthen the causal inferences that can be drawn from this research.