# THREE STUDIES ON THE PERFORMANCE OUTCOMES OF REMOTE WORK ARRANGEMENTS

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# Three Studies on the Performance Outcomes of Remote Work Arrangements

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**CERTIFICATE OF ORIGINALITY**

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# Abstract

With the rapid growth of the digital economy and the onset of the post-pandemic era, remote work is increasingly becoming the new normal in business operations. This shift not only accelerates the process of digital transformation within firms but also promotes profound changes in production and lifestyle. Although remote work is gradually gaining attention from both society and individual employees, there remains a relative scarcity of understanding regarding how remote work affects firms' performance outcomes. Previous research has largely focused on the impact of remote work at the individual level, lacking a systematic exploration of how remote work can build firms' competitive advantage in the context of the digital economy.

Based on this background, this thesis builds on the traditional competition strategy model and introduces the digital competition strategy model to identify three firm performance outcomes that are closely related to competitive advantages in the digital economy era: operational efficiency, innovation performance, and information security. Firstly, this thesis examines the impact of remote work on operational efficiency from a cost leadership perspective. Operational efficiency is a widespread concern for firms implementing remote work practices and is key to how remote work can build a firm's cost leadership competitive advantage in the digital economy era. Secondly, this thesis focuses on the impact of remote work on innovation performance from a differentiation perspective. Innovation performance is a crucial driver for the continuous growth and development of a firm in the digital economy era. Lastly, this thesis explores the impact of remote work on firms' information security from a risk management perspective. In the context of the digital economy, ensuring firms' information security is necessary for stable business development and an indispensable factor in building a competitive advantage for secure development. Based on the Motivation-Ability-

Opportunity (MAO) framework, knowledge search theory, and the socio-technical system view, this thesis explores the impact of remote work on firms' performance outcomes and identifies significant boundary conditions through three studies.

Study 1 explores the impact of remote work on operational efficiency and examines the moderating role of employee relationship (motivational factor), profitability (ability factor), and high-tech industry (opportunity factor) based on the MAO theoretical framework. This study employs econometric analysis methods based on secondary data, utilizing Propensity Score Matching (PSM), Difference-in-Differences (DID), and Difference-in-Difference-Difference (DDD) models to test the hypotheses. The results indicate that remote work reduces operational efficiency in the long term; however, a firm having positive employee relationship, strong profitability, and belonging to the high-tech industry can effectively mitigate the adverse impact of remote work on operational efficiency. Finally, Study 1 uses parallel trend test, placebo test, alternative sample periods, alternative measures of operational efficiency, and alternative measures of remote work to check the robustness of this study.

Study 2 investigates the impact of remote work on innovation performance (innovation quantity and innovation quality) and examines the moderating roles of slack resource and growth opportunity based on knowledge search theory. This study employs negative binomial regression, DID, and DDD to test the hypotheses. The results indicate that remote work can significantly increase both the quantity and quality of innovation. Slack resource weakens the positive impact of remote work on innovation performance; meanwhile, growth opportunity enhances the positive effect of remote work on innovation performance. Additionally, Study 2 conducts robustness checks through alternative dependent variables, the Heckman two-stage analysis, Two-Stage Residual Inclusion (2SRI), and lagged dependent variables.

Study 3 delves into the impact of remote work on information security risks and examines the moderating roles of information technology (IT) capability (technological system) and

managerial capability (social system) from a socio-technical system view. This study differentiates between proactive and reactive remote work and assesses the differential impacts of these two types of remote work on firms' information security risks. This study employs the Linear Probability Model (LPM) to test the hypotheses. The results indicate that both proactive and reactive remote work increase the likelihood and severity of information security risks. IT capability weakens the information security risks introduced by both proactive and reactive remote work. However, managerial capability can effectively mitigate the information security risks associated with proactive remote work, but its moderating effect on the relationship between reactive remote work and information security risks is not significant. In addition, Study 3 validates the robustness of the results through several methods, including the Heckman two-stage analysis, fixed effects logistic regression and Poisson regression, and additional analysis.

This thesis makes significant contributions to both the theory and the practice of remote work. First, by empirically testing the impact of remote work on firms' performance outcomes, this thesis enriches the empirical evidence for remote work research and provides extensive empirical evidence on how remote work affects firms' operational efficiency, innovation performance, and information security. Second, this thesis identifies key boundary conditions in the relationship between remote work and performance from multiple theoretical perspectives, thereby broadening the theoretical lens of remote work research. Third, this thesis reveals the long-term impact of remote work on operational efficiency and offers universal empirical conclusions about the relationship and contingency factors between remote work and operational efficiency, thereby enriching the empirical research in the domain of remote work and operational management. Fourth, this thesis empirically verifies the impact of remote work on innovation performance and identifies important contingency factors that may promote or inhibit the relationship, thus offering new insights into the relationship between remote work

and innovation performance. Fifth, this thesis innovatively distinguishes between proactive and reactive remote work, revealing the impact of these two types of remote work on information security risks, enriching the connotations of remote work, and extending the empirical research related to remote work and risk management.

**KEY WORDS**: Remote work; Operational efficiency; Innovation performance; Information security; Competitive advantage

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# Chapter 1 Introduction

## 1.1 Research Background

### 1.1.1 Practical background

In recent years, the digital economy, emerging as a new economic paradigm following the agricultural and industrial economies, has been driving profound transformations in modes of production, lifestyle, and governance. In 2022, China officially elevated the development of the digital economy to a national strategic level, emphasizing that as crucial carriers of the digital economy, firms should vigorously advance digital transformation. This includes accelerating the application of remote and digital office practices, and extending and expanding the digital transformation across all business processes comprehensively. Simultaneously, with the development and widespread adoption of technologies such as 5G, cloud computing, the Internet of Things (IoT), and artificial intelligence (AI), there has been a global increase in the demand for remote work, solidifying the foundation for the development of the remote work industry. Data indicates that in 2023, the market size of China's remote work industry was approximately 53.46 billion yuan, representing a year-on-year growth of 8.7%[1]. As an increasingly common work arrangement, remote work is becoming an important method for firms to accelerate their digital transformation. It will also have a profound impact on the operational development and security of firms in the context of the digital economy.

Remote work refers to an alternative work arrangement where employees of a company utilize digital technologies and related remote work tools to complete their job tasks from locations outside of their primary workplace (Allen et al., 2015; Bloom et al., 2015; Ge et al., 2022). Compared to traditional office-based work, remote work can reduce commuting costs, lower environmental pollution, enhance employee work satisfaction, and improve work-family

[1] https://m.chyxx.com/pdf/93/55/979355.pdf

balance. According to data from Global Workplace Analytics, the worldwide spread adoption of remote work in 2020, driven by the COVID-19 pandemic, resulted in a reduction of over 51 million metric tons of greenhouse gas emissions[1]. Furthermore, remote work can reduce commuting time, thereby saving additional costs. According to data from The Census Bureau, 10% of American employees spend over two hours commuting daily. The cost savings from reduced commuting through remote work can amount to $20 billion annually[2]. Remote work also helps to reduce unemployment rates. In 2021, remote work positions enabled 3.6 million unemployed workers to regain employment in the US[3]. Even after the pandemic, the demand for remote work remains significantly high. According to a joint survey by the National Development Research Institute of Peking University and Zhaopin Recruitment, up to 83% of job seekers prefer to apply for positions that offer remote work opportunities, and 90% of job seekers hope that their companies would allow permanent remote work after the pandemic ends[4].

Remote work is gradually becoming a focal point of interest for both society and employees, and is emerging as a new norm in business operations. Companies such as Microsoft, Google, Facebook, Twitter, GitLab, and Ctrip have all adopted remote work arrangements. Particularly since the onset of the COVID-19 pandemic in 2020, an increasing number of companies have established remote work arrangements for their employees, considering it as a long-term strategy for business development. Surveys indicate that remote work has become more widespread among businesses compared to the period before the pandemic, with a 30% increase in companies adopting remote work arrangements (Choudhury, 2022). However, despite the growing prevalence of remote work, debates concerning its impact on corporate efficiency persist. Some companies that adopted remote work arrangements early

[1] https://globalworkplaceanalytics.com/global-work-from-home-experience-survey
[2] https://www.census.gov/newsroom/press-releases/2021/one-way-travel-time-to-work-rises.html
[3] https://www.nytimes.com/2021/07/20/business/remote-work-pay-bonus.html
[4] https://www.199it.com/archives/1446965.html

have expressed concerns about long-term remote working. Firms such as Yahoo, HP, and Goldman Sachs have terminated their remote work programs, arguing that remote work could undermine the collaborative atmosphere of the company, jeopardize knowledge sharing, and harm corporate efficiency (Shen, 2023).

For instance, as early as 2013, Marissa Mayer, the former CEO of Yahoo, entirely abolished the company's long-standing remote work policy, stating, "When we work from home, we are sacrificing speed and quality"[1]. Critics labeled this move as a "return to the Stone Age", and accused Mayer of being out of touch with reality (Allen et al., 2015). However, in response to Yahoo's action, several corporations, including Best Buy, HP, and IBM, also subsequently halted their remote work policies shortly thereafter. During the COVID-19 period, companies such as Goldman Sachs and Netflix expressed concerns that remote work was affecting operational efficiency and mandated their employees to return to office work immediately after the pandemic subsided[2]. On the other hand, companies like Microsoft, Airbnb, and Fujitsu have subsequently announced policies allowing their employees to work remotely permanently. The contrasting approaches to remote work among businesses reflect the ongoing debate regarding its impact on operational efficiency. It remains unclear whether the societal and employee benefits brought about by remote work come at the cost of reduced operational efficiency. At a practical level, how remote work affects corporate operational efficiency is a concern commonly shared by managers. Therefore, a pressing question that needs to be addressed is: **How does remote work influence corporate operational efficiency?**

Beyond its impact on operational efficiency, the effect of remote work on corporate innovation performance has also been a focal point of concern for managers. Innovation is considered a crucial competitive advantage for companies to maintain their vitality in the

[1] https://www.latimes.com/business/la-xpm-2013-feb-26-la-fi-yahoo-telecommuting-20130226-story.html
[2] https://www.bbc.com/news/technology-54063648

digital economy era (Usai et al., 2021). Innovation is also a key objective for firms' long-term operational development and growth (Lerner et al., 2011; Ortiz-Villajos & Sotoca, 2018). Many companies adopt remote work with the aim of sparking corporate innovation and enhancing employee creativity. For example, GitHub, a leading global software development platform, has embraced a remote work strategy that allows it to hire the most talented developers from around the world. This approach not only expands the company's talent pool but also brings innovative thinking from diverse cultural backgrounds. However, there is controversy in practice regarding the impact of remote work on innovation. Some companies believe that remote work can hinder internal knowledge sharing and transfer, thereby stifling the cultivation of innovative capabilities. For instance, Marissa Mayer, former CEO of Yahoo, noted that "some of the best decisions and insights come from hallway and cafeteria discussions, meeting new people, and impromptu team meetings", leading to Yahoo's decision to cancel remote work. Additionally, in 2017, IBM announced the termination of its remote work policy that had been in place for eight years, citing that although remote work increased employee satisfaction, face-to-face communication was more crucial for innovation. Therefore, given the debate over the impact of remote work on corporate innovation in practice, a pressing question that needs to be addressed is: **How does remote work affect corporate innovation performance?**

At the same time, the information security issues brought by remote work cannot be underestimated. With the acceleration of digitalization, information security risks and data breaches have become one of the severe challenges faced by companies in the context of the digital economy. Surveys have found that many poor work habits associated with remote work—including the use of public networks and allowing family members to use company equipment—are putting critical business systems and sensitive data at risk. Research data shows that remote work has led to a more than fourfold increase in cybercrime than that of working in an office. For example, in April 2020, Zoom became a focal point in the news due

to a series of data leakage incidents, with four information security incidents exposed. Firstly, without user consent, Zoom shared user data with Facebook through its Software Development Kit (SDK). Subsequently, due to a vulnerability in the user grouping feature, some users' email addresses and profile pictures were exposed to other unfamiliar users with the same email domain. Additionally, videos from over 15,000 Zoom meetings were leaked on Amazon's cloud server and were publicly accessible. Lastly, Zoom suffered a credential stuffing attack, leading to the theft of usernames and passwords of over half a million accounts. With the surge in demand for remote work, remote collaboration tools like Zoom have become targets for global hackers seeking vulnerabilities. These incidents collectively highlight that remote work environments have exposed organizations to heightened cybersecurity vulnerabilities, underscoring the critical imperative for enterprises to strengthen their information security frameworks. This necessitates the implementation of robust data protection protocols and comprehensive security measures tailored to distributed workforce scenarios.

Furthermore, the occurrence of the "Twitter Hack" (referred to as the largest cyber-attack in Twitter's history) underscored the importance of preemptive measures in information security protection for companies adopting remote work. In early 2020, Twitter implemented a comprehensive remote work policy in response to the COVID-19 pandemic, a shift that inadvertently created opportunities for cyber-attacks. Merely three months later, hackers seized this opportunity to launch an attack on Twitter. On July 15, 2020, a 17-year-old hacker and his accomplices breached Twitter's network, gaining control over the Twitter accounts of several high-profile political and business figures, including Barack Obama, Kim Kardashian West, and Elon Musk, as well as various cryptocurrency companies. This cyber-attack directly resulted in economic losses amounting to up to $118,000 worldwide. Some media outlets argue that Twitter's forced shift to remote work due to the COVID-19 pandemic left the company with insufficient time to strengthen its information security measures, making it more

vulnerable to cyber-attacks. They suggest that companies like Twitter should take preemptive actions by implementing robust security measures, rather than attempting to mend the situation after the fact. The Twitter hacking incident has sparked reflections on the information security risks associated with remote work, raising questions about whether the approach to remote work—proactive versus reactive—impacts information security risks in the same manner. Compared to a reactive transition to remote working environments, does a proactive approach to remote work have a different impact on information security risks? How can the information security risks brought by remote work be effectively addressed? Therefore, **how different types of remote work policies affect corporate information security, and how companies can effectively manage and mitigate information security risks in the new normal of remote work**, are pressing issues that businesses are closely monitoring and need to resolve.

Overall, when implementing remote work, businesses urgently need to clarify three key issues: First, how does remote work affect corporate operational efficiency? Does the flexibility offered by remote work come at the cost of sacrificing operational efficiency? From an operational management perspective, operational efficiency is one of the most fundamental business objectives and the most direct outcome of remote work. It can be said that the impact of remote work on corporate operational efficiency is the most urgent issue that operational managers need to address and resolve. Second, how does remote work affect corporate innovation performance? Innovation is the key driver of long-term development for businesses. Whether remote work can lead to innovation and development is critical to the future growth of companies. Third, how does remote work impact corporate information security? What are the differences in information security risks between different types of remote work approaches (proactive vs. reactive remote work)? How to effectively manage and mitigate the information security risks brought by remote work is crucial for the safe operation and stable development of companies implementing remote work strategies. Therefore, recognizing and understanding

how remote work impacts corporate competitive performance is crucial for businesses to effectively implement and govern remote work in the digital economy era. This understanding enables companies to fully leverage the competitive advantages brought by remote work arrangements.

### 1.1.2 Theoretical background

The corporate competition strategy model suggests that businesses can build competitive advantages through a cost-leadership strategy and a differentiation strategy (Miller, 1988; Porter, 1985)[1]. The cost-leadership strategy involves a company achieving synergistic and efficient operations through economies of scale, technological advantages, and cost control (Huo et al., 2014; Porter, 1991). The differentiation strategy involves a company achieving innovative-led development by providing products or services with unique attributes to meet specific consumer needs (Porter, 1991; Su et al., 2017). However, in the context of the digital economy, gaining a competitive advantage requires not only achieving cost leadership and differentiation but also focusing on information security from a risk management perspective (Saunders, 2016). In the era of the digital economy, information security is crucial for ensuring the stable operation and development of a company (Benbya et al., 2020). Risks such as information leakage, data tampering, and cyber attacks can severely damage a company's brand image, customer trust, and competitive advantage. Therefore, effective information security management and risk control measures are essential conditions for ensuring stable business development, and indispensable factors for building a competitive advantage in the context of the digital economy.

In light of the new era and demands of the digital economy, this study builds upon the traditional corporate competition strategy model to develop a corporate digital economy

[1] Porter identified three competitive strategies: cost leadership, differentiation, and focus strategy. Given that the focus strategy is essentially a specific application of either cost leadership or differentiation strategies targeted at a narrow market segment, this research primarily concentrates on cost leadership and differentiation strategies.

competition strategy model (as shown in Figure 1.1). This model evaluates the impact of remote work on corporate competitive-related performance from three perspectives in the era of digital economy: Cost Leadership Strategy, Differentiation Strategy, and Risk Management Strategy.

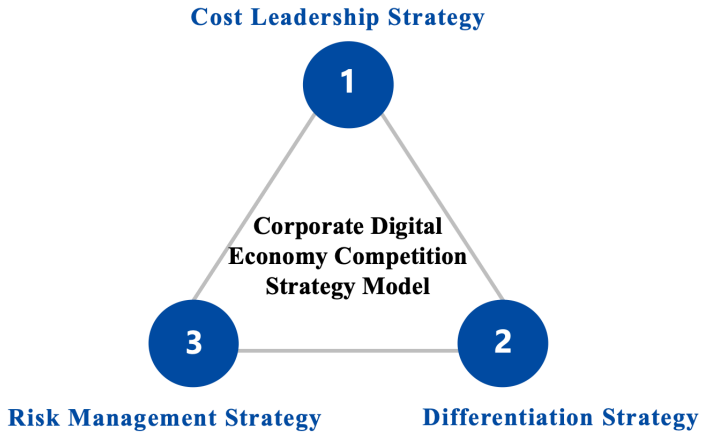


Figure 1.1 Corporate digital economy competition strategy model

**(1) Cost Leadership Strategy: How do remote work arrangements affect firms' operational efficiency?**

From the cost leadership perspective, this study focuses on the impact of remote work on corporate operational efficiency. Operational efficiency involves a company's ability to use its resources effectively and convert them into outputs (Miller & Roth, 1994; Roth & Jackson III, 1995). In essence, operational efficiency is about how a company can achieve the highest level of output with the least input of resources (including costs, labor, time, etc.). Operational efficiency is a core concept in the field of operations management and the main performance outcome of interest from the cost leadership perspective. High operational efficiency can help companies gain a sustained competitive advantage in a fiercely competitive environment.

Through literature review, I have identified three main limitations in existing research on the impact of remote work on corporate operational efficiency. First, most current studies focus on the impact of remote work on individual efficiency, lacking discussion at the corporate level (McDermott & Hansen, 2021; Shen, 2023; Wang et al., 2020). For example, Shen (2023) and

McDermott and Hansen (2021) investigated the impact of government-mandated work-from-home orders on the productivity of GitHub platform users. Shen (2023) found that GitHub users produced less and had a negative output while working from home. McDermott and Hansen (2021) using real-time data from millions of GitHub users worldwide, discovered that during the pandemic, platform users worked longer hours and were more active. Wang et al. (2020) surveyed the productivity of TikTok users during the pandemic, finding that stay-at-home policies in various states increased TikTok users' content productivity but negatively affected the novelty and optimism of their content.

Second, although some studies focus on the impact of remote work on efficiency at the corporate level, the research context is often limited to a single company, lacking large-sample empirical evidence. For instance, Bloom et al. (2015) experimented with 249 call center employees at Ctrip, finding that working from home significantly increased employee productivity; over the nine-month experimental period, the efficiency of employees working from home increased by 13%, with 9% attributed to reduced sick and leave days, and 4% to a quieter and more convenient work environment. Choudhury et al. (2021) examined the impact of geographical work flexibility (Work-from-anywhere) on the productivity of patent examiners at the US Patent and Trademark Office (USPTO), finding that work location flexibility increased the output of patent examiners by 4.4%. Gibbs et al. (2023) analyzed data from over 10,000 employees of an Asian IT company, finding that remote work increased total working hours by about 30% while the average output remained unchanged, leading to the conclusion that remote work reduced company productivity. Additionally, Bao et al. (2022)'s research data came from Baidu, and Ford et al. (2021)'s sample was based on Microsoft. It's evident that while such studies explore the impact of remote work on corporate efficiency, the conclusions drawn are based on data from single companies, lacking generalizability. Especially since the sample specificity, such as call center employees (Bloom et al., 2015;

Emanuel & Harrington, 2021) and patent examiners (Choudhury et al., 2021), whose work neither requires collaboration nor face-to-face communication, are particularly suited for remote work, thus conclusions based solely on single job natures and single samples lack universality and representativeness.

Third, the majority of studies only focus on the impact of remote work on corporate efficiency within the context of the COVID-19 pandemic (e.g., Bai et al., 2021; Ge et al., 2022; Gibbs et al., 2023; McDermott & Hansen, 2021; Shen, 2023; Wang et al., 2020), and the conclusions drawn cannot be directly applied to other scenarios. At the same time, existing literature on the impact of remote work on corporate operational efficiency presents inconsistent findings. Some studies suggest that remote work positively affects corporate efficiency (e.g., Bloom et al., 2015; Choudhury et al., 2021; McDermott & Hansen, 2021), while others argue that remote work may hinder improvements in corporate operational efficiency(e.g., Emanuel & Harrington, 2021; Gibbs et al., 2023; Shen, 2023).

Overall, existing research on the impact of remote work on corporate operational efficiency remains scarce, and the relationship between the two has not yet reached a consensus, with contradictory views prevalent in studies. Particularly, due to data availability, previous research has mainly focused on individual-level discussions, lacking empirical evidence on the impact of remote work on operational efficiency at the corporate level across large samples. Therefore, it is necessary to employ large-sample panel data for empirical testing of the impact of remote work on operational efficiency at the corporate level. Moreover, beyond exploring the question of how remote work impacts corporate operational efficiency, it is increasingly important to investigate “Under what circumstances can remote work enhance corporate operational efficiency?” Only by clarifying the relationship between remote work and corporate operational efficiency, and effectively identifying the moderating effects that influence this relationship, can the potential of remote work be maximized.

***Research gap 1:*** The impact of remote work on corporate operational efficiency is a focal point for managers implementing remote work policies, and it's crucial for building a cost leadership competitive advantage in the context of the digital economy. However, existing research on how remote work affects operational efficiency, and under what conditions it does so, remains insufficient. Previous studies have not reached a unified conclusion. Due to limitations in data availability, current research often focuses on the impact of remote work on individual efficiency, with a lack of exploration at the corporate level. Additionally, previous literature focuses on single subjects and short research time frames. Therefore, there's a need for empirical testing using panel data at the corporate level to examine the impact of remote work on operational efficiency and to identify its significant contingency factors. This approach not only addresses the limitations of previous research but also contributes to a more comprehensive understanding of the strategic value of remote work in influencing corporate efficiency in the digital era.

**(2) Differentiation Strategy: How do remote work arrangements affect firms' innovation performance?**

From a differentiation perspective, this study focuses on the impact of remote work on corporate innovation performance. Corporate innovation performance is considered a key driver for sustained growth and development (Banbury & Mitchell, 1995; Yanadori & Cui, 2013), as well as a measure of vitality for companies in the digital economy era (Usai et al., 2021). Innovation performance is a typical outcome of interest from the differentiation perspective and is aligned with the long-term development goals of companies (Lerner et al., 2011; Ortiz-Villajos & Sotoca, 2018).

Regarding the research question of "How does remote work affect corporate innovation performance?", there has yet to be a consensus formed in previous studies. On one hand, some studies posit that remote work has a positive impact on corporate innovation performance

(Berchicci et al., 2016; Coenen & Kok, 2014). For instance, Berchicci et al. (2016) based on a survey of 248 high-tech small and micro enterprises, found that remote collaborative teams positively affect innovation performance. Gibson and Gibbs (2006) through a combination of structured interviews and questionnaire surveys, discovered that remote work, by leveraging digital communication and collaboration tools, enables team members to overcome the constraints of time and space, promoting information sharing and knowledge flow. Additionally, Majchrzak et al. (2004) found that the remote work environment encourages more flexible workflows and cultures, which helps organizations to rapidly iterate and improve, thereby driving innovation.

On the other hand, some studies have indicated that remote work can hinder internal knowledge sharing and transfer within a company, and suppress the cultivation of innovation capabilities (Hinds & Mortensen, 2005; Taskin & Bridoux, 2010; Yang et al., 2022). Hinds and Mortensen (2005) based on a field experiment involving 43 multinational teams (including 21 remote teams), found that the geographical dispersion of remote team members increased communication barriers and could lead to a lack of trust among team members. This lack of trust and communication barriers reduce interactions among team members, thereby affecting the effective transfer of knowledge and the cultivation of team innovation capabilities. Golden and Raghuram (2010) also highlighted that remote work impacts the ability and willingness of remote workers to share knowledge. Additionally, Gibson and Cohen (2003) pointed out that technology-mediated communication might not fully substitute for the richness and immediacy of face-to-face communication.

As observed, previous research has not reached a consensus on the relationship between remote work and corporate innovation performance. The contradictory conclusions highlight the complexity of remote work's impact on corporate innovation performance. Therefore, in addressing the question of "How does remote work affect corporate innovation performance?",

it's crucial to further explore "Does the impact of remote work on corporate innovation performance vary in different contexts?" It's necessary to pay closer attention to the contingency factors affecting the impact of remote work on corporate innovation performance. However, previous studies have largely focused on the innovation performance of individuals or teams in the remote work literature, with a lack of exploration at the corporate level (Berchicci et al., 2016; Gassmann & Von Zedtwitz, 2003; Silva & Merino, 2017). Additionally, prior research on the relationship between remote work and corporate innovation performance has mostly been conceptual or based on case studies, lacking empirical evidence. The limited empirical studies that exist have primarily utilized survey methods (Berchicci et al., 2016; Gibson & Gibbs, 2006; Golden & Raghuram, 2010), which often face issues of common method bias, while cross-sectional data struggles to establish causality and address endogeneity (Lu et al., 2018). Therefore, employing panel data and applying more rigorous econometric methods to examine the relationship between remote work and corporate innovation performance becomes especially important.

***Research gap 2：*** Innovation performance is key for a company's continuous growth and vitality in the digital economy era, and it is crucial for building a differentiated competitive advantage. However, there is no unified conclusion on the impact of remote work on corporate innovation performance, and contradictory views persist. Moreover, most studies focus on the innovation performance of individuals or teams within remote work settings, highlighting the need for more empirical analysis and discussion at the corporate level. Additionally, past research lacks analysis on the moderating variables of the relationship between remote work and innovation performance, with insufficient understanding of the situational factors that influence this relationship. Existing studies predominantly utilize qualitative analyses or surveys; thus, there is a need for employing panel data and applying more rigorous econometric methods to examine the relationship between remote work and corporate innovation

performance.

**(3) Risk Management Strategy: How do remote work arrangements affect firms' information security?**

From a risk management perspective, this study focuses on the impact of remote work on corporate information security. Corporate information security refers to the protection of corporate information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction (Loch et al., 1992). Information security aims to ensure the confidentiality, integrity, and availability of information—commonly known as the CIA triad (Bishop, 2003). Information security is the most concerned performance outcome from a risk management perspective. In the context of the digital economy, ensuring corporate information security is a necessary condition for the stable development of enterprises and an indispensable factor in building a competitive advantage for secure development.

Although previous studies have highlighted the potential risks of remote work to information security, the majority have been conceptual articles (e.g., Curran, 2020; Evangelakos, 2020; James & Griffiths, 2014; Malecki, 2020), lacking empirical evidence on the relationship between remote work and corporate information security. For instance, Curran (2020) suggests through qualitative analysis that remote work relocates employees, office equipment, and sensitive data from a protected work environment, thus posing severe data breach risks to the business. Similarly, Malecki (2020) emphasizes that remote work introduces unprecedented challenges to information security management, from technical failures to hacker attacks. Okereafor and Manny (2020) describe how the widespread adoption of remote work and video conferencing opens doors to cyber-attacks and malicious hacking incidents, triggering serious cybersecurity and privacy issues.

Current empirical research directly addressing the relationship between remote work and corporate information security is extremely limited, with the few available studies focusing on

assessing key factors that enhance corporate information security in a remote work environment. For example, Lee and Lee (2021) through a survey of 207 remote workers during the pandemic, identified normative and coercive measures as key factors for ensuring the security of corporate remote work. Senapati and Bharathi (2023) found that employees' Internet habits, awareness of cyber-attacks, knowledge of cybersecurity best practices, and adherence to company security policies are effective factors in enhancing corporate information security.

Moreover, existing research lacks a detailed distinction between different forms of remote work, especially in terms of conducting an in-depth analysis of the potential differences in information security risks associated with different types of remote work. Specifically, remote work can be categorized into proactive remote work and reactive remote work. Proactive remote work reflects a company's positive planning and strategic considerations for the future, representing a remote work arrangement based on comprehensive considerations (Allen et al., 2015; Angel Martı´nez Sa´nchez et al., 2007; Stavrou, 2005); while reactive remote work often serves as an emergency response by companies to external crises (e.g., natural disasters, public health crises) (Bai et al., 2021; Ge et al., 2022; Shen, 2023). There is a lack of research delving into how they each uniquely impact the information security challenges faced by companies.

Furthermore, given the challenges that remote work may pose to corporate information security, it is urgent for companies to develop and implement robust information security management strategies to address and mitigate security vulnerabilities arising from remote work practices. However, current research on the contingency factors between remote work and corporate information security remains relatively scarce. This gap in research hampers organizations' capacity to enact effective governance and countermeasures against the information security challenges that remote work entails.

***Research gap 3:*** In the context of the digital economy, the impact of remote work on corporate information security is a focal point from a risk management perspective and is key

to building a competitive advantage for secure development. Investigating how remote work affects a company's information security and how companies can effectively respond to information security risks has become a core issue that businesses urgently need to address. However, compared to other competitive-related performance outcomes, empirical research on the impact of remote work on information security is the scarcest, necessitating more empirical studies to provide direct evidence of the relationship between the two. Previous research has not focused on the potential differences in the impact of different types of remote work (such as proactive remote work and reactive remote work) on information security risks. Furthermore, there is a lack of empirical research exploring the boundary conditions between remote work and corporate information security, leaving unanswered questions about what measures companies should take to manage and mitigate the impact of remote work on information security risks.

## 1.2 Research Objectives

To address the research gaps mentioned regarding the impact of remote work on corporate performance outcomes, this research will explore the impacts of remote work on corporate operational efficiency, innovation performance, and information security through three studies. By doing so, this research aims to systematically investigate how remote work affects these three key competitive performances from the perspectives of cost leadership, differentiation, and risk management. This comprehensive approach will help in building a competitive advantage for companies implementing remote work in the context of the digital economy. Specifically, this research aims to address the following three research questions:

The first research question is "How does remote work impact corporate operational efficiency? Under what circumstances can remote work enhance corporate operational efficiency?" This research question initiates from a cost leadership perspective, aiming to explore the impact of remote work on corporate operational efficiency. Additionally, by

integrating the classic Motivation-Ability-Opportunity (MAO) theoretical framework, Study 1 plans to examine the moderating effects of employee relationship (Motivation factor), corporate profitability (Ability factor), and the high-tech industry (Opportunity factor) on the relationship between remote work and corporate operational efficiency. This approach not only provides insights into the direct effects of remote work on efficiency but also delves into how specific contextual factors might enhance or diminish these effects, offering a more nuanced understanding of how and when remote work can be leveraged to improve operational efficiency within a company.

The second research question is "How does remote work impact corporate innovation performance? Under what circumstances can the impact of remote work on corporate innovation performance be enhanced or diminished?" This research question starts from a differentiation perspective and aims to explore the impact of remote work on corporate innovation performance. Additionally, by integrating knowledge search theory, Study 2 will examine the moderating effects of corporate slack resource and growth opportunity on the relationship between remote work and corporate innovation performance (innovation quantity and innovation quality). This approach aims to shed light on how the presence of slack resource within a company and the perception of future growth opportunities can influence the effectiveness of remote work arrangements in fostering innovation performance.

The third research question is "How do different types of remote work impact corporate information security? How can companies effectively manage the information security risks brought by remote work?" This research question initiates from a risk management perspective. Study 3 will categorize remote work into proactive and reactive modes based on how companies implement remote work, and explore how these two types of remote work influence corporate information security risks. Furthermore, by integrating a socio-technical systems perspective, Study 3 will examine the governance mechanisms through which technological

capabilities (technical systems) and managerial capabilities (social systems) influence the relationship between proactive and reactive remote work and corporate information security risks. This approach aims to uncover the differential impacts of proactive and reactive remote work on information security, and how technology and management can effectively mitigate associated risks, thereby providing a comprehensive understanding of how to safeguard corporate information within organizational remote work environments.

Overall, through these three studies, this thesis constructs a framework for investigating the impact of remote work on corporate performance outcomes within the context of the digital economy. This research systematically explores the mechanisms and contingency factors under which remote work affects operational efficiency, innovation performance, and information security, from the perspectives of cost leadership, differentiation, and risk management, respectively. These three performance outcomes are interdependent and mutually reinforcing: operational efficiency provides the resources and conditions for innovation; sustained innovation can enhance operational efficiency and the level of information security; and information security underpins efficient operations and continuous innovation. Accordingly, the overall framework of the thesis is shown in Figure 1.2.

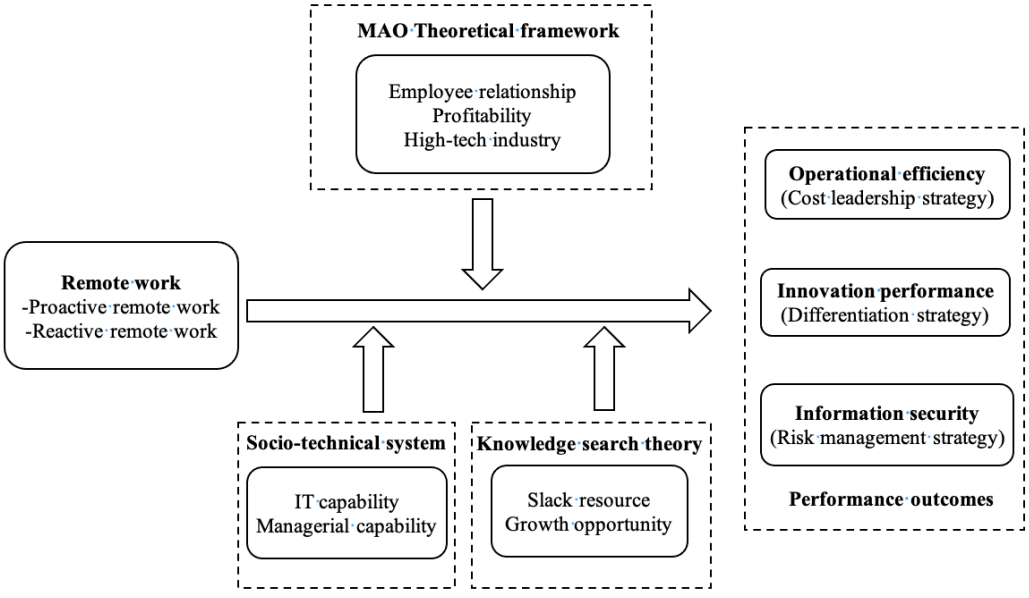


Figure 1.2 Overall framework of the thesis

Specifically, Study 1 investigates the impact of remote work on corporate operational efficiency and examines the moderating roles of employee relationship (Motivation factor), profitability (Ability factor), and the high-tech industry (Opportunity factor) on the relationship between remote work and corporate operational efficiency, by incorporating the MAO (Motivation-Ability-Opportunity) theoretical framework. Study 1 aims to explore whether and how remote work can enhance operational efficiency and establish a cost leadership competitive advantage.

Study 2 explores the impact of remote work on corporate innovation performance (both the quantity and quality of innovations) and, by integrating knowledge search theory, examines the moderating roles of slack resource and growth opportunity on the relationship between remote work and corporate innovation performance. This study aims to investigate whether and how remote work affects corporate innovation performance and builds a differentiation competitive advantage.

Study 3 investigates the impact of proactive and reactive remote work on corporate information security and, combining a socio-technical systems perspective, examines the governance mechanisms through which technological capabilities (Technical system) and managerial capabilities (Social system) factors influence the relationship between proactive and reactive remote work and corporate information security risks. The objective is to explore how different types of remote work affect information security and how to effectively manage the information security risks brought by remote work, thereby building an information security competitive advantage. The conceptual relationships of the three studies are illustrated in Figure 1.3.

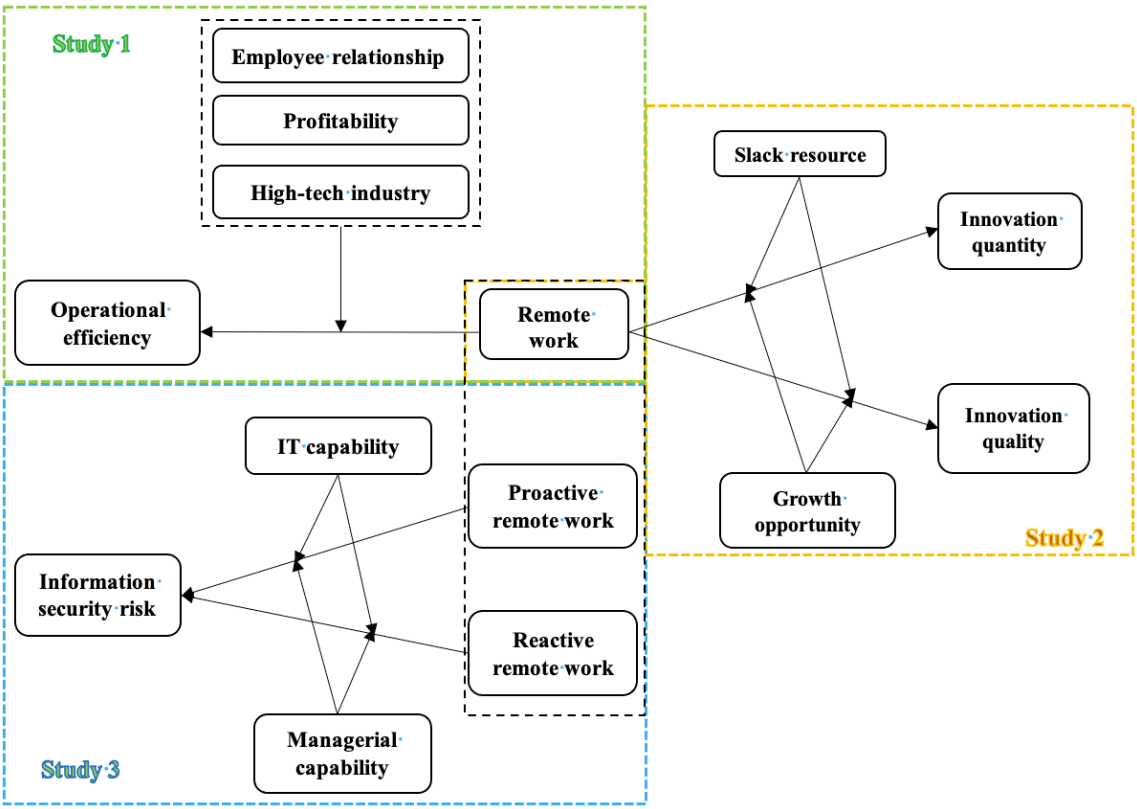


Figure 1.3 Conceptual relationships of three studies

## 1.3 Research Methods

This thesis employs an empirical analysis method based on secondary data to test hypotheses. Unlike survey-based empirical methods, the secondary data research approach, by collecting and analyzing mature and objective data using rigorous econometric models, can overcome the common method bias associated with survey analysis. It also effectively validates the causal relationships between variables (Lu et al., 2018). The data for this research come from public and established databases, offering a wealth of sources and a broad time span. I collect and match secondary data from multiple sources to construct a unique dataset tailored for this thesis.

Specifically, Study 1 adopts econometric models such as Propensity Score Matching (PSM), Difference-in-Difference (DID), and Difference-in-Difference-in-Difference (DDD) to test hypotheses. Study 1 also conducts robustness checks through parallel trend tests, placebo

tests, alternative sample periods, alternative measures of operational efficiency, and alternative measures of remote work. The main databases involved in Study 1 include the Factiva database for collecting corporate remote work announcements, the Compustat database for measuring operational efficiency, profitability, and other financial data, and the KLD STATS (KLD) database for assessing employee relationship. I manually coded the stock codes of companies from the Factiva database, matching the remote work data collected from Factiva and employee relationship data from KLD with the Compustat database to validate the hypotheses of Study 1.

In Study 2, I utilized negative binomial regression, DID, and DDD to test the hypotheses. I also performed robustness checks through parallel trend tests, placebo tests, substitution of the dependent variable, Heckman two-stage analysis, Two-Stage Residual Inclusion (2SRI), lagged dependent variables, etc. The primary databases for Study 2 include the USPTO patent database to measure the quantity and quality of corporate innovations, the Factiva database for collecting corporate remote work data, and the Compustat database for measuring corporate redundant resources, growth opportunities, and other financial indicators. I manually match patent data from the USPTO with the Compustat database using company names and geographic locations.

In Study 3, I employ the Linear Probability Model (LPM) for hypothesis testing, with robustness checks including Heckman two-stage analysis, fixed effects logistic regression and Poisson regression, and additional tests for verifying result stability. The main databases for Study 3 are the Privacy Rights Clearinghouse (PRC) and The Identity Theft Resource Center (ITRC) databases to measure corporate information security risks, represented by data breach events. I manually organize and code the PRC and ITRC databases to form a comprehensive corporate-level information security risk database. Additionally, corporate announcements of proactive and reactive remote work are collected from the Factiva database, corporate IT

capabilities are measured using the InformationWeek500 (IW500) database, and corporate managerial capabilities are assessed based on the Two-Stage Data Envelopment Analysis (DEA) method proposed by Demerjian et al. (2012).

## 1.4 Research Significance

This thesis focuses on how remote work shapes corporate performance outcomes in the context of the digital economy. Through three studies, it delves into the impact mechanisms of remote work on corporate operational efficiency, innovation performance, and information security from the perspectives of cost leadership, differentiation, and risk management. This approach enriches the theoretical perspectives and empirical evidence related to remote work and offers new insights for businesses implementing remote work practices. The significance of this thesis includes the following aspects:

Firstly, this thesis innovatively constructs a corporate-level "remote work-corporate performance outcomes" research framework, and empirically tests the impact of remote work on corporate performance outcomes in the context of the digital economy, which enriches the empirical foundation of remote work-related research. Additionally, by utilizing panel data at the corporate level and combining rigorous econometric estimation models, this thesis not only responds to previous scholars' calls (Belanger, 2005; Feldman & Gainey, 1997) for more rigorous empirical research on the impacts of remote work but also echoes the suggestions of scholars like Siha and Monroe (2006) to explore causal relationships, unveiling the long-term positive and negative impacts of remote work on corporations.

Secondly, this thesis integrates multiple theoretical perspectives to reveal the mechanisms and contingency factors of the impact of remote work on corporate performance outcomes, extending theoretical boundaries and enriching the theoretical foundation of remote work-related research. This responds to the suggestion of Bailey and Kurland (2002) for exploring remote work-related research through more theoretical constructions.

Thirdly, by delving into the impact of remote work on corporate operational efficiency, this thesis provides universal and general empirical research conclusions about the relationship between remote work arrangements and operational efficiency and its contingency factors. It also unveils the long-term impact of remote work arrangements on corporate operational efficiency, enriching empirical research in the fields of remote work and operational management.

Fourthly, this thesis empirically reveals the impact of remote work on corporate innovation performance and explores the contingency factors that influence the relationship between remote work and corporate innovation performance. This thesis empirically demonstrates the positive effects of remote work on both the quantity and quality of corporate innovations, responding to the academic call for a deeper empirical investigation of the relationship between remote work and corporate innovation performance (Coenen & Kok, 2014; Gassmann & Von Zedtwitz, 2003).

Last but not least, this thesis innovatively distinguishes between proactive and reactive remote work, delving into the impact of different types of remote work on corporate information security risks. It enriches the understanding of remote work and expands the empirical research related to remote work and risk management. Additionally, by adopting a socio-technical systems perspective, this thesis innovatively reveals how a company's IT capabilities at the technical system level and managerial capabilities at the social system level moderate the relationship between proactive/reactive remote work and corporate information security risks. This provides important theoretical and practical guidance for achieving effective remote work management and information security protection in the digital economy context.

## 1.5 Thesis Structure

The thesis consists of six chapters. Chapter 1 introduces the research background from

theoretical and practical aspects, identifies existing research gaps in the literature, and raises research questions. Then, this chapter delineates the research methods, outlines the thesis's primary significance, and provides an overview of its structure.

Chapter 2 is the literature review. This chapter encompasses a detailed clarification of related concepts of remote work research, provides a review of current research and main findings, summarizes core theories used in remote work research, and provides brief commentary on existing research.

Chapter 3 is Study 1: Remote work or return to the office? A quasi-natural experiment on the impact of remote work arrangements on firms' operational efficiency. This chapter delves into how remote work arrangements influence firms' operational efficiency, and explores the moderating roles of employee relationship, corporate profitability, and the high-tech industry on the relationship between remote work and operational efficiency based on the MAO theoretical framework.

Chapter 4 is Study 2: The impact of remote work arrangements on firms' innovation performance: The moderating roles of slack resource and growth opportunity. This chapter examines how remote work arrangements influence firms' innovation performance, and investigates the moderating effects of slack resource and growth opportunity on the relationship between remote work and innovation performance following the theoretical lens of knowledge search theory.

Chapter 5 is Study 3: The impact of remote work arrangements on firms' information security: A socio-technical system perspective. This chapter discusses the different types of remote work (proactive and reactive) and their impact on corporate information security risks. Additionally, this chapter employs a socio-technical systems perspective, and explores how firms' IT capabilities (technical system) and managerial capabilities (social system) moderate the relationship between remote work and information security.

Chapter 6 concludes the study and offers future perspectives. This chapter first summarizes the research conclusions and key findings from the three studies. Then, it discusses the theoretical contributions and practical implications. Finally, the chapter addresses the study's limitations and suggests directions and recommendations for future empirical research on remote work.

# Chapter 2 Literature review

## 2.1 Concept of Remote Work

### 2.1.1 Concept development of remote work

The concept of remote work has undergone significant evolution and development since it was first proposed in the 1970s. Initially, the concept was primarily seen as a strategy to alleviate traffic congestion, reduce commuting costs, and improve environmental quality (Nilles, 1976). Influenced by the oil crisis in the United States, engineer Jack Nilles from NASA was the first to use the term “telecommuting” in his research, proposing the idea of using information and communication technologies to work from home, moving work to where the employee is rather than moving the employee to the place of work, as a means to ease traffic problems and reduce energy consumption (Avery & Zabel, 2000). Additionally, with the increase in dual-income families during the 1970s and 1980s, remote work was seen as an effective option for balancing work and family responsibilities (Shamir & Salomon, 1985). The growth of remote work is also closely associated with advances in technology and changes in the economy (Nilles, 1994). In the 1980s and 1990s, with the proliferation of the Internet and advances in technology, the price and size of laptops and mobile devices decreased while speed and bandwidth increased (Kizza, 2003; Olson & Primps, 1984), enabling more employees to work outside the office. Remote work thus began to gain wider application (Allen et al., 2015; Bailey & Kurland, 2002).

After the 1990s, as the global economy shifted from manufacturing to an information economy, digitization, and networking became major trends in social development. This shift greatly increased the number of positions suitable for remote work (Kizza, 2003), particularly in fields such as information technology, financial services, consulting, education, and creative industries. Over time, the concept and practice of remote work expanded, and people began to realize that remote work could not only reduce commuting time and transportation costs but

also improve work efficiency, enhance work-life balance, and increase employee satisfaction and loyalty (Handy & Mokhtarian, 1996; Wiesenfeld et al., 1999). During this period, research on remote work grew rapidly, with increasingly diverse perspectives. Studies on remote work extended from the United States to other countries, including the UK (Mitchell, 1996; Moon & Stanworth, 1997), Finland (Suomi & Pekkola, 1998), Canada (Duxbury & Neufeld, 1999), and Singapore (Teo & Lim, 1999; Teo et al., 1998). The research and practice of remote work expanded, reflecting its increasing relevance and the broader acknowledgment of its potential benefits and challenges.

Entering the 21st century, the rapid development and widespread adoption of technologies such as cloud computing, mobile technology, and collaboration software have provided more robust technical support for remote work, propelling it into a new stage of development. Technological advancements have not only greatly enhanced the feasibility and convenience of remote work but have also provided strong support for its quality and efficiency. Employees can access work files at any time via cloud services, stay in touch with their teams from any corner of the world through mobile devices, and efficiently manage teamwork and projects using collaboration software. This means that employees can work flexibly at any time and place according to personal and work needs (Choudhury et al., 2021; Harris et al., 2015; Marler & Fisher, 2013; Meske et al., 2020). During this period, remote work has been increasingly viewed by many enterprises and organizations as a long-term and flexible work mode that helps achieve work-life balance (De Menezes & Kelliher, 2011; Golden & Gajendran, 2019; Kossek & Lautsch, 2018).

The COVID-19 pandemic that erupted globally in 2020 marked a significant turning point in the development of remote work. Faced with unprecedented challenges brought about by the pandemic, businesses and organizations around the world were compelled to adopt remote work practices to maintain operations (Ge et al., 2022; Kramer & Kramer, 2020). The

widespread implementation of remote work during the pandemic not only accelerated the innovation and development of related technologies, management methods, and organizational cultures, but also led to a deeper appreciation of the considerable potential and challenges of remote work models. Post-pandemic, remote work has gradually become the new normal for many enterprises and organizations. Currently, remote work is evolving towards being more flexible and efficient (Carnevale & Hatak, 2020).

Today, the concept and practice of remote work have evolved from an initial commuting alternative to a widely accepted work arrangement that is driving fundamental changes in work practices. As technology continues to advance and work culture changes, remote work will continue to evolve to meet the needs of the future workplace. Research on remote work is at a pivotal stage, requiring a deeper understanding and exploration of its concepts and practices to maximize its potential and meet the demands of the modern work environment. The evolution of remote work is not only reshaping where and how tasks are performed but is also challenging traditional notions of organizational structure, employee engagement, and work-life integration.

### 2.1.2 The definition of remote work

Despite several decades of research on remote work since the 1970s, there has yet to be a unified conceptual definition established in existing studies. Previous research has utilized a variety of terms to conceptualize remote work, and the lack of a standardized definition has significantly hindered the understanding and development of research in this field (Allen et al., 2015; Bailey & Kurland, 2002; De Menezes & Kelliher, 2011; Gajendran & Harrison, 2007). Therefore, in this section, I briefly review the various terms and definitions of remote work in the literature and define the concept of remote work in this research.

Table 2.1 lists examples of remote work terms used in existing literature. Specifically, “remote work” refers to forms of remote working at alternative locations outside the main workplace, including but not limited to working from home, and often implies full-time remote

work arrangements (e.g., Ferreira et al., 2021; Sull et al., 2020; Yang et al., 2022). The term "work-from-home" places a stronger emphasis on remote working specifically from home and has been widely used in studies during the pandemic (e.g., Bao et al., 2022; Ge et al., 2022; Gibbs et al., 2023; Shen, 2023). "Work-from-anywhere" allows employees to work from any geographical location, not just at home or any specific workplace; this term emphasizes improving efficiency and productivity by granting employees greater freedom and flexibility (e.g., Choudhury et al., 2021). "Telecommuting" refers to the use of information and communication technologies to partially or completely replace traditional work; it highlights that remote work is a technologically supported work arrangement where employees rely on computer-based communication technologies for daily work interactions (e.g., Bélanger et al., 2013; Golden et al., 2006; Kossek et al., 2006). Similarly, "telework" emphasizes the use of technology-mediated communication methods and advanced information processing technologies, enabling employees to complete work tasks outside the traditional office environment using advanced communication technologies (e.g., Garrett & Danziger, 2007; Golden, 2007; Morganson et al., 2010). "Virtual work" refers to a work model where individuals or teams, geographically dispersed, communicate and collaborate through technological means to complete tasks. Virtual work typically has a relatively short lifecycle, leveraging information and communication technologies to overcome the limitations of physical workspaces (e.g., Johns & Gratton, 2013; Raghuram et al., 2001; Raghuram et al., 2019; Tworoger et al., 2013). Additionally, "flexible work arrangements" refer to completing work outside traditional work hours or spaces; this term has a broader scope, encompassing remote work as well as a variety of flexible work plans, such as flexible working hours and compressed workweeks (e.g., Angel Martı´nez Sa´nchez et al., 2007; Coenen & Kok, 2014; De Menezes & Kelliher, 2011; Stavrou, 2005). "Distributed work" refers to employees working across geographical boundaries, often including work in branch offices and different business

units (e.g., Bosch-Sijtsema & Sivunen, 2013).

Table 2.1 Representative terms of remote work

| Terms | Definition | Representative studies |
|---|---|---|
| Remote work | Working remotely not just from home but from any alternative location to the main workplace. | Ferreira et al. (2021); Sull et al. (2020); Yang et al. (2022) |
| Work-from-home | Allowing employees to complete work tasks at home instead of in a conventional office environment, focusing on home as the primary remote work setting. | Bao et al. (2022); Ge et al. (2022); Gibbs et al. (2023); Shen (2023) |
| Work-from-anywhere | Extending remote working to any geographical location, not limited to home or any specific workplace, emphasizing the flexibility to work from various locations. | Choudhury et al. (2021) |
| Telecommuting | Using information and communication technology to partially or completely substitute traditional commuting to and from work. It highlights remote work as a tech-supported arrangement. | Bélanger et al. (2013); Golden et al. (2006); Kossek et al. (2006) |
| Telework | The use of technology-mediated communication and advanced information processing technologies for remote work. | Garrett and Danziger (2007); Golden (2007); Morganson et al. (2010) |
| Virtual work | A work model where individuals or teams, geographically dispersed, use technological means for communication and collaboration to complete work tasks. | Johns and Gratton (2013); Raghuram et al. (2001); Raghuram et al. (2019); Tworoger et al. (2013) |
| Flexible work arrangements | These are work setups that occur outside traditional working hours or spaces, including options like flexible work hours and compressed workweeks, offering broader flexibility in how and when work is done. | Angel Martı´nez Sa´nchez et al. (2007); Coenen and Kok (2014); De Menezes and Kelliher (2011); Stavrou (2005) |
| Distributed work | Employees working across geographic boundaries, use computer-mediated communication technologies to a certain extent to achieve a common goal, often including work in different branch offices and business units. | Bosch-Sijtsema and Sivunen (2013) |

Based on a review of prior literature, this study defines remote work as an alternative work method where enterprise employees utilize Internet digital technologies and related remote work tools to complete work tasks at locations outside their main workplace (Allen et al., 2015; Bailey & Kurland, 2002; Siha & Monroe, 2006). There are several key points that need to be clarified in this definition. First, this definition specifically refers to full-time employees within a business, excluding mobile workers who do not usually work from a fixed office, such as contract temporary workers and field service technicians, as well as remote work arrangements

outside the corporate scope, such as small remote work teams. Second, during remote work, employees complete tasks and communicate through information and communication technology, including but not limited to Internet connections, cloud services, and video conferencing tools. Third, this research does not consider work performed outside of regular working hours as remote work. Following the approach of Allen et al. (2015), this study excludes overtime hours from its definition of remote work. Fourth, the location outside the main workplace refers to any place other than the formal office that is suitable for work, which can include working from home or any other appropriate location outside of home.

The definition of remote work in this research not only emphasizes temporal flexibility, allowing employees to some extent to autonomously arrange their working hours to better balance work and life, but also highlights spatial flexibility, breaking traditional geographical constraints and enabling employees to choose the most suitable work location based on personal preferences and efficiency needs. Overall, this definition provides a comprehensive and clear perspective, deeply revealing the essence and scope of remote work.

## 2.2 Performance Outcomes Related to Remote Work

Through a comprehensive review of the existing research on remote work, the performance outcomes related to remote work can be categorized into three aspects: social, individual, and organizational levels (Allen et al., 2015; Siha & Monroe, 2006). This section will introduce the performance outcomes for each level in detail.

### 2.2.1 Social level

The impact of remote work on the social level includes significant aspects such as alleviating traffic congestion, reducing greenhouse gas emissions, enhancing resilience to risks, and boosting employment rates (Allen et al., 2015; Siha & Monroe, 2006). Specifically, research indicates that remote work can significantly decrease carbon emissions by reducing

the number of commuters, and also lessen the pressure on urban transportation infrastructure development (Kitou & Horvath, 2003; Zhu, 2012). A study by Choo et al. (2005) demonstrated that remote work led to a reduction of over 0.8% in annual vehicle miles traveled in the United States. Additionally, remote work has been shown to significantly improve air quality and reduce atmospheric ozone levels (Giuliano, 1981; Seaman, 1997). Data from Global Workplace Analytics revealed that the global shift to remote work due to the COVID-19 pandemic in 2020 resulted in a reduction of more than 51 million metric tons of greenhouse gas emissions. Furthermore, remote work helps to cut down the time and costs associated with commuting. According to statistics from The Census Bureau, about 10% of employees spend over two hours commuting daily, and the annual cost savings from reduced commuting due to remote work amount to around $20 billion. These societal benefits highlight the potential of remote work not only to enhance individual and organizational outcomes but also to contribute positively to broader environmental and economic goals.

Moreover, remote work enhances societal resilience in facing crises (Allen et al., 2015). It ensures business continuity during adverse weather conditions, flu outbreaks, and other emergencies that could disrupt normal societal operations. As an effective risk mitigation strategy, remote work can help maintain critical services uninterrupted during disasters (Heng et al., 2012). For instance, a series of earthquakes in the late 1980s and early 1990s that devastated California's transportation infrastructure prompted many local agencies to develop satellite work centers and remote working policies (Allen et al., 2015). In October 2012, Hurricane Sandy struck Washington, D.C., leading to the closure of federal government offices for two days; however, about one-third of federal employees were still able to continue their duties through remote work (Allen et al., 2015).

Remote work also positively impacts unemployment rates. Studies indicate that in 2021, remote work positions helped 3.6 million unemployed individuals return to the workforce. It

also increases opportunities for disabled persons to participate in the labor market (West & Anderson, 2005), and opens up more employment opportunities for those living in rural or remote areas (Baker et al., 2006; Simpson et al., 2003). Additionally, remote work effectively promotes local employment rates and mitigates the trend of outsourcing jobs overseas (Ruth & Chaudhry, 2008). These aspects underline the broad societal benefits of remote work, extending beyond environmental and operational advantages to significant socio-economic impacts.

***Brief Commentary:*** The impacts of remote work on societal aspects primarily focus on environmental protection, crisis response, and promoting employment-related social welfare. There is relatively little research in these areas, and it predominantly employs qualitative and conceptual methods, lacking rigorous empirical analysis of the performance impacts of remote work at the societal level.

### 2.2.2 Individual level

Compared to the societal and organizational levels, the individual-level performance outcomes of remote work are more extensively discussed. Research on the individual impacts of remote work primarily focuses on various topics, including work-family balance (Adisa et al., 2022; Dockery & Bawa, 2018; Hill et al., 1998), work-family conflicts (Allen et al., 2000; Allen et al., 2013; Golden et al., 2006; Shockley & Allen, 2007; Zhang et al., 2020), productivity (DuBrin, 1991; Gajendran et al., 2015), job satisfactory (Gajendran & Harrison, 2007; Morganson et al., 2010), organizational commitment (Harker Martin & MacDonnell, 2012; Hunton & Norman, 2010), job stress (Gajendran & Harrison, 2007; Sardeshmukh et al., 2012), turnover intention (Golden, 2006; Moen et al., 2011), and work and life quality (Shamir & Salomon, 1985).

Specifically, previous studies generally suggest remote work arrangements are conducive to improving the work-life balance of employees and reducing their work-family conflicts (Allen et al., 2000; Allen et al., 2013; Golden et al., 2006). For instance, Gajendran and

Harrison (2007) found through a meta-analysis that remote work significantly reduces work-family conflict among employees. Similarly, research by Bailey and Kurland (2002) discovered that remote work significantly promotes work-family balance, especially benefiting dual-career households. However, these conclusions can vary due to environmental factors. For example, Adisa et al. (2022) conducted a multi-method qualitative study and explored how the enforced implementation of remote work during the pandemic reduced flexibility, led to social disconnection, and blurred the boundaries between work and family life, thereby exacerbating work-family conflict.

Additionally, the impact of remote work on individual productivity is a frequently discussed topic. Most studies suggest that remote work can enhance individual productivity (i.e., Baruch & Nicholson, 1997; Choudhury et al., 2021; Gajendran et al., 2015). For instance, Hill et al. (1998) argued that remote work could boost individual productivity by saving the time required for actual commuting. Gajendran et al. (2015) also found that remote work can reduce work interruptions, allowing employees to focus more effectively on their tasks. X. Wang et al. (2020) investigated the productivity of TikTok user content production during the pandemic, finding that work-from-home policies in various states increased TikTok users' content productivity. However, the increase in individual productivity brought about by remote work seems to be related to the specific nature of the job. For example, DuBrin (1991) conducted a survey of 34 remote workers engaged in data encoding and entry, finding that productivity significantly increased for those working from home, primarily related to structured, repetitive, and measurable tasks. Choudhury et al. (2021) also showed that USPTO patent examiners who have the flexibility to work from any location were more efficient than those working only in offices or at home. The nature of data encoding and patent reviewing tasks is relatively independent and does not require frequent interaction and communication, suggesting that the productivity gains from remote work are linked to specific job

characteristics.

At the same time, there are studies presenting contradictory views. For example, Shen (2023) and McDermott and Hansen (2021) explored the impact of government-mandated work-from-home orders on the productivity of GitHub platform users. McDermott and Hansen (2021) used real-time data from millions of GitHub users worldwide, finding that during the pandemic, platform users worked longer hours and were more active; however, Shen (2023) observed a negative impact on the output of GitHub users during the home stay. Thus, contradictory perspectives still exist. Furthermore, most reports of increased productivity under remote work are based on self-reported data ((Bailey & Kurland, 2002; De Menezes & Kelliher, 2011), and few studies use large-scale objective data to examine the impact of remote work on productivity (Bailey & Kurland, 2002; De Menezes & Kelliher, 2011). This highlights the need for more rigorous and extensive empirical studies to fully understand and quantify the productivity effects of remote work.

In addition, Existing research indicates that remote work significantly enhances individual job satisfaction (Gajendran & Harrison, 2007; Morganson et al., 2010). It has been proven to effectively increase individual organizational commitment (Golden, 2006; Harker Martin & MacDonnell, 2012; Hunton & Norman, 2010). Remote work is also associated with lower work stress (Gajendran & Harrison, 2007; Sardeshmukh et al., 2012) and a reduced tendency to leave a job (Golden, 2006; Moen et al., 2011).

At the same time, remote work can have negative impacts on individuals, such as social isolation, career stagnation, and family conflicts (Baruch & Nicholson, 1997). For example, existing research has found that remote work blurs the boundaries between work and life, thereby intensifying conflicts between family and work (Zhang et al., 2020). Studies have also found that remote work can hinder individual careers (Kossek et al., 2006). For instance, in a 7-year study involving 159 women, Glass (2004) found that women with a higher intensity of

remote work experienced slower wage growth.

***Brief Commentary:*** Research on the impact of remote work on the employee level is rich and diverse, encompassing variables related to work, family, and individual outcomes. Studies indicate that remote work has both positive and negative effects on individuals, with conflicting viewpoints still existing and a lack of a unanimous conclusion. Moreover, much of the related empirical research is primarily based on self-reported subjective survey data (Bailey & Kurland, 2002; De Menezes & Kelliher, 2011), and there is a scarcity of studies using large-scale objective datasets to examine the impact of remote work on the individual level (Bailey & Kurland, 2002; De Menezes & Kelliher, 2011).

### 2.2.3 Organizational level

#### （1） Remote work and operational efficiency

Empirical research on the impact of remote work on organizational operational efficiency is still relatively scarce. Early studies explored the impact of remote work on organizational performance using qualitative analysis or literature reviews (Bailey & Kurland, 2002; De Menezes & Kelliher, 2011). Over time, although empirical research has gradually become richer, it is often limited by the difficulty of obtaining corporate-level data, and most studies focus on the impact of remote work on individual efficiency, lacking exploration at the corporate level (McDermott & Hansen, 2021; Shen, 2023; Wang et al., 2020). Additionally, while some studies focus on the impact of remote work on corporate efficiency, the research context is usually limited to a single company, lacking large-sample empirical evidence. For example, a study by Bloom et al. (2015) on 249 call center employees at Ctrip showed that working from home significantly improved employee productivity by 13%, with 9% attributed to reduced sick and personal leave, and 4% due to a quieter and more convenient work environment. Choudhury et al. (2021) explored the impact of work location flexibility on the productivity of USPTO patent examiners, finding a 4.4% increase in output due to location

flexibility. Gibbs et al. (2023) analyzed an Asian IT company and found that remote work increased the total working hours of employees by about 30%, but the average output of employees did not change, suggesting that remote work reduced the company's productivity.

From the above studies, it is evident that while these studies aim to explore the impact of remote work on corporate efficiency, their conclusions are mainly based on data from single companies, thus limiting their generalizability. Particularly, job positions like call center employees (Bloom et al., 2015; Emanuel & Harrington, 2021) and patent examiners (Choudhury et al., 2021) which do not require much collaboration or face-to-face communication, are particularly suited for remote work, making these study results less representative. Furthermore, most research focuses on the impact of remote work on corporate performance in the context of the pandemic (e.g., Bai et al., 2021; Ge et al., 2022; Gibbs et al., 2023; McDermott & Hansen, 2021; Shen, 2023; Wang et al., 2020), and their conclusions cannot be directly generalized to other scenarios.

In summary, the existing literature on the impact of remote work on corporate operational efficiency still shows inconsistencies, with some studies suggesting that remote work positively impacts corporate productivity (e.g., Bloom et al., 2015; Choudhury et al., 2021; McDermott & Hansen, 2021), while others argue that remote work may hinder the improvement of corporate operational efficiency (e.g., Emanuel & Harrington, 2021; Gibbs et al., 2023; Shen, 2023).

***Brief Commentary:*** Previous research on the impact of remote work on corporate operational efficiency is still relatively scarce, and the relationship between the two has not yet reached a consensus, with contradictory viewpoints commonly present in the literature. Particularly, due to data availability issues, past studies have primarily focused on the individual level, lacking empirical evidence on the impact of remote work on operational efficiency at the corporate level over a large sample. Although some studies have focused on

the impact of remote work on corporate efficiency, the research context is often limited to a single company, lacking broad-based empirical evidence. Most studies have only considered the impact of remote work on corporate performance in the context of the pandemic, resulting in conclusions that lack generalizability.

**（2） Remote work and innovation performance**

Regarding the impact of remote work on corporate innovation performance, past research has not yet reached a unified conclusion. On one hand, some studies suggest that remote work has a positive impact on corporate innovation performance (Berchicci et al., 2016; Coenen & Kok, 2014). For instance, Berchicci et al. (2016) based on a survey of 248 high-tech small and medium enterprises, revealed the positive contribution of remote collaboration teams to innovation performance. Gibson and Gibbs (2006) found that remote work enables team members to transcend time and space constraints, facilitating information sharing and knowledge flow. Majchrzak et al. (2004) discovered that remote working environments promote more flexible workflows and cultures, which aid organizations in rapid iteration and updates, thereby accelerating the entire innovation process.

On the other hand, some studies have revealed potential negative impacts of remote work on internal knowledge sharing, which could inhibit the development of innovation capabilities of firms (Hinds & Mortensen, 2005; Taskin & Bridoux, 2010; Yang et al., 2022). Hinds and Mortensen (2005) in their field study of 43 teams (including 21 remote teams) in a multinational corporation found that the geographical dispersion of remote team members increased communication difficulties, possibly leading to a lack of trust within the team. This lack of trust and communication challenges weakens interactions among members, thereby hindering effective knowledge transfer and the cultivation of innovative capabilities. Golden and Raghuram (2010) also noted that remote work impacts the ability and willingness of remote workers to share knowledge. These contradictory findings highlight the complexity of the

impact of remote work on corporate innovation performance.

***Brief Commentary:*** Previous research on the relationship between remote work and corporate innovation performance has not reached a consensus. Most existing studies focus on the innovation performance of individuals or teams engaged in remote work, with a lack of exploration at the corporate level. The majority of these studies are conceptual or case-based, lacking empirical evidence. Additionally, existing research does not sufficiently analyze the contingency factors for the relationship between remote work and innovation performance, and there is still a lack of understanding regarding the situational factors that influence this relationship.

**（3） Remote work and information security**

Compared to other organizational performance outcomes, empirical research on the impact of remote work on corporate information security is particularly scarce. While previous studies have recognized the potential risks to information security posed by remote work, these investigations are predominantly conceptual in nature (e.g., Curran, 2020; Evangelakos, 2020; James & Griffiths, 2014; Malecki, 2020), and there is a lack of empirical evidence detailing the relationship between remote work and corporate information security. For instance, Curran (2020) notes through qualitative analysis that remote work can expose organizations to significant data leakage risks by moving employees, office equipment, and data outside of secure environments. Malecki (2020) also highlights that remote work introduces unprecedented challenges to corporate information security management. Okereafor and Manny (2020) discuss how the widespread use of remote work and video conferencing opens the floodgates for cyber-attacks and malicious hacking incidents, thereby triggering serious cybersecurity and privacy issues.

The few empirical studies primarily focus on factors that influence the effectiveness of corporate security strategies for remote work. For example, Lee and Lee (2021) found through

a survey of 207 remote workers during the pandemic that regulation and enforcement are crucial factors in ensuring the security of corporate remote work. Similarly, Senapati and Bharathi (2023) discovered through an online survey that employees' Internet habits, awareness of cyber-attacks, knowledge of cybersecurity best practices, and compliance with company security policies can effectively enhance corporate information security.

***Brief Commentary:*** There is a severe lack of empirical studies directly relating to the impact of remote work on corporate information security. The limited empirical research available focuses only on factors that can enhance corporate information security in a remote working context, without direct empirical evidence of the relationship between remote work and corporate information security. It is necessary to empirically test the impact of remote work on corporate information security risks to answer how remote work affects corporate information security and to build a competitive advantage in information security in the digital age.

**（4） Remote work and other performance outcomes**

In addition to performance outcomes such as operational efficiency, innovation performance, and information security, existing research has also focused on the impact of remote work on other organizational-level performance outcomes, including financial performance, organizational resilience, organizational culture, and communication and collaboration.

Specifically, past research has explored the impact of remote work on corporate financial performance, including profit, cost, and return on investment. For example, Meyer et al. (2001) showed that remote work is positively correlated with corporate profit (operational income). Sands and Harper (2007) also demonstrated that remote work positively affects corporate assets and equity return rates. Martinez Sanchez et al. (2007) found that remote work and flexibility are positively correlated with corporate performance. Additionally, remote work is often

associated with cost reductions (Bailey & Kurland, 1999), helping businesses reduce expenses such as office space and energy consumption (Bloom et al., 2015).

The impacts of remote work on other organization-related performance aspects include employee retention and recruitment, organizational culture, organizational structure, the relationship between enterprises and employees, and organizational trust (Allen et al., 2015; De Menezes & Kelliher, 2011; Harrington & Ruppel, 1999). Drew and Coulson-Thomas (1996) through interviews and surveys of 100 UK companies, found that remote work affects business process reorganization and organizational restructuring. Moreover, there is an association between remote work and organizational resilience during crises. For instance, Bai et al. (2021) indicated that companies with higher remote work feasibility before the pandemic showed greater resilience during COVID-19. Ge et al. (2022) showed that a company's remote working capability can enhance its crisis response ability during the pandemic, but it may reduce recovery capability. Furthermore, remote work presents some challenges to organizations, especially difficulties in communication and collaboration (Hill et al., 2003), it may lead to reduced interaction among employees, thus impacting team cohesion and organizational culture (Golden et al., 2008). Researchers have also explored the impact of remote work on collaboration and communication. For example, a study by Yang et al. (2022) analyzing data from 61,182 U.S. Microsoft employees found that company-wide remote work during the first six months of COVID-19 weakened internal collaboration and communication.

***Brief Commentary:*** Compared to individual-level studies, research on the impact of remote work at the organizational level is relatively limited and mainly relies on qualitative analysis. This leads to significant limitations in understanding the impact of remote work, especially in the absence of rigorous quantitative analysis based on secondary data, which restricts an objective and in-depth understanding of remote work. Furthermore, existing research on the effects of remote work shows considerable inconsistency, making it necessary

to further explore and identify the contextual factors and situational factors that affect the outcomes of remote work. This not only allows for a more comprehensive assessment of the impacts of remote work but also provides a scientific basis for enterprises to develop more effective remote working strategies, thereby enhancing corporate performance and competitiveness.

## 2.3 Contingency Factors Related to Remote Work

Existing research on the impacts of remote work continues to yield inconsistent conclusions, with some scholars suggesting that the presence of contingency factors may be one reason for these inconsistencies (De Menezes & Kelliher, 2011). However, explorations of moderating effects in existing studies on remote work are relatively scarce (De Menezes & Kelliher, 2011). This section reviews the current research on contingency factors of remote work. Through reviewing studies on contingency factors, this research categorizes the existing moderating factors related to remote work into three aspects: individual level, organizational level, and external environmental factors.

***Individual level.*** Firstly, the research on individual-level moderating factors is more abundant compared to organizational and external environmental factors. Past studies have examined the influence of various factors such as gender, age, years of work experience, commuting time, parental status, presence of children, family size, marital status, remote work experience, perceived career prospects, willingness to work remotely, employee attitudes, job autonomy, and sense of responsibility among employees.

Among these, existing research has identified the presence of children as a crucial factor in individual remote work scenarios (Gibbs et al., 2023; Zhang et al., 2020). For instance, Zhang et al. (2020), in a survey from Germany, found that children not only increased work-family conflict but also led to a redistribution of household chores between spouses, exacerbating gender differences. Gibbs et al. (2023) also noted that households with children

tended to work longer hours and experienced a more significant decrease in individual work efficiency compared to those without children.

Furthermore, an individual's sense of responsibility towards the family also affects the relationship with family conflict. Gajendran and Harrison (2007) discovered that when employees perceive greater career prospects, the positive relationship between remote work and organizational performance is stronger. Employees with more than a year of remote work experience reported lower work-family conflicts and role stress. Previous studies have also found that an individual's willingness to work remotely enhances the impact of remote work on employee performance and organizational commitment (Rothbard et al., 2005). Research indicates that job autonomy reduces the negative impacts of remote work on family-life conflict (Golden et al., 2006). Moreover, an individual's sense of responsibility towards the family also affects the relationship with family conflict. Shockley and Allen (2007) found that individuals with greater family responsibilities benefited from the spatial and temporal flexibility obtained through remote work, positively impacting their ability to balance home and work life. Conversely, the effect was opposite for those with a lower sense of responsibility. Research has also found that age, parental status, years of work experience, and commuting time do not significantly moderate the relationship between remote work and work-family conflict (Allen et al., 2013; Gibbs et al., 2023).

***Organizational level.*** Studies have found that the intensity of remote work arrangements moderates the relationship between remote work and perceived job autonomy, work-family conflict, employer relations, and employee relations (Gajendran & Harrison, 2007). Wiesenfeld et al. (1999) also discovered that the intensity of remote work moderates employees' organizational identification in a remote work setting. Konrad and Mangel (2000) investigated the impact of remote work arrangements on productivity in 195 U.S. companies and found that the impact on productivity depends on employee characteristics. Among these 195 companies,

those with a higher proportion of women experienced a more positive impact on productivity from remote work. Gajendran and Harrison (2007) reached a similar conclusion, finding that companies with a higher proportion of women benefit more from remote work.

Additionally, support from senior management for remote work exerts an effective moderating role in reducing employee absenteeism rates (Menezes & Wood, 2006). Kossek et al. (2006) showed that the impact of remote work on performance depends on the specific nature of the job. Furthermore, research has revealed that the higher the R&D intensity of high-tech enterprises, the stronger the relationship between their degree of remote collaboration and innovation performance (Berchicci et al., 2016). Kuruzovich et al. (2021) highlighted that high-quality remote work software can mitigate the adverse effects of remote work on job performance.

***Environmental level.*** Research has identified the moderating role of geographic regions in the relationship between remote work and individual turnover intentions. Research showed a significant negative correlation in Anglo countries (including the UK, USA, Canada, and Australia) but no effect in Latin American countries (including Argentina, Chile, Bolivia, Puerto Rico, and Peru) (Masuda et al., 2012). Additionally, industry characteristics have also been identified as important moderating factors; it has been found that the capability to use digital technologies for remote work is more critical in non-high-tech industries (Bai et al., 2021).

***Brief Commentary:*** Existing research on the moderating factors related to remote work can be categorized into three areas: individual level, organizational level, and external environmental level. Individual level factors focus on how employees' personal characteristics, family traits, work attitudes, and behavior patterns influence the effectiveness of remote work. This area has received extensive attention and in-depth exploration because individual differences in remote work settings are readily observable and quantifiable. Organizational

level factors include the intensity of remote work, gender ratios among staff, executive support, nature of the job, and R&D intensity. These factors, while equally important, have been less frequently studied and are often limited in scope. External environmental factors consider how geographic regions and industry characteristics can either facilitate or inhibit remote work. These factors are essential for understanding the broader contextual influences on remote work practices but have not been as extensively researched as individual factors. Moving forward, future research should focus more on exploring the organizational and external environmental moderating factors to fully understand the dynamics and complexities of remote work.

## 2.4 Theories Related to Remote Work

### 2.4.1 Social exchange theory

Social exchange theory, proposed by Peter Blau in 1964, is a social psychology theory used to explain the motivations and consequences of behaviors in interpersonal interactions (Blau, 1964). Based on the principles of interdependence and reciprocity, this theory posits that individuals seek to maximize the balance between rewards and costs in social interactions, expecting to receive equivalent returns for what they give and receive. The application of social exchange theory in remote work research manifests in various ways.

Kelliher and Anderson (2010) utilized social exchange theory to explain why employees might increase their work effort, which could be seen as an exchange for the flexibility in work arrangements offered by employers. This finding suggests that organizational provisions of workplace flexibility in remote arrangements may elicit enhanced productivity and discretionary effort through reciprocal exchange mechanisms between employees and their employers. Furthermore, Konrad and Mangel (2000) also employed social exchange theory to explain the relationship between work-life balance programs and performance. Other research highlights the importance of reciprocity, suggesting that when employees benefit from work-

life balance measures, they may reciprocate with improved job performance (Akerlof, 1982). Kuruzovich et al. (2021) integrated social exchange theory to explore the impact of remote work on job outcomes. Tsen et al. (2022) viewed flexible work arrangements through the lens of social exchange theory, suggesting that such arrangements might be perceived by employees as positive actions by the organization, thereby inspiring loyalty and commitment based on the principle of reciprocity, which in turn could reduce turnover intentions.

Overall, social exchange theory provides a powerful framework for understanding and explaining the interactions between employees and employers in remote work settings. This theoretical perspective emphasizes that by implementing flexible work arrangements and work-life balance programs, a positive cycle of reciprocity can be established between employees and employers, thereby enhancing job performance and organizational commitment.

### 2.4.2 Nonpecuniary incentives theory

The theory of nonpecuniary incentives focuses on employees' intrinsic motivations and satisfaction rather than solely relying on material rewards, such as salaries (Agarwal & Ohyama, 2013; Choudhury et al., 2021). This theory posits that employees' work motivation arises not only from external rewards, such as monetary compensation, but also from internal satisfactions, such as personal achievement, autonomy in work, and the pleasure and challenges associated with the work itself. Particularly in contemporary work environments, characterized by high knowledge and innovation competition, non-monetary and intrinsic motivations are considered critical to the success of work arrangements (Agarwal & Ohyama, 2013; Choudhury et al., 2021).

Motivation literature suggests that employees' work motivations are based on the incentives they expect to gain from participating in work and their preferences for these incentives (Choudhury et al., 2021; Kryscynski, 2021; Sauermann & Cohen, 2010). Incentives are categorized into two types: intrinsic and extrinsic. Extrinsic incentives involve external

factors and monetary benefits, such as salary; intrinsic incentives mean that employees derive motivation from within themselves or the activity itself, often reflecting nonpecuniary motives (Sauermann & Cohen, 2010). Previous research has explored the role of nonpecuniary incentives in prosocial contributions (Carnahan et al., 2017), social rewards (Kryscynski, 2021), and intellectual challenges (Sauermann & Cohen, 2010).

In remote work research, the application of nonpecuniary incentives theory is particularly prominent. Remote work arrangements, which aim to provide greater work flexibility allowing employees more control over their work time and location, are considered a significant nonpecuniary benefit (Choudhury et al., 2021). Such arrangements may prompt organizations to focus on intrinsic motivation, problem-solving, and innovative solutions, thereby increasing overall employee satisfaction and productivity. Past research has demonstrated that nonpecuniary incentives can stimulate employees' intrinsic motivations, leading to greater work effort and more positive work outcomes (Agarwal & Ohyama, 2013; Choudhury et al., 2021; Kryscynski, 2021; Sauermann & Cohen, 2010). Additionally, Choudhury et al. (2021) pointed out that remote work arrangements, as a form of nonpecuniary incentive, can shape employees' behavior and guide their actions, resulting in high-quality work outputs.

### 2.4.3 Organizational control theory

Organizational control theory primarily focuses on how organizations can guide, adjust, and assess the behavior and performance of employees through a series of control mechanisms to ensure the achievement of organizational goals (Ouchi & Johnson, 1978; Pianese et al., 2023). According to previous research, organizational control can be divided into three main forms: outcome control, behavior control, and social control (Ouchi & Johnson, 1978). Outcome control emphasizes monitoring outcomes by setting performance goals and standards, allowing employees considerable autonomy in achieving these predefined objectives. Behavior control focuses on guiding and monitoring the behavior of employees to ensure that they

perform their work according to specific procedures and standards. Social control relies on the organizational culture and values, encouraging employees through socialization processes to internalize organizational goals and values to guide their behavior.

In the remote work literature, organizational control theory is often used to discuss how to effectively manage and monitor remote employees who are dispersed across different geographical locations in the absence of physical supervision. The remote working environment poses unique challenges to organizational control, especially in terms of behavior control, as remote work limits traditional supervision and face-to-face communication. Kurland and Egan (1999) explored the issues of management control in the context of remote work. Pianese et al. (2023) suggested that remote working environments require organizations to rely more on outcome control and social control, rather than traditional behavior control. In remote work settings, organizations tend to adopt more outcome-control strategies while implementing behavior control using information technology; they also effectively utilize social control by building strong organizational cultures and values to enhance employee autonomy.

### 2.4.4 Boundary theory

Boundary theory, originating from the fields of social and organizational psychology, primarily explores how individuals delineate boundaries between different roles and identities. According to boundary theory, individuals establish and manage boundaries between their work life and personal life to achieve either segmentation or integration of roles, thereby affecting work efficiency, life satisfaction, and overall well-being. Boundaries can be physical, psychological, emotional, or temporal, and are classified as either rigid or permeable based on their permeability and flexibility. Rigid boundaries imply that individuals tend to keep work and personal life strictly separate; permeable boundaries mean there is more interaction and flexibility between these two areas.

Within the remote work paradigm, boundary theory provides a theoretical lens through

which scholars have extensively investigated the dissolution and reconstruction of work-life boundaries, elucidating their subsequent effects on employee job satisfaction, task performance, and quality-of-life indicators. Adisa et al. (2022) used boundary theory to explore the impact of COVID-19 on employees' boundary management and work-life balance. Kossek et al. (2006) examined the impact of boundary management on work and family efficiency through surveys and interviews from two Fortune 500 companies with remote work policies. Allen et al. (2021) analyzed how boundary management in remote work settings affects employees' work-nonwork balance through the lens of boundary theory. Tsen et al. (2022) explored how flexible work arrangements affect the boundaries between work and family life, thereby impacting employees' intentions to leave. Their research suggested that remote work might lead to the blurring of boundaries between employees' work and family lives, adversely affecting their intentions to leave. This application of boundary theory to remote work underscores the importance of understanding and managing work-life boundaries to ensure that remote work settings do not negatively impact employees' lives but instead promote a balanced and productive environment.

### 2.4.5 Other theories

In addition to the theories mentioned earlier such as social exchange theory, nonpecuniary incentives theory, organizational control theory, and boundary theory, a few studies on remote work have also focused on other theoretical frameworks. For example, some researchers have integrated the Media Richness Theory (Daft & Lengel, 1986; Dennis & Kinney, 1998) to examine the impact of the communication media used by remote employees on performance (Higa et al., 2000). Pierce and Newstrom (1980) applied the Work Adjustment Model to explain how remote work affects employees' attitudes, behavior, and overall performance. This model posits that a better match between an individual's abilities or skills and job demands leads to higher job performance, and it has also been used to analyze the relationship between remote

work arrangements and job performance (Baltes et al., 1999). Hackman and Oldham (1975) suggest that the fundamental characteristics of a job, such as job autonomy and flexibility, can alter employees' psychological states at work, which in turn affects job performance. Combining this model, remote work is posited to provide employees with autonomy and satisfaction, thereby enhancing their job performance (Dodd & Ganster, 1996; Gröpel & Kuhl, 2009). Karasek Jr (1979) also proposed that high levels of autonomy (e.g., choice over work arrangements) enable employees to better cope with high job demands, thus mitigating the adverse effects of high demands.

***Brief Commentary:*** The theoretical foundation of existing research on remote work is somewhat weak. Through a review of the literature and theoretical frameworks, I found that most studies on remote work lack a solid theoretical base, especially when conducting empirical research. Few studies formulate and test hypotheses based on appropriate theories. Additionally, the existing theoretical perspectives are primarily focused on the individual level (De Menezes & Kelliher, 2011), while theoretical support at the organizational level is relatively lacking (De Menezes & Kelliher, 2011). Therefore, to fully understand the impacts of remote work on performance outcomes and the conditions under which it operates, there is an urgent need to deepen the theoretical understanding of remote work. This will also promote theoretical development and innovation in research related to remote work. Table 2.2 summarizes the representative theories of remote work research.

Table 2.2 Representative theories of remote work research

| Theory | Arguments | Representative studies |
|---|---|---|
| Social exchange theory | Flexible work arrangements and work-life balance programs can create a positive cycle of reciprocity between employees and employers, enhancing employees' job performance and organizational commitment. Within the remote work paradigm, when employees perceive the flexibility offered by their company, they are likely to reciprocate with increased work efficiency and effort. | Kelliher and Anderson (2010); Kuruzovich et al. (2021); Tsen et al. (2022) |
| Nonpecuniary incentives theory | Remote work, as a significant nonpecuniary incentive, can stimulate intrinsic motivation in employees, leading to greater work effort and more positive work outcomes. | Agarwal and Ohyama (2013); Choudhury et al. (2021); Kryscynski (2021); Sauermann and Cohen (2010) |
| Organizational control theory | Organizational control theory is often used to discuss how to effectively manage and monitor remote employees who are dispersed across different geographical locations without physical supervision. The remote work environment necessitates that organizations rely more on outcome control and social control rather than traditional behavioral control. | Biron and Van Veldhoven (2016); Groen et al. (2018); Katz (1987); Kossek et al. (2006); Kurland and Egan (1999); Pianese et al. (2023) |
| Boundary theory | Boundary theory is widely applied to analyze how remote work changes the boundaries between work and personal life, and how these changes affect employees' job satisfaction, work performance, and quality of life. | Adisa et al. (2022); Allen et al. (2021); Kossek et al. (2006); Tsen et al. (2022) |

# Chapter 3 Study 1: Remote Work or Return to the Office? A Quasi-natural Experiment on the Impact of Remote Work Arrangements on Firms' Operational Efficiency

## 3.1 Introduction

The COVID-19 pandemic forced millions of employees to rapidly switch to remote work mode (Choudhury et al., 2021), which had emerged as a more desirable and feasible work option during the crisis (Ge et al., 2022). Considering the potential benefits of work flexibility, employee motivation, and cost savings (Whiting, 2020), several firms have made remote work a formal company policy and permanent arrangement for some of their employees (Boland et al., 2020). Gallup reported that even before the COVID-19 pandemic, over 43% of Americans worked remotely at least once a week (Dunn, 2020). Almost two-thirds of U.S. workers in a McKinsey survey said they wanted to remote work more than 3 days a week when the pandemic was over. Many governments and nongovernmental organizations also advocate remote work arrangements, promoting such work arrangements as socially responsible acts and environmentally friendly practices (Dunn, 2020). Remote work arrangements are becoming increasingly prevalent work arrangements that induce profound transformations in the way people work and live.

However, even though remote work may benefit society and employees in many ways, it is not clear whether the perceived benefits come at the expense of the productivity of firms implementing remote work. There is a long-standing debate among leading companies about how effective remote work is for firms and to what extent firms can further improve remote work implementation. The early encounters cultivate a sense of optimism; however, many companies are expressing doubts regarding the long-term viability of remote work (Gibbs et al., 2021). In particular, several firms that implemented remote work with enthusiasm in the early years seem to be increasingly skeptical about the benefits of remote work arrangements

(Shen, 2023). Yahoo!, HP, and Netflix have abandoned their remote work programs, warning that remote work could undermine the collaborative environment, endanger knowledge sharing, and hurt firm efficiency in the long term (Allen et al., 2015; Bai et al., 2021; BBC, 2020; Guynn, 2013; Shen, 2023). For example, Yahoo!'s former CEO, Marissa Mayer, expressed concerns about the remote work policy and abolished such programs completely in 2013 (Guynn, 2013). Recently, CEOs of leading multinational corporations, such as Goldman Sachs and Netflix, stated that remote work is an aberration and took measures to reverse remote work arrangements so as to restore firms to normal operations (BBC, 2020). However, Airbnb and Fujitsu allow their staff to remote work permanently, exacerbating the debate about the issue of remote work implementation.

Whether to implement remote work in the long term is a dilemma that many organizations currently confront and is a pressing issue for researchers and practitioners to address. One of the most essential issues in this context is how remote work influences firms' operational efficiency, but our knowledge about this question is scarce. Although the literature has examined the role of remote work on productivity, most studies focused on the individual level (e.g., Bloom et al., 2015; Choudhury et al., 2021; Shen, 2023) or concentrated on the context of the pandemic (e.g., Bai et al., 2021; Ge et al., 2022). Empirical evidence on the long-term relationship between remote work and firm-level operational efficiency remains limited. In this study, I aimed to address this important research question and provide insightful implications for remote work implementation decisions by empirically investigating the influence of remote work arrangements on firms' operational efficiency in the long term.

I employed a quasi-natural experiment to investigate the role of remote work arrangements on firms' operational efficiency based on publicly listed U.S. firms from 2010 to 2020. I collected secondary data from various data sets, including Compustat, Factiva, and the KLD STATS (KLD) datasets. I obtained firm-level remote work data based on a firm's formally

announced remote work policies from Factiva. I measured operational efficiency based on the stochastic frontier estimation (SFE) methodology of a firm's relative efficiency in the industry (based on 2-digit standard industrial classification [SIC] codes;(Lam et al., 2016). I also followed the Motivation-Ability-Opportunity (MAO) framework and scrutinized how employee relationships (based on KLD databases; (Gambeta et al., 2019; Luo et al., 2014; Wang et al., 2009), corporate profitability (based on Compustat database; (Banker et al., 2011; Lam et al., 2022), and high-tech industry (based on 4-digit SIC codes; (Fan et al., 2022) moderate the relationship between remote work arrangements and operational efficiency.

I employed the propensity score matching (PSM) method to build matched pairs, which ensured similarities between the treatment group and the control group to a large extent. Next, I conducted a staggered difference-in-differences (DID) analysis to explore differences in firms' operational efficiency for firms that implement remote work arrangements or not. The PSM-DID estimation allowed us to cope with the issues of endogeneity (Lu et al., 2018). Our results revealed that remote work arrangements may damage firms' operational efficiency, and such negative impact enlarged over time, suggesting a long-term negative impact of remote work arrangements on firms' operational efficiency. This result shows the dark side of the long-term implementation of remote work (i.e., remote work arrangements may bring work flexibility at the expense of firms' operational efficiency). However, I further found that such negative effects can be reduced if firms have strong employee relationships, adopt a product differentiation strategy, and belong to the high-tech industry. These findings remain consistent across a variety of robustness tests and extension estimations.

Our findings provide empirical evidence regarding the negative impact of remote work on firms' operational efficiency based on firm-level data spanning more than a decade. I also demonstrate the mitigating roles of MAO factors on the negative link between remote work and operational efficiency. Our results provide hints for enterprises and policymakers to duly

consider the firms' operational elements when making remote work arrangements. Overall, our study sheds light on how firms can effectively organize and manage remote work arrangements and better reduce the negative impacts of remote work arrangements on firms' operational efficiency.

## 3.2 Theoretical Background and Hypothesis Development

### 3.2.1 Impact of remote work on firms' operational efficiency

Operational efficiency refers to the extent to which a firm efficiently integrates and transforms its resources into operating outcomes (Miller & Roth, 1994; Roth & Jackson III, 1995). In other words, operational efficiency focuses on how organizations can achieve the maximum output with the minimum input (cost, labor, time, etc.). High operational efficiency enables organizations to obtain a sustained competitive advantage and achieve sustainable development in a highly competitive environment. Therefore, this study examines how remote work arrangements affect the operational efficiency of firms.

Specifically, social exchange theory (SET) conceptualizes the exchange relationship between individuals and organizations as a series of mutually beneficial, reciprocal interactions (Cook et al., 2013; Cropanzano & Mitchell, 2005; Lui et al., 2009; Wu et al., 2014). According to SET, when a firm provides effective rewards and incentives to its employees, the latter are often inclined to exert extra effort for the organization out of a sense of gratitude and reciprocity, thereby enhancing work efficiency (Flynn, 2005; Wayne et al., 1997; Yee et al., 2008). Following the theoretical lens of SET, the autonomy and work flexibility afforded by remote work can increase employees' perceptions of reciprocity and their inclination to reciprocate, thus enhancing their work motivation. Moreover, from the perspective of nonpecuniary incentives, remote work arrangements, as a kind of nonpecuniary incentives provided by firms, can stimulate employees' reciprocity, thereby boosting their work motivation and the overall operational efficiency of the organization (Cropanzano & Mitchell, 2005). Specifically, remote

work may enhance productivity by providing nonpecuniary incentives such as work flexibility to employees. Remote work gives employees schedule flexibility and empowers them to choose their work locations, leading to a high total utility of individuals (Choudhury et al., 2021). Remote work is generally linked to job autonomy, which indicates the extent to which employees are allowed to work with freedom, independence, and discretion (Hackman & Oldham, 1976). Autonomy is connected with a high level of working enthusiasm and motivation. Given the autonomy brought by remote work, employees may increase the sense of reciprocity and "gift exchange," thus increasing their work motivation. For instance, Fujitsu encourages permanent remote work and asserts that such autonomy can enhance team collaboration and individual output. Therefore, I propose the following hypothesis:

***H1a: Remote work arrangements lead to higher operational efficiency of firms in general.***

However, despite remote work having the potential to improve firms' operational efficiency by enhancing employee motivation through increased flexibility and autonomy, the dispersion of organizational resources and the challenges associated with employee supervision inherent in remote work arrangements may negate its positive effects. Consequently, this study further explores the potential adverse impacts of remote work arrangements on operational efficiency and proposes a competing hypothesis.

Specifically, resource dependence theory emphasizes that firms need to effectively manage and allocate resources to improve efficiency (Hillman et al., 2009; Singh et al., 2011). However, remote work may lead to the dispersion of resources (such as information, technology, and human capital), which increases the difficulty of resource management, thus affecting the operational efficiency of firms. In contrast to the traditional office environment, the remote working environment makes the centralized management of resources more difficult. For example, in the remote working environment, employees are scattered in different geographical

locations, and the transmission of information mainly relies on E-mail, online meetings, and other ways, which may lead to incomplete information transmission and poor communication, thus affecting employees' work efficiency and collaborative problem-solving ability. Yang et al. (2022) found that during the COVID-19 pandemic, firm-wide remote work significantly weakened the collaboration and information exchange among employees within the firm. At the same time, remote work may also lead to the dispersion of technical resources. In a traditional office environment, employees can share the same office equipment and software tools, which helps improve productivity and collaboration. However, in the context of remote work, employees use their own devices and digital tools to work, which can lead to differentiated and underutilized technology resources, thereby reducing the operational efficiency of the firm. Additionally, according to organizational control theory (Ouchi & Johnson, 1978), remote work arrangements weaken the direct supervision and control of management over employee behavior. Remote work makes it difficult for managers to supervise employees directly and monitor employees' work progress and performance. Thus, it is impossible for managers to make timely feedback and adjustments towards their employees, which may lead to the decline of employees' work quality and efficiency. Therefore, for employees with weak self-management ability, remote work may reduce their work efficiency, and then affect the overall operational efficiency of firms (Allen et al., 2015). Based on this, this study proposes a competing hypothesis relative to H1a:

***H1b: Remote work arrangements lead to lower operational efficiency of firms in general.***

### 3.2.2 Moderating roles of MAO factors

The Motivation-Ability-Opportunity (MAO) theoretical framework was first proposed by theorists in the field of human resources, and has been widely applied to research at the individual level (Guenzi & Nijssen, 2020). In recent years, more and more scholars have used

the MAO theoretical framework to explain and predict organizational behavior at the organizational and operational levels, including decision-making, executive power, and strategic planning (Boudreau et al., 2003; Mohsen & Eng, 2016; Siemsen et al., 2008; Wuyts et al., 2015). According to the MAO theoretical framework, the successful implementation of firms' policies and arrangements in the organization is determined by three key factors: motivation, ability, and opportunity (Mohsen & Eng, 2016; Siemsen et al., 2008). Motivation refers to the internal driving force that drives the actions of individuals and organizations; ability refers to the ability or skill of an individual or organization to perform an action; and opportunity refers to the conditions or opportunities for individuals and organizations to take actions. MAO theoretical framework holds that only when motivation, ability, and opportunity are present and the synergies between them can the best performance and results be achieved (Mohsen & Eng, 2016; Siemsen et al., 2008).

In this study, I employ the MAO theoretical framework to examine the moderating effects of motivation, ability, and opportunity factors on the relationship between remote work and firms' operational efficiency. First, regarding the motivation factor, I focus on the moderating effect of employee relationship. In a remote work environment, the motivation of employees is crucial to the efficiency of business operations (Flammer & Kacperczyk, 2016; Gambeta et al., 2019; Harrison et al., 2010). Superior employee relationship will enhance employees' intrinsic motivation, improve employees' self-management ability and commitment to work, and thus keep employees efficient and motivated while working remotely. Second, regarding the ability factor, I focus on the moderating effect of profitability. The profitability of a firm can be regarded as the embodiment of its overall capability, because profitability represents the effectiveness of a firm in resource allocation, financial management, and market competition (Seiford & Zhu, 1999; Yee et al., 2008). Firms highly profitable are usually able to provide better technical support, training resources, and management systems (Mithas et al., 2012),

which are an important support for the success of remote work. Third, regarding the opportunity factor, I focus on the moderating roles of the high-tech industry. The nature of work in the high-tech industry is often knowledge-intensive and information-intensive which is more suitable for remote work (Bai et al., 2021; Decker et al., 2020; Heckler, 2005). Firms in high-tech industries are also more likely to adapt to digital transformation, with technologies such as cloud computing, artificial intelligence, and automation providing the basis for telecommuting.

**（1） Employee relationship**

According to stakeholder literature, employees are important internal stakeholders of enterprises, and employee relationship is defined as the process of interaction, relationship construction, and sustainable development between firms and employees. A good employee relationship is reflected in the stable commitment, mutual understanding, and cooperation and mutual benefit based on long-term interests between firms and employees (Flammer & Kacperczyk, 2016; Gambeta et al., 2019; Harrison et al., 2010). Good employee relationships are built through high levels of cooperation, trust, a balance of power, and shared goals and values (Gambeta et al., 2019; Harrison et al., 2010). I believe that employee relationship, as an important motivational factor, lays the foundation for the effectiveness of remote work on the operational efficiency of firms.

According to organizational control theory, remote work arrangements diminish the direct supervision and control managers have over employee behavior. Given that employees working remotely often experience less direct oversight and control (Gajendran & Harrison, 2007), firms increasingly rely on employees' self-motivation to achieve operational goals. In this context, positive employee relations help establish a psychological contract between the firm and its employees, encouraging them to deliver high-quality output (Gambeta et al., 2019), thereby ensuring productivity and efficiency while working remotely. The MAO theoretical framework also suggests that when individuals or organizations are motivated to do

something—that is, when the motivational factor is present—they are more likely to fully leverage their agency (Boudreau et al., 2003; Siemsen et al., 2008). Good employee relationship can enhance employees' intrinsic motivation, such as job satisfaction, sense of belonging, and loyalty. In a remote working environment, employees with positive employee relationship possess stronger self-management capabilities and commitment to their work, making them more likely to maintain high efficiency and enthusiasm while working remotely. Thus, positive employee relations allow firms to reduce short-term and opportunistic behaviors among employees (Gambeta et al., 2019), thereby mitigating the potential risks inherent in remote work arrangements. Based on this, the study posits that employee relationship positively moderate the relationship between remote work and operational efficiency. I thus put forward the following hypothesis:

***H2: Employee relationship positively moderates the relationship between remote work arrangements and firms' operational efficiency, that is, when firms have good employee relationship, the positive (negative) impact of remote work arrangements on operational efficiency can be enhanced (weakened).***

**（2） Profitability**

Based on MAO framework, an organization's capability, including the availability of resources, the adaptability of organizational structures, and the level of employee skills and knowledge, determines its success in achieving strategic objectives and responding to environmental changes. Previous studies have considered a firm's profitability as a reflection of its overall capability (Maury, 2018; Mithas et al., 2012; Seiford & Zhu, 1999; Shah & Shin, 2007; Yee et al., 2008). Profitability represents a firm's effectiveness in resource allocation, financial management, and market competition, enabling better investment in technology, talent, and systems (Barney, 2001; Wernerfelt, 1984), thereby enhancing its flexibility and efficiency in responding to environmental changes.

This study posits that the level of organizational capability in terms of profitability positively moderates the relationship between remote work and operational efficiency for three reasons. Firstly, from the perspective of resource dependence theory, remote work may lead to the dispersion of resources such as information, technology, and human resources, necessitating more effective management and allocation of resources to enhance operational efficiency (Hillman et al., 2009; Singh et al., 2011). Companies with high profitability often have more resources, allowing for greater investment in remote working infrastructure, which helps increase the efficiency of remote work and reduce productivity losses due to resource dependence. For example, highly profitable firms can purchase more advanced remote working software and provide efficient IT support to ensure a stable and efficient remote working environment (Mithas et al., 2012). Secondly, firms with higher profitability possess greater flexibility and adaptability, more likely to rapidly respond to market changes, and adjust management strategies to accommodate remote work needs (e.g., implementing flat management) (Karim & Shetu, 2023). In a remote working environment, a flexible organizational structure promotes better communication and collaboration, improving overall operational efficiency (Karim & Shetu, 2023). Thirdly, more profitable firms are better equipped to provide effective employee training, enhancing employees' self-management capabilities and skills in using telecommuting tools. This not only improves individual employee efficiency but also enhances overall operational efficiency through knowledge sharing and team collaboration. In summary, I argue that firms with high profitability can positively moderate the relationship between remote work arrangements and operational efficiency through effective resource allocation, flexible organizational adaptation, and continuous improvement of employee skills. Accordingly, this study proposes the following hypothesis:

***H3: Firms' profitability positively moderates the relationship between remote work***

***arrangements and firms' operational efficiency, that is, when firms have strong profitability, the positive (negative) impact of remote work arrangement on operational efficiency can be enhanced (weakened).***

**（3） High-tech industry**

Based on MAO framework, opportunity refers to the conditions or chances for individuals and organizations to take actions. Not all businesses are suitable for remote work, those in the high-tech industry inherently possess advantages in implementing remote work strategies. This study posits that the high-tech industry, as a significant opportunity factor, is also a critical moderating variable in the relationship between remote work and operational efficiency. Specifically, firms in the high-tech industry are characterized by high R&D investments and innovation, with products and services often involving complex technologies and processes (Bai et al., 2021; Decker et al., 2020; Heckler, 2005). In such an environment, the nature of work tends to be knowledge-intensive and innovative. Compared to routine tasks, employees' work involves more independent thinking and the formulation of innovative solutions (Bai et al., 2021). Therefore, this nature of work aligns with the remote work model, allowing employees to arrange their work and rest times more freely without the constraints of traditional office environments. Many high-tech companies, such as Amazon, Apple, Google, and GitHub, also offer remote work arrangements at varying degrees to stimulate their workers' work motivation (Choudhury et al., 2021).

Moreover, digital information technologies facilitate effective remote work arrangements (Allen et al., 2015). Compared to businesses in other industries, high-tech firms have access to more open and available digital resources. When implementing remote work, high-tech firms can better utilize existing advanced digital information technologies and communication tools, effectively supporting the needs of remote work. This not only helps employees maintain communication and collaboration despite geographical dispersion (Yang et al., 2022), but also

promotes knowledge sharing and innovation, thus positively impacting the operational efficiency of the firm. Additionally, high-tech companies often have more open organizational cultures that encourage innovation and self-motivation among employees, enabling these firms to better adapt to the changes brought by remote work and overcome the challenges that arise. In conclusion, this study suggests that the high-tech industry can positively moderate the relationship between remote work and operational efficiency, and thus put forward the following hypothesis:

***H4: High-tech industry positively moderates the relationship between remote work arrangements and firms' operational efficiency, that is, when firms belong to high-tech industry, the positive (negative) impact of remote work arrangement on operational efficiency can be enhanced (weakened).***

## 3.3 Research Methods

### 3.3.1 Data collection

In this study, I focused on publicly listed U.S. firms. For each of the sample firms, I collected panel data from a variety of datasets to measure our research variables. First, to obtain firm-level data on remote work, I identified firms' formal announcements of remote work-related policies from 2010 to 2020 by searching Factiva, a well-known dataset integrating news and articles from multiple sources such as *Dow Jones Institutional News*, *Business Wire*, and *PR Newswire*. The keywords in our search included *"*remote work," "work-from-home," and other similar terms such as "remote work," "teleworking," "telecommuting," and "workplace flexibility." I focused on publicly listed firms when searching in Factiva because their financial data were more readily available. Another benefit of focusing on publicly listed firms is that they abide by more stringent reporting obligations and garner greater public and media attention, making them more inclined to disclose their remote work policies. Thus, I included "NYSE" and "NASDAQ" as keywords in our search. If the firm had more than one remote

work announcement during the period, I identified their first remote work arrangements.

Initially, I found 4,569 arrangements of publicly listed U.S. firms from 2010 to 2020 by searching Factiva. For every article found via Factiva, I manually coded and read the text to scrutinize announcements related to our research settings. I first excluded duplicate articles of firms' remote work policies that were reported by multiple publication sources to prevent double counting. I then excluded irrelevant announcements, including those related to surveys and polls, market forums and others. For example, I removed announcements such as the Jive Software's (NASDAQ: JIVE) survey released on October 1, 2015, which reported that 72 percent of employees desired increased workplace technology enabling remote work capabilities. After these processes, I removed 2,934 announcements, leaving 1,635 announcements. Next, to capture firms' strategic remote work policies rather than temporary responses to exogenous events, I eliminated announcements related to contingent remote work arrangements precipitated by natural disasters or emergency situations. This criterion excluded cases such as WellCare Health Plans' (NYSE: WCG) announcement on September 11, 2017, regarding the activation of emergency remote work protocols in response to Hurricane Irma. I also excluded announcements implemented by subsidiaries of the listed parent company. I included only the earliest remote work announcement issued during the sample period. After these processes, I further removed 1,355 announcements, leaving 280 announcements from 280 different firms. Because of missing data among various datasets, I further reduced the sample size to 275 to perform PSM analysis and run DID regression.

I found 275 firms that were publicly listed and that announced their initial remote work arrangements from 2010 to 2020. For example, Washington GAS (NYSE: WGL) announced it "collaborate[s] with Telework to implement teleworking as a new business strategy" on April 22, 2010. The Hershey Company (NYSE: HSY) announced that the firm "introduced SmartFlex, a suite of policies and a mindset for balancing work and personal time that

encourages employees to make smart choices for themselves" in 2016. Figure 3.1 shows the detailed step-by-step data collection and cleaning process. The one-way ANOVA test shows no significant difference across our samples at distinct estimation steps ($p > 0.1$) regarding general firm-level characteristics such as firm size and ROA, showing no evidence of sampling bias. I also illustrate the industry distribution of 275 U.S. firms' remote work arrangements in Table 3.1.

Collecting data from Factiva is a labor-intensive task due to the vast amount of information it contains. To obtain the most relevant and accurate information on corporate remote work announcements, researchers established the following filtering rules, as illustrated in Figure 3.1:

(1) Exclude duplicate reports from different news media sources about the same company's remote work announcement to avoid double counting; (2) Exclude clearly irrelevant news reports, such as surveys, opinion polls, market forums, and university news that are not corporate announcements; (3) Exclude remote work announcements related to brief emergency events, such as storms, hurricanes, and shooting incidents, since companies affected by these events typically resume normal operations within a week; (4) Exclude remote work announcements not made by the publicly listed company itself, such as those from subsidiaries of the listed parent company; (5) Consider only the earliest remote work policy announcement made by a company during the sample period as the initial policy implementation date; (6) Exclude company announcements with missing information, such as those lacking a specific date for the remote work announcement.

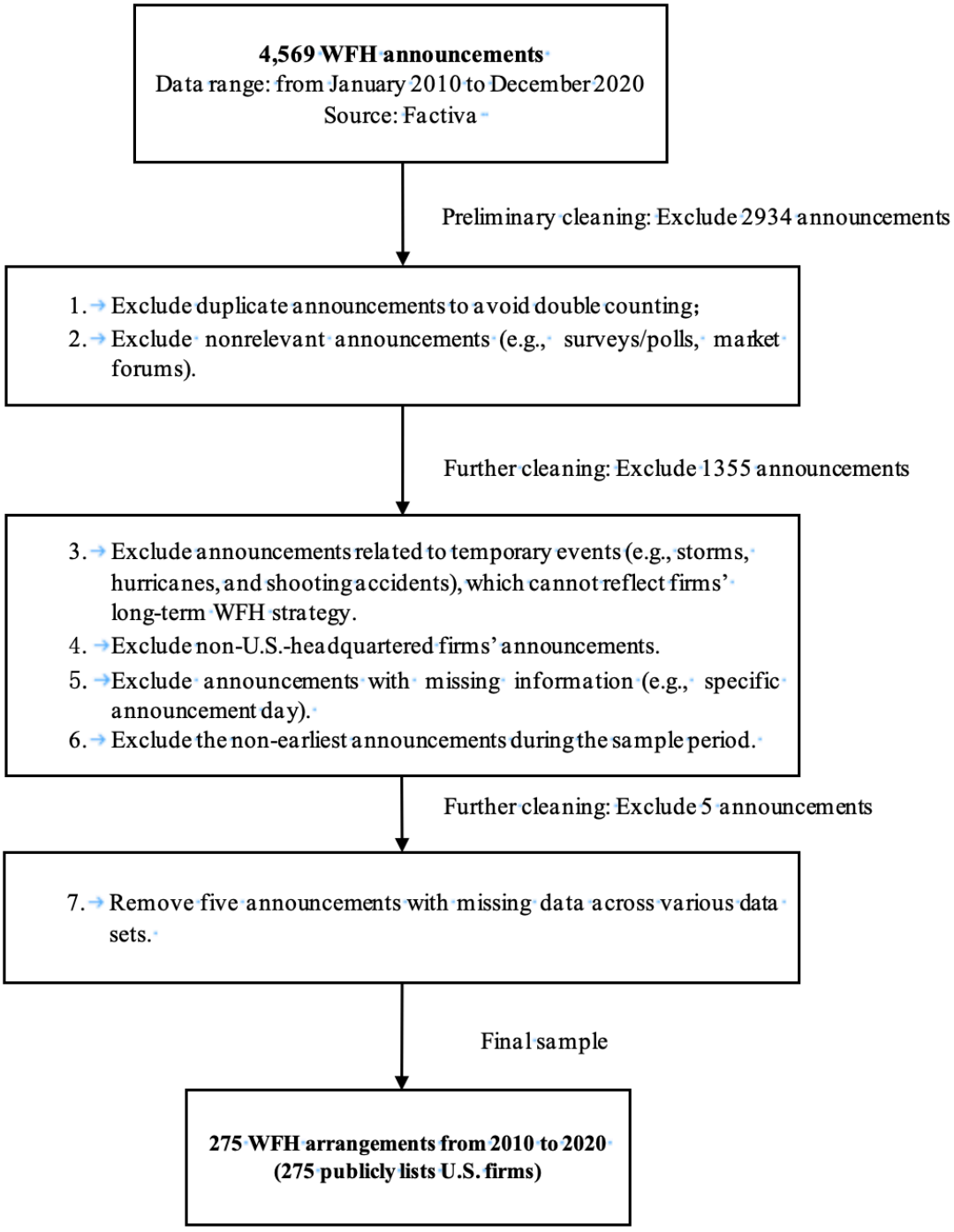


Figure 3.1 Remote work announcements collection and cleaning process

Table 3.1 Distribution of sample firms across industries

| SIC code | Industry | Frequency | Percentage |
|---|---|---|---|
| 73 | Business services | 72 | 26.18 |
| 60 | Depository institutions | 34 | 12.36 |
| 36 | Electronic and other electrical equipment and Components, except computer equipment | 16 | 5.82 |
| 63 | Insurance carriers | 16 | 5.82 |
| 28 | Chemicals and allied products | 14 | 5.09 |
| 49 | Electric, gas, and sanitary services | 10 | 3.64 |
| 48 | Communications | 9 | 3.27 |
| 61 | Nondepository credit institutions | 9 | 3.27 |
| 20 | Food and kindred products | 7 | 2.55 |
| 37 | Transportation equipment | 7 | 2.55 |
| 35 | Industrial and commercial machinery and computer equipment | 6 | 2.18 |
| 45 | Transportation by air | 6 | 2.18 |
| 59 | Miscellaneous retail | 6 | 2.18 |
| 87 | Engineering, accounting, research, management, and Related services | 6 | 2.18 |
| Other SIC codes | Other industries | 57 | 20.73 |
| All SIC codes | All industries | 275 | 100.00 |

### 3.3.2 Measures

I obtained accounting and financial data from Compustat to measure operational efficiency. Based on operational efficiency research (e.g., Chuang et al., 2019; Dutta et al., 2005; Lam et al., 2016; Li et al., 2010), I employed the SFE methodology to compute firms' operational efficiency. There are a number of specific advantages of this estimation method. First, SFE models the efficiency of converting various operational resources (e.g., number of employees, cost of goods sold, capital expenditures) into operational output. Compared with traditional measures that use a single financial indicator (e.g., operating income or inventory turnover) to measure operational efficiency, SFE provides a more comprehensive measure of the overall operational efficiency of a firm (Lam et al., 2016). Second, compared with traditional estimation models, SFE can estimate the optimal (frontier) level of a firm's production or cost function, measuring production efficiency or cost efficiency by the difference between the observed value and the optimal value. This method also takes into account the impact of efficiency differences and random errors and can more accurately capture

efficiency changes, except those caused by random shocks (Vandaie & Zaheer, 2014). Third, traditional measurement methods of operational efficiency do not consider industry heterogeneity (Eroglu & Hofer, 2011), but SFE can measure the relative efficiency of an enterprise in its industry (Dutta et al., 2005; Lam et al., 2016), allowing comparison of results across different industries.

The SFE techniques incorporate a composite error term to better capture efficiency changes beyond those induced by random shocks (Lam et al., 2016). More specifically, I build a production function to represent the relationships among operational resources (i.e., number of employees [NOE], cost of goods sold [CGS], capital expenditure [CE], and operational output [i.e., operating income (OI)]) using the following equation:

$$\ln(OI)_{ijt} = \alpha_0 + \alpha_1 \ln(NOE)_{ijt} + \alpha_2 \ln(CGS)_{ijt} + \alpha_3 \ln(CE)_{ijt} + \varepsilon_{ijt} - \eta_{ijt}, \quad (3\text{-}1)$$

where *i*, *j*, and *t* are firm, industry (two-digit SIC code), and year indices, respectively. $\varepsilon_{ijt}$ is the stochastic random errors, and $\eta_{ijt}$ indicates the technical inefficiency of firm *I* compared to the frontier in the same industry *j* and year *t*. $\eta_{ijt}$ ranges from 0 to 1, with 0 indicating no technical inefficiency. Thus, I computed the operational efficiency of firms *i* in industry *j* in year *t* as follows:

$$Operational\ Efficiency_{ijt} = 1 - \widehat{\eta_{ijt}}. \quad (3\text{-}2)$$

For the moderating variables, I calculated firms' employee relationship scores based on KLD, which measures the strength and quality of firms' employee relationships. KLD ratings come from various data sources, including firm SEC filings, annual reports, government questionnaires, statement releases, and scholarly articles, all of which have well-established

validity and reliability (e.g., Choi & Wang, 2009; Luo et al., 2014). KLD has 14 dimensions to measure the extent of organizational practices in maintaining high-quality, long-term relations with employees, including employee participation, retirement benefits, no-layoff policies, union relations, and health and safety issues (Coombs & Gilley, 2005; Luo et al., 2014). Given the constraints of the KLD database and the temporal scope of the study, I measured the strength of the employee relationship in this study using nine dimensions: union relations, cash profit sharing, employee involvement, employee health and safety, supply chain labor standards, labor management, controversial sourcing, human capital management, and other strengths. If a firm has an advantage in each of these dimensions, the score is 1, otherwise, it is 0. I calculated employee relationship scores by finding the sum of the nine strengths (Gambeta et al., 2019; Luo et al., 2014; Wang et al., 2009). In our sample, the highest score achieved by a firm was 8.

The measurement of corporate profitability in this study is sourced from the Compustat database. Following previous research, profitability is assessed using the profit margin (Mithas et al., 2012; Shah & Shin, 2007; Yee et al., 2008). Because companies with strong profitability often have higher profit margins due to their superior and unique products and services, or closer customer relationships. Consistent with prior practices, this study calculates the profit margin by dividing operating income by sales revenue. In robustness checks, the study also uses the gross margin as an alternative measure—calculated as the ratio of sales revenue minus the cost of goods sold to sales revenue—which yielded consistent results.

I identified high-tech firms based on SIC industry codes to measure a firm's technology strategic positioning. Following Fan et al. (2022) and Modi and Mishra (2011), I coded our sample firms into technology-based (denoted as 1) and nontechnology-based industries (denoted as 0) based on four-digit SIC codes, including 3511–3599, 3612–3699, and 3812–3873. I also used alternative measures with two-digit SIC codes, including SIC 35 (industrial

and commercial machinery and computer equipment); SIC 36 (electronic and other electrical equipment and components, except computer equipment); SIC 37 (transportation equipment); SIC 38 (measuring, analyzing, and controlling instruments; photographic, medical, and optical supplies; watches and clocks); and SIC 283 (pharmaceutical companies) because of their intensive patent activity, following prior research (e.g., Bai et al., 2021; Decker et al., 2020; Heckler, 2005), and the results were consistent.

I included a series of PSM matching variables as independent variables, which may influence firms' remote work adoption. First, I included several firm characteristics such as firm size, ROA, ROE, leverage, and market-to-book ratio (Hendricks et al., 2009; Thirumalai & Sinha, 2011). Specifically, firm size serves as a crucial factor in determining firms' remote work adoption (Ge et al., 2022). Large companies have greater financial capacity than small companies to absorb the significant expenses associated with implementing remote work arrangements. I employed the logarithmically transformed total asset volume as the metric for determining firm size. Enhanced profitability may precede remote work implementation. Firms that exhibit strong ROA and ROE are better positioned to allocate significant financial resources to the implementation of remote work arrangements. Companies with high levels of leverage may be more cautious about risk and may thus be less inclined to adopt remote work practices (Ge et al., 2022). Moreover, the market-to-book ratio is also involved because a firm with a higher market value may pay more attention to employees' work-life balance.

Second, I incorporate employee relationships, competitive strategies, and technology types as matching variables because they are likely to influence firms' remote work adoption. Specifically, firms that cultivate a strong employee relationship are more inclined to offer their employees increased opportunities for achieving work-life balance, thereby demonstrating a greater propensity to implement remote work arrangements in their daily operations (Allen et al., 2015). Moreover, firms that adopt a product differentiation strategy are more likely to offer

alternative remote work options to enhance the motivation and creativity of their knowledge workers. Also, jobs in high-tech firms are often knowledge-intensive rather than focused on routine tasks, so high-tech firms are more inclined to provide employees with flexible work options (Bai et al., 2021).

If I correlate the variables that determine selection in the first-stage model with the outcome in the second-stage model, it cannot satisfy the exclusion restriction condition, thus impairing the reliability of the results obtained through the estimation approach. In our study, if the PSM matching variables determining remote work adoption also influence operational efficiency, the exclusion restriction condition cannot be met, which may cause bias in the results. For example, although employee relationships may determine a firm's remote work decision, as discussed above, it may also affect a firm's operational efficiency. Accordingly, I follow Wolfolds and Siegel (2019) to identify and incorporate variables or instruments that "affect selection but not the outcome" in the first-stage model to satisfy the exclusion restriction conditions and obtain more reliable results. Therefore, I employ two instruments in this study: the annual number of remote work arrangements in the industry (based on the two-digit SIC code) and worldwide attention to remote work (based on Google search frequency). Specifically, I calculated an industry's remote work number by adding up the total number of remote work announcements in the same industry every year and log-transferring it. A firm is more likely to make remote work arrangements in a certain fiscal year if many of its industry peers adopt the same remote work strategy, but this is unlikely to directly influence the firms' operational efficiency. Additionally, I considered worldwide attention to remote work as another instrument because firms' strategy to make remote work arrangements may be influenced by public attention and the "heat of topic," whereas such public interest is unlikely to exert a direct impact on firms' operational efficiency. In alignment with the established methodology in previous literature (Bao et al., 2023; Kong & Lin, 2021; Liu & Tsyvinski,

2021), I used the Google Search Volume Index (SVI) for the search topic "Remote Work" to capture the extent of worldwide attention paid to remote work. I obtained the SVI value from Google Trends and adjusted the original monthly data to yearly by calculating the average SVI every year as our proxy. The index values of SVI represent Google search interest relative to the highest point for the given region in a given period. If the value of SVI is 100, it indicates the peak popularity for the term in a given period. If the value of SVI is 50, it means that the term is half as popular in a given period. A score of 0 means there is not enough data for this term. We obtained the monthly SVI of remote work over the period from January 2010 to December 2020 from Google Trends. Also, I calculated the average SVI every year as our proxy for the worldwide attention to remote work. I further verified that both instruments do not significantly correlate with firms' operational efficiency ($p > 0.1$), satisfying the exclusion restriction condition.

As a result, our PSM matching variables include two instruments (the industry's remote work number and worldwide attention to remote work), employee relationships, competitive strategies, technology types, and five firm-level variables (firm size, ROA, ROE, leverage, and market-to-book ratio) that may be related to firms' remote work decisions. In Table 3.2, I summarized the detailed introduction of the variables involved in this study.

Table 3.2 Variable measurements in Study 1

| Variables | Measures | Data sources | References |
|---|---|---|---|
| Operational efficiency | A firm's efficiency in converting operational inputs, such as employee expenditure (EMP), cost of goods sold (CGS), and capital expenditure (CEX), into operational output (OI) based on stochastic Frontier estimation | COMPUSTAT | Lam et al. (2016) |
| remote work arrangements | Code 1 if a firm has a remote work arrangement in the fiscal year and 0 otherwise | FACTIVA | Lam et al. (2016) |
| Firm size | A firm's total assets based on a logarithmic transformation | COMPUSTAT | Li et al. (2022) |
| ROA | A firm's returns on assets | COMPUSTAT | Ye et al. (2020) |
| ROE | A firm's return on equity | COMPUSTAT | Ye et al. (2020) |
| Firm leverage | Long-term liabilities plus current liabilities over total assets | COMPUSTAT | Ge et al. (2022) |
| Mark-to-book ratio | A firm's market value of equity divided by book value of equity | COMPUSTAT | Li et al. (2022) |

| | | | |
|---|---|---|---|
| Employee relationship | Summing the number of strengths related to employee relationship | KLD | Gambeta et al. (2019) |
| Product differentiation | Operating income over revenues | COMPUSTAT | (Banker et al., 2011) |
| High-tech Industry | Code 1 for high-tech industries (four-digit SIC codes, including 3511–3599, 3612–3699, and 3812–3873) and 0 for other industries | COMPUSTAT | Fan et al. (2022) |
| Industry's remote work number | The total number of remote work firms in the same industry based on a logarithmic transformation | COMPUSTAT, FACTIVA | Boffelli and Johansson (2020) |
| Worldwide attention to remote work | The average SVI value of remote work in the fiscal year | GOOGLE TRENDS | Liu and Tsyvinski (2021) |

### 3.3.3 PSM analysis

I investigated whether a firm's formal remote work policy has a positive impact on operational efficiency. However, a firm's remote work decision is not random and may depend on other internal and external factors (Ketokivi & McIntosh, 2017). Such unforeseen factors might in turn influence firms' operational efficiency, causing potential self-selection bias and endogeneity issues (Ketokivi & McIntosh, 2017). To address this problem, I followed the literature and applied the propensity-score matching technique (PSM, Rosenbaum & Rubin, 1983; Shi et al., 2017; Ye et al., 2020). PSM is a statistical method used to create treatment and control groups by matching individuals based on their likelihood of receiving the treatment. By matching individuals with similar characteristics to the treatment group, a set of quasi-control groups can be obtained. This matching process allows for the control of confounding variables, resulting in the estimation of the net effects between variables (Rosenbaum & Rubin, 1983). In our case, the control firms should have had a similar propensity to adopt a remote work policy as sample firms but eventually did not adopt it.

I first constructed a binary logistic regression model to identify potential factors that affect firms' intention to develop a remote work policy. After obtaining the propensity scores by running the probit model, I applied nearest-neighbor matching to select control firms that have the most similar probability measures as the sample firms (Rosenbaum & Rubin, 1983; Shi et al., 2017).

### 3.3.4 DID analysis

I used the staggered difference-in-difference specifications (DID;(Fan et al., 2022; Lam et al., 2022) to examine the influence of remote work policy on firms' operational efficiency. The staggered DID model is a widely employed method of assessing the impact of a specific policy or initiative by estimating the treatment effect. DID compares differences in operational efficiency between the sample and control firms before and after the remote work policy and estimates the relative changes in those differences. Following the classic DID model (Wooldridge, 2010), the estimated model is as follows:

$$y_{it} = \beta_0 + \beta_1 Treat_i + \beta_2 \boldsymbol{Treat_i \times Post_{it}} + \gamma X_{it} + \delta year_t + \Gamma Industry_j + \varepsilon_{ijt} \quad (3\text{-}3)$$

where the subscripts *i*, *j*, and *t* refer to firm *i*, industry *j*, and year *t*, respectively. $y_{ijt}$ refers to the operational efficiency of firm *i* in industry *j* and year *t*, and $\beta_0$ is the intercept for each firm. $Treat_i$ is a dummy variable, with the sample firms coded as "1" and control firms coded as "0". $Post_{it}$ is also a dummy variable, which is coded as "1" after the policy and "0" before the policy. $\beta_2$ (H1) estimates the interaction between $Treat_i$ and $Post_{it}$, representing the effect of the remote work policy on operational efficiency. $X_{ijt}$ includes the whole set of control variables. $Year_t$ represents the year dummies, and $Industry_j$ represents the industry dummy. $\varepsilon_{ijt}$ is the error term. It is important to acknowledge that including $Post_{it}$ as a separate variable in the model is not necessary because I have already accounted for the effects of the year-fixed effects (Lam et al., 2022).

In addition, to examine the long-term effect of remote work on operational efficiency, I further construct two dummy variables, $Post_{it}$ (0–2) and $Post_{it}$ (3–5), where $Post_{it}$ represents the first 2 years of implementing remote work arrangements in the firm. Specifically, when *t* = 0 to *t* = 2, $Post_{it}$(0–2) is coded as "1," otherwise it is "0." $Post_{it}$(3–5) represents

the third to fifth years of implementing remote work arrangements. If $t = 3$ to $t = 5$, $Post_{it}(3–5)$ is coded as "1," otherwise it is "0." By constructing these two dummies, I can further reveal and compare the long-term impact of remote work arrangements on operational efficiency.

### 3.3.5 DDD analysis

To test the moderating effects, I employed a triple interaction term in the DID model, known as the difference-in-difference-in-difference (DDD) model. The estimated model is as follows:

$$y_{it} = \beta_0 + \beta_1 \boldsymbol{Treat_i} + \beta_2 \boldsymbol{Moderator_{ijt}} + \beta_3 \boldsymbol{Treat_i} \times \boldsymbol{Post_{it}} + \beta_4 \boldsymbol{Treat_i} \times \boldsymbol{Moderator_{ijt}} + \beta_5 \boldsymbol{Treat_i} \times \boldsymbol{Post_{it}} \times \boldsymbol{Moderator_{ijt}} + \gamma X_{ijt} + \delta year_t + \Gamma Industry_j + \varepsilon_{ijt} \quad (3\text{-}4)$$

where $Moderator_{ijt}$ refers to the three moderators of firm $i$ in the industry $j$ and year $t$. $\beta_5$ estimates the triple interaction of $Treat_i \times Post_{it} \times Moderator_{ijt}$, representing the moderating effects of employee relationships (H2), strategic positioning of product differentiation (H3), and high-tech industry (H4). The other variables are the same as those in Equation (3-3).

## 3.4 Results Analysis

### 3.4.1 Descriptive statistics and correlation analysis

After integrating data from different datasets and applying the PSM-DID (Propensity Score Matching - Difference in Differences) analysis, this study obtained a complete sample consisting of 1,769 company-year observations. Tables 3.3 and 3.4 report the descriptive statistics and correlation analysis of the variables involved in this study, respectively. It can be observed that the range of operational efficiency is from 0.021 to 0.993, with an average value of 0.675 and a standard deviation of 0.125. This indicates that the proportion of companies with

high and low operational efficiency is nearly equal in the sample, suggesting that the sample has good representativeness.

Table 3.3 Descriptive statistics in Study 1

| Variables | Mean | SD | Min | Max |
|---|---|---|---|---|
| Operational efficiency | 0.675 | 0.157 | 0.021 | 0.993 |
| Treat | 0.357 | 0.479 | 0 | 1 |
| Post | 0.254 | 0.436 | 0 | 1 |
| Treat*Post | 0.254 | 0.436 | 0 | 1 |
| Firm size | 8.656 | 2.014 | 0.070 | 12.370 |
| ROA | 0.037 | 0.240 | −8.849 | 0.452 |
| ROE | 0.013 | 0.293 | −6.871 | 0.596 |
| Leverage | 0.778 | 2.952 | −9.905 | 14.620 |
| Market-to-book ratio | 0.806 | 2.680 | −9.905 | 14.620 |
| High-tech industry | 0.137 | 0.344 | 0 | 1 |
| Product differentiation | 0.204 | 0.184 | −4.549 | 0.858 |
| Employee relationships | 0.807 | 1.388 | 0 | 8 |
| Industry’s remote work number | 2.216 | 1.237 | 0 | 4.234 |
| Worldwide attention to remote work | 36.670 | 14.540 | 20.170 | 58.420 |

*Notes.* Observation = 1,769.

Table 3.4 Correlation analysis in Study 1

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Operational efficiency | 1 | | | | | | | | | | | | | |
| (2) Treat | 0.014*** | 1 | | | | | | | | | | | | |
| (3) Post | -0.002 | 0.506*** | 1 | | | | | | | | | | | |
| (4) Treat*Post | -0.002 | 0.506*** | 1.000*** | 1 | | | | | | | | | | |
| (5) Firm size | 0.167*** | 0.164*** | 0.108*** | 0.108*** | 1 | | | | | | | | | |
| (6) ROA | 0.040*** | 0.038*** | 0.021*** | 0.021*** | 0.388*** | 1 | | | | | | | | |
| (7) ROE | 0.146*** | 0.044*** | 0.025*** | 0.025*** | 0.219*** | 0.269*** | 1 | | | | | | | |
| (8) Leverage | 0.021*** | 0.010*** | 0.008*** | 0.008*** | 0.212*** | 0.083*** | 0.071*** | 1 | | | | | | |
| (9) Market-to-book ratio | 0.053*** | 0.146*** | 0.091*** | 0.091*** | 0.209*** | 0.153*** | 0.048*** | 0.331*** | 1 | | | | | |
| (10) High-tech industry | -0.034*** | -0.006** | 0.001 | 0.001 | -0.180*** | -0.064*** | -0.009*** | -0.081*** | 0.009*** | 1 | | | | |
| (11) Product differentiation | 0.043*** | 0.032*** | 0.018*** | 0.018*** | 0.244*** | 0.311*** | 0.104*** | 0.058*** | 0.045*** | -0.146*** | 1 | | | |
| (12) Employee relationships | 0.064*** | 0.204*** | 0.104*** | 0.104*** | 0.265*** | 0.052*** | 0.063*** | 0.030*** | 0.182*** | 0.033*** | 0.041*** | 1 | | |
| (13) Industry's remote work number | -0.132*** | 0.130*** | 0.059*** | 0.059*** | 0.018*** | -0.029*** | 0.031*** | -0.031*** | 0.025*** | 0.206*** | -0.038*** | 0.061*** | 1 | |
| (14) Worldwide attention to remote work | 0.033*** | 0.002 | 0.065*** | 0.065*** | 0.056*** | 0.018*** | 0.010*** | 0.014*** | 0.036*** | 0.003 | -0.011*** | -0.018*** | -0.041*** | 1 |

*Notes.* * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

### 3.4.2 PSM results

Table 3.5 illustrates the probit model results for estimating propensity scores. Our results show that the probability of firms' implementing remote work is related to various factors, including large firm size, low financial leverage, high market-to-book ratio, better employee relationships, and more industry peers' remote work arrangements each year. Based on these propensity scores, I conducted one-to-four matching in the year of remote work with a caliper of 0.05 (Fan et al., 2022; Levine & Toffel, 2010). The findings from the balancing test, as shown in Table 3.5, suggest a high level of matching quality. After the PSM, the pseudo-R-squared decreases significantly from 0.242 to 0.003, indicating that the paired groups are similar regarding the pretreatment covariates. The balancing test for covariate differences shows nonsignificant differences between the treatment and control groups. The standardized bias value exhibits a substantial decrease following the matching process, indicating a considerable improvement in matching quality; the means (medians) of standardized bias decline from 50.4% (38.6%) to 2.7% (2.8%).

Table 3.5 Probit model for estimating propensity score in Study 1

| | **Probit Coef.** | **Standard Err.** |
|---|---|---|
| Firm size | 0.2183*** | 0.0107 |
| ROA | 0.0151 | 0.0911 |
| ROE | 0.1136 | 0.0699 |
| Leverage | −0.0364*** | 0.0074 |
| Market-to-book ratio | 0.0000*** | 7.5224 |
| Employee relationships | 0.1366*** | 0.1857 |
| Profit differentiation | 0.0094 | 0.0080 |
| High-tech industry | 0.0187 | 0.1437 |
| Industry's remote work number | 0.1753*** | 0.0267 |
| Worldwide attention to remote work | 0.0735*** | 0.0179 |
| Observations | 49,640 | |
| Pseudo-$R^2$ | 0.3033 | |
| LR chi2(56) = 309.4100 | 2544.12 | |
| Prob > chi2 = 0.0000 | 0.0000 | |

*Notes:* * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 3.6 Balancing test results in Study 1

| | Mean before matching | | | Mean after matching | | |
|---|---|---|---|---|---|---|
| | Treated | Control | T (*p*-value) | Treated | Control | T (*p*-value) |
| Firm size | 8.9497 | 5.8595 | 34.70 (0.000) | 8.9497 | 8.9054 | 0.40 (0.687) |
| ROA | 0.0287 | −0.3353 | 5.45 (0.000) | 0.0287 | 0.0089 | 1.05 (0.294) |
| ROE | 0.0154 | −0.1946 | 6.90 (0.000) | 0.0154 | 0.0139 | 0.16 (0.869) |
| Leverage | 0.8228 | 0.6427 | 2.04 (0.041) | 0.8228 | 0.9235 | −0.69 (0.487) |
| Market-to-book ratio | 1933 | 329.88 | 26.81 (0.000) | 1933 | 2140.8 | −1.14 (0.254) |
| Employee relationships | 0.0267 | 0.0062 | 5.50 (0.000) | 0.0267 | 0.0263 | 0.03 (0.974) |
| Profit differentiation | 0.1129 | −2.8907 | 5.51 (0.000) | 0.1129 | −0.0565 | 1.23 (0.220) |
| High-tech industry | 0.1214 | 0.1567 | −2.77 (0.000) | 0.1214 | 0.1182 | 0.20 (0.844) |
| Industry's remote work number | 2.1209 | 1.3077 | 19.70 (0.000) | 2.1209 | 2.0977 | 0.42 (0.678) |
| Worldwide attention to remote work | 38.504 | 28.565 | 22.62 (0.000) | 38.472 | 38.524 | −0.06 (0.951) |

### 3.4.3 DID results

Table 3.7 reports the DID (Difference in Differences) results of remote working on corporate operational efficiency. Model 1, which includes only control variables, shows that company size, return on assets, and market value significantly affect corporate operational efficiency. Model 2 reports the estimated coefficients of remote working on operational efficiency. The results indicate that, compared to companies that do not implement remote work policies, the implementation of remote working not only fails to enhance corporate operational efficiency but significantly reduces it ($\beta$ = -0.024, $p < 0.01$). Specifically, companies that implement remote working have a 2.4% lower operational efficiency than those that do not. Therefore, the results support Hypothesis 1b and reject Hypothesis 1a, namely, that remote working significantly reduces corporate operational efficiency.

I further found that the negative impact of remote work arrangements on operational efficiency increases over time, suggesting a long-term influence of remote work arrangements. In Model 3, the results show that after the implementation of remote work arrangements, firms' operational efficiency is increasingly reduced. Compared with firms without remote work arrangements, firms implementing remote work arrangements suffer decreased operational efficiency by 1.9% (in their relative position in the industry) in year 0 to year 2 and by 3.0% in year 3 to year 5. Therefore, this study empirically reveals that in the long term, the negative

impact of remote work arrangements on the operational efficiency of firms is gradually exacerbated.

Table 3.7 DID results in Study 1

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Firm size | 0.012*** | 0.012*** | 0.013*** |
| | (0.002) | (0.002) | (0.002) |
| ROA | 0.563*** | 0.546*** | 0.557*** |
| | (0.073) | (0.073) | (0.077) |
| ROE | −0.007 | −0.006 | −0.029 |
| | (0.023) | (0.023) | (0.020) |
| Firm leverage | −0.001 | −0.001 | −0.000 |
| | (0.001) | (0.001) | (0.001) |
| Market-to-book ratio | −0.000*** | −0.000** | −0.000*** |
| | (0.000) | (0.000) | (0.000) |
| Treat | | −0.001 | −0.004 |
| | | (0.009) | (0.009) |
| Treat * Post | | **−0.024*** ** | |
| | | **(0.009)** | |
| Treat * Post(0–2) | | | **−0.019*** |
| | | | **(0.011)** |
| Treat * Post(3–5) | | | **−0.030**** |
| | | | **(0.015)** |
| Year FE | YES | YES | YES |
| Industry FE | YES | YES | YES |
| Constant | 0.590*** | 0.587*** | 0.545*** |
| | (0.052) | (0.053) | (0.071) |
| Observations | 1769 | 1769 | 1769 |
| Adjusted $R^2$ | 0.328 | 0.333 | 0.331 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; post is omitted because of year fixed.

### 3.4.4 DDD results

After applying the DID model to analyze treatment effects, I subsequently employed the DDD model to assess moderating effects. The inclusion of a triple-interaction term in the model captures the impact of the moderators. Model 1 in Table 3.8 shows that the negative impact of remote work arrangements on operational efficiency weakens when firms have better employee relationships ($\beta = 0.021$, $p < 0.01$), **supporting Hypothesis 2.** The result of the moderating effect is consistent with our expectations that firms having strong employee relationships are more likely to benefit from remote work arrangements. Model 2 shows that the negative impact of remote work arrangements on operational efficiency is mitigated when firms have a product differentiation strategy ($\beta = 0.432$, $p < 0.01$); thus, **Hypothesis 3 is supported.** Model 3

demonstrates that the negative influence of remote work arrangements on operational efficiency decreases for firms operating in high-tech industries ($\beta$ = 0.087, p < 0.01), **supporting Hypothesis 4.** These results further show that firms with appropriate operational strategies and characters can benefit from remote work arrangements.

Table 3.8 DDD results in Study 1

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Firm size | 0.008** | 0.013*** | 0.002 |
| | [0.003] | [0.002] | [0.002] |
| ROA | 0.697*** | 0.557*** | 0.323*** |
| | [0.077] | [0.072] | [0.059] |
| ROE | -0.140*** | -0.006 | 0.002 |
| | [0.037] | [0.021] | [0.017] |
| Firm leverage | -0.001 | -0.001 | -0.001 |
| | [0.002] | [0.001] | [0.001] |
| Market-to-book ratio | -0.000** | -0.000** | -0.000** |
| | [0.000] | [0.000] | [0.000] |
| Treat | 0.009 | -0.005 | 0.047*** |
| | [0.014] | [0.009] | [0.015] |
| Treat * Post | -0.058*** | -0.030*** | -0.093*** |
| | [0.017] | [0.010] | [0.018] |
| Employee relationships (ER) | -0.005 | | |
| | [0.005] | | |
| Treat*ER | -0.001 | | |
| | [0.003] | | |
| Treat * Post * ER | **0.021*** ** | | |
| | **[0.007]** | | |
| Profitability (PC) | | -0.163*** | |
| | | [0.053] | |
| Treat*PC | | 0.436*** | |
| | | [0.036] | |
| Treat * Post* PC | | **0.432*** ** | |
| | | **[0.072]** | |
| Hightech | | | 0.030 |
| | | | [0.022] |
| Treat*Hightech | | | -0.020 |
| | | | [0.049] |
| Treat * Post* Hightech | | | **0.087*** ** |
| | | | **[0.025]** |
| Year FE | YES | YES | YES |
| Industry FE | YES | YES | YES |
| Constant | 0.654*** | 0.586*** | 0.630*** |
| | [0.070] | [0.054] | [0.052] |
| Observations | 1769 | 1769 | 1769 |
| Adjusted $R^2$ | 0.398 | 0.341 | 0.473 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; post is omitted because of year fixed.

### 3.4.5 Parallel trends test

To capture the treatment effect, the DID analysis assumed parallel performance trends (Fan et al., 2022; Lam et al., 2022), requiring a common trend in operational efficiency between the treatment control groups before the year of the remote work arrangement. I thus performed a common parallel trend test to examine the difference in operational efficiency between these two groups by employing the following model:

$$Operational\ Efficiency_{ijt} = \beta_0 + \sum_t \boldsymbol{\beta_t}\, \boldsymbol{Treat_i} \times \boldsymbol{Year_t} + \gamma X_{ijt} + \delta year_t + \Gamma Industry_j + \varepsilon_{ijt} \quad (3\text{-}5)$$

where $Year_t$ refers to the number of years relative to the remote work year. For example, if a firm implemented remote work arrangements in 2015, the corresponding time indicators would be $t = -2$ for 2013, $t = -1$ for 2014, $t = 1$ for 2016, and $t = 2$ for 2017. $year_t$ is a dummy variable that indicates 1 in year $t$ and 0 otherwise. $Treat_i$ equals 1 if firm $i$ has announced a remote work policy in the analyzing period and 0 otherwise. The other variables are the same as in our main analysis. I set (−6, +6) years relative to the year of remote work as our period of analysis. The benchmark group is the year prior to the remote work year.

I presented the parallel trend results in Table 3.9 and depicted the estimated coefficients and confidence intervals with respect to the number of years relative to remote work year in Figure 1. Table 7 reveals that the coefficients for the previous 6 years against the relative year of remote work are nonsignificant ($p > 0.1$). Results shown in Figure 1 suggest no pretreatment differences in operational efficiency between the paired groups with the corresponding 95% confidence intervals, which supports the parallel trends assumption. Additionally, Table 3.9 demonstrates that the estimation effects for the years after the year of remote work arrangements are significantly negative. In particular, the negative impact on operational efficiency increased over time. Similarly, results in Figure 3.2 demonstrate that 1 year after the implementation of remote work, operational efficiency showed a significant downward trend.

In the long term, the negative impact of remote work on the operational efficiency of firms gradually increases. Therefore, the finding of the parallel trend test is consistent with the main analysis results of this study, which further confirms the robustness of the results.

Table 3.9 Results of parallel trend test in Study 1

| | Operational efficiency | |
|---|---|---|
| Independent variable | Estimate | SE |
| Year (t−6) * Treat | 0.011 | (0.014) |
| Year (t−5) * Treat | −0.020 | (0.022) |
| Year (t−4) * Treat | −0.013 | (0.021) |
| Year (t−3) * Treat | −0.033 | (0.023) |
| Year (t−2) * Treat | 0.009 | (0.020) |
| Year (t) * Treat | −0.016 | (0.013) |
| Year (t+1) * Treat | **−0.023**$^{*}$ | **(0.013)** |
| Year (t+2) * Treat | **−0.039**$^{*}$ | **(0.020)** |
| Year (t+3) * Treat | **−0.046**$^{**}$ | **(0.021)** |
| Year (t+4) * Treat | **−0.049**$^{**}$ | **(0.022)** |
| Year (t+5) * Treat | **−0.062**$^{**}$ | **(0.030)** |
| Year (t+6) * Treat | **−0.029**$^{*}$ | **(0.016)** |
| Firm size | 0.015$^{***}$ | (0.002) |
| ROA | 0.114 | (0.107) |
| ROE | −0.006 | (0.009) |
| Leverage | 0.006$^{***}$ | (0.002) |
| Market-to-book ratio | −0.000 | (0.000) |
| Year dummy | YES | |
| Industry dummy | YES | |
| Constant | 0.850$^{***}$ | (0.025) |
| Observations | 1769 | |
| Adjusted $R^2$ | 0.299 | |

*Note*. Standard errors in parentheses. $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

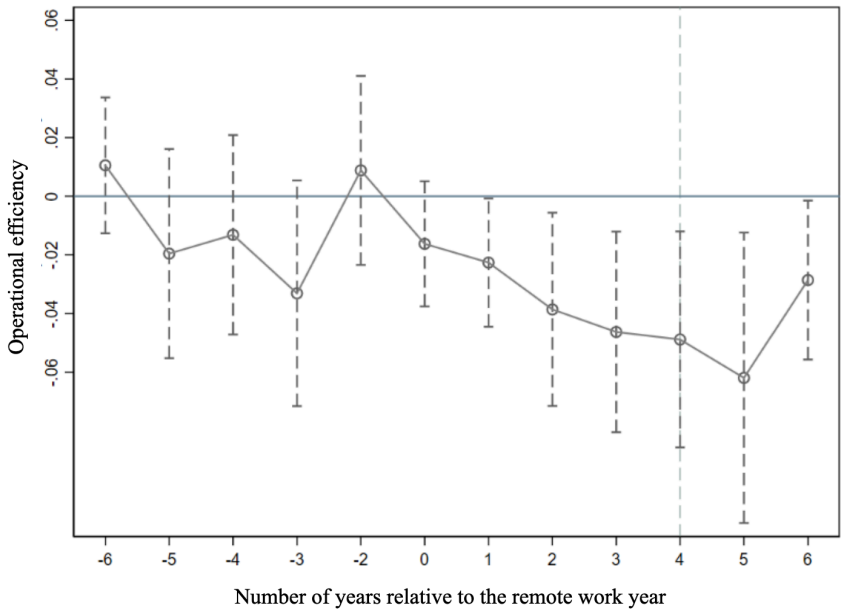


Figure 3.2 The parallel trend test plot in Study 1

### 3.4.6 Placebo test

I conducted a placebo test as an additional check. Following prior studies (Fan et al., 2022; Lam et al., 2022; Liu & Lu, 2015), I randomly generated false years of firms' remote work announcements during our sample period (2010–2020) and randomly selected 275 firms to be fake treated firms that make remote work arrangements. If firms with actual remote work arrangements can reduce operational efficiency, I expect that the falsified estimated coefficients should be insignificant and far from our true coefficients. I repeated the whole process of DID estimation 1,000 times and plotted the coefficients of fake Treat*Post in Figure 3.3. The results in Figure 3.3. revealed that the majority of estimated coefficients derived from false remote work announcements predominantly concentrate around zero and significantly deviate from the actual coefficient (−0.024), which is marked as a vertical dashed line. The majority of the *p*-values are larger than those of the real coefficients. The placebo test results further show that our findings are likely to be a true effect.

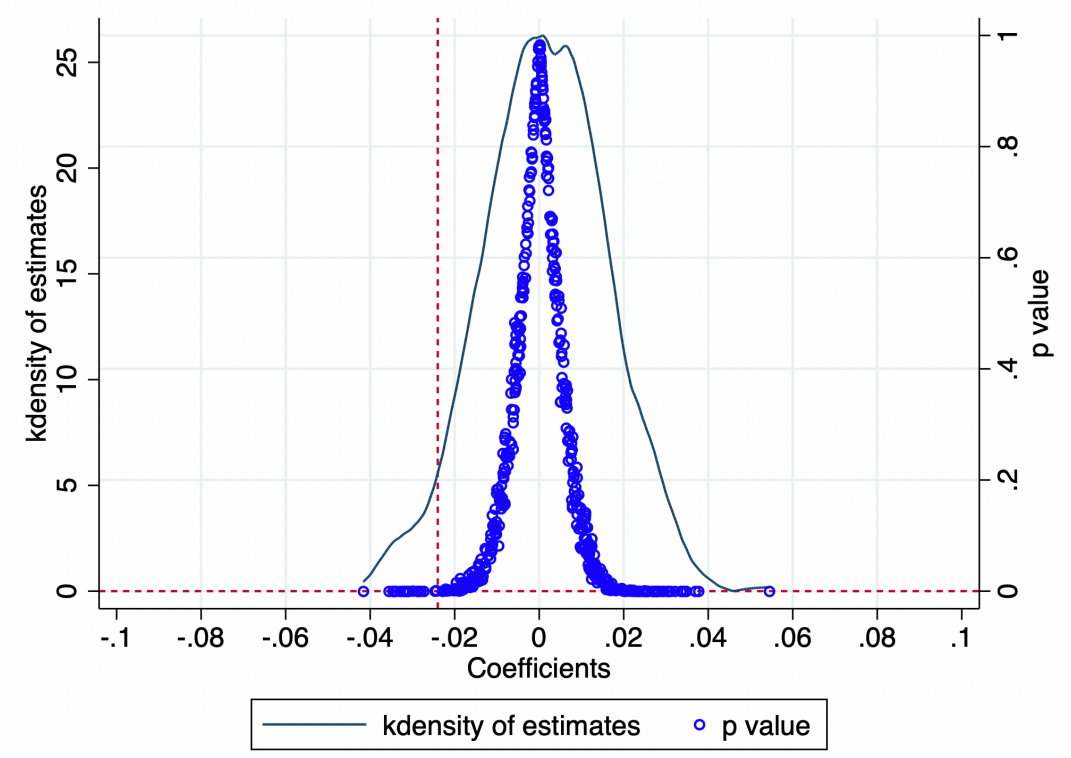


Figure 3.3 The placebo test plot in Study 1

### 3.4.7 Robustness and sensitivity checks

In this section, I employed a range of methodologies to investigate the robustness and sensitivity of the findings through alternative analysis periods, alternative measurements, and alternative dependent variables.

***Alternative Analyzing Period***

I examined the robustness of our results by using data from different periods to perform PSM-DID analysis. The COVID-19 pandemic in 2020 forced firms to make remote work arrangements, which might make a difference in firms' operational efficiency. I thus adjusted the sample data by using data before COVID-19, eliminating the data after 2020. I got the same results after rerunning the PSM-DID analysis (see Table 3.10), suggesting that our results are robust and free from the pandemic.

Table 3.10 Robustness test: Alternative analyzing period

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Firm size | 0.015*** | 0.010*** | 0.015*** | 0.004 |
| | [0.003] | [0.004] | [0.003] | [0.003] |
| ROA | 0.012 | 0.727*** | 0.012 | -0.102*** |
| | [0.007] | [0.085] | [0.007] | [0.014] |
| ROE | 0.057*** | -0.132*** | 0.060*** | 0.049*** |
| | [0.012] | [0.047] | [0.012] | [0.010] |
| Firm leverage | -0.001 | 0.002 | -0.001 | -0.001 |
| | [0.002] | [0.002] | [0.002] | [0.002] |
| Market-to-book ratio | -0.000 | -0.000** | -0.000 | -0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Treat | 0.003 | 0.004 | -0.004 | 0.032 |
| | [0.010] | [0.014] | [0.010] | [0.020] |
| Treat * Post | **-0.019*** | -0.047*** | -0.023** | -0.063*** |
| | **[0.011]** | [0.017] | [0.012] | [0.024] |
| Employee relationships (ER) | | -0.006 | | |
| | | [0.005] | | |
| Treat*ER | | 0.001 | | |
| | | [0.003] | | |
| Treat * Post * ER | | **0.022***** | | |
| | | **[0.007]** | | |
| Profitability (PC) | | | -0.107 | |
| | | | [0.073] | |
| Treat*PC | | | 0.482*** | |
| | | | [0.053] | |
| Treat * Post* PC | | | **0.364***** | |
| | | | **[0.093]** | |
| Hightech | | | | 0.046* |
| | | | | [0.024] |
| Treat*Hightech | | | | 0.125*** |

| | | | | |
|---|---|---|---|---|
| | | | | [0.027] |
| Treat * Post* Hightech | | | | **0.075**$^{***}$ |
| | | | | **[0.023]** |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Constant | 0.474$^{***}$ | 0.501$^{***}$ | 0.470$^{***}$ | 0.509$^{***}$ |
| | [0.111] | [0.115] | [0.111] | [0.107] |
| Observations | 1318 | 1318 | 1318 | 1318 |
| Adjusted $R^2$ | 0.291 | 0.378 | 0.299 | 0.430 |

*Note*. Standard errors in parentheses; $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

***Alternative Measurement of Operational Efficiency***

Following the approach of Li et al. (2022), I involved alternative measurement of operational efficiency by using a nonlinear stochastic function. More specifically, I constructed the squared and interaction terms among NOE, CGS, and CE in Equation (3-2) as follows, and I obtained consistent results with our main analysis. The results appear in Table 3.11.

$$\ln(OI)_{ijt} = \alpha_0 + \alpha_1 \ln(NOE)_{ijt} + \alpha_2 \ln(CGS)_{ijt} + \alpha_3 \ln(CE)_{ijt} + \alpha_4 \ln(NOE)_{ijt}{}^2 + \alpha_5 \ln(CGS)_{ijt}{}^2 + \alpha_6 \ln(CE)_{ijt}{}^2 + \alpha_7 \ln(NOE)_{ijt} \times \ln(CGS)_{ijt} + \alpha_8 \ln(NOE)_{ijt} \times \ln(CE)_{ijt} + \alpha_9 \ln(CGS)_{ijt} \times \ln(CE)_{ijt} + \varepsilon_{ijt} - \eta_{ijt} \quad (3\text{-}6)$$

Table 3.11 Robustness test: Alternative measurements of operational efficiency

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Firm size | 0.020$^{***}$ | 0.023$^{***}$ | 0.020$^{***}$ | 0.008$^{***}$ |
| | [0.003] | [0.004] | [0.003] | [0.003] |
| ROA | 0.008 | 0.719$^{***}$ | 0.008 | -0.058$^{***}$ |
| | [0.010] | [0.107] | [0.010] | [0.016] |
| ROE | 0.123$^{***}$ | -0.040 | 0.124$^{***}$ | 0.130$^{***}$ |
| | [0.047] | [0.029] | [0.046] | [0.043] |
| Firm leverage | -0.001 | 0.001 | -0.000 | -0.001 |
| | [0.002] | [0.002] | [0.002] | [0.002] |
| Market-to-book ratio | 0.000 | -0.000 | 0.000 | 0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Treat | 0.000 | 0.013 | -0.001 | 0.007 |
| | [0.012] | [0.016] | [0.013] | [0.035] |
| Treat * Post | **-0.024**$^{**}$ | -0.050$^{***}$ | -0.032$^{***}$ | -0.096$^{***}$ |
| | **[0.012]** | [0.018] | [0.012] | [0.033] |
| Employee relationships (ER) | | -0.009 | | |
| | | [0.006] | | |
| Treat*ER | | -0.004 | | |
| | | [0.004] | | |
| Treat * Post * ER | | **0.022**$^{***}$ | | |
| | | **[0.006]** | | |
| Profitability (PC) | | | 0.050 | |
| | | | [0.126] | |
| Treat*PC | | | 0.304$^{***}$ | |

| | | | | |
|---|---|---|---|---|
| | | | [0.091] | |
| Treat * Post* PC | | | **0.499**$^{***}$ | |
| | | | **[0.120]** | |
| Hightech | | | | 0.029 |
| | | | | [0.022] |
| Treat*Hightech | | | | 0.009 |
| | | | | [0.093] |
| Treat * Post* Hightech | | | | **0.055**$^{**}$ |
| | | | | **[0.024]** |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Constant | 0.490$^{***}$ | 0.528$^{***}$ | 0.492$^{***}$ | 0.406$^{***}$ |
| | [0.095] | [0.040] | [0.095] | [0.073] |
| Observations | 1525 | 1525 | 1525 | 1525 |
| Adjusted $R^2$ | 0.266 | 0.389 | 0.270 | 0.394 |

*Note*. Standard errors in parentheses; $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

### *Alternative Dependent Variables*

Given that remote work arrangements reduce operational efficiency, it is necessary to investigate whether remote work arrangements reduce a firm's actual financial profitability (Lam, 2018). I examined additional dependent variables (ROA) to examine the effect of remote work arrangements on firms' economic influence. Results shown in Model 1 and Model 2 (Table 3.12) illustrate that the impact of remote work arrangements significantly reduced firms' ROA, and such a negative impact gradually increased over the long term. Additionally, I also replicate our baseline analyses using operating income as dependent variables to check the robustness of our results. Models 3 and 4 in Table 3.12 illustrate that the results are consistent with our baseline analysis, further supporting our findings. Taken together, our results reveal that our findings are robust, and firms adopting remote work arrangements in the long term may gain work flexibility at the expense of efficiency and economic gains. These findings enable us to have a more comprehensive view of the long-term influence of remote work on a firm's performance.

Table 3.12 Robustness test: Alternative dependent variables

| | DV: ROA | | DV: Operating Income | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Treat * Post | **−0.022**$^{***}$ | | **−0.041**$^{***}$ | |
| | **(0.006)** | | **(0.009)** | |
| Treat * Post(0–2) | | **−0.014**$^{**}$ | | **−0.029**$^{***}$ |
| | | **(0.007)** | | **(0.007)** |
| Treat * Post(3–5) | | **−0.025**$^{***}$ | | **−0.036**$^{***}$ |
| | | **(0.008)** | | **(0.007)** |
| Controls | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Observations | 2519 | 2519 | 2519 | 2519 |
| Adjusted $R^2$ | 0.117 | 0.116 | 0.489 | 0.484 |

*Note*. Standard errors in parentheses; $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

### 3.4.8 Further analysis

Remote work announcements obtained from Factiva can be considered policy-level data of firms' remote work arrangements. Although I have double-checked the actual practice of firms' remote work arrangements by examining archival documents and searching historical web pages (archived online), the measure of remote work via searching announcements still have limitations that cannot capture the actual remote work implementation of firms at practice levels. Based on this, I employed another remote work database from the FlexJobs website (https://www.flexjobs.com/) to capture the practical-level data of remote work.

Specifically, I refer to the firms' awards data for remote jobs based on FlexJobs, which is a comprehensive job search website providing access to flexible and remote job opportunities that offer work-life balance. FlexJobs has an extensive network of reputable employers looking to hire remote and flexible employees, catering to a wide range of industries such as health care, education, marketing, and customer service. With its top-notch reputation, FlexJobs is a vital platform for job seekers looking for flexible work environments, serving as an indispensable tool for both employers and job seekers.

FlexJobs has annually announced the one hundred leading companies providing remote job opportunities since 2014. By meticulously examining the remote job posting records of over 54,000 companies documented in their database, they have successfully identified companies that offer an exceptional number of positions conducive to remote work. The companies are chosen based on several factors, including the number of remote job listings they have posted on FlexJobs, their history of offering remote work, the overall quality of their remote job offerings, and other criteria related to workplace flexibility. By leveraging the data from FlexJobs, I can capture the actual impact of remote work implementation in practice.

Therefore, I hand-coded the data by searching the top one hundred companies with remote jobs annually listed in FlexJobs from 2014 to 2022. I generated two variables: *Award* and *Point*. Award is a dummy variable, and I coded it as 1 if the focal firm received the Top 100 FlexJobs award in the fiscal year, and 0 otherwise. Then I generated the Point variable. According to the annual ranking of the top one hundred companies with strong remote work performance on the FlexJobs website, I assigned these one hundred firms scores ranging from 1 to 100. The top-ranking position was awarded 100 points, the subsequent position received 99 points, with a progressive decrement pattern continuing thereafter, and the 100th position was allocated 1 point. I log-transformed the points in our analysis.

Table 3.13 shows the regression analysis results using FlexJobs data (Award) as an alternative measure of remote work. Consistent with our baseline results, results in Table 3.13 illustrate that firms receiving remote work awards from FlexJobs may damage their operational efficiency ($\beta = -0.024$, $p < 0.01$). Additionally, firms having good employee relationships ($\beta = 0.024$, $p < 0.01$), pursuing product differentiation strategy ($\beta = 0.401$, $p < 0.01$), and belonging to the high-tech industry ($\beta = 0.058$, $p < 0.01$) can significantly reduce the negative impact of remote work awards on operational efficiency, further supporting our baseline findings.

Table 3.13 Results of using FlexJobs data (Award)

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Firm size | 0.019*** | 0.019*** | 0.019*** | 0.020*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROA | -0.005*** | -0.005*** | -0.005*** | -0.002 |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| ROE | 0.041*** | 0.041*** | 0.041*** | 0.042*** |
| | [0.002] | [0.002] | [0.002] | [0.003] |
| Firm leverage | -0.002*** | -0.002*** | -0.002*** | -0.002*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Market-to-book ratio | 0.000 | 0.000 | 0.000 | 0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Award | **-0.024*** ** | -0.023*** | -0.027*** | -0.094*** |
| | **[0.007]** | [0.007] | [0.008] | [0.015] |
| Employee relationships (ER) | | 0.009* | | |
| | | [0.005] | | |
| Award * ER | | **0.024*** ** | | |
| | | **[0.006]** | | |
| Profitability (PC) | | | 0.000* | |
| | | | [0.000] | |
| Award * PC | | | **0.401*** ** | |
| | | | **[0.066]** | |
| High-tech industry | | | | -0.347*** |
| | | | | [0.006] |
| Award * High-tech | | | | **0.058*** ** |
| | | | | **[0.015]** |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Constant | 0.869*** | 0.869*** | 0.869*** | 0.860*** |
| | [0.006] | [0.006] | [0.006] | [0.006] |
| Observations | 31867 | 31867 | 31867 | 31867 |
| Adjusted $R^2$ | 0.335 | 0.335 | 0.335 | 0.347 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3.14 shows the results of using FlexJobs data (Point) as an alternative measurement of remote work. Model 1 suggests a significant and negative relationship between remote work and operational efficiency ($\beta = -0.006$, $p < 0.01$). Models 2–4 show the results of moderating roles of employee relationships ($\beta = 0.005$, $p < 0.01$), product differentiation strategy ($\beta = 0.102$, $p < 0.01$), and high-tech industry ($\beta = 0.015$, $p < 0.01$), which are also aligned with our baseline findings. To sum up, using FlexJobs data as an alternative measurement of remote work further shows our findings are robust.

Table 3.14 Results of using FlexJobs Data (Point)

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Firm size | 0.019*** | 0.019*** | 0.020*** | 0.019*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROA | -0.005*** | -0.005*** | -0.002 | -0.005*** |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| ROE | 0.041*** | 0.041*** | 0.042*** | 0.041*** |
| | [0.002] | [0.002] | [0.003] | [0.002] |
| Firm leverage | -0.002*** | -0.002*** | -0.002*** | -0.002*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Market-to-book ratio | 0.000 | 0.000 | 0.000 | 0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Point | **-0.006*** ** | -0.006*** | -0.024*** | -0.007*** |
| | **[0.002]** | [0.002] | [0.004] | [0.002] |
| Employee relationships (ER) | | 0.009* | | |
| | | [0.005] | | |
| Point * ER | | **0.005*** ** | | |
| | | **[0.001]** | | |
| Profitability (PC) | | | 0.000* | |
| | | | [0.000] | |
| Point * PC | | | **0.102*** ** | |
| | | | **[0.017]** | |
| High-tech industry | | | | -0.347*** |
| | | | | [0.006] |
| Point * High-tech | | | | **0.015*** ** |
| | | | | **[0.004]** |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Constant | 0.869*** | 0.869*** | 0.860*** | 0.869*** |
| | [0.006] | [0.006] | [0.006] | [0.006] |
| Observations | 31867 | 31867 | 31867 | 31867 |
| Adjusted $R^2$ | 0.335 | 0.335 | 0.347 | 0.335 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## 3.5 Discussion and Conclusion

### 3.5.1 Results discussion

#### （1） Impacts of remote work on firms' operational efficiency

The study finds that remote working negatively impacts corporate operational efficiency; companies that implement remote working arrangements have an operational efficiency 2.4% lower than those that do not. This conclusion aligns with previous research exploring the relationship between remote working and productivity. Most past studies have found that remote working positively influences individual efficiency (e.g., Bloom et al., 2015; Choudhury et al., 2021; McDermott & Hansen, 2021). However, some research has revealed

negative outcomes between remote working and individual productivity (Gibbs et al., 2023; Shen, 2023). For example, Emanuel and Harrington (2021) observed that the productivity of call center employees at a large U.S. company who switched to remote working during the pandemic was significantly lower than when working in the office. Shen (2023) also found that the output of GitHub platform users was lower during the pandemic. Gibbs et al. (2023) reported that although the working hours of employees at an Asian IT company increased with remote working, their productivity decreased. It is evident that past research still presents inconsistent conclusions. These studies primarily focus on assessing individual productivity, are often limited to a single company's context, or only consider the short-term impacts during the pandemic, lacking comprehensive, long-term, and general conclusions about the effects of remote working on corporate operational efficiency at the enterprise level.

I reveal that firms implementing remote work may suffer from operational efficiency reductions in the long term. One possible explanation is that coordination, communication, and collaboration, which are core to operational efficiency, may be undermined under remote work. Although remote work can maintain the features of a modern workplace, aspects such as face-to-face collaboration and coaching cannot easily be replicated in a virtual environment (Allen et al., 2015; Gibbs et al., 2023). Firms' operational efficiency may rely on socially complex and operationally sophisticated elements of firms' resources, routines, and capabilities (Lam et al., 2016). The development of these characteristics results from dynamic interactions among various internal sources and systems of firms. Consequently, a firm's ability to attain optimal operational efficiency is established through the dynamic exchange of communication and information among its employees and entire organizational systems. However, remote work arrangements resulted in the collaborative network of employees becoming more static and isolated. For example, Yang et al. (2022) revealed that remote work significantly decreased synchronous communication and increased asynchronous communication, which undermined

effective communication and information sharing within and across firms. Firms' routines and operations may be disturbed in the long run, impeding their operational efficiency.

In addition, focus time (time spent working without distractions) and various social indicators (i.e., family harmony) can be important predictors of productivity. The literature has shown that remote work may trigger family-to-work conflict (Zhang et al., 2020) and blur the boundaries between work and life (Adisa et al., 2022). As a result, employees working at home cannot guarantee effective focus time. In particular, researchers have found that there exist significant gender differences in employee outputs. Female workers' productivity is more prone to decline when they work at home because of childcare and household responsibilities (Allen et al., 2015). The removal of instrumental and emotional support may intensify workloads, and social disconnection may also reduce employee productivity, thus hindering firms' operational efficiency.

**（2）The moderating roles of MAO factors**

This study delves into the relationship between remote working and corporate operational efficiency, examining the moderating effects of factors within the Motivation-Ability-Opportunity (MAO) framework. First, the research finds that employee relations positively moderate the relationship between remote working and operational efficiency. Specifically, companies with good employee relationships can mitigate the negative impact of remote working on operational efficiency. In line with the study's hypotheses, good employee relations provide a foundation for the implementation of remote working. Drawing on stakeholder theory, when the needs and expectations of stakeholders are met, companies can more smoothly implement changes and strategies. This conclusion highlights the critical role of stakeholders, especially employees, in the implementation process of remote working (Flammer & Kacperczyk, 2016; Gambeta et al., 2019). Maintaining positive employee relations helps build a psychological contract between the company and its employees, sparking intrinsic motivation

and self-discipline (Gambeta et al., 2019), thus ensuring employees remain efficient under a remote working model.

Secondly, the study finds that corporate profitability positively moderates the relationship between remote working and operational efficiency. More specifically, companies with higher profitability can effectively alleviate the negative impact of remote working on operational efficiency. Corporate profitability is a comprehensive reflection of overall competitiveness (Maury, 2018; Mithas et al., 2012; Seiford & Zhu, 1999; Shah & Shin, 2007; Yee et al., 2008), demonstrating a company's advantage and efficiency in resource allocation, financial operations, and market competition. This finding supports the resource dependence theory perspective. Remote working may cause a dispersion of organizational resources, especially in information, technology, and human resources. However, companies with higher profitability often have more abundant resource reserves and can invest more in remote working infrastructure and technology. Through these investments, companies can mitigate productivity losses due to resource dispersion, manage and allocate resources more effectively, and thus enhance operational efficiency. In other words, a good profitability status provides robust resource support, allowing companies to maintain or even improve their operational efficiency while implementing remote working (Hillman et al., 2009; Singh et al., 2011).

Thirdly, the results show that the high-tech industry positively moderates the relationship between remote working and operational efficiency. This finding aligns with the MAO theoretical framework, which suggests that organizations need favorable conditions or opportunities to implement actions and strategies. Consistent with the study's hypotheses, companies in the high-tech industry have distinct advantages in implementing remote working arrangements (Shen, 2023). Several reasons contribute to this: firstly, the nature of work in high-tech companies, centered around technological innovation and research and development, differs from traditional factory assembly line operations and is highly dependent on knowledge

and innovation (Bai et al., 2021; Decker et al., 2020; Heckler, 2005). In these companies, employee responsibilities often focus on independent thinking and developing innovative solutions, making the flexibility of remote working highly compatible with the work characteristics of high-tech companies. Moreover, high-tech companies possess the digital resources required for remote working. These companies are typically equipped with advanced digital information technologies and communication tools, providing a solid technical foundation for remote working (Yang et al., 2022). This means that in high-tech companies, employees can use these digital resources more efficiently to complete work tasks. Lastly, the cultural backdrop of high-tech companies highly aligns with remote working. High-tech companies tend to have an open organizational culture that promotes autonomous innovation and self-motivation among employees. Remote working provides a flexible work environment where employees can independently schedule work and rest without the constraints of a traditional office, further enhancing creativity and self-drive.

### 3.5.2 Theoretical implications

The theoretical contributions of this study are significant in two main aspects: First, this research investigates the impact of remote working on corporate operational efficiency, providing empirical findings with universal applicability regarding the relationship between remote working and operational efficiency at the corporate level. It also unveils the long-term negative effects of remote working on operational efficiency, thus enriching the empirical research related to remote working and operational management. This contribution is vital as it not only addresses a gap in the current literature but also challenges the prevailing assumption that remote working invariably leads to improved productivity by showing its potential downsides at the organizational level.

Second, by integrating the Motivation-Ability-Opportunity (MAO) theoretical framework, this study deepens the understanding of the contextual factors affecting the relationship

between remote working and operational efficiency. It explores how factors related to motivation, ability, and opportunity moderate this relationship, identifying effective mechanisms and situational factors that can mitigate the adverse effects of remote working on operational efficiency. This aspect of the study enriches its theoretical boundaries by offering insights into how different conditions and capacities within a company influence the outcomes of remote working policies. Such findings are crucial for organizations considering or optimizing remote working arrangements, providing them with a nuanced understanding of when and how remote working might benefit or hinder their operations.

### 3.5.3 Managerial implications

I offer firm-level evidence to the question that is important to operations managers: What is the long-term influence of remote work arrangements on firms' efficiency? The empirical results of our study illustrate the significance of the long-term rather than the short-term impact of remote work arrangements. Such a long-term view becomes even more important in the post-pandemic era with increasing debate and concerns on whether to implement remote work in the long term or return to offices (Shen, 2023). Our study helps address such concerns by guiding practitioners on how remote work influences operational efficiency and how firms might mitigate such long-term negative impacts from remote work arrangements.

Our empirical results alert firms to keep the potential long-term damage to the operational efficiency of remote work arrangements in mind. Firms should be mindful that remote work arrangements may damage firms' operational efficiency in the long term, but this negative effect can be reduced if firms take positive and effective actions. Specifically, managers should be aware that different operating strategies and characteristics can influence the effectiveness of remote work arrangements. Firms need to consider their operational strategies and characteristics when implementing remote work in their firms and determining their optimal remote work portfolio. This includes establishing strong employee relationships,

adopting a product differentiation strategy, and thoroughly assessing the specifics of their industry to determine the most effective remote work setup for their needs.

Despite remote work arrangements' having a negative influence on operational efficiency, it seems unrealistic to suggest firms should stop all kinds of remote work alternatives for the sake of long-term operational efficiency. Because remote work is increasingly expected by both employees and society, I still believe more and more firms will implement related policies as a future working mode. Therefore, instead of suggesting a complete termination of remote work, I contend it is imperative for both firms and policymakers to acknowledge the potential unfavorable consequences associated with remote work arrangements (e.g., operational efficiency damage) and develop appropriate operational strategies to allow firms to benefit from remote work arrangements.

# Chapter 4 Study 2: Impact of Remote Work Arrangements on Firms' Innovation Performance: The Moderating Roles of Slack Resource and Growth Opportunity

## 4.1 Introduction

Innovation has been well recognized as a crucial component of firms' competitive strategies (Banbury & Mitchell, 1995; Yanadori & Cui, 2013). It is also fundamental to firms' vitality and long-term development goals in the digital economy era (Lerner et al., 2011; Ortiz-Villajos & Sotoca, 2018). Remote work, as a new work model under the backdrop of the digital economy, is playing an increasingly significant role in boosting corporate innovation performance. For instance, high-tech companies such as Amazon, Apple, and Google have implemented remote work programs as a means to stimulate the creativity of their knowledge-based employees (Agarwal & Ohyama, 2013; Choudhury et al., 2021; Kryscynski, 2021; Sauermann & Cohen, 2010).

However, debates still exist in previous research regarding the relationship between remote working and corporate innovation performance. Some studies indicate that remote work may hinder internal knowledge sharing and transfer, thereby suppressing the cultivation of innovation capabilities (Hinds & Mortensen, 2005; Taskin & Bridoux, 2010; Yang et al., 2022). On the other hand, other studies suggest that remote work can have a positive impact on new product development by promoting cross-departmental collaboration (Berchicci et al., 2016; Coenen & Kok, 2014).

Research on the impact of remote working on innovation performance still has significant gaps, and remains in its early stages (Konrad-Maerk, 2023; Xiao et al., 2021). Previous research has primarily been conceptual or based on case studies, lacking empirical evidence. Some studies focus on the innovation performance of remote working teams or individuals, with a

lack of exploration at the corporate level (Berchicci et al., 2016; Gassmann & Von Zedtwitz, 2003; Silva & Merino, 2017). For example, X. Wang et al. (2020) explored the impact of the COVID-19 lockdowns on TikTok platform users in terms of content creation, finding that content creators in locked-down areas published significantly more content than those in non-locked-down areas. Although this study explored the positive impact of remote work on the quantity of innovation, it focused on the impact of remote work on individual creativity during the pandemic context, lacking a general examination of remote work's impact on corporate-level innovation performance. Furthermore, the empirical study by Xiao et al. (2021) found that longer commuting times are associated with poorer corporate innovation performance. However, this study only considered the physical commuting distance and did not explore the true impact of remote work (which does not require commuting) on innovation. Therefore, empirical research on the impact of remote work on corporate-level innovation performance remains scarce. This study aims to explore the effects of remote work on firms' innovation performance (innovation quantity and quality) to fill the empirical research gap in the relationship between remote work and innovation performance.

Knowledge search view posits that firms generate new knowledge by driving search motivation, broadening search breadth, and deepening search depth (Ferreras-Méndez et al., 2015; Laursen & Salter, 2006; Terjesen & Patel, 2017). Search motivation refers to the sum of the intrinsic psychological factors and external conditions that drive an individual or organization to actively seek, acquire, and utilize knowledge. Effective knowledge search behavior typically results from a combination of intrinsic and extrinsic motivations. Intrinsic motivation enhances the interest and internal drive of individuals or organizations toward knowledge search, while extrinsic motivation provides the conditions for such searches. Search motivation is considered the initial condition and key driving force for knowledge search behavior. Search breadth refers to the diversity and extent of knowledge sources involved in

the knowledge exploration process; while search depth refers to the thoroughness with which an enterprise explores and utilizes various knowledge sources (Chen et al., 2022; Laursen & Salter, 2006). Drawing on the knowledge search theory, this study suggests that remote work enhances corporate innovation in terms of both quantity and quality by stimulating employees' motivation for knowledge search, broadening the breadth of knowledge search, and deepening the depth of knowledge search (Choudhury et al., 2021; Mariani & Nambisan, 2021; Xiao et al., 2021).

Furthermore, the knowledge search theory indicates that the mere process of knowledge search may not be sufficient to support successful corporate innovation. Enterprises need to make significant efforts to assimilate and utilize knowledge in order to generate innovation (Savino et al., 2017). Existing literature shows that an organization's slack resource and growth opportunity affect its efforts toward innovation (Chen et al., 2022; Savino et al., 2017). Slack resource represents the current financial resources of the company, and growth opportunity represents the future growth prospects of the company. However, firms with excessive slack resources tend to utilize existing resources rather than actively seek new avenues for innovation (Chen et al., 2022; Jia et al., 2023), thus hindering their efforts to leverage remote work for knowledge acquisition. Conversely, growth opportunity mitigates the firm's risk-averse attitude towards innovative projects (Chen et al., 2022; Miroshnychenko et al., 2020). When employees believe their company has greater growth opportunities, they adopt a more positive and optimistic attitude towards the firms' future development (Yanadori & Cui, 2013), motivating them to invest more effort into innovation activities through remote work. Based on this, the study further explores how slack resource and growth opportunity moderate the relationship between remote work and corporate innovation performance.

Therefore, this study aims to answer two research questions: (1) How does remote work affect firms' innovation performance (both in terms of innovation quantity and quality)? (2)

How do slack resource and growth opportunity moderate the relationship between remote work and firms' innovation performance? This study uses panel data, collecting secondary data from multiple datasets. I employ a negative binomial fixed effect regression and incorporate a difference-in-difference (DID) approach among other econometric models to validate the relationship between remote work and innovation performance. Specifically, I utilize patent information from the United States Patent and Trademark Office (USPTO) to measure the quantity and quality of corporate innovation (Babina et al., 2024; Bernstein, 2015; Xiao et al., 2021). Remote work announcements at the corporate level are obtained from the Factiva database. Meanwhile, slack resource and growth opportunity are measured using the Compustat database (Chen et al., 2022; Yanadori & Cui, 2013), along with other financial data of the firms. Additionally, I employ various methods to further verify the robustness of the results, including using alternative dependent variables, Heckman two-stage estimation, two-stage residual inclusion (2SRI), and lagged dependent variables.

The findings reveal that remote work positively affects both innovation quantity and quality. Slack resource negatively moderates the relationship between remote work and innovation performance, while growth opportunity positively moderates this relationship. The conclusions of this study offer significant theoretical contributions and practical implications. First, this study applies the knowledge search theory to understand the impact of remote work on firms' innovation performance and identify the contextual factors, thereby enriching the application of the knowledge search theory in remote work studies and extending the theoretical boundaries. Second, the study enriches previous studies by exploring the impact of remote work on firms' innovation performance. Specifically, the findings are based on panel data at the corporate level, empirically revealing the positive effects of remote work on both the quantity and quality of corporate innovation, and deepening the understanding of the relationship between remote work and corporate innovation performance. Third, by exploring

how slack resource and growth opportunity moderate the relationship between remote work and innovation performance, this study enriches the understanding of the contextual factors for remote work and innovation performance. This study identifies factors that inhibit and promote the enhancement of corporate innovation performance through remote work, which provides valuable insights for businesses and policymakers to effectively utilize remote work to stimulate corporate innovation performance.

## 4.2 Theoretical Background and Hypothesis Development

### 4.2.1 Knowledge search view

Knowledge search view is an important theoretical framework for explaining and understanding how organizations acquire and utilize new knowledge to foster innovation and enhance performance (Ferreras-Méndez et al., 2015; Laursen & Salter, 2006; Terjesen & Patel, 2017). According to this theory, organizations need to extensively gather and integrate both internal and external knowledge resources. This process often involves rearranging and combining knowledge elements or connecting different pieces of knowledge in new ways, thereby fostering innovative outcomes such as patents (Chen et al., 2022; Laursen & Salter, 2006). In the digital economy era, the importance of the knowledge search theory has become increasingly prominent. The rapid development of digital technologies and the widespread use of the Internet have enabled the rapid generation and wide dissemination of vast knowledge resources, but have also brought about issues of information overload and fragmentation. The knowledge search theory provides important theoretical support for organizations to efficiently search for and utilize knowledge in the digital economy landscape.

According to the knowledge search theory, firms create new knowledge by stimulating motivation for knowledge search, increasing search breadth, and deepening search depth (Ferreras-Méndez et al., 2015; Laursen & Salter, 2006; Terjesen & Patel, 2017). Search

motivation refers to the combined influence of intrinsic and extrinsic motivations for knowledge search by individuals or organizations. Intrinsic motivation arises from internal knowledge search needs and interests within individuals or organizations. Knowledge search driven by intrinsic motivation is often more proactive and spontaneous, leading individuals or organizations to explore knowledge more deeply and extensively under this drive. Extrinsic motivation stems from external environmental factors, and knowledge search driven by extrinsic motivation often has clear purposes and objectives. Search breadth refers to firms drawing various knowledge elements from multiple knowledge sources to enhance innovation capability. Search depth refers to firms being able to delve into implicit and detailed knowledge within specific knowledge sources to gain a profound understanding of these knowledge elements (Chen et al., 2022; Laursen & Salter, 2006). In the innovation literature, the knowledge search theory is widely applied (Chen et al., 2022; Ferreras-Méndez et al., 2015; Laursen & Salter, 2006; Terjesen & Patel, 2017; Wang et al., 2020). For example, Chen et al. (2022) combined the knowledge search theory to explore the impact of supplier concentration on innovation performance. Wang et al. (2020) investigated the moderating effect of the dual knowledge search strategy on the non-linear relationship between the openness of external knowledge and innovation performance. Based on this, this study suggests that remote work promotes firms' innovation performance by stimulating intrinsic motivation for employee knowledge search, broadening and deepening the breadth and depth of knowledge search.

### 4.2.2 Impact of remote work on firms' innovation performance

Innovation is widely recognized as a key source of competitive advantage for businesses (Crossan & Apaydin, 2010). Innovation refers to the process of introducing or adopting, absorbing, and utilizing new methods within a firm, thereby renewing and expanding the scope of products, services, and markets to form the firm's competitive advantage (Crossan & Apaydin, 2010; Kim et al., 2012). Innovation performance reflects the ability of firms to

introduce new technologies, optimize processes, open new markets, and implement innovative strategies in management practices, helping firms maintain a leading position in intense market competition.

Previous research has indicated that innovation performance comprises two important dimensions: innovation quantity and innovation quality (Aggarwal & Hsu, 2014; Valentini, 2012). Innovation quantity typically refers to the number of innovation projects or new products introduced by a firm within a certain period. This includes new products, services, technologies, processes, business models, and so forth. Innovation quantity can reflect the firm's level of innovation activity and its pursuit of market adaptability and diversification. On the other hand, innovation quality focuses on the value and impact of innovation, evaluating the actual contribution of innovative outcomes to the market, technological advancement, or firm performance. Studies have shown that innovation quantity and innovation quality complement each other, and firms should strive for the coordinated development of both dimensions (Valentini, 2012). Building on this, the study delves into how remote work influences firm innovation quantity and quality, thereby providing important insights into the relationship between remote work and firms' innovation performance.

Drawing on knowledge search theory, this study proposes that remote work arrangements can enhance both the quantity and quality of firm innovation through three key mechanisms: heightened knowledge search motivation, expanded search breadth, and increased search depth. First, remote work environments stimulate employees' knowledge search motivation and creative potential by providing greater autonomy and flexibility. Research indicates that remote workers experience reduced workplace pressures (Ashforth et al., 2000; Gajendran & Harrison, 2007), and possess more discretionary time for ideation and exploration (Allen et al., 2015; Siha & Monroe, 2006; Xiao et al., 2021). This individual-level exploratory knowledge search behavior enriches organizational knowledge repositories and innovation capabilities,

ultimately enhancing innovation quality (Xiao et al., 2021). Leading technology firms have strategically leveraged remote work policies as mechanisms to foster employee creativity and innovation (Agarwal & Ohyama, 2013; Choudhury et al., 2021; Kryscynski, 2021; Sauermann & Cohen, 2010).

Second, remote work transcends geographical constraints, enabling firms to access and assimilate external information and resources more extensively. This expanded search breadth allows organizations to explore diverse knowledge domains and market opportunities, accelerating innovation processes and increasing innovation output quantity (Allen et al., 2015; Choudhury et al., 2021).

Third, remote work necessitates the adoption of digital collaboration tools and platforms, including cloud storage systems, project management applications, and virtual meeting platforms. These technological enablers facilitate cross-functional information sharing and communication, providing richer inputs for innovation activities (Benitez et al., 2020; Mariani & Nambisan, 2021). Moreover, remote work arrangements enable firms to attract and integrate talent from diverse backgrounds and disciplines, fostering heterogeneous knowledge integration that deepens knowledge resource utilization and enhances innovation quality.

In summary, through its effects on knowledge search motivation, search breadth, and search depth, remote work positively influences both innovation quantity and quality. Remote work arrangements increase innovation quantity by enabling exploration of more diverse possibilities, while simultaneously enhancing innovation quality through the integration of broader and more heterogeneous knowledge resources. Based on this theoretical foundation, we propose the following hypotheses:

***H1a: Remote work positively influences firm innovation quantity.***

***H1b: Remote work positively influences firm innovation quality.***

### 4.2.3 The moderating roles of slack resource and growth opportunity

Slack resources refer to the surplus resources that a firm possesses beyond what is strictly required for its immediate operational needs (George, 2005). In the realm of operations management, slack resources are often perceived as a double-edged sword, sparking considerable scholarly debate (Chen et al., 2022; George, 2005; Jia et al., 2023; Wiengarten et al., 2017). On one hand, research suggests that slack resources, acting as a buffer, can support a firm's operational activities, enabling firms to better cope with fluctuations in supply and demand. Additionally, slack resources can enhance a firm's responsiveness and reliability in turbulent external environments (Kovach et al., 2015). On the other hand, slack resources may imply underutilization and inefficiency in resource allocation (Jia et al., 2023; Wiengarten et al., 2017). Scholars prompt calls for firms to reduce such excess resources to streamline operations and improve efficiency (Chen et al., 2022; Jia et al., 2023; Wiengarten et al., 2017). For instance, Marlin and Geiger (2015a) found that excess resources could lead to a decline in efficiency and diminish a company's willingness to take risks, thereby negatively impacting overall performance. Moreover, Jia et al. (2023) suggested that slack resources might impede collaboration with supply chain partners and have adverse effects on engagement in sustainable development activities. However, prior studies have seldom explored the moderating role of slack resources in the relationship between remote work and innovation performance. Thus, this study aims to delve deeper into how slack resources moderate the influence of remote work on firm innovation performance.

In the context of remote work, this study proposes that slack resources will negatively moderate the relationship between remote work and innovation performance. According to the knowledge search theory, the knowledge collected by firms must undergo deep absorption and application processes to foster innovation (Chen et al., 2022; Savino et al., 2017). However, firms with excessive slack resources may be more inclined to utilize existing resources rather

than actively seeking new innovative pathways (Chen et al., 2022; Jia et al., 2023). This dependence may lead to firms overlooking the innovation potential brought about by remote work, thereby inhibiting the growth of innovation quantity.

Moreover, abundant slack resources may weaken the firm's urgent need and initiative to enhance innovation quality (Chen et al., 2022; Marlin & Geiger, 2015b). Firms within the "resource comfort zone" may feel they can afford the risk of failure, reducing their focus and collective efforts on innovation quality. Even if remote work opens the path for high-quality innovation, the presence of slack resources may reduce the firm's investment and attempts to achieve innovation, thereby negatively impacting innovation quality (Wiengarten et al., 2017). Additionally, in the presence of resource redundancy, firms may fail to allocate resources to projects most likely to yield innovative outcomes. This lack of strategic resource allocation may hinder firms from fully leveraging the innovation potential of remote work, thereby negatively affecting both the quantity and quality of innovation.

In summary, this study suggests that slack resources will negatively moderate the relationship between remote work and firm innovation performance (both innovation quantity and innovation quality), and proposes the following hypotheses:

***H2a: Slack resources negatively moderate the relationship between remote work and innovation quantity, such that when firms have more slack resources, the positive impact of remote work on innovation quantity will be weakened.***

***H2b: Slack resources negatively moderate the relationship between remote work and innovation quality, such that when firms have more slack resources, the positive impact of remote work on innovation quality will be weakened.***

Firms' growth opportunity refers to the future potential of a firm, which encompasses the possibilities for its expansion, development, and innovation. Growth opportunities are not only reflected in a firm's current business activities and profitability, but also in its capacity to

explore new markets, develop new products, adopt new technologies, and enter new fields (Chen et al., 2022; David et al., 2006; Yanadori & Cui, 2013). The growth opportunities directly impact a firm's market value and investor expectations, serving as crucial indicators for investors to assess a firm's future profit potential. Previous research has indicated that firms with more growth opportunities are more motivated to engage in innovation activities (Chen et al., 2022; Yanadori & Cui, 2013). This motivation stems from responding to investor expectations and maintaining long-term competitiveness. Innovation activities can help companies explore new markets, enhance the value of products and services, and reduce costs and risks, thus maintaining a leading position in fierce market competition (Chen et al., 2022; Yanadori & Cui, 2013).

Based on this, this study suggests that growth opportunities, as an important facilitating factor, will strengthen the positive effect of remote work on firms' innovation performance. First, firms with greater growth opportunities tend to adopt more open and flexible resource allocation methods (Yanadori & Cui, 2013), which creates a more relaxed environment for remote work, enabling firms to collaborate across regions, share knowledge and skills, and stimulate innovative thinking. Secondly, growth opportunities alleviate the risk-averse attitude that companies hold toward innovation projects (Chen et al., 2022; Miroshnychenko et al., 2020), providing employees with a freer and more flexible working environment to explore innovative solutions. In such an environment, employees are more likely to engage in high-risk, high-reward innovative attempts, thereby enhancing the overall innovation quality of the company. Furthermore, when employees believe that their firm has greater growth opportunities, they hold a more positive and optimistic attitude towards the firm's future development (Yanadori & Cui, 2013). This positivity motivates them to invest more effort into the innovative activities of remote work. Finally, firms with growth opportunities place greater emphasis on long-term strategic planning, effectively integrating remote work models to

promote innovation and growth. By clarifying long-term goals and strategies, firms can better guide the direction of remote work, ensuring that innovation activities align with the overall goals of the company, thereby maximizing the innovation potential of remote work.

To sum up, this study suggests that growth opportunities positively moderate the relationship between remote work and innovation quantity and innovation quality, and proposes the following hypotheses:

***H3a: Growth opportunities positively moderate the relationship between remote work and innovation quantity, such that when firms have greater growth opportunities, the positive impact of remote work on innovation quantity will be strengthened.***

***H3b: Growth opportunities positively moderate the relationship between remote work and innovation quality, such that when firms have greater growth opportunities, the positive impact of remote work on innovation quality will be strengthened.***

## 4.3 Research Methods

### 4.3.1 Data collection

To examine the hypotheses proposed in this study, I obtained data from publicly listed companies recorded in the Compustat database between 2010 and 2019. Because the United States Patent and Trademark Office (USPTO) made significant adjustments to its patent database following the impact of the COVID-19 pandemic in 2020. These adjustments, including provisions authorized under the CARES Act, allowed eligible applicants to defer fee payments and postpone submission of documents. Therefore, to ensure the comparability of data and eliminate the potential effects of the COVID-19 pandemic, this study exclusively included data from 2010 to 2019.

The panel data utilized in this study were constructed from multiple sources. Specifically, the independent variable of remote work at the corporate level was sourced from the Factiva database. I manually collected remote work announcements by conducting keyword searches

in the Factiva database. Detailed methods for data collection in the Factiva database are provided in Chapter Three. The dependent variable of firms' innovation performance (including innovation quantity and innovation quality) was sourced from the United States Patent and Trademark Office (USPTO). USPTO data encompass detailed information on all patents and their respective companies in the United States, including technical details of inventions, applicants, application dates, authorization dates, patent classifications, and citation information. Previous literature has indicated that firms' patent activities reflect the quality and extent of corporate innovation, and utilizing patent activity as a measure of innovation has been widely recognized (Bernstein, 2015; Hall et al., 2001; Lanjouw et al., 1998). USPTO is a representative database for studying firm innovation performance and has been extensively utilized in prior research (Babina et al., 2024; Flammer & Kacperczyk, 2016; Xiao et al., 2021; Yanadori & Cui, 2013; Zou et al., 2023). Following previous research, this study focuses on utility patents, as they constitute over 90% of all patents granted by USPTO (Xiao et al., 2021). The moderating variables of slack resources and growth opportunities, as well as control variables of financial and industry data, were sourced from the Compustat database.

To construct a firm-year panel dataset tailored to this study, I manually matched patent data from USPTO with the Compustat database based on the company's name and geographic location. Simultaneously, I manually compiled stock ticker codes of companies from the Factiva database and matched this information with Compustat data. In cases where the unique identifiers for companies could not be fully matched, I searched company websites or other sources to further ensure the accuracy of the matches. Ultimately, this study includes 11,522 valid firm-year observations.

### 4.3.2 Measures

#### （1） Dependent variables

The dependent variables in this study are innovation quantity and innovation quality, with

data sourced from the patent database of USPTO. To measure innovation quantity, this study, based on prior research, uses the number of "patent applications" rather than "patent grants" as the metric (Bernstein, 2015; Chen et al., 2022; Xiao et al., 2021; Yanadori & Cui, 2013). This approach is mainly based on two considerations: First, the process from patent application to grant, which undergoes examination, can take from several months to years. Given the potentially lengthy duration from application to grant, previous research generally considers patent application a more accurate reflection of a firm's immediate innovation activities than patent grant (Chen et al., 2022; Fang et al., 2017). Second, this study focuses on exploring firms' innovation behaviors after the implementation of remote work models, thus emphasizing the output timing of innovation results rather than when these results receive patent grants (Xiao et al., 2021). Therefore, this study measures the innovation quantity by the total number of patent applications filed by firms in a given year. It is important to note that this study only counts patent applications that eventually receive grants, ensuring that the inventions considered meet the USPTO's minimum quality standards (Xiao et al., 2021). This is because research by Carley et al. (2015) found that only about 55% of all patent applications received by the USPTO eventually get granted, indicating that the granted patents meet certain quality requirements set by the USPTO.

Furthermore, to quantify innovation quality, this study draws on previous research and measures it through the frequency of citations after patent grants. Earlier studies show that patents vary in their significance and quality (Hall et al., 2005; Xiao et al., 2021). Citation frequency is an indicator of a patent's scientific value. A cited patent indicates that it forms the basis of subsequent patent research and defines the scope of rights for the patents that cite it (Xiao et al., 2021). Empirical research by Trajtenberg (1990) shows that the frequency of citations a patent receives reflects the value and originality of that innovation. The citation record also mirrors the economic value of the innovation outcomes, as it is closely related to

the firm's market value (Hall et al., 2005; Hall et al., 2007; Somaya, 2012). Based on this, the study uses the number of citations received by the granted patents of firms as the measure of innovation quality.

**（2） Independent variable**

In this study, the independent variable is the implementation of remote work policies by firms, with data sourced from corporate announcements collected from the Factiva database. I manually collected companies that implemented remote work policies and meticulously recorded the specific dates on which these policies were initiated. To ensure the accuracy and reliability of the data, I also conducted multiple verifications through news reports and company websites. The study employs dummy variable coding to represent the implementation of remote work. If a company announced the adoption of a remote work policy within the year, the dummy variable is coded as 1, 0 otherwise.

**（3） Moderating variables**

In this study, the moderating variables are slack resources and growth opportunities. Slack resources represent the existing financial resources of a firm, while growth opportunities represent the prospects for future development of the firm (Chen et al., 2022). Slack resources refer to the financial resources that are readily available and can be flexibly utilized by the firm (Wiengarten et al., 2017). A higher level of slack resources means that a firm has more financial resources available for allocation to other purposes (George, 2005). In this study, slack resources are measured by the ratio of current assets minus current liabilities to total assets (Ye et al., 2020). Growth opportunities represent the expected upward trend in future income for a firm (David et al., 2006). Drawing on previous literature, this study measures growth opportunities using the ratio of market value to the book value of assets (Chen et al., 2022; Yanadori & Cui, 2013). Market value represents the market's assessment of the expected future returns. A higher ratio of market value to book value indicates that investors have positive

expectations for the firm's future earnings growth (Chen et al., 2022; Yanadori & Cui, 2013).

**（4） Control variables**

This study considers a range of control variables that may impact innovation performance. These include firm size, return on assets (ROA), return on equity (ROE), R&D intensity, financial leverage, inventory turnover, industry concentration (HHI), industry munificence, and industry dynamism.

Specifically, Larger firms typically have more resources to invest in innovation activities, including R&D and marketing. This can potentially lead to economies of scale, reducing the relative cost per innovation project and thus enhancing innovation performance (Phelps, 2010). Firm size is measured using the natural logarithm of total assets in millions of dollars (Hendricks et al., 2009; Li et al., 2022). A higher ROA indicates more efficient asset management and utilization, suggesting that a firm is better at converting resources into profits. Such firms may have greater capacity to invest in innovation and achieve better innovation performance. ROA is measured by the ratio of net return to total assets (Fan et al., 2022). Higher ROE indicates effective use of shareholder capital to generate returns, including investments in innovation projects, which could positively impact innovation performance. ROE is measured by the ratio of net return to total equity (Ye et al., 2020).

Moreover, the higher the R&D intensity, the stronger the firm's ability to absorb knowledge, which facilitates improved innovation outputs and performance (Cohen & Levinthal, 1990). Higher financial leverage indicates a higher level of debt, which could limit a firm's capacity to invest in uncertain innovation activities, potentially negatively impacting innovation performance. Leverage is measured by the ratio of total liabilities to total assets(Iqbal et al., 2022; Nemlioglu & Mallick, 2021). A high inventory turnover rate generally means that a company can efficiently sell its inventory, freeing up more funds for R&D activities. Additionally, companies with high inventory turnover rates can usually respond more

quickly to market changes, supporting the development of new products and innovations (Song et al., 2023). Inventory turnover is measured by the ratio of the cost of goods sold to the total ending inventory (Hendricks et al., 2009; Song et al., 2023).

Industry concentration reflects the number and size of dominant firms in the market. High concentration may reduce market competition, impacting the motivation and pressure to innovate, potentially reducing innovation performance (Zhou et al., 2017). Industry concentration is measured using the Herfindahl-Hirschman Index (HHI), which is calculated by summing the squares of the market shares of firms within an industry. Higher industry munificence means an industry has abundant resources and significant market growth potential, which could provide more opportunities and incentives for innovation, thereby enhancing innovation performance (Chen et al., 2022). Industry munificence is measured by calculating the regression coefficient of industry sales relative to the past five-year average sales for that industry (four-digit SIC code). High industry dynamism means the industry experiences rapid and unpredictable changes, possibly forcing firms to continually adapt and innovate to maintain competitiveness. Thus, high industry dynamism could encourage more active innovation activities and enhance innovation performance (Cannella Jr et al., 2008). Industry dynamism is measured by comparing the standard error of the regression coefficient to the average sales of the industry (four-digit SIC code) over the past five years. Additionally, the study incorporates year and industry dummy variables to control for unobserved temporal and industry effects. In Table 4.1, I summarize detailed descriptions of the variables involved in this study.

Table 4.1 Variable measurements in Study 2

| Variables | Measures | Data sources | References |
|---|---|---|---|
| Innovation quantity | Count variable：Number of patent applications in the current year | USPTO | Xiao et al. (2021) |
| Innovation quality | Count variable：Number of patent citations in the current year | USPTO | Xiao et al. (2021) |

| | | | |
|---|---|---|---|
| Remote work | Dummy variable：Coded as 1 if the firm adopts remote work arrangements within the year, otherwise 0 | FACTIVA | Lam et al. (2016) |
| Slack resource | Ratio of current assets minus current liabilities to total assets | COMPUSTAT | Ye et al. (2020) |
| Growth opportunity | Market value of the firm divided by the book value of its assets. | COMPUSTAT | Yanadori and Cui (2013) |
| Firm size | A firm's total assets based on a logarithmic transformation | COMPUSTAT | Li et al. (2022) |
| ROA | A firm's returns on assets | COMPUSTAT | Ye et al. (2020) |
| ROE | A firm's return on equity | COMPUSTAT | Ye et al. (2020) |
| Firm leverage | Long-term liabilities plus current liabilities over total assets | COMPUSTAT | Ge et al. (2022) |
| R&D intensity | R&D expenditure divided by total assets | COMPUSTAT | Padgett and Galan (2010) |
| Inventory turnover | Cost of goods sold divided by total ending inventory | COMPUSTAT | Song et al. (2023) |
| Industry concentration | HHI | COMPUSTAT | Cheng and Nault (2007) |
| Industry munificence | Regression coefficient of industry sales relative to the past five-year industry average | COMPUSTAT | Chen et al. (2022) |
| Industry dynamism | Standard error of the regression coefficient relative to the five-year average sales of the industry | COMPUSTAT | Chen et al. (2022) |

### 4.3.3 Model setting

Given that the dependent variables of innovation quantity and innovation quality in this study are typical count variables that do not follow a normal distribution, the common analytical methods include Poisson regression and negative binomial regression (Cameron & Trivedi, 2005; Cameron & Trivedi, 2010; Cameron & Trivedi, 2013; Chen et al., 2022). However, poisson regression requires the condition of equal means and variances. If the sample variance exceeds the mean, indicating "overdispersion," the effectiveness of Poisson estimates is reduced. Previous research suggests that negative binomial regression is commonly used in the presence of unobservable heteroscedasticity (Cameron & Trivedi, 2005). Negative binomial regression method allows the conditional variance to exceed the conditional mean, effectively addressing the problem of sample overdispersion and significantly improving estimation

efficiency (Cameron & Trivedi, 2005; Cameron & Trivedi, 2010). In this study, due to the overdispersed count nature of the dependent variables, I employ a panel negative binomial regression model to test the impact of remote work on firms' innovation performance. Additionally, to correct for heteroscedasticity and serial correlation, the study uses robust standard errors clustered at the firm level. Industry and year fixed effects are also included to control for unobserved industry characteristics and effects that vary over time(Chen et al., 2022). This methodological approach helps ensure that the results are reliable and accurately reflect the relationships being studied.

### 4.3.4 DID and DDD analysis

In order to explore the impact of remote work on firms' innovation performance, this study employs a time-varying difference-in-difference (DID) model to compare the differences in innovation performance before and after the intervention of remote work policies (Beck et al., 2010; Wooldridge, 2010). Traditional DID models assume that all firms in the treatment group are affected by the policy at the same point in time. However, in the context of this study, the timing of the implementation of remote work arrangements varies across firms. Therefore, a multi-period DID model is used to account for different timing of treatment across firms (Beck et al., 2010). This approach allows for a more precise comparison of the differences in innovation performance between treatment and control group firms before and after the implementation of remote work, and to estimate the relative changes in these differences. The estimated model is structured as follows:

$$y_{it} = \beta_0 + \beta_1 Treat_i + \beta_2 \boldsymbol{Treat_i} \times \boldsymbol{Post_{it}} + \gamma X_{it} + \delta year_t + \Gamma Industry_j + \varepsilon_{ijt} \quad (4\text{-}1)$$

where the subscripts *i*, *j*, and *t* refer to firm *i*, industry *j*, and year *t*, respectively. $y_{it}$ refers to the innovation quantity or innovation quality of firm *i* in year *t*. $\beta_0$ is the intercept for each

firm. $Treat_i$ is a dummy variable, with the sample firms coded as "1" and control firms coded as "0". $Post_{it}$ is also a dummy variable, which is coded as "1" after the policy and "0" before the policy. $\beta_2$ (H1a and H1b) estimates the interaction between $Treat_i$ and $Post_{it}$, representing the effect of the remote work on innovation quantity and innovation quality. $X_{ijt}$ includes the whole set of control variables. $Year_t$ represents the year dummies, and $Industry_j$ represents the industry dummy. $\varepsilon_{ijt}$ is the error term. It is important to acknowledge that including $Post_{it}$ as a separate variable in the model is not necessary because I have already accounted for the effects of the year-fixed effects (Lam et al., 2022).

To test the moderating effects of this study, I employed a triple interaction term in the DID model, known as the difference-in-difference-in-difference (DDD) model. The estimated model is as follows:

$$y_{it} = \beta_0 + \beta_1 \boldsymbol{Treat_i} + \beta_2 \boldsymbol{Moderator_{ijt}} + \beta_3 \boldsymbol{Treat_i \times Post_{it}} + \beta_4 \boldsymbol{Treat_i \times Moderator_{ijt}} + \beta_5 \boldsymbol{Treat_i \times Post_{it} \times Moderator_{ijt}} + \gamma X_{ijt} + \delta year_t + \Gamma Industry_j + \varepsilon_{ijt} \quad (4\text{-}2)$$

where $Moderator_{ijt}$ refers to the two moderators in this study. $\beta_5$ estimates the triple interaction of $Treat_i \times Post_{it} \times Moderator_{ijt}$, representing the moderating effects of slack resources (H2a and H2b) and growth opportunity (H3a and H3b). The other variables are the same as those in Equation (4-1).

## 4.4 Results Analysis

### 4.4.1 Descriptive statistics and correlation analysis

After integrating data from various datasets, this study obtained a complete sample consisting of 11,522 firm-year observations. Tables 4.2 and 4.3 present the descriptive statistics and correlation analysis of the variables involved in this study, respectively. The results indicate

that the average number of innovations in the sample is 55.890, with a standard deviation of 267.600, suggesting that on average, firms apply for approximately 56 invention patents per year. The average quality of innovations is 169.500 with a standard deviation of 1207, indicating that patents in the sample are cited on average about 170 times. Additionally, the variances of the dependent variables are significantly larger than their means, justifying the use of a panel negative binomial regression model for estimation in this study.

Table 4.2 Descriptive statistics in Study 2

| Variables | Mean | SD | Min | Max |
|---|---|---|---|---|
| Innovation quantity | 55.890 | 267.600 | 0 | 8702 |
| Innovation quality | 169.500 | 1207 | 0 | 63555 |
| Treat | 0.058 | 0.234 | 0 | 1 |
| Post | 0.012 | 0.107 | 0 | 1 |
| Treat*Post | 0.012 | 0.107 | 0 | 1 |
| Slack resource | 2.944 | 2.620 | 0.003 | 44.800 |
| Growth opportunity | 5.346 | 1.750 | -4.782 | 12.970 |
| Firm size | 6.981 | 2.476 | 0.106 | 12.290 |
| ROA | -0.106 | 0.706 | -19.390 | 0.459 |
| ROE | 0.000 | 6.451 | -526.600 | 209.200 |
| R&D intensity | 0.103 | 0.192 | 0 | 2.873 |
| Leverage | 0.577 | 2.356 | -10.280 | 15.420 |
| Inventory turnover | 1.822 | 0.892 | 0.027 | 6.195 |
| Industry concentration | 0.054 | 0.057 | 0.011 | 0.683 |
| Industry munificence | 0.522 | 0.168 | 0.126 | 0.814 |
| Industry dynamism | 0.032 | 0.521 | -1 | 0.999 |

*Notes.* Observation = 11,522.

Table 4.3 Correlation analysis in Study 2

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Innovation quantity | 1 | | | | | | | | | | | | | | | |
| (2) Innovation quality | 0.518*** | 1 | | | | | | | | | | | | | | |
| (3) Treat | 0.164*** | 0.120*** | 1 | | | | | | | | | | | | | |
| (4) Post | 0.142*** | 0.046*** | 0.482*** | 1 | | | | | | | | | | | | |
| (5) Treat*Post | 0.142*** | 0.046*** | 0.520*** | 0.929*** | 1 | | | | | | | | | | | |
| (6) Slack resource | -0.044*** | -0.025*** | -0.032*** | -0.021*** | -0.021*** | 1 | | | | | | | | | | |
| (7) Growth opportunity | 0.214*** | 0.153*** | 0.155*** | 0.101*** | 0.101*** | -0.070*** | 1 | | | | | | | | | |
| (8) Firm size | 0.212*** | 0.138*** | 0.160*** | 0.103*** | 0.103*** | -0.138*** | 0.267*** | 1 | | | | | | | | |
| (9) ROA | 0.036*** | 0.028*** | 0.037*** | 0.019*** | 0.019*** | 0.089*** | -0.046*** | 0.388*** | 1 | | | | | | | |
| (10) ROE | 0.003 | 0.002 | 0.000 | 0.000 | 0.000 | -0.001 | -0.033*** | 0.002 | 0.005* | 1 | | | | | | |
| (11) R&D intensity | -0.053*** | -0.039*** | -0.043*** | -0.026*** | -0.026*** | -0.046*** | 0.100*** | -0.414*** | -0.579*** | 0.003 | 1 | | | | | |
| (12) Leverage | 0.020*** | 0.001 | 0.012*** | 0.011*** | 0.011*** | -0.057*** | 0.190*** | 0.213*** | 0.083*** | -0.037*** | -0.098*** | 1 | | | | |
| (13) Inventory turnover | 0.017** | 0.007 | 0.010*** | 0.003 | 0.003 | -0.195*** | 0.058*** | 0.085*** | 0.027*** | -0.003 | -0.022*** | 0.027*** | 1 | | | |
| (14) Industry concentration | -0.007 | -0.011* | 0.001 | -0.001 | 0.009*** | -0.011*** | 0.001 | -0.031*** | 0.013*** | 0.000 | -0.146*** | 0.019*** | 0.043*** | 1 | | |
| (15) Industry munificence | 0.053*** | -0.004 | -0.045*** | -0.020*** | -0.020*** | 0.136*** | 0.018*** | -0.158*** | -0.055*** | -0.002 | 0.082*** | -0.025*** | -0.121*** | -0.190*** | 1 | |
| (16) Industry dynamism | 0.013* | 0.013* | 0.025*** | 0.009*** | 0.009*** | -0.012*** | 0.011*** | 0.016*** | 0.006* | 0.001 | -0.004 | -0.002 | 0.034*** | 0.038*** | -0.086*** | 1 |

*Notes.* * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

### 4.4.2 DID results

Table 4.4 reports the DID results concerning the impact of remote work on innovation quantity and innovation quality of firms. Models 1 and 3 include only control variables. Consistent with the expectations of this study, firm size and R&D intensity positively affect both innovation quantity and quality, whereas financial leverage has a negative impact. Interestingly, the results show that ROA, negatively affects innovation quantity but positively affects innovation quality. A possible explanation is that a high ROA may lead firms to focus more on long-term investment returns, preferring to pursue higher-quality innovations rather than simply increasing the quantity of innovations in the short term.

Model 2 reports the estimated coefficients for the impact of remote work on innovation quantity. The findings indicate that firms implementing remote work arrangements significantly increase their innovation quantity compared to those without such arrangements ($\beta = 0.732$, $p < 0.01$). Specifically, firms with remote work arrangements have an 73.2% more patent applications than those without remote work arrangements. Based on the mean of the sample, firms practicing remote work file 41 more patent applications annually than those not practicing remote work. Therefore, the results support Hypothesis 1a, which posits that remote work significantly increases a firm's innovation quantity.

Model 4 reports the estimated coefficients for the impact of remote work on innovation quality. The results indicate that firms implementing remote work policies significantly enhance their innovation quality ($\beta = 0.427$, $p < 0.05$). Firms with remote work policies have an innovation quality 42.7% higher than those without. Using the sample mean as a benchmark, firms practicing remote work have their patents cited 72 more times per year than those not practicing remote work. Thus, the results support Hypothesis 1b, stating that remote work significantly increases a firm's innovation quality.

Table 4.4 DID results in Study 2

| | Innovation quantity | | Innovation quality | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Firm size | 0.596*** | 0.594*** | 0.526*** | 0.526*** |
| | [0.009] | [0.009] | [0.018] | [0.018] |
| ROA | -0.086** | -0.082** | 0.152*** | 0.154*** |
| | [0.036] | [0.036] | [0.051] | [0.051] |
| ROE | 0.001 | 0.001 | 0.003 | 0.003 |
| | [0.001] | [0.001] | [0.002] | [0.002] |
| R&D intensity | 2.653*** | 2.647*** | 3.686*** | 3.689*** |
| | [0.187] | [0.187] | [0.358] | [0.358] |
| Leverage | -0.016** | -0.019*** | -0.055*** | -0.056*** |
| | [0.007] | [0.007] | [0.017] | [0.017] |
| Inventory turnover | 0.023 | 0.022 | -0.011 | -0.010 |
| | [0.021] | [0.021] | [0.044] | [0.044] |
| Industry concentration | -0.750 | -0.707 | -2.634 | -2.654 |
| | [1.182] | [1.176] | [1.791] | [1.792] |
| Industry munificence | -0.170 | -0.191* | 0.245 | 0.241 |
| | [0.110] | [0.109] | [0.248] | [0.249] |
| Industry dynamism | -0.005 | -0.001 | -0.032 | -0.029 |
| | [0.030] | [0.029] | [0.064] | [0.064] |
| Treat | 0.592*** | 0.437*** | 0.662*** | 0.587*** |
| | [0.062] | [0.056] | [0.090] | [0.090] |
| Treat*Post | | **0.732*** ** | | **0.427** ** |
| | | **[0.180]** | | **[0.200]** |
| Constant | 0.038 | 0.059 | 3.277*** | 3.302*** |
| | [0.504] | [0.503] | [0.843] | [0.844] |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Observations | 11522 | 11522 | 11522 | 11522 |
| Pseudo $R^2$ | 0.147 | 0.147 | 0.080 | 0.080 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; post is omitted because of year fixed.

### 4.4.3 DDD results

After applying the DID model to analyze the relationship between remote work and firms' innovation performance, this study further employed the DDD model to test the moderating effects of slack resource and growth opportunity on the relationship between remote work and firms' innovation performance. Table 4.5 reports the estimation results of the DDD model. Models 1 and 3 report the moderating role of slack resource. Model 1 shows that slack resource negatively moderates the relationship between remote work and innovation quantity ($\beta = -0.359$, $p < 0.01$). This indicates that slack resource weakens the positive impact of remote work arrangements on innovation quantity, supporting Hypothesis 2a. Similarly, Model 3 shows that

slack resource also negatively moderates the relationship between remote work and firm innovation quality (β = -0.346, p < 0.01), supporting Hypothesis 2b.

Models 2 and 4 report the moderating role of growth opportunity. The results of Model 2 indicate that growth opportunity positively moderates the relationship between remote work and innovation quantity (β = 0.344, p < 0.01). When growth opportunity is high, the positive impact of remote work on innovation quantity is enhanced, thus supporting Hypothesis 3a. The results of Model 4 indicate that growth opportunity positively moderates the relationship between remote work and innovation quality (β = 0.392, p < 0.01). When growth opportunity is high, the positive impact of remote work on innovation quality is similarly increased, thus supporting Hypothesis 3b.

Table 4.5 DDD results in Study 2

| | Innovation quantity | | Innovation quality | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Firm size | 0.642*** | 0.454*** | 0.590*** | 0.354*** |
| | [0.010] | [0.011] | [0.017] | [0.026] |
| ROA | -0.201*** | 0.100 | 0.067 | 0.670*** |
| | [0.055] | [0.077] | [0.050] | [0.150] |
| ROE | 0.001 | -0.001 | 0.002 | -0.027*** |
| | [0.001] | [0.005] | [0.002] | [0.010] |
| R&D intensity | 2.759*** | 2.731*** | 3.981*** | 3.475*** |
| | [0.184] | [0.188] | [0.338] | [0.405] |
| Leverage | -0.017*** | -0.093*** | -0.044*** | -0.142*** |
| | [0.007] | [0.009] | [0.013] | [0.013] |
| Inventory turnover | 0.023 | 0.007 | -0.030 | 0.022 |
| | [0.020] | [0.021] | [0.041] | [0.051] |
| Industry concentration | -0.326 | -0.548 | -1.939 | -1.627 |
| | [1.132] | [1.244] | [1.716] | [1.977] |
| Industry munificence | -0.179* | -0.146 | 0.218 | 0.072 |
| | [0.105] | [0.103] | [0.253] | [0.245] |
| Industry dynamism | 0.001 | 0.006 | -0.002 | 0.043 |
| | [0.028] | [0.027] | [0.060] | [0.059] |
| Treat | 0.588*** | -0.132 | 0.801*** | -0.174 |
| | [0.105] | [0.183] | [0.193] | [0.325] |
| Treat*Post | 1.285*** | -2.280*** | 0.926*** | -2.937*** |
| | [0.268] | [0.490] | [0.338] | [0.644] |
| Slack | 0.101*** | | 0.139*** | |
| | [0.007] | | [0.017] | |
| Treat*Slack | -0.081** | | -0.098 | |
| | [0.032] | | [0.060] | |
| Treat*Post*Slack | **-0.359*** ** | | **-0.346*** ** | |
| | **[0.072]** | | **[0.109]** | |
| Growth | | 0.294*** | | 0.441*** |
| | | [0.012] | | [0.030] |
| Treat*Growth | | 0.059** | | 0.033 |

| | | | | |
|---|---|---|---|---|
| | | [0.026] | | [0.045] |
| Treat*Post* Growth | | **0.344**$^{***}$ | | **0.392**$^{***}$ |
| | | **[0.073]** | | **[0.086]** |
| Constant | -0.774 | -0.702 | 2.116$^{***}$ | 1.541$^{*}$ |
| | [0.504] | [0.528] | [0.793] | [0.896] |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Observations | 11522 | 11522 | 11522 | 11522 |
| Pseudo $R^2$ | 0.151 | 0.167 | 0.083 | 0.096 |

*Note*. Standard errors in parentheses; $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$; post is omitted because of year fixed.

### 4.4.4 Parallel trends test

One of the core premises of the Difference-in-Differences (DID) model is the parallel trends assumption, which requires that in the absence of the intervention, the treated group and the control group should exhibit consistent development trends (Callaway & Sant'Anna, 2021). For this study, this means that before the introduction of the remote work policy, firms that implemented the policy (treatment group) and those that did not (control group) should demonstrate similar trajectories in innovation performance. To ensure the accuracy of the research results, I conduct a parallel trends test using the dependent variable of innovation quantity. The specific model used for this test is as follows:

$$PatentNum_{it} = \beta_0 + \sum_t \beta_t \boldsymbol{Treat_i} \times \boldsymbol{Year_t} + \gamma X_{ijt} + \delta year_t + \Gamma Industry_j + \varepsilon_{ijt} \quad (4\text{-}3)$$

where $PatentNum_{it}$ represents the number of patent applications of firm $i$ in year $t$. $Year_t$ refers to the number of years relative to the remote work year. For example, if a firm implemented remote work arrangements in 2015, the corresponding time indicators would be $t = -2$ for 2013, $t = -1$ for 2014, $t = 1$ for 2016, and $t = 2$ for 2017. $year_t$ is a dummy variable that indicates 1 in year $t$ and 0 otherwise. $Treat_i$ represents the treatment group dummy variable. In this study, the period for testing parallel trends is set to three years before and five years after the implementation of the remote work policy.

Table 4.6 presents the results of the parallel trends test for Study 2, and Figure 4.1 illustrates the estimated coefficients and confidence intervals (corresponding to 95%

confidence intervals) relative to the years firms implemented remote work arrangements. Table 4.6 shows that the estimated coefficients for the three years prior to the implementation of remote work arrangements are not significant ($p > 0.1$). The results depicted in Figure 4.1 also demonstrate that there are no differences in innovation quantity between the treatment and control groups in the three years preceding the event. Therefore, these results support the parallel trends assumption required for a valid DID analysis.

Additionally, Figure 4.1 visually indicates a significant upward trend in innovation quantity one year after the implementation of remote work. This demonstrates that firms increase their innovation quantity following the adoption of remote work arrangements. Thus, the conclusions from the parallel trends test are consistent with the main effects analysis of the study, further confirming the robustness of the research findings.

Table 4.6 Results of parallel trend test in Study 2

| | Innovation quantity | |
|---|---|---|
| | Estimate | SE |
| Year (t-3) * Treat | 0.323 | [0.202] |
| Year (t-2) * Treat | 0.304 | [0.244] |
| Year (t) * Treat | 0.348 | [0.266] |
| Year (t+1) * Treat | **0.580**$^{*}$ | **[0.313]** |
| Year (t+2) * Treat | **0.636**$^{**}$ | **[0.309]** |
| Year (t+3) * Treat | **1.112**$^{**}$ | **[0.443]** |
| Year (t+4) * Treat | **1.464**$^{***}$ | **[0.508]** |
| Year (t+5) * Treat | **0.937**$^{***}$ | **[0.347]** |
| Firm size | 0.535$^{***}$ | [0.018] |
| ROA | 0.159$^{***}$ | [0.052] |
| ROE | 0.003 | [0.002] |
| R&D intensity | 3.787$^{***}$ | [0.359] |
| Leverage | -0.056$^{***}$ | [0.017] |
| Inventory turnover | 0.008 | [0.043] |
| Industry concentration | -2.560 | [1.779] |
| Industry munificence | 0.252 | [0.248] |
| Industry dynamism | -0.020 | [0.063] |
| Constant | 3.147$^{***}$ | [0.835] |
| Year FE | YES | |
| Industry FE | YES | |
| Observations | 11522 | |
| Pseudo $R^2$ | 0.080 | |

*Note*. Standard errors in parentheses. $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

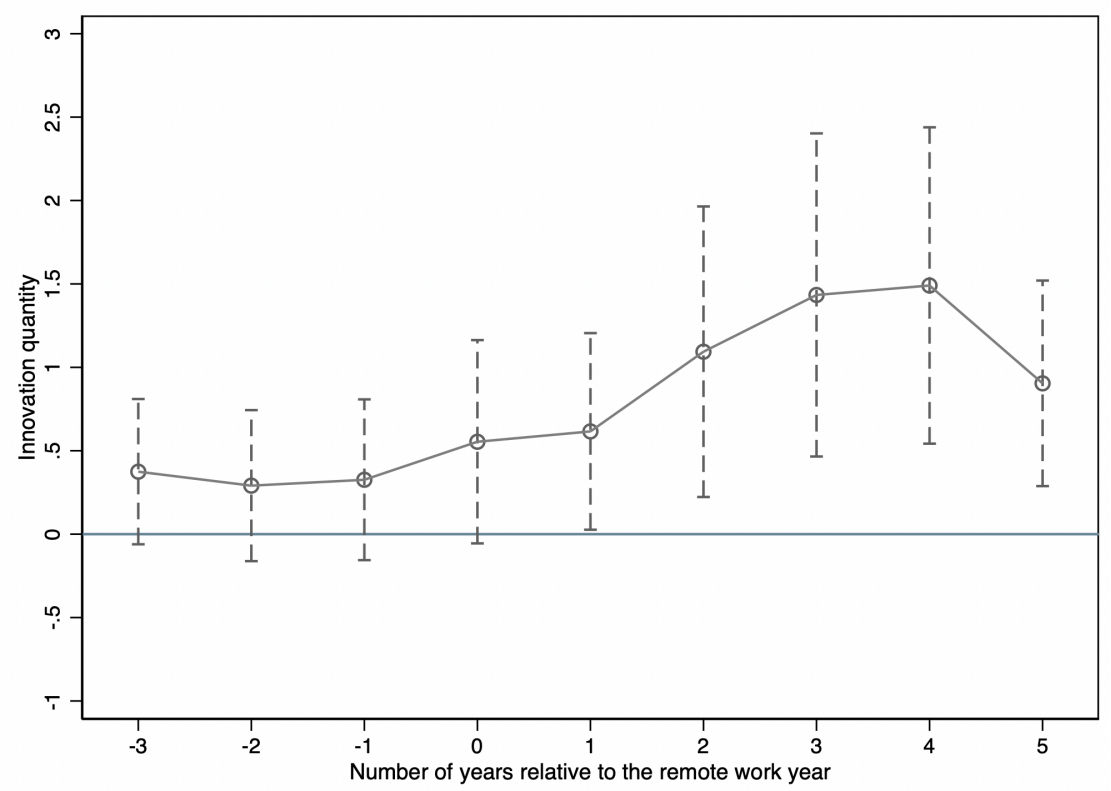


Figure 4.1 The parallel trend test plot in Study 2

### 4.4.5 Placebo test

This study further employed a placebo test by constructing a fake treatment group (Fan et al., 2022; Lam et al., 2022; Liu & Lu, 2015). Following previous research (Fan et al., 2022; Lam et al., 2022), I randomly selected firms within the sample observation period (2010-2019) and assigned rake remote work implementation years to these firms. If firms with actual remote work arrangements can improve innovation performance, I expect that the falsified estimated coefficients should be insignificant and far from our true coefficients. I repeated the whole process of DID estimation 1,000 times and plotted the coefficients of fake Treat*Post in Figure 4.2. The results in Figure 4.2 revealed that the majority of estimated coefficients derived from false remote work announcements predominantly concentrate around zero and significantly deviate from the actual coefficient (0.732 in Table 4.4), which is marked as a vertical dashed line. The majority of the *p*-values are larger than those of the real coefficients. The placebo test results further show that our findings are likely to be a true effect.

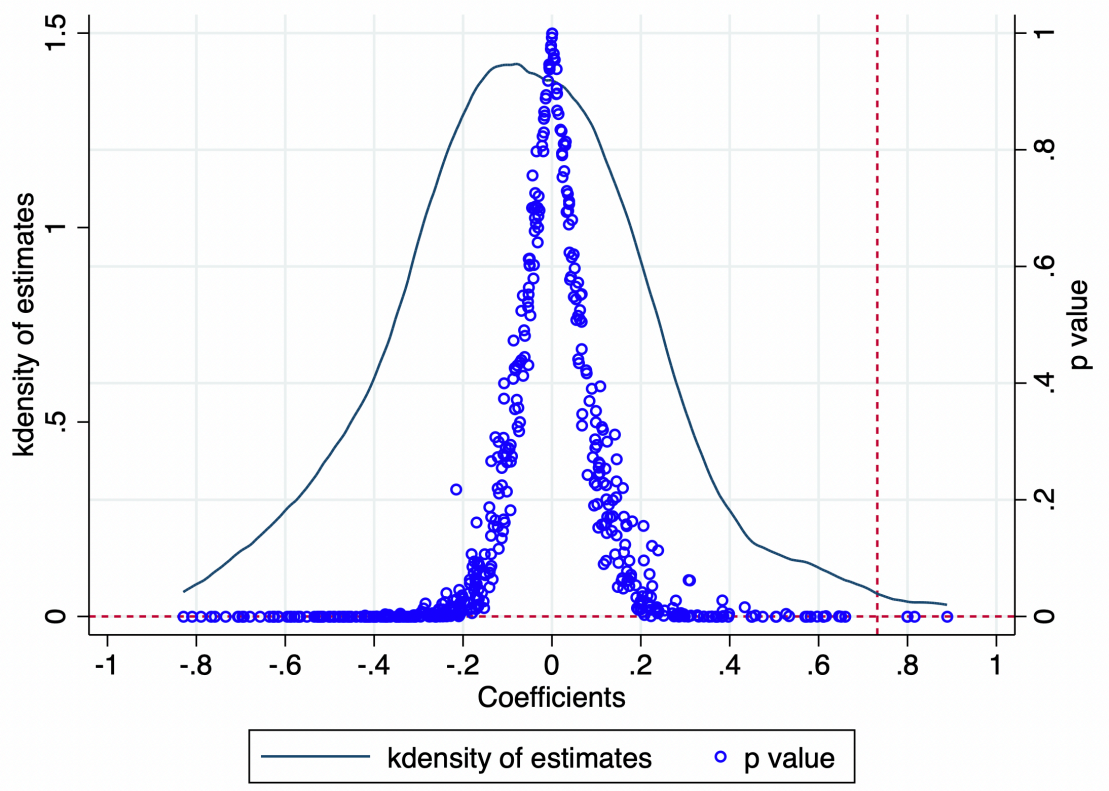


Figure 4.2 The placebo test plot in Study 2

### 4.4.6 Robustness checks

To further verify the robustness of the findings in this study, the researchers employed a series of robustness checks to confirm the stability and reliability of the results. These checks include the substitution of dependent variables, the Heckman two-stage analysis, the Two-Stage Residual Inclusion (2SRI) method, and the use of lagged dependent variables. Each of these methods addresses different potential biases and limitations in the study's design and analysis, which are described below:

**（1） Alternative measures of dependent variables**

Drawing on previous studies (Bernstein, 2015; Xiao et al., 2021), this study introduced alternative measures for the dependent variables—Scaled Number (adjusted innovation quantity) and Scaled Citation (adjusted innovation quality)—to validate the robustness of the results. Specifically, the number of patents and citation frequencies vary over time and across technological fields due to shifts in technological significance or changes in patent systems. Thus, simple comparisons of patent application numbers and citation counts may provide a

skewed interpretation of data. Thus, to more accurately assess innovation quantity and quality, the study constructed adjusted patent numbers and adjusted citation counts as alternative variables for the dependent variables (Bernstein, 2015; Xiao et al., 2021).

To adjust the count of patents, I assigned a weight to each patent based on the average number of patents applied for by other firms within the same USPTO patent technology category and year. This means that in technology fields where more patents are granted, the weight of each individual patent is relatively lower. The total adjusted patent count is obtained by summing the weights of all adjusted patents a firm holds within a year. Similarly, for adjusted citation counts, I divided each patent's citation count by the average citation count in its year and technology category.

The results shown in Table 4.7, Models 1 and 4, indicate that remote work positively affects both adjusted innovation quantity and adjusted innovation quality, with the estimates consistent with the baseline DID regression results (Table 4.4). Moreover, Models 2 and 5 demonstrate that slack resource negatively moderates the relationship between remote work and innovation performance; Models 3 and 6 show that growth opportunity positively moderates the relationship. These robustness test results align with those from the DDD model (Table 4.5), further substantiating the robustness of the study's findings.

Table 4.7 Robustness test: Alternative measure of dependent variables

| | Scaled Number | | | Scaled Citation | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
| Firm size | 0.007*** | 0.007*** | 0.006*** | 0.006*** | 0.006*** | 0.005*** |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.001] |
| ROA | -0.001 | -0.000 | 0.000 | -0.003 | -0.003 | 0.004 |
| | [0.001] | [0.001] | [0.002] | [0.002] | [0.002] | [0.002] |
| ROE | -0.000 | -0.000 | -0.001** | -0.000 | -0.000 | -0.001* |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| R&D intensity | 0.034*** | 0.035*** | 0.039*** | 0.027*** | 0.028*** | 0.041*** |
| | [0.004] | [0.004] | [0.005] | [0.006] | [0.005] | [0.006] |
| Leverage | -0.002*** | -0.002*** | -0.003*** | -0.002* | -0.002* | -0.002** |
| | [0.001] | [0.001] | [0.001] | [0.001] | [0.001] | [0.001] |
| Inventory turnover | -0.000 | -0.000 | -0.002*** | -0.001* | -0.001** | -0.003*** |
| | [0.000] | [0.000] | [0.001] | [0.000] | [0.000] | [0.000] |
| Industry concentration | -0.000 | 0.000 | -0.000 | -0.005 | -0.004 | -0.004 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | [0.006] | [0.006] | [0.00] | [0.007] | [0.007] | [0.008] |
| Industry munificence | 0.001 | 0.001 | 0.001 | -0.001 | -0.000 | -0.001 |
| | [0.001] | [0.001] | [0.001] | [0.001] | [0.001] | [0.002] |
| Industry dynamism | -0.076 | -0.048 | -0.173 | -0.347 | -0.328 | -0.298 |
| | [0.203] | [0.204] | [0.203] | [0.246] | [0.245] | [0.253] |
| Treat | 0.009** | 0.017** | -0.033** | 0.020*** | 0.028*** | -0.027* |
| | [0.004] | [0.007] | [0.014] | [0.004] | [0.009] | [0.015] |
| Treat*Post | **0.076***** | 0.128*** | -0.130*** | **0.074***** | 0.128*** | -0.148*** |
| | [0.018] | [0.032] | [0.047] | [0.019] | [0.034] | [0.050] |
| Slack | | 0.001* | | | 0.001* | |
| | | [0.000] | | | [0.000] | |
| Treat*Slack | | -0.005** | | | -0.004* | |
| | | [0.002] | | | [0.002] | |
| Treat*Post*Slack | | **-0.030***** | | | **-0.032***** | |
| | | **[0.009]** | | | **[0.009]** | |
| Growth | | | 0.003*** | | | 0.005*** |
| | | | [0.001] | | | [0.001] |
| Treat*Growth | | | 0.006*** | | | 0.006** |
| | | | [0.002] | | | [0.002] |
| Treat*Post* Growth | | | **0.026***** | | | **0.028***** |
| | | | **[0.007]** | | | **[0.008]** |
| Constant | 0.461*** | 0.445*** | 0.571*** | 0.595*** | 0.584*** | 0.636*** |
| | [0.146] | [0.147] | [0.146] | [0.152] | [0.153] | [0.152] |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 11522 | 11522 | 11522 | 11522 | 11522 | 11522 |
| Pseudo $R^2$ | 0.478 | 0.481 | 0.510 | 0.356 | 0.360 | 0.388 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

### （2） Heckman two-stage analysis

To mitigate potential sample selection bias, I employed the two-stage Heckman correction method proposed by Heckman (1979). This method involves estimating the probability of sample selection in the first stage and obtaining the Inverse Mills Ratio (IMR) as a control variable in the second-stage regression to correct for any sample selection bias.

In the first stage, whether a firm implemented remote work was used as the dependent variable in a Probit model. The model included the control variables from the baseline regression analysis and incorporated year and industry fixed effects to eliminate the impacts of industry characteristics and temporal trends. In the second stage, the IMR obtained from the first stage was included as an additional control variable in the regression analysis to test the main effects and moderating effects. The results of the second-stage Heckman test, as presented in Table 4.8, showed that after correcting for selection bias, Models 1 and 4 displayed main effects that were consistent with the original DID results. Similarly, Models 2, 3 and Models 5,

6 showed moderating effects consistent with the DDD results. Thus, the Heckman two-stage correction results indicate that after adjusting for selection bias, the findings of the study remain robust.

**（3） Two-stage residual inclusion**

Despite the implementation of DID model with year and industry fixed effects, there may still be endogeneity issues between remote work and innovation performance. Therefore, this study further employed the 2SRI method to address potential endogeneity issues. This method is particularly suited for non-linear models, as opposed to traditional Two-Stage Least Squares (2SLS) (Menon et al., 2020; Terza et al., 2008).

In the first stage of 2SRI, an instrumental variable is used to regress the endogenous explanatory variable, and the residuals between actual observations and predicted values are calculated. In this study, I use the Industry's remote work number as the instrumental variable. The rationale behind this choice is that if many firms within the same industry adopt remote work policies, it is more likely that a particular company will also adopt such a policy in a given year (Boffelli & Johansson, 2020). This instrumental variable is expected to have a minimal direct impact on a firm's innovation performance. In the second stage, the residuals predicted from the first stage are included as an additional explanatory variable in the non-linear regression model. This helps to address the issue of endogeneity by controlling for unobserved confounders. The results reported in Table 4.9 show that after correcting for potential reverse causality leading to endogeneity, the findings remain consistent with those from the DID and DDD analyses, which further underscores the robustness of the study's results.

Table 4.8 Robustness test: Heckman two-stage analysis

| | Innovation quantity | | | Innovation quality | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
| Firm size | 0.535*** | 0.633*** | 0.393*** | 0.387*** | 0.511*** | 0.238*** |
| | [0.022] | [0.026] | [0.021] | [0.043] | [0.041] | [0.050] |
| ROA | -0.113*** | -0.186*** | 0.122 | 0.057 | 0.018 | 0.675*** |
| | [0.040] | [0.056] | [0.079] | [0.067] | [0.061] | [0.149] |
| ROE | 0.001 | 0.001 | -0.002 | 0.002 | 0.001 | -0.027*** |
| | [0.001] | [0.001] | [0.005] | [0.002] | [0.002] | [0.010] |
| R&D intensity | 2.386*** | 2.722*** | 2.591*** | 3.252*** | 3.714*** | 3.269*** |
| | [0.217] | [0.217] | [0.208] | [0.402] | [0.390] | [0.404] |
| Leverage | -0.014** | -0.014** | -0.087*** | -0.042*** | -0.038*** | -0.138*** |
| | [0.007] | [0.007] | [0.009] | [0.013] | [0.012] | [0.014] |
| Inventory turnover | -0.307*** | -0.303*** | -0.242*** | -0.353*** | -0.357*** | -0.225*** |
| | [0.021] | [0.021] | [0.024] | [0.044] | [0.042] | [0.050] |
| Industry concentration | -0.027 | 0.426 | 0.152 | -1.516 | -0.998 | -1.165 |
| | [1.205] | [1.183] | [1.255] | [1.999] | [1.930] | [2.268] |
| Industry munificence | -0.202* | -0.215* | -0.213* | 0.354 | 0.270 | 0.036 |
| | [0.116] | [0.112] | [0.109] | [0.259] | [0.267] | [0.273] |
| Industry dynamism | 0.010 | 0.006 | 0.009 | 0.002 | 0.012 | 0.040 |
| | [0.031] | [0.029] | [0.028] | [0.065] | [0.064] | [0.063] |
| IMR | -0.422*** | -0.007 | -0.451*** | -1.181*** | -0.616** | -0.898*** |
| | [0.148] | [0.158] | [0.137] | [0.292] | [0.281] | [0.293] |
| Treat | 0.441*** | 0.547*** | -0.113 | 0.603*** | 0.780*** | -0.221 |
| | [0.060] | [0.113] | [0.195] | [0.098] | [0.210] | [0.342] |
| Treat*Post | **0.740*** ** | 1.386*** | -2.351*** | 0.409** | 0.957*** | -2.941*** |
| | **[0.185]** | [0.281] | [0.499] | [0.206] | [0.370] | [0.661] |
| Slack | | 0.102*** | | | 0.132*** | |
| | | [0.008] | | | [0.017] | |
| Treat*Slack | | -0.065* | | | -0.089 | |
| | | [0.035] | | | [0.064] | |
| Treat*Post*Slack | | **-0.387*** ** | | | **-0.345*** ** | |
| | | **[0.075]** | | | **[0.120]** | |
| Growth | | | 0.289*** | | | 0.441*** |
| | | | [0.013] | | | [0.033] |
| Treat*Growth | | | 0.059** | | | 0.043 |
| | | | [0.028] | | | [0.047] |
| Treat*Post* Growth | | | **0.352*** ** | | | **0.389*** ** |
| | | | **[0.074]** | | | **[0.088]** |
| Constant | 0.140*** | 0.101*** | -0.071*** | 1.170*** | 1.150*** | 1.027*** |
| | [0.015] | [0.015] | [0.016] | [0.020] | [0.020] | [0.023] |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 11522 | 11522 | 11522 | 11522 | 11522 | 11522 |
| Pseudo $R^2$ | 0.147 | 0.151 | 0.167 | 0.082 | 0.084 | 0.098 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4.9 Robustness test: 2SRI analysis

| | Innovation quantity | | | Innovation quality | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
| Firm size | 0.500*** | 0.628*** | 0.451*** | 0.476*** | 0.550*** | 0.320*** |
| | [0.011] | [0.014] | [0.015] | [0.028] | [0.027] | [0.038] |
| ROA | 0.029 | -0.185*** | 0.125 | 0.180*** | 0.083 | 0.712*** |
| | [0.033] | [0.055] | [0.080] | [0.056] | [0.054] | [0.150] |
| ROE | -0.000 | 0.001 | -0.001 | 0.003 | 0.001 | -0.027*** |
| | [0.001] | [0.001] | [0.005] | [0.002] | [0.002] | [0.010] |
| R&D intensity | 3.063*** | 2.695*** | 2.753*** | 3.633*** | 3.946*** | 3.517*** |
| | [0.213] | [0.191] | [0.196] | [0.372] | [0.350] | [0.431] |
| Leverage | -0.028*** | -0.015** | -0.090*** | -0.058*** | -0.044*** | -0.144*** |
| | [0.008] | [0.007] | [0.009] | [0.017] | [0.013] | [0.014] |
| Inventory turnover | -0.158*** | 0.016 | 0.016 | -0.035 | -0.062 | 0.008 |
| | [0.021] | [0.022] | [0.023] | [0.045] | [0.044] | [0.048] |
| Industry concentration | -1.763*** | 0.374 | 0.232 | -1.426 | -0.864 | -1.045 |
| | [0.412] | [1.181] | [1.225] | [1.932] | [1.895] | [2.202] |
| Industry munificence | 1.183*** | -0.216* | -0.231** | 0.256 | 0.218 | -0.001 |
| | [0.104] | [0.113] | [0.109] | [0.268] | [0.273] | [0.266] |
| Industry dynamism | 0.171*** | 0.010 | 0.000 | 0.015 | 0.036 | 0.046 |
| | [0.034] | [0.030] | [0.029] | [0.068] | [0.064] | [0.062] |
| Residuals | -23.272*** | -1.214 | 1.252 | -10.302** | -8.812* | -4.996 |
| | [1.692] | [2.492] | [2.403] | [4.806] | [5.001] | [5.653] |
| Treat | 0.474*** | 0.550*** | -0.093 | 0.589*** | 0.805*** | -0.177 |
| | [0.078] | [0.113] | [0.195] | [0.098] | [0.212] | [0.352] |
| Treat*Post | **3.715*** ** | 2.593 | -3.637 | 10.734** | 9.782** | 1.983 |
| | **[1.682]** | [2.499] | [2.455] | [4.776] | [4.979] | [5.639] |
| Slack | | 0.102*** | | | 0.143*** | |
| | | [0.007] | | | [0.018] | |
| Treat*Slack | | -0.067* | | | -0.095 | |
| | | [0.035] | | | [0.065] | |
| Treat*Post*Slack | | **-0.387*** ** | | | **-0.369*** ** | |
| | | **[0.075]** | | | **[0.115]** | |
| Growth | | | 0.295*** | | | 0.453*** |
| | | | [0.013] | | | [0.033] |
| Treat*Growth | | | 0.055* | | | 0.034 |
| | | | [0.028] | | | [0.048] |
| Treat*Post* Growth | | | **0.361*** ** | | | **0.399*** ** |
| | | | **[0.075]** | | | **[0.090]** |
| Constant | -1.080*** | -0.954* | -0.991* | 3.089*** | 1.907** | 1.413 |
| | [0.112] | [0.562] | [0.529] | [0.934] | [0.907] | [1.017] |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 11522 | 11522 | 11522 | 11522 | 11522 | 11522 |
| Pseudo $R^2$ | 0.123 | 0.151 | 0.167 | 0.081 | 0.084 | 0.097 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

### （4） Lagged dependent variables

To further address potential endogeneity issues arising from reverse causality, this study employed lagged dependent variables by one and two periods to test the robustness of the findings. The results for these lagged variables are displayed in Tables 4.10 and 4.11. The

results show that even after introducing lagged dependent variables, the estimates remain consistent with the baseline regression results (Tables 4.4 and 4.5), suggesting that the positive relationship between remote work and innovation performance are not simply a product of reverse causality. Thus, the robustness checks using lagged dependent variables further ensure the reliability of the study's findings.

Table 4.10 Robustness test: Lag one term

| | Innovation quantity$_{t+1}$ | | | Innovation quality$_{t+1}$ | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
| Firm size | 0.637*** | 0.649*** | 0.535*** | 0.591*** | 0.622*** | 0.449*** |
| | [0.008] | [0.009] | [0.011] | [0.017] | [0.015] | [0.024] |
| ROA | -0.054 | -0.085** | 0.269*** | 0.215** | 0.128** | 0.753*** |
| | [0.041] | [0.040] | [0.077] | [0.097] | [0.060] | [0.161] |
| ROE | -0.003*** | -0.003*** | -0.005 | -0.007*** | -0.005*** | -0.025*** |
| | [0.001] | [0.001] | [0.005] | [0.002] | [0.001] | [0.008] |
| R&D intensity | 2.727*** | 2.717*** | 3.320*** | 4.249*** | 4.214*** | 4.282*** |
| | [0.176] | [0.174] | [0.188] | [0.314] | [0.303] | [0.320] |
| Leverage | -0.017*** | -0.017*** | -0.067*** | -0.058*** | -0.028*** | -0.130*** |
| | [0.006] | [0.006] | [0.010] | [0.011] | [0.009] | [0.013] |
| Inventory turnover | 0.007 | 0.011 | 0.018 | -0.195*** | -0.010 | 0.024 |
| | [0.020] | [0.020] | [0.024] | [0.039] | [0.037] | [0.039] |
| Industry concentration | 0.269 | 0.402 | 0.402 | -2.265*** | -1.686 | -0.684 |
| | [1.152] | [1.151] | [1.139] | [0.577] | [2.169] | [2.149] |
| Industry munificence | 0.006 | 0.006 | 0.002 | 0.237*** | 0.026 | -0.009 |
| | [0.028] | [0.028] | [0.027] | [0.073] | [0.056] | [0.057] |
| Industry dynamism | -0.296*** | -0.296*** | -0.339*** | 0.432* | 0.094 | -0.119 |
| | [0.103] | [0.103] | [0.102] | [0.242] | [0.243] | [0.247] |
| Treat | 0.307*** | 0.243** | 0.102 | 0.604*** | 0.362* | -0.036 |
| | [0.057] | [0.110] | [0.193] | [0.106] | [0.194] | [0.322] |
| Treat*Post | **0.737*** ** | 1.473*** | -2.138*** | 0.622*** | 1.588*** | -2.189*** |
| | **[0.162]** | [0.244] | [0.479] | [0.196] | [0.318] | [0.792] |
| Slack | | 0.035*** | | | 0.080*** | |
| | | [0.005] | | | [0.015] | |
| Treat*Slack | | 0.019 | | | 0.043 | |
| | | [0.036] | | | [0.063] | |
| Treat*Post*Slack | | **-0.425*** ** | | | **-0.574*** ** | |
| | | **[0.062]** | | | **[0.094]** | |
| Growth | | | 0.188*** | | | 0.365*** |
| | | | [0.013] | | | [0.027] |
| Treat*Growth | | | 0.023 | | | 0.015 |
| | | | [0.027] | | | [0.044] |
| Treat*Post* Growth | | | **0.342*** ** | | | **0.329*** ** |
| | | | **[0.069]** | | | **[0.100]** |
| Constant | -1.087** | -1.363** | -1.545*** | 0.590*** | 1.373 | 0.183 |
| | [0.549] | [0.556] | [0.545] | [0.226] | [1.020] | [0.987] |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 9793 | 9793 | 9793 | 9793 | 9793 | 9793 |
| Pseudo $R^2$ | 0.159 | 0.159 | 0.174 | 0.068 | 0.087 | 0.099 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4.11 Robustness test: Lag two term

| | Innovation quantity$_{t+2}$ | | | Innovation quality$_{t+2}$ | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Firm size | 0.644*** | 0.653*** | 0.543*** | 0.600*** | 0.621*** | 0.451*** |
| | [0.009] | [0.009] | [0.011] | [0.016] | [0.016] | [0.025] |
| ROA | -0.082* | -0.110** | 0.053 | 0.266*** | 0.186*** | 0.523*** |
| | [0.046] | [0.050] | [0.074] | [0.074] | [0.072] | [0.174] |
| ROE | -0.002** | -0.002** | -0.001 | -0.001 | -0.001 | -0.019 |
| | [0.001] | [0.001] | [0.002] | [0.002] | [0.002] | [0.024] |
| R&D intensity | 2.764*** | 2.735*** | 3.132*** | 4.302*** | 4.219*** | 4.048*** |
| | [0.185] | [0.184] | [0.202] | [0.309] | [0.307] | [0.358] |
| Leverage | -0.016*** | -0.015** | -0.060*** | -0.032*** | -0.029*** | -0.113*** |
| | [0.006] | [0.006] | [0.009] | [0.010] | [0.010] | [0.020] |
| Inventory turnover | 0.007 | 0.013 | 0.009 | -0.040 | -0.037 | -0.022 |
| | [0.021] | [0.021] | [0.025] | [0.033] | [0.034] | [0.036] |
| Industry concentration | -0.328 | -0.253 | 0.233 | -3.923 | -4.018 | 0.096 |
| | [1.214] | [1.218] | [1.261] | [2.514] | [2.526] | [2.206] |
| Industry munificence | 0.001 | 0.002 | 0.014 | -0.000 | 0.014 | 0.028 |
| | [0.028] | [0.028] | [0.027] | [0.060] | [0.059] | [0.062] |
| Industry dynamism | -0.193* | -0.189* | -0.271** | -0.188 | -0.190 | -0.221 |
| | [0.107] | [0.107] | [0.106] | [0.234] | [0.239] | [0.244] |
| Treat | 0.293*** | 0.218** | 0.147 | 0.427*** | 0.248 | 0.059 |
| | [0.062] | [0.108] | [0.186] | [0.089] | [0.175] | [0.342] |
| Treat*Post | **0.740*** ** | 1.474*** | -2.217*** | 0.622*** | 1.656*** | -2.019** |
| | **[0.163]** | [0.241] | [0.499] | [0.181] | [0.299] | [0.925] |
| Slack | | 0.026*** | | | 0.071*** | |
| | | [0.006] | | | [0.016] | |
| Treat*Slack | | 0.024 | | | 0.067 | |
| | | [0.035] | | | [0.061] | |
| Treat*Post*Slack | | **-0.429*** ** | | | **-0.569*** ** | |
| | | **[0.061]** | | | **[0.091]** | |
| Growth | | | 0.187*** | | | 0.361*** |
| | | | [0.013] | | | [0.030] |
| Treat*Growth | | | 0.017 | | | 0.009 |
| | | | [0.025] | | | [0.046] |
| Treat*Post* Growth | | | **0.354*** ** | | | **0.313*** ** |
| | | | **[0.071]** | | | **[0.118]** |
| Constant | -0.918 | -1.112* | -1.525** | 2.928** | 2.625** | -0.100 |
| | [0.590] | [0.592] | [0.606] | [1.280] | [1.274] | [1.075] |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 8748 | 8748 | 8748 | 8748 | 8748 | 8748 |
| Pseudo $R^2$ | 0.158 | 0.158 | 0.173 | 0.082 | 0.083 | 0.094 |

*Note*. Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## 4.5 Discussion and Conclusions

### 4.5.1 Results discussion

Based on panel data of publicly listed companies from 2010 to 2019, this study utilizes fixed-effects negative binomial regression and DID estimation to empirically test the impact of remote work on firms' innovation performance. Additionally, the study delves into the moderating effects of slack resource and growth opportunity, enhancing the understanding of crucial contextual factors in the relationship between remote work and innovation performance.

**（1） Impacts of remote work on firms' innovation performance**

This study finds that remote work significantly enhances firm innovation performance, including both the quantity and quality of innovation. This conclusion provides strong empirical evidence to the ongoing debate about the effects of remote work on innovation performance. Based on knowledge search theory, this study discovers that remote work enhances innovation by stimulating the motivation for knowledge search, expanding the breadth of knowledge exploration, and deepening the depth of knowledge engagement (Choudhury et al., 2021; Mariani & Nambisan, 2021; Xiao et al., 2021). The findings confirm that remote work can break geographic boundaries, facilitating the participation of diverse members and stakeholders in innovation efforts and promoting the integration of heterogeneous knowledge. This aligns with prior research on remote collaboration and virtual innovation teams (Berchicci et al., 2016; Gassmann & Von Zedtwitz, 2003; Lin et al., 2023; Silva & Merino, 2017), such as the study by Berchicci et al. (2016) which noted a positive impact of remote collaboration teams on innovation performance.

Although previous research emphasized that face-to-face communication and frequent interactions are essential for sharing tacit knowledge and enhancing innovation capabilities (Allen et al., 2015; Haldin-Herrgard, 2000; Hardwick et al., 2012; Koskinen et al., 2003). This study finds that, with the aid of digital collaboration technologies (Usai et al., 2021), remote

work can accelerate the flow of information and decision-making processes, facilitating knowledge sharing (Panahi et al., 2013), and enabling innovation projects to move more rapidly from concept to implementation phase. Furthermore, as an incentive policy for work-life balance (Choudhury et al., 2021; Kryscynski, 2021), remote work provides flexibility in terms of time and location, allowing employees to work when and where they feel most comfortable and efficient. This can enhance employee satisfaction, stimulate creativity, and foster innovative capabilities, thus enriching previous research on the relationship between employee relationship and firms' innovation performance (Gambeta et al., 2019). The conclusions of this study also provide theoretical justification for companies to adopt remote work to enhance employee creativity and innovation performance.

**（2） The moderating roles of slack resource and growth opportunity**

Following knowledge search theory, this study further explores the moderating roles of slack resource and growth opportunity on the relationship between remote work and firms' innovation performance. The findings indicate that slack resource negatively moderates the relationship between remote work and innovation performance; that is, when firms have excess slack resource, the positive relationship between remote work and innovation performance are diminished. This conclusion supports the viewpoint of knowledge search theory that for innovation to occur, the knowledge acquired by firms must undergo a thorough absorption and application process (Chen et al., 2022; Savino et al., 2017). An excess of slack resource leads to resource entrapment, reducing the firm's search and utilization of external knowledge. Additionally, an abundance of resources can create inertia and a "resource curse" (Badeeb et al., 2017; Ross, 1999), where there is a lack of motivation for firms to explore new knowledge, thereby weakening the effectiveness of remote work in promoting innovation (Chen et al., 2022; Jia et al., 2023). These findings enrich previous research on the negative impacts of slack resources (Marlin & Geiger, 2015a, 2015b; Wiengarten et al., 2017).

Prior literature discussing the relationship between slack resources and innovation performance has observed similar phenomena. Some studies have shown that ample resources can provide the necessary support to foster innovative activities within firms, but other research has found that an excess of resources might lead to wastefulness and managerial inefficiency, thus negatively affecting innovation (George, 2005; Marlin & Geiger, 2015b; Nohria & Gulati, 1996). These findings align with the results of this study, suggesting that firms need to find a balance in resource allocation to maximize the utility of remote work for innovation.

This study further finds that growth opportunity positively moderates the relationship between remote work and firms' innovation performance. Specifically, when firms have favorable growth opportunity, the positive impact of remote work on both the quantity and quality of innovation is enhanced. This finding aligns with the anticipated hypothesis and confirms that growth opportunity is a critical moderating variable that strengthens the positive relationship between remote work and innovation performance. Favorable growth opportunity represents a firms' market value and the positive expectations of its stakeholders (Yanadori & Cui, 2013), suggesting that firms are more motivated to engage in innovative activities facilitated by remote work (Billett et al., 2007; David et al., 2006). Consequently, these opportunities can unleash the innovative potential of remote working. This research conclusion is consistent with the findings of Chen et al. (2022) and Yanadori and Cui (2013), which observed that growth opportunity could stimulate firms to integrate and transform the knowledge they acquire.

Overall, the findings regarding the moderating effects further validate the perspectives of knowledge search theory, which posits that both current financial resources and future growth opportunities can influence organizational innovation efforts (Chen et al., 2022; David et al., 2006; Miroshnychenko et al., 2020; Savino et al., 2017). The findings underscore the complexity and dynamic nature of how remote work can drive innovation depending on

organizational context and external opportunities.

### 4.5.2 Theoretical implications

Our study provides substantial theoretical implications in three main aspects. First, this study is pioneering in applying the knowledge search theory to the literature of remote work, significantly enriching its application and expanding the boundaries of the theory. Specifically, the study uses this theoretical framework to understand the effects of remote work on firm innovation performance. By demonstrating how remote work stimulates employees' knowledge search motivations, broadens the scope of knowledge exploration, and deepens the depth of knowledge acquisition (Ferreras-Méndez et al., 2015; Laursen & Salter, 2006; Terjesen & Patel, 2017), this study not only provides a systematic theoretical basis to past empirical findings but also opens up new theoretical directions for future research on the relationship between remote work and innovation performance.

Second, this study advances our understanding of the remote work-innovation relationship by providing robust empirical evidence of how remote work arrangements influence firm-level innovation performance. While remote work has gained increasing scholarly attention, empirical research examining its impact on organizational innovation outcomes remains nascent (Konrad-Maerk, 2023; Xiao et al., 2021). Prior literature exhibits several notable limitations. First, existing studies have predominantly relied on conceptual frameworks or case-based analyses, lacking large-scale empirical validation (Coenen & Kok, 2014). Second, when empirical evidence is present, the analytical focus has primarily been at the individual or team level, leaving firm-level implications largely unexplored (Berchicci et al., 2016; Gassmann & Von Zedtwitz, 2003; Silva & Merino, 2017). This study not only responds to previous scholars' calls by exploring the impact of remote work on firm innovation performance from an empirical perspective (Coenen & Kok, 2014; Gassmann & Von Zedtwitz, 2003), but also aligns with the suggestions of scholars like Xiao et al. (2021) to investigate the

effects of remote work on different dimensions of innovation performance. The findings of this study clearly demonstrate that remote work can stimulate corporate innovation vitality, proving to be a key factor in enhancing both the quantity and quality of firm innovations.

Third, this study explores the moderating effects of slack resource and growth opportunity, enriching our understanding of the contingency factors for the relationship between remote work and innovation performance. Specifically, this study finds that slack resource may inhibit the positive effects of remote work on innovation performance, while growth opportunity can enhance these effects. The conclusions regarding moderating effects further validate the perspectives of knowledge search theory, that a firm's current financial resources and future growth opportunities exert varying impacts on organizational innovation efforts (Chen et al., 2022; David et al., 2006; Miroshnychenko et al., 2020; Savino et al., 2017). Slack resource leads to resource dependency, reducing the motivation to explore new knowledge and technologies and thus weakening the role of remote work in promoting firm innovation (Chen et al., 2022; Jia et al., 2023). Conversely, growth opportunity represents positive expectations for the firm's future development potential, motivating firms to engage more dynamically in innovation activities facilitated by remote work (Billett et al., 2007; David et al., 2006), thereby unleashing the innovative potential of remote work.

### 4.5.3 Practical implications

Our study provides significant insights for managers and policymakers on effectively utilizing remote work to unleash firms' innovation potential. First, the study finds that the implementation of remote work significantly enhances both the quantity and quality of firm innovation. This suggests that managers fully leverage the advantages of remote work to stimulate the firm's innovation vitality. The flexibility and autonomy offered by remote work help to foster employee creativity. Additionally, remote work breaks geographical boundaries, promoting the sharing of heterogeneous knowledge and the collision of ideas. Therefore, firms

should focus on how to stimulate employees' innovative thinking and facilitate the collection and exchange of knowledge through remote work environments, such as by establishing online collaboration platforms and organizing virtual innovation workshops to further enhance the firm's innovative capabilities.

Second, the study informs managers about the adverse effects of having an excess of slack resource in a remote work environment. When there is an abundance of slack resource, the positive impact of remote work on firm innovation performance diminishes, as the overallocation of resources leads to reduced efficiency and weakened motivation for innovation. Consequently, managers should assess and optimize resource allocation to prevent excess slack resource from negatively impacting innovative drive. Specifically, this can be achieved through refined management and dynamic adjustments, ensuring resources are invested in projects and activities that generate the most innovative value, thus improving resource utilization efficiency.

Lastly, our study finds that growth opportunity can enhance the positive effects of remote work on firm innovation performance. For corporate management, this finding emphasizes the need to consider the firms' growth opportunities when formulating remote work policies and innovation strategies. In firms with high growth opportunities, the remote work model is more likely to have a positive effect. Therefore, when implementing remote work arrangements, firms should maintain flexibility and adaptability, and proactively identify growth opportunity. Simultaneously, firms can provide employees with the necessary technical support and innovation incentives, such as sufficient online learning resources, and innovation reward programs, thus ensuring that innovative activities in a remote work environment are carried out effectively. By fully leveraging the positive impact of remote work on innovation performance, firms can maximize the potential of remote work, thereby promoting continuous innovation and development.

# Chapter 5 Study 3: Impacts of Remote Work Arrangements on Firms' Information Security: A Socio-technical System View

## 5.1 Introduction

In the rapidly evolving era of the digital economy, remote work is increasingly becoming a component of modern corporate digital operations. However, the implementation of remote work introduces significant information security risks for businesses, including data breaches, unauthorized access, and cyber-attacks. A survey by CyberArk found that 77% of remote employees use unmanaged personal devices to access company systems. Furthermore, common remote working practices such as reusing the same passwords and allowing family members to use work devices are exposing critical business systems and sensitive data to risk[1]. IBM's latest data breach report also noted that in 2023, the global average cost of data breaches reached $4.45 million, marking a 15% increase from three years earlier[2]. Consequently, exploring the impact of remote work on corporate information security and how to effectively manage the information security risks associated with remote work has become a pressing topic for in-depth discussion.

Previous research has recognized the potential impact of remote work on information security risks, such as Curran (2020) highlighting that relocating employees, office equipment, and data out of secure environments can pose significant data breach risks to organizations. However, these studies have primarily relied on conceptual articles (e.g., Curran, 2020; Evangelakos, 2020; James & Griffiths, 2014; Malecki, 2020), and lack empirical evidence on the relationship between remote work and firms' information security.

Moreover, past research has not addressed the specific types of remote work, such as proactive and reactive remote work, and therefore fails to thoroughly investigate the potential

[1]https://www.cyberark.com/press/remote-work-study-how-cyber-habits-at-home-threaten-corporate-network-security/
[2]https://www.ibm.com/reports/data-breach

differences in information security risks that these two types of remote work might entail. Specifically, remote work can be categorized into two types: proactive remote work and reactive remote work. Proactive remote work reflects a firm's forward-looking planning and strategic layout, representing a remote work policy adopted based on well-considered decisions (Allen et al., 2015; Angel Martı´nez Sa´nchez et al., 2007; Stavrou, 2005). In this model, remote work is part of the company culture, emphasizing flexible work arrangements for employees, focusing on their well-being, and integrating into the business operations. Firms with proactive remote work may establish comprehensive remote work policies, detailed procedures, and necessary technical support systems in advance. In contrast, reactive remote work typically occurs when firms are forced to respond to external pressures or unforeseen events (such as natural disasters or health crises) (Bai et al., 2021; Ge et al., 2022; Shen, 2023). For example, the COVID-19 pandemic in 2020 forced many firms globally to hastily switch to remote working modes to comply with health and safety regulations and maintain business continuity. However, there is currently a lack of empirical research exploring how these two types of remote work—proactive and reactive—affect firms' information security risks. Based on this, this study intends to delve into the impact of proactive and reactive remote work on firms' information security risks.

Considering the potential adverse impacts of remote work on corporate information security risks, it is crucial for firms to adopt effective measures to manage and mitigate these risks. This focus is not only a key concern for firms but also a pressing research issue that needs to be addressed. However, empirical studies exploring the boundary conditions of the relationship between remote work and corporate information security are scarce, leaving unanswered questions about the measures firms should take to manage and mitigate the impact of remote work on information security risks.

Based on the socio-technical system view, organizations are viewed as complex entities

where technical systems and social systems are interwoven (Appelbaum, 1997; Bostrom & Heinen, 1977; Emery & Trist, 1960; Trist & Bamforth, 1951). The technical system encompasses hardware, tools, technological solutions, and procedural workflows, while the social system consists of organizational members, structural design, and the network of relationships between these elements. Socio-technical system view advocates for an integrative approach, considering both technological and social system factors in enhancing organizational effectiveness. This view has been widely applied in operations management research to help understand and explain how performance can be enhanced by improving systems. For instance, Hadid et al. (2016) focused on the impact of lean services at both technological and social levels on organizational operational and financial efficiency. Siawsh et al. (2021) explored the application of the socio-technical system perspective in the field of emergency supply chain management. Kull et al. (2013) used the socio-technical system view to analyze governance mechanisms in supply chain partnerships. Therefore, the socio-technical system perspective provides a suitable theoretical framework for comprehensively analyzing how firms can integrate technological means and social strategies to manage the information security risks brought about by remote work.

From the socio-technical system perspective, this study identifies two factors that may moderate the relationship between remote work and firms' information security: IT capability (technical system) and managerial capability (social system). In the technical system, a firm's IT capability refers to its unique and difficult-to-replicate ability to mobilize, deploy information technology resources, and integrate other complementary resources (Bharadwaj, 2000; Chae et al., 2014). An IBM survey report indicates that organizations using secure artificial intelligence and automation technologies save an average of $1.76 million in operational costs resulting from data breaches, compared to organizations that do not use these technologies. At the level of the social system, this study focuses on the moderating role of

managerial capability. Managerial capability involves the skills and experience accumulated by a firm's management in strategy formulation, decision-making, human resources coordination, organizational culture nurturing, and crisis response (Holcomb et al., 2009). Therefore, this study posits that by effectively integrating both IT and managerial capabilities, firms can respond more flexibly and effectively to the information security challenges posed by remote work, thereby reducing potential information security risks.

Accordingly, this study aims to answer two research questions: (1) How do proactive and reactive remote work impact firms' information security risks? (2) How do IT capability and managerial capability moderate the relationship between proactive and reactive remote work and firms' information security risks? This study utilizes panel data, gathers secondary data from multiple datasets, and employs econometric models such as the linear probability model (LPM) to test the hypotheses. Specifically, this study measures firms' information security risks using data from two mainstream data breach databases: the Privacy Rights Clearinghouse (PRC) and the Identity Theft Resource Center (ITRC) (Liu et al., 2020; Wang & Ngai, 2022). Proactive and reactive remote work announcements are sourced from the Factiva database at the firm level. IT capability is measured using the InformationWeek database (Chae et al., 2014; Mishra et al., 2013). Managerial capability is quantified using a two-stage method that combines Data Envelopment Analysis (DEA) and Tobit regression models (DEA-Tobit), drawing on the approach of Demerjian et al. (2012). Additionally, financial data for publicly listed companies is measured using the Compustat database. Moreover, the study employs the Heckman two-stage estimation, alternative estimation models, and additional analyses to further verify the robustness of the results.

The study finds that both proactive and reactive remote work increase firms' information security risks, including the likelihood and severity of data breaches. These outcomes confirm that remote work can pose significant risks to corporate information security. Further findings

indicate that when firms possess strong IT capabilities, the adverse impacts of both proactive and reactive remote work on information security are mitigated. This result underscores the important role of IT capability in effectively managing information security risks in remote work settings. However, the study also finds that while managerial capability plays a significant and effective moderating role in the relationship between proactive remote work and information security risks, its moderating effect is not significant in the context of reactive remote work. This outcome suggests that when firms proactively adopt remote work models, the management's strategic planning, communication coordination, and security resource allocation can significantly reduce the information security risks associated with remote work. In contrast, in scenarios of reactive remote work, firms may not have sufficient time for adequate managerial preparation and response, leading to a failure of managerial capabilities in mitigating information security risks.

The conclusions of this study offer significant theoretical and practical implications. First, by distinguishing between proactive and reactive remote work at the organizational level, this study enriches the conceptual understanding of remote work and expands the related empirical foundation. Second, the study empirically reveals the negative impacts of both proactive and reactive remote work on firms' information security, filling a gap in the existing literature regarding the relationship between remote work and firms' information security. It also deepens the understanding of this relationship and broadens the empirical basis of remote work studies. Third, this study incorporates the socio-technical system view by examining the moderating roles of IT capability (technical system) and managerial capability (social system) in the relationship between remote work and information security. This enriches the understanding of the boundary conditions for remote work and identifies key governance mechanisms that can mitigate the information security risks associated with remote work. Overall, this study provides vital insights for business managers to understand and effectively address the

challenges of information security in a remote working environment. It highlights the importance of integrating strong IT and managerial capabilities to safeguard against the heightened risks posed by remote work settings.

## 5.2 Theoretical Background and Hypothesis Development

### 5.2.1 Impacts of proactive and reactive remote work on firms' information security

Proactive and reactive remote work represent two distinct remote work strategies. Proactive remote work is actively implemented by firms based on long-term planning and strategic considerations (Allen et al., 2015; Angel Martı´nez Sa´nchez et al., 2007; Stavrou, 2005). Typically a part of the company culture and business model, proactive remote work involves the advanced formulation of policies, processes, and technological infrastructure to support employees working efficiently from home or any non-traditional office locations. This strategy emphasizes flexibility, employee welfare, and the potential for cost savings and productivity gains through remote work (Bloom et al., 2015). Conversely, reactive remote work is a strategy that firms are forced to adopt in response to external factors or emergencies, such as natural disasters or health crises (Shen, 2023). In the rapidly evolving digital economy, the implementation of remote work models undoubtedly increases potential information security risks, including data breaches, unauthorized access, and cyberattacks.

This study posits that both proactive and reactive remote work increase firms' information security risks. Specifically, proactive remote work can potentially heighten a firm's information security risks in several ways. First, in a remote setting, employees often use personal devices or networks that lack the stringent security measures, such as sophisticated antivirus software, robust firewalls, or intrusion detection systems (Curran, 2020). These less secure personal or home office setups are more vulnerable to malware, cyberattacks, and information theft, thereby significantly raising the risk of sensitive corporate data being intercepted or leaked.

Second, remote work environments typically do not have centralized security monitoring and management. In an office, the IT department can centrally oversee and maintain network security. In contrast, in a remote setup, monitoring is complicated by employees using various devices and connecting from multiple locations, which can each act as potential entry points for cyber threats (Grimm, 2021). Third, the independence associated with remote work may lead to lapses in secure data management practices among employees. The absence of direct oversight might result in overlooking best practices like avoiding unauthorized data sharing, maintaining password security, or safeguarding against the transmission of sensitive information over unsecured networks. These lapses could substantially increase the risk of data breaches within the firm. Therefore, this study suggests that proactive remote work increases a firm's information security risks.

Similarly, this study posits that reactive remote work can trigger information security risks for firms. Reactive remote work is often an emergency response measure that businesses are forced to adopt due to unforeseen events such as natural disasters or epidemics, typically without adequate preparation or contingency plans (Ge et al., 2022). The rapid shift to this work model can lead to deficiencies in technical resources, security policies, and employee training, thereby exposing vulnerabilities. Specifically, due to the swift transition to remote work, firms may not have sufficient time to establish or expand necessary security infrastructure, such as secure VPN connections, data encryption technologies, and multi-factor authentication systems (Curran, 2020; Grimm, 2021; Malecki, 2020). Moreover, employees forced into remote work may lack adequate information security training (Rothman, 2000), resulting in a deficiency of vigilance and expertise when handling sensitive data and securing personal and business assets. In emergency situations, firms may fail to revise or implement security policies and procedures tailored to the remote work environment promptly, leaving employees without clear security guidance. Therefore, this study suggests that reactive remote

work increases corporate information security risks. Based on the foregoing, this study proposes the following hypotheses:

***H1a: Proactive remote work increases firms' information security risks.***

***H1b: Reactive remote work increases firms' information security risks.***

### 5.2.2 The moderating roles of IT capability and managerial capability

From the socio-technical system view, organizations are viewed as integrative wholes composed of both technical and social systems. The technical system includes equipment, tools, technology, and processes, while the social system comprises people, organizational structures, and their interrelationships (Appelbaum, 1997; Bostrom & Heinen, 1977; Emery & Trist, 1960; Trist & Bamforth, 1951). This perspective emphasizes a holistic approach, focusing on the synergy and balance between technological and social factors. If an organization overly prioritizes the technical aspects while neglecting the social dimensions, or satisfies social demands while overlooking the possibilities and limitations of technology, its system efficacy may be compromised (Emery & Trist, 1960). In this study, the socio-technical system view provides a comprehensive framework for examining how firms can manage risks through a combination of technological and social means, particularly in the relationship between remote work and information security risks. Specifically, drawing on the socio-technical system view, this study proposes two moderating mechanisms for managing the information security risks associated with remote work: IT capability and managerial capability.

#### （1） The moderating roles of IT capability

Following the socio-technical system view, IT capability at the level of the technical system refers to a firm's comprehensive strength in IT infrastructure. IT capability encompasses not only traditional security tools such as firewalls, encryption technologies, multi-factor authentication, and virtual private networks (VPNs) (Tariq et al., 2022; Telo, 2019), but also includes cloud security solutions and blockchain-based security management tools

(Mikalef & Gupta, 2021). The application of these technologies not only enables employees to securely access corporate resources from any location but also provides comprehensive protection for sensitive data, thereby reducing the risks of unauthorized access and other security threats associated with remote work. In the scenario of proactive remote work, a robust IT capability supports firms by enabling them to take proactive security measures through pre-planning and thus building a defensive system (Brünker et al., 2023). For instance, the use of advanced encryption and intrusion detection systems helps protect sensitive corporate data, ensuring business continuity and data security. Therefore, when an organization possesses strong IT capabilities, the positive impact of proactive remote work on corporate information security risks is mitigated.

Similarly, in the context of reactive remote work, the importance of IT capability is also highlighted. Reactive remote work refers to the mode of remote work that firms are forced to implement in a short time due to external factors, such as pandemics(Ge et al., 2022). Compared to proactive remote work, firms might lack adequate time to prepare for the transition to reactive remote work, increasing their vulnerability to security risks. However, strong IT capabilities enable firms to swiftly adapt to remote work scenarios and implement necessary security measures. For instance, firms with robust IT capabilities can more rapidly deploy cloud-based security solutions to protect remote devices, providing essential security measures and safeguards for their remote work operations, thereby mitigating potential information security threats. Therefore, when an organization possesses strong IT capabilities, the adverse impact of reactive remote work on corporate information security risks is lessened. Overall, this study posits that IT capability is critical in managing information security risks associated with remote work. A robust IT capability can significantly aid organizations in effectively reducing the information security risks associated with remote work. Consequently, this study proposes the following hypotheses:

***H2a: IT capability negatively moderates the relationship between proactive remote work and firms' information security risks, such that the positive impact of proactive remote work on information security risks is mitigated when the firm possesses strong IT capability.***

***H2b: IT capability negatively moderates the relationship between reactive remote work and firms' information security risks, such that the positive impact of reactive remote work on information security risks is mitigated when the firm possesses strong IT capability.***

**（2） The moderating roles of managerial capability**

From the socio-technical system view, this study considers the moderating role of managerial capability within the social system on the relationship between remote work and information security. Managerial capability refers to the ability of organizational leaders to effectively manage and lead, typically encompassing skills and knowledge in planning, organizing, leading, and controlling (Holcomb et al., 2009). It includes effective resource allocation, employee motivation and guidance, and the achievement of organizational goals, representing a comprehensive capacity that covers decision-making, strategic thinking, team building, and change management. Managerial capability is also one of the key factors in gaining a competitive advantage for an organization (Barney, 1991). Previous research on information security has demonstrated that leaders' managerial capabilities play a crucial role in the management of information security (Haislip et al., 2021; Kwon & Johnson, 2013; Wang & Ngai, 2022). Therefore, in analyzing the relationship between remote work and information security risks, this study suggests that managerial capability is an essential social system factor.

This study posits that strong managerial capability can effectively mitigate the adverse impacts of proactive remote work on firms' information security risks. First, organizational leaders with strong managerial capabilities can effectively deploy and coordinate resources, creating additional value through resource utilization (Holcomb et al., 2009). Previous research has also emphasized the importance of managerial capabilities, such as excellent interpersonal

skills and effective coordination abilities, in deploying security resources and facilitating interdepartmental coordination (Barton et al., 2016; Hu et al., 2012; Kayworth & Whitten, 2010; Wang & Ngai, 2022). Therefore, firms with robust managerial capabilities can more effectively plan and implement security strategies, allocate security resources, and respond swiftly to security incidents during the implementation of proactive remote work arrangements. Second, firms with strong managerial capabilities are more effective in providing training and guidance to employees (Holcomb et al., 2009), such as helping employees better adapt to the remote work model, training them on security protocols, and mitigating security risks. Thus, strong managerial capabilities can effectively alleviate the adverse effects of proactive remote work on information security. Finally, firms with strong managerial capabilities can also cultivate a positive security culture (Wang & Ngai, 2022). The leadership's emphasis on information security can be conveyed to employees through organizational values and behavioral norms, encouraging them to naturally consider information security factors in their daily work, thereby proactively adopting security measures in a remote work environment. Based on this, the study suggests that robust managerial capabilities can help firms maintain or enhance their information security level while implementing proactive remote work, thereby reducing the security risks associated with remote work.

Additionally, this study proposes that managerial capability can effectively moderate the relationship between reactive remote work and information security risks. Although reactive remote work forces firms into remote working modes without prior preparation, those with strong managerial capabilities can reduce security risks in remote work environments through more efficient and effective management practices. First, firms with strong managerial capabilities can swiftly mobilize organizational resources and technical support in response to the demands of reactive remote work, ensuring that employees can securely access corporate networks and systems from home or any remote location (Ge et al., 2022). Second, firms with

strong managerial capabilities are more likely to have contingency plans and emergency response strategies, such as data protection and privacy policies, which help maintain information security under the reactive remote work model (Bao et al., 2019). Finally, firms with robust managerial capabilities exhibit higher agility (Harsch & Festing, 2020). Firms with strong managerial capabilities could quickly adjust staffing and provide training, enabling employees to smoothly transition to the new work model and understand how to protect sensitive data and information while working remotely. Accordingly, this study proposes the following hypotheses:

***H3a: Managerial capability negatively moderates the relationship between proactive remote work and firms' information security risks, such that the positive impact of proactive remote work on information security risks is mitigated when firms have strong managerial capability.***

***H3b: Managerial capability negatively moderates the relationship between reactive remote work and firms' information security risks, such that the positive impact of reactive remote work on information security risks is mitigated when firms have strong managerial capability.***

## 5.3 Research Methods

### 5.3.1 Data collection

To test the hypotheses, I collected annual matched data of publicly listed companies from Compustat during 2010-2021. The panel data involved in this study were constructed by matching databases from multiple sources. Due to the lack of a standardized identifier available across databases (such as the company's unique identifiers like ticker or gvkey), I conducted manual collection and coding efforts, and matched databases from different sources to build a unique dataset tailored for this study. The following sections detail the data sources and

measurement methods for the variables in this study.

The independent variables in this study are proactive and reactive remote work, with data sourced from the Factiva database. I conducted keyword searches in the Factiva database to manually collect firm-level announcements regarding remote work. Detailed methods for collecting data from the Factiva database can be found in Chapter 3, Study 1. For all news articles retrieved from Factiva, I meticulously read the content of each news report to identify announcements related to the remote work policies of the sample companies. I recorded the stock codes, announcement dates, and specific contents of the announcements. Ultimately, I obtained announcements for proactive remote work from 104 companies and for reactive remote work from 171 companies. Specifically, the typical reactive remote work announcements include Twitter (NYSE: TWTR) announcing their employees to work remotely in the face of virus' spread on March 3, 2020. CapStar Financial Holdings (NASDAQ: CSTR) launched comprehensive initiatives including work-from-home arrangements as part of their COVID-19 response strategy on March 23, 2020. Intuitive (NASDAQ: ISRG) instituted global work-from-home policies for the majority of their workforce during Covid-19 on April 28, 2020.

The dependent variable in this study is firms' information security risk, with data sourced from two mainstream data breach databases: the Privacy Rights Clearinghouse (PRC)[1] and the Identity Theft Resource Center (ITRC)[2]. These databases are widely recognized in the field of information security and data breaches and have been extensively utilized by previous researchers ((Liu et al., 2020; Wang & Ngai, 2022). Established in 1992, the PRC is a non-profit organization dedicated to protecting consumer privacy. It provides a comprehensive database that records various data breach incidents and privacy infringement cases, aimed at

[1] https://privacyrights.org/
[2] http://www.idtheftcenter.org/

raising public awareness about personal information protection. The ITRC, founded in 1999, is a non-profit organization committed to assisting victims of identity theft. It manages a specialized database that includes detailed information on identity theft and data breaches, supporting victims and helping to prevent such offenses. I manually compiled and coded all information about data breaches from these two databases, including the names of the companies involved, the year of the incident, types of data breaches, and detailed descriptions of the events. Additionally, the researchers merged the data breach events from both databases and eliminated duplicate entries to obtain a comprehensive record of corporate data breaches. Ultimately, the researchers collected data on 1230 corporate data breach incidents involving 820 publicly listed companies.

IT capability is sourced from the InformationWeek 500 database (hereafter referred to as IW500). Initiated by InformationWeek magazine, the IW500 ranking aims to identify companies that excel in IT, serving as industry benchmarks. This ranking includes data from companies across various sectors, such as financial services, healthcare, retail, manufacturing, and energy. The IW500 ranking criteria focus on technological innovation, complexity, alignment with business strategy, and commercial value, utilizing a scoring system that evaluates the IT capabilities of enterprises. The evaluation panel comprises industry analysts, IT executives, and researchers. Consequently, the IW500 serves as a recognized and authoritative method for measuring corporate IT capability, extensively utilized in previous research (Bharadwaj, 2000; Chae et al., 2014; Mishra et al., 2013; Wang & Ngai, 2022).

Managerial capability is measured using the two-stage data envelopment analysis (DEA) method pioneered by Demerjian et al. (2012). The use of DEA to assess managerial capability has been well recognized (Demerjian et al., 2013; Koester et al., 2017). The subsequent section will detail the method of measuring managerial capability using DEA. The control variables, such as financial and industry data, are sourced from the Compustat database.

To construct our comprehensive dataset, I employed a multi-stage data integration approach drawing from multiple authoritative sources. I manually recorded the stock codes (Ticker) of companies from Factiva, PRC, ITRC, and IW500. These data were subsequently matched with Compustat financial data. This primary matching procedure utilized stock ticker symbols as the principal identifier, supplemented by company legal names to ensure accuracy. To address potential matching discrepancies arising from corporate restructuring, name changes, or merger and acquisition activities, I implemented a rigorous verification protocol. When automatic matching procedures failed to establish definitive correspondence, I conducted manual verification through multiple channels, including corporate websites, historical SEC filings (10-K reports), business news archives, and company historical records. The resulting dataset comprises 39,656 company-year observations, representing a robust foundation for empirical analysis.

### 5.3.2 Measures

#### （1） Dependent variables

In this study, the dependent variable is information security risk, with data sourced from the PRC and ITRC databases. Building on previous research, this study uses corporate data breach as a proxy for information security risk. Specifically, the study measures the likelihood and severity of information security risks by data breach dummy variables and count variables. The likelihood of data breach is measured by whether a firm experienced a data breach event within the year; if a data breach occurred, the likelihood of data breach is coded as 1, otherwise, it is 0. Additionally, the severity of data breach is assessed by the frequency of data breach events a firm experiences in a year, with a higher frequency indicating a higher severity of information security risk. I calculate the frequency of a firm’s data breaches that occurred within the year. Table 5.1 lists some representative examples of data breach events.

Table 5.1 Representative examples of data breach events

| Ticker | Company | Year | Event type | Event description |
|---|---|---|---|---|
| MCD | McDonald's Corporation | 2013 | External cause (Hacker attack) | "Hackers stole McDonald's customer credit card information and sold it for profit." |
| AAPL | APPLE INC | 2014 | External cause (Hacker attack) | "Hackers conducted a man-in-the-middle attack on China's iCloud servers, intercepting email addresses, passwords, messages, photos, and personal contacts." |
| AMP | Ameriprise Financial Services, Inc. | 2015 | External cause (Physical theft) | "A data breach occurred at the company where customer information was stolen: the office was broken into, filing cabinets were forcibly opened, and customer files were stolen. Customer files contained names, birth dates, medical information, driver's licenses, social security, and account numbers." |
| GOOGL | Google | 2016 | External cause (Third party) | "A third-party benefits management provider inadvertently sent a file containing Google employees' personal information to a benefits manager at another institution." |
| TD | TD Bank | 2016 | Internal cause (Human error) | "An employee accessed and leaked customer confidential information, which included names, addresses, birth dates, social security numbers, and account numbers." |
| FDX | FedEx | 2018 | Internal cause (Accidental operation) | "Due to Amazon Web Services (AWS) cloud storage servers not being password protected, the personal information of thousands of FedEx customers worldwide was exposed online. This included passports, driver's licenses, and application forms sent by agents containing names, home addresses, and postal codes." |

**（2） Independent variables**

The independent variables, proactive and reactive remote work, are derived from firms' announcements collected via the Factiva database. I gathered announcements to record the dates and types of remote work policies implemented by firms. Proactive and reactive remote work are coded as dummy variables. If the remote work announcement is proactive, indicating a firm-initiated remote work policy, the dummy variable for proactive remote work is set to 1; otherwise, it is set to 0. If the remote work announcement is reactive, indicating a remote work arrangement enforced by external factors like COVID-19, the dummy variable for reactive remote work is set to 1; otherwise, it is 0.

**（3） Moderating variables**

***IT capability*** The measure of IT capability is derived from the IW500 database. Existing research generally regards using the IW500 database to measure a firm's IT capability as an

authoritative and credible approach (e.g., Bharadwaj, 2000; Chae et al., 2014; Mishra et al., 2013; Wang & Ngai, 2022). Following prior studies, this study codes IT capability as a dummy variable, where a firm's presence in the IW500 ranking in a given year indicates strong IT capability, coded as 1; otherwise, it is coded as 0. Additionally, as some firms may only appear in the IW500 rankings during specific years within the sample period, using a single year's ranking to measure IT capability might lead to bias. Therefore, this study also considers an alternative measure. Specifically, if a firm is recognized as a technology leader in the IW500 at any year during the sample period, it is coded as 1; otherwise, it is coded as 0. The results obtained from these two different measures of IT capability are consistent.

***Managerial capability*** Following the approach of Demerjian et al. (2012), this study uses the two-stage DEA method to measure managerial capability. Initially, I calculated the overall efficiency of all sample listed companies based on the DEA method. Subsequently, a Tobit regression model is used to decompose the overall efficiency into components attributable to firm characteristics and those due to managerial capability. The residuals extracted from this regression represent the managerial ability (Koester et al., 2017).

The combined DEA-Tobit two-stage approach offers three main advantages (Demerjian et al., 2013): First, it expands the research sample coverage across different industries. Traditional DEA methods face significant variability in defining input and output indicators across industries and different economic attributes of firms, leading to results that lack comparability for cross-industry analysis. In contrast, the two-stage DEA method can encompass all sample companies, transcending industry boundaries. Second, it enhances the robustness of the research findings. The indicators used in the two-stage DEA method are primarily based on firms' financial reports, which are highly credible, thus making the conclusions more robust and reliable. Third, this method effectively reduces measurement errors caused by noise. Traditional proxy measures often include many factors beyond

management's control, which should not be attributed to managerial ability. The two-stage DEA method enables a more accurate assessment of managerial capabilities and reduces interference from non-ability factors. The specific calculation method is as follows:

**Step one: Calculate efficiency using DEA.** Use Cost of Goods Sold (COGS), Selling, General & Administrative expenses (SG&A), Net Property, Plant & Equipment (PPE), Net Intangible Assets (Intan), Research & Development (R&D) expenditures, and Goodwill as input variables, and Operating Revenue (Sales) as the output variable. Efficiency values are calculated for each industry using the DEA model, denoted as q. The formula for the first stage is as follows:：

$$max_v\theta = \frac{Sales}{v_1 COGS + v_2 SG\&A + v_3 PPE + v_4 Intan + v_5 R\&D + v_6 Goodwill} \tag{5-1}$$

**Step two: Using the Tobit model to calculate the residuals.** In this model, the dependent variable is the firm efficiency value calculated from the DEA model. The explanatory variables include the natural logarithm of total assets (TotalAssets), market share (MarketShare), free cash flow (FreeCashFlow), the natural logarithm of firm age (Age), industry concentration (HHI), property rights (PropertyRight), and the presence of overseas subsidiaries (ForeignCurrency). The residuals from this regression are then used to represent managerial capability. The formula for the second stage is as follows:

$$q = \alpha_0 + \alpha_1 \ln(TotalAssets) + \alpha_2 MarketShare + \alpha_3 FreeCashFlow + \alpha_4 \ln(Age) + \alpha_5 HHI + \alpha_6 PropertyRight + \alpha_7 ForeignCurrency \tag{5-2}$$

**（4） Control variables**

This study incorporates a series of controls that could potentially impact firms' data breaches. These factors include firm size, financial leverage, return on assets (ROA), return on equity (ROE), R&D intensity, slack resource, and industry concentration (HHI). Specifically,

larger firms with wider business scopes are more likely to be exposed to information security risks. Therefore, firm size is controlled for its impact on information security risks, measured using the natural logarithm of total assets in millions of dollars (Hendricks et al., 2009; Li et al., 2022). Firms with more financial resources have greater capacity to invest in information security, and thus this study controls for financial leverage, ROA and ROE. Financial leverage is measured as the total debt divided by total assets. ROA is measured as net return over total assets to reflect profitability and efficiency in asset utilization (Fan et al., 2022). ROE is measured as net income divided by total shareholders' equity, indicating profitability relative to owners' equity (Ye et al., 2020). Moreover, a higher R&D intensity suggests more valuable information that might attract cyber threats, thereby increasing information security risks. R&D intensity is measured by the ratio of R&D expenditures to total assets (Padgett & Galan, 2010). Slack resource refers to resources that exceed the daily operational needs, which can provide firms with resilience and recovery capabilities in the face of information security incidents (Wiengarten et al., 2017). Slack resources are measured as the ratio of current assets minus current liabilities (net working capital) to total assets (Ye et al., 2020). Additionally, the competitive landscape within an industry also affects information security for firms, and thus this study controls industry concentration (Kwon & Johnson, 2014; Wang & Ngai, 2022). The Herfindahl-Hirschman Index (HHI), is used to measure industry concentration by calculating the sum of the squares of the market shares of firms within an industry, reflecting the dispersion of firm sizes and the level of competition in the market. I also control for firm and year fixed effects to account for unobserved heterogeneity across firms and over time. In Table 5.2, I provide a detailed description of the variables in this study.

Table 5.2 Variable measurements in Study 3

| Variables | Measures | Data sources | References |
|---|---|---|---|
| Data breach dummy | Dummy variable: Encoded as 1 if the firm experienced a data breach in the given year, otherwise 0. | PRC，ITRC | D'Arcy et al. (2020) |

| | | | |
|---|---|---|---|
| Data breach number | Count variable: A firm's total number of data breach incidents that occurred in the given year. | PRC，ITRC | D'Arcy et al. (2020) |
| Proactive remote work | Dummy variable: Encoded as 1 if the firm implemented a proactive remote work arrangement in the given year, otherwise 0. | FACTIVA | Lam et al. (2016) |
| Reactive remote work | Dummy variable: Encoded as 1 if the firm implemented a reactive remote work arrangement in the given year, otherwise 0. | FACTIVA | Lam et al. (2016) |
| IT capability | Dummy variable: Encoded as 1 if the firm is listed in the IW500, otherwise 0. | IW500 | Chae et al. (2014) |
| Managerial capability | DEA-Tobit two-stage model | Peter Demerjian data | Demerjian et al. (2012) |
| Firm size | Natural logarithm of total assets | COMPUSTAT | Li et al. (2022) |
| ROA | Net income/Total assets | COMPUSTAT | Ye et al. (2020) |
| ROE | Net income/Total equity | COMPUSTAT | Ye et al. (2020) |
| Firm leverage | Total debt/Total assets | COMPUSTAT | Ge et al. (2022) |
| R&D intensity | R&D expenditure/Total assets | COMPUSTAT | Padgett and Galan (2010) |
| Slack resource | (Current assets-Current liabilities)/Total assets | COMPUSTAT | Ye et al. (2020) |
| Industry concentration | HHI | COMPUSTAT | Cheng and Nault (2007) |

### 5.3.3 Model setting

Based on prior research related to data breach risks (D'Arcy et al., 2020; Haislip et al., 2021; Wang & Ngai, 2022), this study employs a Linear Probability Model (LPM) and incorporates firm and year fixed effects, with robust standard errors clustered at the firm level. The use of the LPM to estimate the main effects and moderating effects is justified for several reasons: First, LPM provides results that are straightforward to understand, and these results are consistent with estimates from nonlinear models (D'Arcy et al., 2020). Second, when using fixed effects analysis, the LPM can effectively avoids potential biases that could arise with nonlinear models (D'Arcy et al., 2020). Third, nonlinear fixed effects models, which are estimated using conditional maximum likelihood, use only data that changes over time and exclude data that does not change. This means observations that did not experience a data breach during the sample period would be excluded from the main analysis (D'Arcy et al.,

2020; Haislip et al., 2021; Wang & Ngai, 2022). Yet, the LPM, on the other hand, can effectively include these observations. Last but not least, compared to nonlinear models like logistic regression, the LPM is more effective in handling situations where the dependent variable is infrequent (King & Zeng, 2001). Based on these considerations, the study employs a fixed effects LPM for the estimation. Additionally, for robustness checks, the study employs a Poisson fixed effects model and a conditional logistic regression model to validate the robustness of the results (detailed in Section 5.4.4). The specific formulation of the main effect is as follow：

$$Databreach_{it+1} = \alpha_i + \beta_1 PRW_{it} + \beta_2 RRW_{it} + X_{it} + \gamma_t + \delta_i + \varepsilon_{it} \quad (5\text{-}3)$$

where $Databreach_{it+1}$ represents the likelihood and severity of data breach of firm *i* in year *t+1,* respectively. $\alpha_i$ represents the intercept for each firm. $PRW_{it}$ is the proactive remote work arrangement of firm *i* in year *t,* $RRW_{it}$ is the reactive remote work arrangement of firm *i* in year *t.* $\beta_1$ and $\beta_2$ estimate the impacts of proactive and reactive remote work on firms data breach risks, respectively. $X_{it}$ includes the whole set of control variables. $\gamma_t$ represents the year fixed effect and $\delta_i$ is the firm fixed effect. $\varepsilon_{it}$ is the error term.

To examine the moderating effects, this study adds IT capability, managerial capability, and their interactions with proactive and reactive remote work in Equation (5-3). The specific equation is as follows:

$$\begin{aligned} Databreach_{it+1} &= \alpha_i + \beta_1 PRW_{it} + \beta_2 RRW_{it} + \beta_3 IT_{it} + \beta_4 MA_{it} + \beta_5 IT_{it} \times PRW_{it} \\ &+ \beta_6 IT_{it} \times RRW_{it} + \beta_7 MA_{it} \times PRW_{it} + \beta_8 MA_{it} \times RRW_{it} + X_{it} + \gamma_t + \delta_i \\ &+ \varepsilon_{it} \end{aligned} \quad (5\text{-}4)$$

where $IT_{it}$ represents the IT capability of firm *i* in year *t.* $MA_{it}$ represents managerial

capability of firm *i* in year *t*. $\beta_5$ and $\beta_6$ represent the moderating effects of IT capability on the relationship between proactive and reactive on data breach, respectively. $\beta_7$ and $\beta_8$ represent the moderating effects of managerial capability on the relationship between proactive and reactive on data breach, respectively. The other variables are the same as those in Equation (5-3).

## 5.4 Analysis of Results

### 5.4.1 Descriptive statistics and correlation analysis

After integrating data from various sources, this study has compiled a comprehensive sample consisting of 39,656 firm-year observations. Descriptive statistics and correlation analyses for the variables included in this study are presented in Tables 5.3 and 5.4, respectively. It is observed that in this sample, the minimum number of data breaches experienced by any firm in a year is 0, while the maximum number is 4. This indicates that within the study's sample, certain firms encountered as many as four data breaches within a single year.

Table 5.3 Descriptive statistics in Study 3

| Variables | Mean | SD | Min | Max |
|---|---|---|---|---|
| Data breach likelihood | 0.013 | 0.112 | 0 | 1 |
| Data breach severity | 0.014 | 0.131 | 0 | 4 |
| Proactive remote work | 0.001 | 0.036 | 0 | 1 |
| Reactive remote work | 0.002 | 0.043 | 0 | 1 |
| IT capability | 0.003 | 0.052 | 0 | 1 |
| Managerial capability | 0.008 | 0.132 | -0.282 | 0.697 |
| Firm size | 5.487 | 2.759 | 0.009 | 12.380 |
| Leverage | 0.427 | 2.473 | -10.920 | 15.120 |
| ROA | -0.658 | 2.716 | -23 | 0.452 |
| ROE | -0.042 | 1.880 | -8.712 | 9.875 |
| R&D intensity | 0.191 | 0.434 | 0 | 3.090 |
| Slack resource | -0.312 | 4.213 | -42.310 | 0.948 |
| HHI | 0.058 | 0.063 | 0.011 | 0.334 |

*Note.* Observation = 39,656.

Table 5.4 Correlation analysis in Study 3

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Data breach likelihood | 1 | | | | | | | | | | | | |
| (2) Data breach severity | 0.941*** | 1 | | | | | | | | | | | |
| (3) Proactive remote work | 0.043*** | 0.043*** | 1 | | | | | | | | | | |
| (4) Reactive remote work | 0.013*** | 0.014*** | -0.001 | 1 | | | | | | | | | |
| (5) IT capability | 0.016*** | 0.020*** | 0.006** | 0.004* | 1 | | | | | | | | |
| (6) Managerial capability | 0.026*** | 0.028*** | 0.012*** | 0.014*** | 0.036*** | 1 | | | | | | | |
| (7) Firm size | 0.124*** | 0.121*** | 0.033*** | 0.036*** | 0.056*** | 0.015*** | 1 | | | | | | |
| (8) Leverage | 0.020*** | 0.019*** | -0.003 | 0.006** | 0.006** | -0.027*** | 0.206*** | 1 | | | | | |
| (9) ROA | 0.023*** | 0.022*** | 0.007** | 0.009*** | 0.009*** | -0.013*** | 0.384*** | 0.080*** | 1 | | | | |
| (10) ROE | 0.008** | 0.007** | 0.003 | -0.001 | -0.001 | 0.026*** | 0.007** | -0.213*** | -0.147*** | 1 | | | |
| (11) R&D intensity | -0.033*** | -0.032*** | -0.009** | -0.011** | -0.019*** | 0.043*** | -0.423*** | -0.096*** | -0.576*** | 0.052*** | 1 | | |
| (12) Slack resource | 0.015*** | 0.014*** | 0.005 | 0.006* | 0.005 | -0.031*** | 0.290*** | 0.056*** | 0.754*** | -0.088*** | -0.373*** | 1 | |
| (13) HHI | 0.041*** | 0.038*** | 0.000 | 0.005* | 0.002 | -0.042*** | -0.038*** | 0.024*** | 0.012*** | 0.010*** | -0.164*** | -0.002 | 1 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

### 5.4.2 Baseline results

Table 5.5 reports baseline results in Study 3, examining the impact of proactive and reactive remote work on firms' data breach risks. Models 1 and 2 have data breach likelihood as the dependent variable, assessing whether a firm experienced a data breach in a given year; Models 3 and 4 have data breach severity as the dependent variable, measuring the frequency of data breaches occurring within the year. Models 1 and 3 include only control variables. Consistent with our expectations, firm size and R&D intensity positively influence the data breach risks, indicating that larger firms and those with higher R&D intensity face greater information security risks. Additionally, ROA negatively affects data breach risk, suggesting that firms with better financial resources can more effectively mitigate risks. The effects of financial leverage, ROE, slack resource, and HHI on data breaches were not significant.

Model 2 presents the estimated coefficients for the effects of proactive and reactive remote work on the likelihood of data breaches within firms. The findings reveal that both proactive remote work ($\beta = 0.089$, $p < 0.05$) and reactive remote work ($\beta = 0.060$, $p < 0.1$) significantly heighten the likelihood of experiencing data breaches. Specifically, firms engaging in proactive remote work practices experience an 8.9% increase in the likelihood of data breaches, while those adopting reactive remote work practices see a 6.0% increase.

Model 4 reports the estimated coefficients for the impact of proactive and reactive remote work on the severity of data breaches. The results show that proactive remote work ($\beta = 0.080$, $p < 0.05$) and reactive remote work ($\beta = 0.081$, $p < 0.1$) significantly increase the severity of data breaches. Specifically, the severity of data breaches increases by 8.0% for firms with proactive remote work and 8.1% for those with reactive remote work. Thus, the baseline results support H1a and H1b, indicating that both proactive and reactive remote work significantly increase firms' information security risks.

Table 5.5 The results of main effects in Study 3

| | Data breach likelihood$_{t+1}$ | | Data breach severity$_{t+1}$ | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Firm size | 0.006*** | 0.005*** | 0.006*** | 0.006*** |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| Leverage | -0.000 | -0.000 | -0.000 | -0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROA | -0.001*** | -0.001*** | -0.001*** | -0.001*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROE | -0.000 | -0.000 | -0.000 | -0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| R&D intensity | 0.004*** | 0.004*** | 0.005*** | 0.005*** |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| Slack resource | 0.000 | 0.000 | 0.000 | 0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| HHI | -0.030 | -0.029 | -0.013 | -0.012 |
| | [0.062] | [0.062] | [0.067] | [0.067] |
| Proactive remote work | | **0.089**** | | **0.080**** |
| | | **[0.041]** | | **[0.040]** |
| Reactive remote work | | **0.060*** | | **0.081*** |
| | | **[0.033]** | | **[0.045]** |
| Year FE | YES | YES | YES | YES |
| Firm FE | YES | YES | YES | YES |
| Constant | -0.017*** | -0.017*** | -0.022*** | -0.022*** |
| | [0.004] | [0.004] | [0.005] | [0.005] |
| Observations | 39656 | 39656 | 39656 | 39656 |
| Adjusted $R^2$ | 0.040 | 0.041 | 0.040 | 0.041 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Robust standard errors clustered by firm are in parentheses.

### 5.4.3 Moderating effects results

Table 5.6 reports the results of the moderating effects. Models 1 and 3 explore the moderating roles of IT capability on the relationship between both types of remote work and information security risks. The results indicate that IT capability negatively moderates the impact of proactive remote work on the likelihood of data breaches (β = -0.167, p < 0.01) and the severity of data breaches (β = -0.229, p < 0.05), supporting H2a. Similarly, IT capability also negatively moderates the impact of reactive remote work on the likelihood of data breaches (β = -0.109, p < 0.05) and the severity of data breaches (β = -0.152, p < 0.1), supporting H2b. These findings suggest that stronger IT capabilities reduce the negative impacts of both proactive and reactive remote work on information security risks. This aligns with our expectation that firms with robust IT capabilities can effectively manage the information security risks associated with remote work.

Models 2 and 4 demonstrate the moderating effects of managerial capability on the relationship between proactive and reactive remote work and information security risks. The results reveal that managerial capability significantly reduces the impact of proactive remote work on the likelihood ($\beta = -0.432$, $p < 0.1$) and severity ($\beta = -0.677$, $p < 0.1$) of data breaches, supporting H3a. The moderating effects of managerial capability (43.2% and 67.7%) are substantially greater than those of IT capability (16.7% and 22.9%), indicating that managerial capability more effectively mitigates the information security risks posed by proactive remote work compared to IT capability. However, it is noteworthy that the moderating effects of managerial capability on the relationship between reactive remote work and both the likelihood and severity of data breaches are not significant, rejecting H3b. This finding suggests that the moderating role of managerial capability is not significant when firms engage in reactive remote work.

Table 5.6 The results of moderating effects in Study 3

| | Data breach likelihood$_{t+1}$ | | Data breach severity$_{t+1}$ | |
|---|---|---|---|---|
| | Model 1 | Model 2 | | Model 1 |
| Firm size | 0.005*** | 0.005*** | 0.006*** | 0.006*** |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| Leverage | -0.000 | -0.000 | -0.000 | -0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROA | -0.001*** | -0.001*** | -0.001*** | -0.001*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROE | -0.000 | -0.000 | -0.000 | -0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| R&D intensity | 0.004*** | 0.004*** | 0.005*** | 0.005*** |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| Slack resource | 0.000 | 0.000 | 0.000 | 0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| HHI | -0.030 | -0.029 | -0.012 | -0.012 |
| | [0.062] | [0.062] | [0.066] | [0.066] |
| Proactive remote work | 0.091** | 0.116** | 0.123** | 0.163** |
| | [0.042] | [0.051] | [0.058] | [0.077] |
| Reactive remote work | 0.025 | 0.010 | 0.037 | 0.024 |
| | [0.026] | [0.020] | [0.035] | [0.033] |
| IT capability (IT) | 0.039 | | 0.062 | |
| | [0.042] | | [0.067] | |
| Proactive remote work *IT | **-0.167*** ** | | **-0.229** ** | |
| | **[0.060]** | | **[0.090]** | |
| Reactive remote work *IT | **-0.109** ** | | **-0.152*** | |
| | **[0.053]** | | **[0.083]** | |
| Managerial capability (MA) | | 0.017** | | 0.026** |
| | | [0.007] | | [0.010] |
| Proactive remote work *MA | | **-0.432*** | | **-0.677*** |
| | | **[0.228]** | | **[0.391]** |
| Reactive remote work *MA | | 0.157 | | 0.119 |
| | | [0.139] | | [0.145] |
| Year FE | YES | YES | YES | YES |
| Firm FE | YES | YES | YES | YES |
| Constant | -0.016*** | -0.016*** | -0.021*** | -0.021*** |
| | [0.004] | [0.004] | [0.005] | [0.005] |
| Observations | 39656 | 39656 | 39656 | 39656 |
| Adjusted $R^2$ | 0.041 | 0.042 | 0.042 | 0.043 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Robust standard errors clustered by firm are in parentheses.

### 5.4.4 Endogeneity tests and robustness checks

Despite controlling for year and firm fixed effects and employing lagged measures, potential endogeneity issues may still exist between firms' adoption of proactive and reactive remote work and data breaches. Therefore, this study employs a series of endogeneity and robustness tests to address these concerns and validate the robustness of the results.

**(1) Heckman two-stage analysis**

To mitigate potential sample selection bias, this study utilizes the Heckman two-stage analysis method proposed by Heckman (1979). The primary purpose of this method is to correct for biases that may arise from the sample selection process by first estimating the probability of sample selection in the first stage, and then using the Inverse Mills Ratio (IMR) derived from the first stage as a control variable in the second-stage regression analysis.

In the first stage, whether firms implement proactive or reactive remote work is modeled as the dependent variable in a Probit model, which includes the control variables from the baseline regression as independent variables. Year and firm fixed effects are also included to eliminate the impact of individual characteristics and time trends. In the second stage, the IMR obtained from the first stage is included as an additional control variable in the regression analysis to test the main and moderating effects.

The results of the Heckman test in the second stage are shown in Tables 5.7 and 5.8. The IMR is significant at the 5% level, indicating the presence of selection bias in the study sample. After correcting for this bias, Table 5.7 shows the Heckman test results for the main effects: both proactive and reactive remote work continue to positively impact the likelihood and severity of corporate data breaches, consistent with the main effects reported in Table 5.5. Table 5.8 presents the Heckman test results for the moderating effects, showing that IT capability significantly and negatively moderates the impact of both proactive and reactive remote work on the likelihood and severity of data breaches. Moreover, managerial capability negatively

moderates the impact of proactive work but shows no significant moderating effect on the relationship between reactive remote work and information security risks, consistent with the results presented in Table 5.6. Therefore, the Heckman two-stage test results demonstrate that, even after correcting for selection bias, the findings of this study remain robust.

Table 5.7 Robustness test of main effects: Heckman two-stage analysis

| | Data breach likelihood$_{t+1}$ | Data breach severity$_{t+1}$ |
|---|---|---|
| | Model 1 | Model 2 |
| Firm size | 0.007*** | 0.009*** |
| | [0.001] | [0.001] |
| Leverage | -0.000 | -0.000 |
| | [0.000] | [0.000] |
| ROA | -0.001*** | -0.001*** |
| | [0.000] | [0.000] |
| ROE | -0.000 | -0.000 |
| | [0.000] | [0.000] |
| R&D intensity | 0.007*** | 0.008*** |
| | [0.001] | [0.002] |
| Slack resource | 0.000 | 0.000 |
| | [0.000] | [0.000] |
| HHI | -0.044 | -0.027 |
| | [0.069] | [0.074] |
| Proactive remote work | **0.091**** | **0.081**** |
| | **[0.042]** | **[0.040]** |
| Reactive remote work | **0.067**** | **0.089*** |
| | **[0.034]** | **[0.046]** |
| IMR | 0.007** | 0.008** |
| | [0.003] | [0.004] |
| Year FE | YES | YES |
| Firm FE | YES | YES |
| Constant | -0.045*** | -0.057*** |
| | [0.014] | [0.017] |
| Observations | 36893 | 36893 |
| Adjusted $R^2$ | 0.039 | 0.040 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Robust standard errors clustered by firm are in parentheses.

Table 5.8 Robustness test of moderating effects: Heckman two-stage analysis

| | Data breach likelihood$_{t+1}$ | | Data breach severity$_{t+1}$ | |
|---|---|---|---|---|
| | Model 1 | Model 2 | | Model 1 |
| Firm size | 0.280*** | 0.280*** | 0.336*** | 0.336*** |
| | [0.043] | [0.042] | [0.056] | [0.055] |
| Leverage | 0.000 | 0.000 | 0.000 | 0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROA | 0.054*** | 0.054*** | 0.065*** | 0.065*** |
| | [0.008] | [0.008] | [0.011] | [0.011] |
| ROE | 0.004*** | 0.004*** | 0.005*** | 0.005*** |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| R&D intensity | 0.465*** | 0.464*** | 0.559*** | 0.558*** |
| | [0.071] | [0.070] | [0.094] | [0.093] |
| Slack resource | 0.014*** | 0.014*** | 0.017*** | 0.017*** |
| | [0.002] | [0.002] | [0.003] | [0.003] |
| HHI | -2.007*** | -2.004*** | -2.387*** | -2.386*** |
| | [0.324] | [0.320] | [0.411] | [0.405] |
| Proactive remote work | 0.082* | 0.108** | 0.112* | 0.153** |
| | [0.042] | [0.051] | [0.059] | [0.077] |
| Reactive remote work | 0.013 | 0.002 | 0.022 | 0.014 |
| | [0.025] | [0.019] | [0.033] | [0.031] |
| IMR | 1.455*** | 1.454*** | 1.749*** | 1.749*** |
| | [0.224] | [0.221] | [0.296] | [0.291] |
| IT capability (IT) | 0.016 | | 0.036 | |
| | [0.047] | | [0.075] | |
| Proactive remote work *IT | **-0.145**** | | **-0.204**** | |
| | **[0.063]** | | **[0.096]** | |
| Reactive remote work *IT | **-0.114**** | | **-0.159*** | |
| | **[0.056]** | | **[0.088]** | |
| Managerial capability (MA) | | 0.004 | | 0.010 |
| | | [0.007] | | [0.009] |
| Proactive remote work *MA | | **-0.435*** | | **-0.680*** |
| | | **[0.230]** | | **[0.394]** |
| Reactive remote work *MA | | 0.110 | | 0.062 |
| | | [0.133] | | [0.139] |
| Year FE | YES | YES | YES | YES |
| Firm FE | YES | YES | YES | YES |
| Constant | -5.716*** | -5.710*** | -6.873*** | -6.873*** |
| | [0.879] | [0.868] | [1.161] | [1.142] |
| Observations | 36893 | 36893 | 36893 | 36893 |
| Adjusted $R^2$ | 0.058 | 0.059 | 0.060 | 0.061 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Robust standard errors clustered by firm are in parentheses.

**(2) Alternative estimation model**

Following previous data breach literature (D'Arcy et al., 2020; Haislip et al., 2021), this study adopts a fixed effects LPM in the baseline and moderating analysis. This approach ensures that all observations within the sample, including those firms that did not experience any data breaches during the sample period, are included in the regression analysis. To further ensure the robustness of the results, the study employs alternative models to test whether the estimates vary with changes in the model. Considering that the likelihood of data breaches is a binary variable, fixed effects logistic regression (Logit) is used for estimation (Wang & Ngai, 2022). Additionally, for the alternative dependent variable of data breach severity (a count variable), I employ the fixed effects Poisson estimation (Cameron & Trivedi, 2013; Wooldridge, 2010). The results from these alternative models, shown in Tables 5.9 and 5.10, are consistent with the baseline analysis results, thereby further demonstrating the robustness of our findings.

Table 5.9 Robustness test of main effects: Alternative estimation model

| | Data breach likelihood$_{t+1}$ (Logit) | Data breach severity$_{t+1}$ (Poisson) |
|---|---|---|
| | Model 1 | Model 2 |
| Firm size | 0.487*** | 0.424*** |
| | [0.024] | [0.020] |
| Leverage | -0.017 | -0.027 |
| | [0.017] | [0.019] |
| ROA | 0.061 | 0.102 |
| | [0.058] | [0.079] |
| ROE | 0.012 | 0.042 |
| | [0.046] | [0.052] |
| R&D intensity | 0.715*** | 0.411** |
| | [0.202] | [0.207] |
| Slack resource | -0.013 | -0.025 |
| | [0.031] | [0.033] |
| HHI | -3.526 | 2.928*** |
| | [2.817] | [0.496] |
| Proactive remote work | **1.189*** ** | **1.582*** ** |
| | **[0.431]** | **[0.364]** |
| Reactive remote work | **0.959**** | **1.208*** ** |
| | **[0.446]** | **[0.396]** |
| Year FE | YES | YES |
| Firm FE | YES | YES |
| Constant | -7.175*** | -7.813*** |
| | [1.360] | [0.242] |
| Observations | 37531 | 37531 |
| Adjusted $R^2$ | 0.178 | 0.137 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Robust standard errors clustered by firm are in parentheses.

Table 5.10 Robustness test of moderating effects: Alternative estimation model

| | Data breach likelihood$_{t+1}$ (Logit) | | Data breach severity$_{t+1}$ (Poisson) | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Firm size | 0.430*** | 0.486*** | 0.422*** | 0.418*** |
| | [0.020] | [0.024] | [0.020] | [0.020] |
| Leverage | 0.004 | -0.017 | -0.025 | -0.026 |
| | [0.015] | [0.017] | [0.019] | [0.019] |
| ROA | 0.428 | 0.055 | 0.103 | 0.097 |
| | [0.278] | [0.057] | [0.080] | [0.076] |
| ROE | 0.021 | 0.011 | 0.043 | 0.041 |
| | [0.040] | [0.045] | [0.051] | [0.052] |
| R&D intensity | 0.704* | 0.691*** | 0.409** | 0.365* |
| | [0.373] | [0.202] | [0.208] | [0.205] |
| Slack resource | 0.002 | -0.011 | -0.024 | -0.024 |
| | [0.042] | [0.032] | [0.034] | [0.034] |
| HHI | 3.189*** | -3.557 | 2.934*** | 2.896*** |
| | [0.474] | [2.800] | [0.495] | [0.496] |
| Proactive remote work | 1.935*** | 1.300*** | 1.646*** | 1.717*** |
| | [0.414] | [0.496] | [0.364] | [0.344] |
| Reactive remote work | 1.333*** | -0.145 | 0.606 | 0.454 |
| | [0.443] | [0.648] | [0.461] | [0.631] |
| IT capability (IT) | 0.355 | | 0.441 | |
| | [0.346] | | [0.376] | |
| Proactive remote work *IT | **-3.523*** ** | | **-6.073*** ** | |
| | **[1.147]** | | **[1.150]** | |
| Reactive remote work *IT | **-4.749*** ** | | **-6.249*** ** | |
| | **[1.127]** | | **[1.155]** | |
| Managerial capability (MA) | | 0.147 | | 0.251 |
| | | [0.303] | | [0.283] |
| Proactive remote work *MA | | **-4.997*** | | **-4.484**** |
| | | **[2.809]** | | **[1.770]** |
| Reactive remote work *MA | | 1.273 | | 0.421 |
| | | [1.924] | | [1.661] |
| Year FE | YES | YES | YES | YES |
| Firm FE | YES | YES | YES | YES |
| Constant | -7.658*** | -7.132*** | -7.806*** | -7.781*** |
| | [0.236] | [1.354] | [0.243] | [0.238] |
| Observations | 37531 | 37531 | 37531 | 37531 |
| Adjusted $R^2$ | 0.139 | 0.177 | 0.137 | 0.137 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Robust standard errors clustered by firm are in parentheses.

### 5.4.5 Additional analysis

In this section, I further differentiate between two types of data breach risks: internal data breach risks and external data breach risks (Angst et al., 2017; Cheng et al., 2017), thereby delving into the impact of proactive and reactive remote work on these distinct types of data breach risks. Specifically, following the approach of Holtfreter and Harrington (2015) data breaches can be categorized based on the responsible party for the breach's occurrence, namely internal and external data breach risks. Internal data breach risks refer to breaches caused by internal factors such as employee negligence, malicious theft, or internal technical failures. External data breach risks refer to breaches resulting from external factors, such as hacker attacks, theft by external parties, or leaks from third parties. To operationalize these categories, I carefully review the details of each data breach incident and construct dummy variable and count variable to measure internal and external data breaches, respectively.

Table 5.11 reports the results of additional analyses, examining the impacts of proactive and reactive remote work on different types of data breaches within firms. The results from Models 1 and 2 indicate that neither proactive nor reactive remote work has a significant impact on internal data breaches, suggesting that data breaches associated with remote work are rarely due to internal factors.

Models 3 and 4 examine the impacts of proactive and reactive remote work on external data breaches. The results indicate that proactive remote work does not significantly affect external data breaches. In contrast, reactive remote work significantly increases the likelihood and severity of external data breaches. This suggests that firms compelled to adopt remote work due to external factors, such as emergencies or regulatory demands, may face heightened external data security risks, including cyberattacks. Conversely, when firms proactively choose remote work and allocate sufficient time to plan and implement necessary security measures, the risks of both internal and external data breaches do not significantly increase. This could

be because firms with proactive remote work policies are more capable of managing their information security environments effectively. In contrast, those who adopt reactive remote work may have to rapidly transition work modes under less prepared conditions, creating security vulnerabilities that can be exploited. These findings highlight the critical importance of early warning systems and preparedness for managing information security risks in remote work arrangements, underscoring the need for timely and effective governance measures to mitigate these risks.

Table 5.11 Further analysis results in Study 3

| | Internal data $breach_{t+1}$ (Dummy) | Internal data $breach_{t+1}$ (Number) | External data $breach_{t+1}$ (Dummy) | External data $breach_{t+1}$ (Number) |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Firm size | 0.002*** | 0.002*** | 0.004*** | 0.004*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Leverage | 0.000 | -0.000 | -0.000 | -0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROA | -0.000*** | -0.000*** | -0.000*** | -0.001*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| ROE | -0.000 | -0.000 | -0.000 | -0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| R&D intensity | 0.002*** | 0.002*** | 0.003*** | 0.004*** |
| | [0.000] | [0.000] | [0.001] | [0.001] |
| Slack resource | 0.000 | 0.000 | -0.000 | 0.000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| HHI | -0.050** | -0.048** | 0.018 | 0.027 |
| | [0.020] | [0.020] | [0.056] | [0.062] |
| Proactive remote work | 0.037 | 0.036 | 0.044 | 0.039 |
| | [0.032] | [0.032] | [0.033] | [0.032] |
| Reactive remote work | 0.017 | 0.016 | **0.055*** | **0.051*** |
| | [0.018] | [0.018] | **[0.031]** | **[0.031]** |
| Year FE | YES | YES | YES | YES |
| Firm FE | YES | YES | YES | YES |
| Constant | -0.005*** | -0.006*** | -0.013*** | -0.016*** |
| | [0.002] | [0.002] | [0.004] | [0.004] |
| Observations | 39654 | 39654 | 39654 | 39654 |
| Adjusted $R^2$ | 0.034 | 0.033 | 0.027 | 0.027 |

*Notes.* * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; Robust standard errors clustered by firm are in parentheses.

## 5.5 Discussion and Conclusion

### 5.5.1 Results discussion

This study leverages panel data on publicly listed firms and employs econometric methods such as the LPM to empirically test the effects of proactive and reactive remote work on firms' information security. This study provides robust empirical evidence for the study of the relationship between remote work and information security. Additionally, integrating a socio-technical systems view, this study further explores the moderating effects of IT capability at the technical system level and managerial capabilities at the social system level, enhancing our understanding of the critical boundary conditions between remote work and information security. Overall, the findings of this study aim to deepen insights into the outcomes of remote work concerning information security and offer guidance and reference for firms to effectively implement remote work strategies while managing their adverse impacts on information security.

**(1) Impacts of proactive and reactive remote work on firms' information security**

This study finds that both proactive and reactive remote work significantly increase the likelihood and severity of information security risks within firms. This conclusion echoes previous research on the relationship between remote work and firms' information security, suggesting that remote work poses a significant challenge to firms' information security management (e.g., Curran, 2020; Evangelakos, 2020; James & Griffiths, 2014; Malecki, 2020). In traditional office settings, sensitive corporate data is typically safeguarded within the firm's internal network. However, in a remote work environment, employees access these networks and resources via the Internet from diverse locations, thereby broadening the cybersecurity perimeter and offering potential attackers numerous entry points. Additionally, when employees use personal devices and networks to access company data, the inherently less secure home networks and public Wi-Fi further amplify the risk of data breaches. Previous

research also underscores that 77% of corporate information security risks stem from the use of unsecured home networks (Philip et al., 2023).

Moreover, the findings reveal a notable distinction in information security outcomes between reactive and proactive remote work implementations. Contrary to initial expectations, reactive remote work arrangements demonstrate a lower likelihood of data breaches compared to proactive remote work. This phenomenon can be attributed to several key factors. First, employees in proactive remote work settings typically engage more extensively with remote access technologies and cloud services, necessitating multiple stages of data transmission and storage (Grimm, 2021). This increased data flow inherently expands the attack surface, enhancing the probability of unauthorized access or inadvertent data leakage. Furthermore, the broader scope of proactive remote work implementations naturally extends the organization's risk exposure. Second, organizations implementing reactive remote work often exhibit heightened risk awareness and security consciousness, possibly due to the immediate pressures that necessitated the transition. Conversely, proactive remote work adoption may suffer from an optimism bias, where organizations potentially underestimate the complexity and magnitude of cybersecurity challenges. This reduced threat perception might lead to less rigorous security measures, ultimately contributing to increased vulnerability.

Furthermore, this study discovers that reactive remote work leads to more severe data breaches compared to proactive remote work. The likely reason is that under a reactive remote work context, firms are often forced to adopt remote work strategies due to external pressures, thus lacking adequate preparation and resource allocation to ensure information security (Babbs, 2020), such as security contingency planning and employee security training (Lee & Lee, 2021). In reactive remote work environments, employees may lack sufficient security training and awareness, potentially being less vigilant about possible security threats. In such cases, when data breaches occur, they might involve larger volumes of data and have a broader

impact, thereby increasing the severity of the data breaches resulting from reactive remote work. Additionally, firms operating under reactive remote work may lack timely technical support and agile response mechanisms (Curran, 2020; Grimm, 2021), making it more challenging to respond swiftly and effectively to security incidents. This lack of rapid response capabilities can exacerbate the consequences of data breaches, leading to more severe outcomes. Therefore, insufficient preparedness and support under reactive remote work conditions can cause greater damage to a firm's information security.

In the additional analyses, this study differentiated between internal and external data breaches based on the responsible party for the breach (Angst et al., 2017; Cheng et al., 2017; Holtfreter & Harrington, 2015), and delved into the impacts of proactive and reactive remote work on internal and external data breach risks. The results indicate that reactive remote work significantly increases the risk of external data breaches but has no effect on internal data breach risks. This finding suggests that the data breach risks associated with reactive remote work predominantly stem from external attacks and threats, rather than internal factors. Under reactive remote work conditions, firms may lack the necessary time and resources to invest in external network protections. For instance, firewalls, intrusion detection systems, and data encryption technologies may not be adequately configured and updated, making the organization more susceptible to external attacks and threats. This vulnerability highlights the critical need for enhanced security measures in firms that adopt remote work, especially on a reactive basis, to mitigate the heightened risks of external data breaches.

**(2) The moderating roles of IT capability and managerial capability**

Integrating a socio-technical systems view, this study further explores how IT capabilities (technical system) and managerial capabilities (social system) moderate the relationship between both proactive and reactive remote work and firms' information security risks. The results show that IT capabilities negatively moderate the relationship between remote work

(both proactive and reactive) and information security risks; that is, firms with strong IT capabilities can mitigate the information security risks associated with remote work. This conclusion is consistent with our expectations and indicates that IT capabilities are crucial for reducing the information security risks brought about by remote work.

Previous research has also indicated that IT support is a vital factor for the success of remote work (Siha & Monroe, 2006). Firms with robust IT capabilities provide a more advanced and comprehensive technological infrastructure for remote work, which includes but is not limited to secure network connections (e.g., VPNs), endpoint protection, data encryption, access controls, and intrusion detection systems (Tariq et al., 2022; Telo, 2019). Moreover, firms with strong IT capabilities are often able to adapt more quickly to new working environments and respond promptly to potential security threats. As a result, firms can promptly identify and rectify security vulnerabilities in a remote work setting, thereby mitigating information security risks.

Interestingly, this study finds that managerial capability negatively moderates the relationship between proactive remote work and information security risks; yet the moderating effect is not significant in the case of reactive remote work. This result partially supports previous research findings, suggesting that managerial capability plays a crucial role in managing corporate information security (Barton et al., 2016; Haislip et al., 2021; Hu et al., 2012; Kwon & Johnson, 2013; Wang & Ngai, 2022). When firms proactively adopt remote work, management involvement, strategic planning, and the development of security policies significantly reduce the information security risks associated with remote work (Wang & Ngai, 2022).

However, the study reveals that in scenarios where firms implement reactive remote work, managerial capability fails to effectively mitigate information security risks. This finding aligns with the arguments that managers' bounded rationality and overconfidence may result in a

misalignment between the perceived uncertainties of external risks and the actual level of information security (Liu et al., 2011). Additionally, reactive remote work is often a mode of operation hastily implemented due to external factors, such as public health emergencies. Under these circumstances, management may not have adequate time for sufficient preparation and response, leading to the ineffectiveness of management measures. Even with strong managerial capability, it can be challenging to swiftly adjust and effectively respond to information security risks. Moreover, the effective deployment of managerial capability necessitates substantial cooperation between managers and employees. In a reactive remote work environment, the absence of effective preparation between management and staff may hinder the effectiveness of managerial capability. In contrast, proactive remote work allows firms to allocate sufficient preparation time, typically accompanied by more comprehensive planning and stronger resource allocation. Consequently, management can more systematically guide the implementation of remote work and ensure the effective execution of corresponding information security measures.

### 5.5.2 Theoretical implications

The theoretical implications of this study are threefold: First, the study identifies and differentiates between two distinct types of remote work at the organizational level—proactive and reactive—thereby advancing our conceptual understanding of remote work. Previous studies commonly treated remote work as a homogeneous entity, overlooking the distinct impacts different forms of remote work could have on information security. This study innovatively establishes clear conceptual distinctions between proactive and reactive remote work, thus enriching the existing scholarly dialogue on this topic (Allen et al., 2015; Angel Martı´nez Sa´nchez et al., 2007; Siha & Monroe, 2006). Proactive remote work is strategically implemented by organizations as part of their long-term development and strategic goals, emphasizing flexibility and employee autonomy (Allen et al., 2015; Angel Martı´nez Sa´nchez

et al., 2007; Stavrou, 2005). In contrast, reactive remote work arises from external pressures or unforeseen events, and is often a contingency measure adopted by organizations without sufficient preparation (Ge et al., 2022). The nuanced perspectives introduced in this study offer a novel lens for exploring the multidimensionality and complexity of remote work. This distinction enables a more precise understanding of how different remote work arrangements impact organizational information security, providing valuable insights for future research in this area.

Second, this study empirically reveals the impact of proactive and reactive remote work on firms' information security risks, offering new insights into the complex relationship between remote work and information security. Although previous research has acknowledged the information security risks associated with remote work, these studies have primarily been conceptual (e.g., Curran, 2020; Evangelakos, 2020; James & Griffiths, 2014; Malecki, 2020), and lack empirical data support. Moreover, such literature often fails to distinguish between proactive and reactive remote work, thereby not fully revealing the potential differences in their impacts on information security risks. This study innovatively utilizes panel data derived from multiple data sources and employs LPM estimation to empirically test the effects of proactive and reactive remote work on firms' information security risks. This fills a notable gap in the literature and provides empirical evidence of the negative impacts of remote work on information security.

Third, this study employs a socio-technical system view to examine the moderating effects of IT capability (technical system) and managerial capability (social system) on the relationship between proactive and reactive remote work and firms' information security. This approach enhances our understanding of the boundary conditions governing the remote work-information security nexus and identifies effective mechanisms for managing the information security risks inherent in different remote work models. Prior research has seldom explored

these boundary conditions, thus leaving unresolved the crucial question of how to effectively mitigate the information security risks introduced by remote work. Drawing on the socio-technical system framework (Appelbaum, 1997; Bostrom & Heinen, 1977; Emery & Trist, 1960; Trist & Bamforth, 1951), this study innovatively reveals that IT capability at the technical system and managerial capability at the social system level significantly moderate the impacts of proactive and reactive remote work on corporate information security risks. Specifically, the findings indicate that robust technological capabilities not only significantly reduce the information security risks associated with proactive remote work but also effectively curb the risks stemming from reactive remote work. This emphasizes the pivotal role of corporate technological capabilities and the associated IT infrastructure in alleviating the information security challenges posed by remote work, corroborating earlier studies on the critical importance of IT in managing corporate information security (Curran, 2020; Grimm, 2021; Siha & Monroe, 2006).

Moreover, the study notes that while managerial capability can effectively reduce the information security risks linked to proactive remote work, their effectiveness diminishes in scenarios involving reactive remote work. This finding suggests that managerial capability is not universally effective across all remote work scenarios, particularly when organizations engage in remote work without sufficient preparation, thereby limiting the efficacy of management strategies in controlling information security risks. This analysis uncovers the varying impacts of different types of remote work on information security risks, thereby enriching the existing body of research on the relationship between remote work and information security. In summary, this study elucidates the significant governance mechanisms needed to mitigate the information security risks posed by different types of remote work through the lens of socio-technical systems, significantly advancing our knowledge in this area.

### 5.5.3 Practical implications

This study provides crucial insights for business managers to understand and effectively address the information security challenges posed by remote work environments. First, the study finds that both voluntarily chosen and forced remote work models introduce information security risks for firms. Thus, managers need to adopt a proactive and systematic perspective to recognize and tackle the security challenges associated with remote work. As the digital economy thrives, remote work, being a significant aspect of corporate digital transformation, is increasingly becoming the norm in the digital age. Therefore, firms implementing remote work should actively confront the information security challenges it brings and take measures to effectively manage these risks.

Second, the study highlights the critical importance of IT capability in managing the information security risks arising from remote work. Regardless of whether it is proactive or reactive remote work, robust IT capability can significantly mitigate information security risks. These findings encourage managers to invest in advanced information security technologies, such as end-to-end encryption, secure gateways, and intrusion detection systems, to strengthen technical protective measures and safeguard corporate data and networks. Strong IT capability can support firms to enhance their emergency response and risk defense capabilities. Therefore, the study prompts managers to pay close attention to developing comprehensive IT capability and improving the allocation of technology-related resources in their daily business operations.

Third, the study reveals that managerial capability is only effective in mitigating the information security risks associated with proactive remote work, not reactive remote work. This finding underscores the necessity of enhancing managerial skills to manage information security risks more effectively under proactive remote work arrangements. It also cautions managers against complacency, highlighting that exceptional managerial abilities do not guarantee effective risk management under all circumstances. Particularly, when unexpected

events or crises prompt a shift to remote work, managerial capability alone may not suffice to prevent data breaches. This emphasizes the critical role of advance planning and robust management practices in safeguarding information security.

Lastly, firms should heighten their crisis preparedness, prioritize the development and support of information security within their daily operations, and ensure that emergency plans and adaptable management strategies are in place to swiftly enhance information security measures as needed. Firms are encouraged to proactively build a strong information security framework, formulate comprehensive security policies and procedures, and conduct regular security training for employees. Such initiatives ensure that staff understand the significance of information security and are equipped with the necessary skills to uphold it.

# Chapter 6 Conclusions

## 6.1 Summary of Study Findings

This study examines the relationship between remote work adoption and firm performance through multiple theoretical lenses, integrating the digital economy competitive strategy framework, Motivation-Ability-Opportunity (MAO) theory, knowledge search theory, and socio-technical systems perspective. The study is structured around three fundamental dimensions of competitive strategy: cost leadership, differentiation, and risk management, while exploring critical boundary conditions that moderate these relationships. Specifically, (1) from a cost leadership perspective, this study investigates the impact of remote work on operational efficiency, identifying the moderating roles of employee relationship, profitability, and the specific context of the high-tech industry. (2) From a differentiation perspective, this study explores how remote work affects innovation performance, recognizing the moderating effects of slack resource and growth opportunity. (3) From a risk management perspective, this study examines the impacts of proactive and reactive remote work on information security risks, pinpointing the moderating influences of IT capability and managerial capability. The key findings of these studies are summarized below.

**First, the study finds that compared to firms without remote work practices, those implementing remote work experience a decrease in overall operational efficiency. Moreover, the negative impact on operational efficiency tends to increase over time. However, firms with good employee relationship, strong profitability, or those in the high-tech industry can mitigate the adverse effects of remote work on operational efficiency.**

This thesis reveals that remote work negatively affects a firm's operational efficiency. On average, operational efficiency decreases by 2.4% for firms that implement remote work compared to those that do not. In the long run, the detrimental impact of remote work on

operational efficiency grows. This empirical finding suggests that implementing remote work at the corporate level could lead to reduced operational efficiency. This is because key factors that enhance operational efficiency in a remote work environment—such as coordination, communication, and collaboration—may be hindered, potentially causing the network of employee cooperation to become rigid and isolated. This, in turn, weakens effective internal and cross-organizational communication and information sharing. Moreover, employees remote working often struggle to ensure sufficient, uninterrupted focused work time. This not only blurs the boundaries between work and home but can also lead to stress among employees in maintaining a work-life balance. Additionally, social isolation and the lack of face-to-face emotional support in a remote work environment affect productivity and creativity, which ultimately reflects a decline in operational efficiency.

However, the study further discovers that firms with good employee relationships can mitigate the negative impact of remote work on operational efficiency. Positive employee relationship helps build a psychological contract between the firm and its employees, stimulating intrinsic motivation and self-management skills, ensuring that employees remain productive even in a remote setting. Furthermore, firms with strong profitability can effectively alleviate the impact of remote work on operational efficiency. Healthy profit margins provide firms with sufficient resources to invest more in the infrastructure and technology required for remote work. Firms with robust profitability can avoid productivity losses caused by resource dispersion and allocate these resources more efficiently, thus significantly improving operational efficiency. Additionally, firms in the high-tech industry can soften the negative impact of remote work on operational efficiency. The flexibility of remote work aligns well with the work characteristics and corporate culture of high-tech firms, which possess extensive digital resources to support remote working, providing solid technical support for remote operations.

**Second, this thesis finds remote work can effectively enhance a firm's innovation performance, including both the quantity and quality of innovations. Additionally, the study identifies that when a firm has an excess of slack resource, the positive impact of remote work on innovation performance is diminished. Conversely, when a firm has favorable growth opportunity, the positive impact of remote work on innovation performance is enhanced.**

The study reveals that remote work significantly boosts a firm's innovation performance by stimulating the motivation for knowledge search, expanding the breadth of knowledge search, and deepening the depth of knowledge exploration. Remote work breaks down traditional geographic constraints, enabling team members and stakeholders to transcend spatial boundaries and engage collectively in innovative activities. This diversified collaboration fosters the integration and collision of heterogeneous knowledge. Moreover, remote work provides tremendous flexibility in terms of work hours and locations, allowing employees to work during their most comfortable and productive times and settings. This flexibility not only enhances employee satisfaction but also provides fertile ground for the expression of creative thinking and innovative capabilities. Employees can explore and experiment with new ideas more freely without the constraints of traditional office models, thereby igniting more innovative sparks. Additionally, remote work offers firms opportunities to collaborate on and absorb cross-cultural ideas and methods, bringing new perspectives and solutions to firm innovation, thus enhancing both the quantity and quality of innovations.

Furthermore, the study identifies distinct moderating effects of a firm's slack resource and growth opportunity on the relationship between remote work and innovation performance. The findings reveal that when a firm possesses excessive slack resource, the beneficial impact of remote work on both the quantity and quality of innovation is curtailed. This observation aligns with the knowledge search perspective, which posits that knowledge acquired by a firm must

be thoroughly absorbed and applied to foster innovation. However, an abundance of slack resource can lead to resource entrapment, diminishing the firm's motivation to seek new information. Additionally, the accumulation of excessive resources can induce organizational inertia and a resource curse, sapping the firm's drive to explore new knowledge and thus diminishing the effectiveness of remote work in enhancing innovation.

Conversely, when firms encounter favorable growth opportunity, the positive impact of remote work on innovation outputs is amplified. Favorable growth opportunity signal market potential and positive stakeholder expectations, which invigorate firms to participate in innovative activities more actively within remote work environments. Thus, growth opportunity empowers firms to integrate and apply acquired knowledge, significantly enhancing the dynamics of innovation in terms of both quantity and quality. This study provides essential insights into how firms can effectively harness resources and capitalize on growth opportunity to boost innovation performance in a remote work context.

**Third, this thesis finds both proactive and reactive remote work increase the likelihood and severity of information security risks for firms. Nevertheless, firms with strong IT capability can mitigate the information security risks associated with both remote work models. When firms possess strong managerial capability, they can effectively alleviate the information security risks associated with proactive remote work, but the moderating effect is not significant for reactive remote work.**

The study reveals that both proactive and reactive remote work types increase the likelihood and severity of information security risks for firms. In remote work settings, employees access the firm's network and resources from various locations via the Internet, which not only expands the boundaries of network security but also provides more avenues for potential attackers. Moreover, when employees use personal devices and networks to connect to company data, the risks of data breaches further increase due to the typically lower security

of home networks and public Wi-Fi compared to corporate networks. The study also compares the different impacts of proactive and reactive remote work on information security risks. While the likelihood of data breaches is lower in reactive remote work, the severity of risks when breaches do occur is higher. In proactive remote work, employees may more frequently use remote access technologies and cloud services, increasing the stages of data transmission and storage and thereby raising the risk of unauthorized access or accidental leaks. In contrast, in reactive remote work scenarios, employees may lack the necessary security training and awareness, making them less vigilant about potential security threats. Consequently, when data breaches occur, they have a wider impact, leading to more severe consequences for reactive remote work.

The moderating mechanisms find that firms with strong IT capability can reduce the information security risks brought by remote work, regardless of the remote work model. Firms with advanced IT capability can build a more secure and robust support system for remote work, covering secure network connections, endpoint protection, data encryption, access control management, and intrusion detection. Thus, IT capability is a key element in mitigating the threats to information security posed by remote work. Interestingly, the study notes that while managerial capability plays a positive moderating role in the relationship between proactive remote work and information security risks, its effect is not pronounced for reactive remote work. On one hand, the bounded rationality and overconfidence of business managers may lead to a misalignment between the perceived uncertainty of external risks and the internal level of information security. On the other hand, in reactive remote work scenarios, firms are often forced to implement remote work quickly due to external factors, leaving management with insufficient time for adequate planning and response. Consequently, even firms with strong managerial capability may struggle to adjust and respond effectively to information security risks in the short term, thus diminishing their role in risk reduction.

## 6.2 Theoretical Implications

This research advances the understanding of remote work as a strategic imperative in the digital economy through empirical investigation of its multidimensional effects on firm performance. By examining the impacts on operational efficiency, innovation capabilities, and information security—along with their contingency factors —this research makes several theoretical contributions. The study extends existing frameworks of digital economy competitive strategy by demonstrating how remote work functions as a strategic lever across three fundamental dimensions of digital competition. First, it enriches cost leadership theory by elucidating how remote work arrangements optimize operational efficiency contingent upon organizational contextual factors. Second, it advances the differentiation strategy literature by explicating the mechanisms through which distributed work enhances innovative capabilities and knowledge creation. Third, it contributes to risk management theory by delineating the differential information security outcomes between proactive and reactive remote work implementation approaches.

**First, the thesis enhances the empirical foundation of remote work research by analyzing the impact of remote work on performance outcomes at the firm level. It offers extensive empirical evidence on how remote work affects operational efficiency, innovation performance, and information security.**

Due to challenges in accessing firm-level remote work data, most previous studies have concentrated on the individual level with limited exploration of organizational impacts. Additionally, related empirical studies have often relied on qualitative analysis or subjective data from employee self-reported surveys, which lack rigorous econometric analysis based on objective secondary data (Bailey & Kurland, 2002; De Menezes & Kelliher, 2011). This has led to significant limitations in understanding the impact of remote work on firms' performance. Consequently, scholars have advocated for the use of large-sample empirical methods in future

remote work research to draw broader conclusions, and stressed the importance of longitudinal research designs to establish causal relationships (De Menezes & Kelliher, 2011).

In this thesis, I innovatively collect firm-level remote work data from corporate announcements and utilize large-scale panel data along with rigorous econometric estimation models to test the impact of remote work on firms' performance empirically. This not only responds to previous scholars' calls for more robust empirical research methods to investigate the effects of remote work (Belanger, 2005; Feldman & Gainey, 1997), but also supports the recommendations of scholars Siha and Monroe (2006) by employing a longitudinal research design to uncover the causal relationships between remote work and business performance outcomes. Specifically, the empirical results of this thesis reveal that remote work reduces operational efficiency, promotes innovation performance, and increases information security risks. These findings provide a comprehensive understanding of the intricate positive and negative effects of remote work on long-term business development in the digital economy context.

**Second, this thesis integrates multiple theoretical perspectives to identify significant boundary conditions in the relationship between remote work and performance, thereby enriching the theoretical landscape of remote work research.**

Existing literature on remote work often lacks a solid theoretical foundation, with most studies missing robust theoretical frameworks, especially in empirical research where few studies build and test hypotheses based on appropriate theories. Additionally, existing theoretical perspectives primarily focus on the individual level, exploring how remote work affects individual performance outcomes, with relatively less theoretical support at the organizational level (De Menezes & Kelliher, 2011). This research employs various theoretical perspectives to examine the impact of remote work on firm-level competitive performance and to identify its boundary conditions, responding to suggestions by scholars such as Bailey and

Kurland (2002) to deepen theoretical construction in remote work studies.

Specifically, Study 1 integrates the Motivation-Ability-Opportunity (MAO) framework, identifying that employee relationship (motivation factor), firm profitability (ability factor), and high-tech industry (opportunity factor) can effectively mitigate the negative impact of remote work on operational efficiency. Study 2 uses knowledge search theory to verify that slack resource negatively moderates while growth opportunity positively moderates the relationship between remote work and innovation performance. Study 3, adopting a socio-technical system view, identifies the differing roles of IT capability and managerial capability in mitigating the information security risks associated with remote work. By integrating diverse theoretical perspectives, this thesis not only deepens the understanding of the relationship between remote work and performance outcomes, but also enriches the theoretical framework of existing remote work research.

**Third, this thesis examines the impact of remote work on firms' operational efficiency from a cost leadership perspective, providing universal and general empirical findings on the relationship between remote work and operational efficiency, along with its boundary conditions. It also unveils the long-term effects of remote work on operational efficiency, enriching the empirical evidence regarding their relationship.**

Existing research on how remote work affects firms' operational efficiency is still relatively scarce, and there is no clear consensus, with conflicting views evident in the literature. Previous studies have primarily focused on individual-level analysis (i.e., Chow & Chew, 2006; McDermott & Hansen, 2021; Shen, 2023; Wang et al., 2020), and large-sample studies on the corporate level are rare. Although a few studies have addressed the impact of remote work on corporate productivity, these are often limited to case studies of specific firms, lacking broad empirical support. Furthermore, most related research has been concentrated during the pandemic period. This study, utilizing long-term panel data, comprehensively examines the

long-term impact of remote work on firms' operational efficiency, offering generalizable and universally applicable conclusions. Additionally, by integrating the MAO theoretical framework, this study innovatively explores the moderating mechanisms of employee relationship, profitability, and high-tech industry that can effectively mitigate the negative effects of remote work on operational efficiency. The findings provide strong empirical support for a deeper understanding of the relationship between remote work and operational efficiency.

**Fourth, this thesis takes a differentiation perspective to empirically examine the impact of remote work on firms' innovation performance, including both the quantity and quality of innovations. It also enriches the empirical research by revealing the contingency factors that affect the relationship between remote work and innovation performance.**

Existing research on remote work and innovation performance has primarily focused on conceptual discussions or case studies, with relative scarcity in empirical testing. While some empirical studies have examined the impact of remote work on team or individual innovation performance, in-depth exploration at the corporate level has been rare. Moreover, the literature has not reached a consensus on how remote work influences corporate innovation, particularly in terms of the contingency factors for the relationship between remote work and innovation performance. By utilizing firm-level panel data, this thesis empirically demonstrates the positive impact of remote work on both the quantity and quality of innovations, responding to the academic call for empirical research to deepen understanding of the relationship between remote work and innovation performance (Coenen & Kok, 2014; Gassmann & Von Zedtwitz, 2003). Furthermore, by integrating knowledge search theory, the thesis further explores the moderating roles of slack resource and growth opportunity on the relationship between remote work and innovation performance. This deepens the understanding of the contingency factors under which remote work influences innovation performance, thereby revealing key factors

that either promote or inhibit the effectiveness of remote work in promoting firms' innovation performance.

**Fifth, this thesis explores in depth how proactive and reactive remote work impact firms' information security risks, thereby enriching the understanding of remote work and expanding empirical research related to remote work and risk management.**

Empirical research directly exploring the link between remote work and firms' information security is exceedingly scarce. The few existing studies have focused on analyzing the drivers for enhancing corporate information security in a remote work environment (Angst et al., 2017; D'Arcy et al., 2020; Gwebu et al., 2018; Lee & Lee, 2021), but they have not delved into how remote work influence firms' information security. Additionally, previous research often treated remote work as a homogeneous concept, overlooking how different types of remote work might impact information security differently. By distinguishing between proactive and reactive remote work, this study enriches the conceptual content of remote work and opens new avenues for understanding the diversity and complexity of remote work, as well as providing new insights into how different remote work modalities affect corporate information security. Moreover, by integrating a socio-technical system view, the study innovatively reveals how a firm's IT capability and managerial capability can moderate the relationship between proactive/reactive remote work and information security risks, offering valuable theoretical and practical guidelines for managing and safeguarding against the information security risks posed by remote work.

## 6.3 Practical Implications

This thesis explores the impact of remote work on firms' performance outcomes and identifies its boundary conditions, offering valuable guidance for firms leveraging remote work as a strategic tool in digital transformation. The identified boundary conditions offer specific guidance for organizations to align their remote work policies with their competitive

positioning, resource endowments, and technological capabilities. These insights are particularly valuable for firms seeking to enhance their competitive advantage in an increasingly digital business environment.

First, this thesis provides invaluable insights and guidance for business managers and policymakers in evaluating and implementing remote work strategies, emphasizing the importance of recognizing the potential advantages and risks of remote work. In the post-pandemic era, an increasing number of firms are faced with the decision of whether to continue remote work arrangements or revert to traditional office settings. By offering detailed empirical evidence, this thesis aids managers in better understanding how remote work affects firms' performance, thereby enabling more informed decision-making regarding the implementation of remote work.

Second, this thesis underscores the importance for firms implementing remote work to actively cultivate strong employee relationships and focus on improving their profitability, thereby effectively mitigating the negative impacts of remote work on operational efficiency. The thesis also encourages firms in the high-tech industry to proactively explore the possibilities of remote work. For firms viewing remote work as a long-term strategy, establishing and reinforcing connections with employees is especially vital. Firms can enhance employee relationships by creating open communication channels, offering competitive compensation and benefits, establishing fair performance evaluation systems, and providing continuous training and career development opportunities. Moreover, firms should focus on increasing profitability to support the resource demands of remote work, thus reducing its negative impact on operational efficiency. This includes investing in remote work technologies, providing necessary hardware and software tools, and offering online training courses to boost productivity. For firms in the high-tech industry, this study encourages active exploration of the potential of remote work. High-tech firms possess unique advantages in implementing

remote work due to the flexible nature of their work, rich digital resources, and a corporate culture highly compatible with remote working. These attributes enable them to effectively counteract the adverse effects of remote work on operational efficiency.

Third, this thesis offers valuable insights for firms on how to effectively utilize remote work to boost innovation, while also pointing out the negative effects of slack resource and the beneficial impact of growth opportunity within a remote working environment. The research demonstrates that remote work significantly improves both the quantity and quality of innovations. This finding encourages managers to fully exploit the advantages of remote work to enhance the firms' innovative potential. Firms should investigate methods to stimulate employees' creativity and foster knowledge sharing and collaboration in a remote work environment. Additionally, this study highlights the importance of recognizing the potential negative impacts of slack resource in a remote work setting. Excessive resources can reduce a firm's innovation efficiency and motivation. Therefore, when implementing remote work, firms should carefully manage resource redundancy by evaluating and optimizing resource allocation to avoid surplus and reduce its adverse effects on innovation performance. Lastly, the study indicates that growth opportunity can significantly enhance the positive impact of remote work on innovation performance. In adopting remote work models, firms should maintain flexibility and adaptability, actively seek out growth opportunity and potential and exploit these opportunities.

Fourth, this study emphasizes the importance for managers to fully recognize and address the information security challenges that may arise with remote work. Specifically, firms implementing remote work should proactively face and address the information security challenges it presents, employing effective measures to mitigate these risks. Regardless of whether the remote work model is proactive or reactive, robust IT capability can significantly reduce the risks associated with remote work. This implies that managers need to invest in and

upgrade information security technologies, including end-to-end encryption, secure gateways, and intrusion detection systems, to ensure a solid line of defense. Furthermore, this study reveals that managerial capability effectively reduces information security risks in proactive remote work environments, but is less effective in reactive settings. These findings not only emphasize the importance of enhancing managerial capability to suppress security risks in proactive settings but also remind managers that even with excellent managerial skills, potential security threats should not be overlooked. Particularly when sudden events force a shift to remote work, traditional managerial abilities may be limited in addressing information security challenges. This underscores the necessity of advance planning and flexible management in ensuring information security.

Last but not least, this research offers crucial implications for organizational responses to future COVID-19-like disruptions, emphasizing the strategic importance of establishing robust remote work contingency plans. The findings underscore the necessity of proactive infrastructure development, including advanced IT systems, security protocols, and management capabilities, rather than reactive adaptations. Furthermore, the research demonstrates that remote work, when properly implemented, can serve as a catalyst for innovation rather than merely a crisis response mechanism. These insights suggest that organizations should integrate remote work capabilities into their core operational strategies, focusing on both technological readiness and managerial competencies. This proactive approach would not only enhance organizational resilience during crises but also position firms to leverage remote work as a strategic tool for sustained competitive advantage in an increasingly digital business environment.

## 6.4 Limitations and Future Research

Based on multi-source panel data from publicly listed companies and employing rigorous econometric methods, this thesis empirically tests the impact of remote work on firms'

performance outcomes and identifies relevant boundary conditions. While this thesis contributes significantly to the theory and practice of remote work, it also presents certain limitations and provides directions for future research.

First, this thesis focuses only on the remote work practices of publicly listed companies. Although using data from listed companies provides convenient access to well-documented financial information and disclosure systems, which facilitate the construction of panel data for this study, it may not fully represent the broader spectrum of remote work practices, particularly overlooking the specific practices and impacts within small and medium-sized enterprises. Future research should consider exploring remote work across different types of firms to make the findings more universally applicable and generalizable.

Second, the measurement of firm-level remote work data in this study was manually collected from the Factiva database. However, using announcements related to remote work policies only reflects the planned arrangements at the policy level and does not necessarily represent the actual implementation of remote work. Although I have verified the actual implementation of remote work in various companies through multiple channels and used FlexJobs data as an alternative measurement in Study 1, this measurement still has limitations and does not capture the details of remote work practices comprehensively. Therefore, future research should explore and utilize more diverse sources of firm-level remote work data to thoroughly assess and understand the complexities of remote work.

Third, this thesis innovatively differentiates between proactive and reactive remote work types and explores their different impacts on firms' information security risks. However, given the high complexity and diversity of remote work practices, the existing classification framework could be further refined. For example, remote work could be further differentiated into work-from-home and work-from-anywhere, or consider different degrees of implementation detail. Future research could explore more types of remote work, thereby

enriching and deepening the understanding of the remote work concept.

Fourth, this thesis focuses on exploring the impact of remote work on firms' performance outcomes, aiming to fully understand how remote work affects corporate performance in the context of the digital economy. Yet, this thesis does not examine the antecedents of remote work. Since understanding the factors that influence the implementation of remote work is also crucial for successfully adopting remote work strategies, future studies could consider thoroughly exploring the antecedents that affect the successful implementation of remote work, thus deepening a comprehensive understanding of remote work.

Fifth, this study is limited by its lack of industry-specific analysis in examining the differential effects of remote work implementation across sectors. While our findings provide general insights into remote work outcomes, they do not capture the nuanced variations that may exist across different industrial contexts. Future research could conduct comparative analyses between service-oriented and manufacturing sectors to understand how industry-specific characteristics shape remote work effectiveness. Researchers might also investigate the moderating effects of industry-specific attributes, such as technological intensity, innovation requirements, and knowledge complexity, on remote work outcomes. Moreover, future studies could explore the optimal configuration of hybrid work arrangements across different industries, examining how sector-specific operational demands and organizational characteristics influence the effectiveness of various remote work models. Such industry-specific analyses would not only enhance our theoretical understanding of remote work boundary conditions but also provide more targeted practical implications for organizations operating in different industrial contexts.

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