THE IMPACT OF RESPONSIBLE PRODUCTION ON MARKET, FINANCIAL, AND OPERATIONAL PERFORMANCE

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The Impact of Responsible Production on Market, Financial, and Operational Performance

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CERTIFICATE OF ORIGINALITY

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Abstract

As the significance of sustainability continues to escalate, responsible production, designated as the twelfth sustainable development goal (SDG12), has emerged as a viable strategy for Chinese manufacturers to attain the triple bottom line (TBL) of economic, social, and environmental sustainability. Nevertheless, manufacturers exhibit reluctance to embrace responsible production practices due to the associated economic uncertainties and heightened cost investments. This thesis presents three interconnected studies to assess these practices' impact on market, financial, and operational performance in both the short and long term.

Study 1 delves into the short-term market reaction to manufacturers' adoption of responsible production practices, exploring the moderating effects of firm size and financial slack. Leveraging a dataset encompassing 392 manufacturers that implemented these practices from 2016 to 2023, this study utilizes an event study methodology to uncover the positive market valuation associated with adopting responsible production practices. Through cross-sectional regression analysis, this study reveals that firm size and financial slack amplify the market value gains derived from adopting these practices, particularly amidst the COVID-19 pandemic. These findings provide valuable managerial insights to guide firms' transition towards responsible production while preserving and enhancing their firm value.

Study 2 evaluates the financial performance of resource-responsible production while examining the moderating effects of digital transformation and political connections. This study establishes the positive influence of resource-responsible production on financial performance by employing propensity score matching and difference-in-differences (PSM-DID) analysis on a dataset of 3,022 firm-year observations. The findings indicate that digital transformation and political connections amplify this positive impact, underscoring their pivotal role in enhancing the organization-resource relationship for financial success. This study contributes to the natural resource-based view literature by highlighting the significance of digital transformation and political connections in fostering sustainable financial performance. These insights offer practical guidance for managers seeking to effectively integrate resource-responsible production practices into their operations and for policymakers aiming to achieve sustainability goals.

Study 3 assesses the influence of green gamification and its interactive effects on state ownership and R&D investment on operational efficiency. Utilizing a two-stage difference-in-differences (2SDID) analysis of 18,297 firm-year observations, the study finds that firms designated as green exemplars generally attain higher operational efficiency, with the most pronounced gains observed in the long term. Intriguingly, the results indicate that state ownership reinforces, while R&D investment diminishes, the positive impact of green gamification on operational efficiency. This research contributes novel insights to the operations management (OM) literature by underscoring the value of green gamification in enhancing operational efficiency and elucidating the moderating effects of organizational (state ownership) and technological (R&D investment) factors on this relationship. The findings offer practical recommendations for policymakers and manufacturers to harness green gamification strategies for greater efficiency gains.

This thesis advances the literature about responsible production for sustainability by revealing its significance in performance improvement under varying conditions. More importantly, it provides managerial and policy implications for resource allocation to effectively embrace responsible production and achieve sustainable development.

Keywords: responsible production; market value, financial performance, operational efficiency, event study; difference-in-differences analysis; resource-based view; green gamification

Selected Publications During My PhD Study

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Chapter 1 Introduction

1.1 Research Background

1.1.1 Practical Background

Responsible production represents a viable and essential approach for manufacturers to address the pressing challenges posed by environmental deterioration and evolving market requirements (Tseng et al., 2018; Liu et al., 2021). In 2015, the United Nations General Assembly (UN-GA) set up the sustainable development goals (SDGs), which are a collection of seventeen interlinked goals designed to create a “shared blueprint for peace and prosperity for people and the planet, now and into the future”[1]. Notably, responsible consumption and production, as a twelfth goal (SDG 12), is of paramount importance for the actions of businesses and consumers to achieve the aims of advanced technological capacity, improved resource efficiency, and reduced global waste.

As a major manufacturing base, China suffers increasing environmental hazards including extreme weather and air pollution, calling for a solution to relieve the damages particularly those caused by manufacturing operations. China is the world’s second-largest economic entity selling massive volumes of products to overseas markets annually, and also the largest emitter with 10.668 billion tons of CO2 discharged in 2020, accounting for more than half of global emissions[2]. To overcome such challenges, the Chinese government has implemented the circular economy-related legislation reported in the 12th-five (2011-2015) and 13th-five (2016-2020) Economic and Sustainable Plans[3]. In addition, the Chinese government has embraced “carbon neutrality” to arrive at the aim of net-zero carbon dioxide emissions by 2060 and an “emission peak” to be reached by 2030[4]. Accordingly, it is worthwhile to understand responsible production in developing markets, especially China, for reducing environmental damage and reaping a sustainable economy.

Responsible production acts as a double-sided sword because there exists a trade-off between implementation costs and social benefits (Mao and Wang, 2019; Jeong and Lee, 2022). For example, responsible production can mitigate urban drought and improve the use of

1 https://sdgs.un.org/goals (accessed on March 22, 2024)
2 https://www.weforum.org/agenda/2022/11/visualizing-changes-carbon-dioxide-emissions-since-1900/ (accessed on March 22, 2024)
3 http://en.xfafinance.com/html/13th_Five-year_Plan/ (accessed on March 22, 2024)
4 https://chinadialogue.net/en/climate/are-chinas-new-2030-climate-targets-ambitious-enough/?amp&gad_source=1&gclid=CjwKCAjwte-vBhBFEiwAQSv_xaMShhNHWDItnTOGyTJkBfRRnLtrG1rDkkxCyw6R4QBIZT3Zx_oOlBoCR0gQAvD_BwE (accessed on March 22, 2024)

renewable resources (Zhang et al., 2019). In addition, responsible production brings entrepreneurial opportunities and meets the requirements of global markets (Li et al., 2019). Despite the importance of responsible production, its implementation costs, such as financial investment and extra staff management, may make firms difficult to steadily keep in a healthy environment of continuous funding (Mao and Wang, 2019). Therefore, many manufacturers still hesitate about the value of adopting responsible production because of the additional cost incurred. Against this background, the investigations should be further extended to evaluating the influence of responsible production on firm performance, such as market, financial, and operational performance.

1.1.2 Theoretical Background

Given the importance of responsible production, scholars have shown great interest in investigating its impact on firm-level outcomes (D'Angelo et al., 2022; Salam et al., 2022; Yang and Jiang, 2023). Notwithstanding, the literature on the consequences of responsible production has generated mixed and inconsistent results, including positive, negative, and insignificant relationships (Wong et al., 2018; Vargas-Berrones et al., 2019; Jeong and Lee, 2022). Remarkably, the preponderance of research in this field has predominantly focused on developed markets, with a particular emphasis on firms located in the United States and Europe (Modi and Mishra, 2011; Demirel and Danisman, 2019). Conversely, emerging countries, where rapid population growth and unchecked resource depletion have exacerbated resource scarcity and environmental degradation, have garnered comparatively less attention (Zhao and Bai, 2021). Given this context, our study endeavors to bridge this gap by investigating the nexus between responsible production and firm performance in developing markets.

Prior studies have starkly focused on either CSR (Shou et al., 2020; Stekelorum, 2020) or corporate environmental responsibility (CER) (Wong et al., 2018; Zhang and Ouyang, 2021; Gao and Wan, 2022), which differs from responsible production highlighting a firm’s responsibility in the production process. In the literature, CSR can build a firm’s reputation and send positive signals to the externality (Shou et al., 2020), while responsible production emphasizes a firm’s internal business operations. However, few studies have investigated the market responses to responsible production practice adoption in emerging markets. Against this background, Study 1 estimates the short-term market performance of responsible production practices adoption.

Most of the previous studies investigate green production and safety/quality production

(Wiengarten et al., 2017; Ghosh, 2019; Seth and Rehman, 2022), but less attention is paid to resource responsibility in a product's life cycle. Moreover, evidence suggests that environmental responsibility (e.g., the adoption of environmental management systems and low-carbon initiatives) can lower energy efficiency (Jeong and Lee, 2022) and decrease labor productivity (Sartal et al., 2020). Furthermore, the literature on the outcomes of resource responsibility has yielded mixed and inconsistent results because of the tradeoff between resource saving and economic returns (Ahmad et al., 2023). To advance the knowledge, Study 2 examines the impact of resource-responsible production on financial performance and the boundary conditions of the above relationship.

The policymakers have integrated gamification into green manufacturing policies to encourage green awareness and stimulate green actions for sustainability (Chai et al., 2018; Yang et al., 2023). Specifically, the integration of gamification into green practices can invoke green awareness and promote supply chain performance (Oppong-Tawiah et al., 2020; Yang et al., 2023; Zhang and Anwar, 2023). However, little is relatively known about the relationship between green gamification and operational performance. To extend the literature, Study 3 investigates the relationship between green gamification and operational efficiency in emerging markets.

1.2 Research Questions

In particular, the relationship between responsible production and firm performance may vary from firm-level structural characteristics, internal capabilities, and external networks. The boundary conditions of the above relationship need to be further investigated. Accordingly, this thesis is motivated to address the following three research questions.

RQs of Study 1: Does responsible production bring positive short-term market responses? How do firm-level characteristics (i.e., firm size and financial slack) influence the market value of responsible production practice adoption?

RQs of Study 2: Does resource-responsible production promote financial performance? How do internal capabilities (i.e., digital transformation) and external networks (i.e., political connections) influence the linkage between resource-responsible production and financial performance?

RQs of Study 3: Does green gamification enhance operational efficiency? How do organizational (i.e., state ownership) and technological (i.e., R&D investment) characteristics influence the impact of green gamification on operational efficiency?

1.3 Research Objectives

To answer the above research questions, this thesis has several research objectives that guide our empirical investigation. The core objective of this thesis focuses on the impact of responsible production on market, financial, and operational performance from short-term and long-term perspectives. Accordingly, this thesis offers theoretical implications by revealing the role of responsible production in determining firm performance. More importantly, this thesis informs manufacturers to embrace responsible production for sustainability.

First, this thesis reveals the positive market reaction to responsible production practices adoption by theoretically and empirically emphasizing the significance of resource abundance, which can be reflected by firm size and financial slack, in promoting the value creation of responsible production.

Second, this thesis addresses the paradox of the relationship between resource saving and economic returns by uncovering the positive association between resource-responsible production and financial performance as well as highlighting the importance of external networks (i.e., political connections) and internal capabilities (i.e., digital transformation) in achieving superior performance.

Third, this thesis unveils the role of green gamification in improving operational efficiency by revealing the substitutive role of R&D investment as well as the complementary role of state ownership in the linkage between green gamification and operational efficiency.

1.4 Research Framework and Methods

This thesis has conducted three interrelated studies to investigate the market, financial, and operational performance of responsible production practices in the short and long terms. Figure 1.1 illustrates the overall research framework guiding this thesis. Table 1.2 outlines theoretical lenses and research methods. From a holistic perspective, Study 1 estimates the short-term value of responsible production practices adoption. From a specific view, this thesis also classifies resource production into resource (i.e., resource-responsible production) and environmental (i.e., green gamification) aspects. Study 2 investigates the economic returns of resource-responsible production, while Study 3 gauges the operational efficiency of green gamification, in the long run.

In terms of research methods, Study 1 employs the event study approach to estimate the market value of responsible production. Using a cross-sectional regression model, this study uncovers the moderating role of firm size and financial slack on the market value of responsible production practices adoption. Several robustness tests, along with propensity score matching (PSM) and Heckman two-step procedures to address selection bias, are conducted to ensure the validity of our results. The additional analysis reveals the moderating role of COVID-19 in the market responses to responsible production practices adoption. Study 2 uses the PSM-DID method to gauge the relationship between resource-responsible production and financial performance and the boundary conditions of political connections and digital transformation. In addition, this study performs the pre-trend test, placebo test, endogeneity test, and other robustness tests. Furthermore, the heterogeneity test shows the moderating role of political connections and digital transformation based on group analysis. Study 3 adopts the two-stage difference-in-differences (2SDID) method to estimate the impact of green gamification on operational efficiency. Specifically, this study uses stochastic frontier estimation to calculate operational efficiency. Additionally, this study employs a two-way fixed effect (TWFE) model and CSDID to validate the results. Moreover, several robustness tests, including the pre-trend test, placebo test, and endogeneity test are conducted to ensure the validity of the results. Furthermore, the mechanism tests also investigate the moderating role of state ownership and R&D investment as well as reveal the subtle differences between market, financial, and operational performance caused by green gamification.

In terms of research theories, Study 1 adopts legitimate theory and resource-based view as the theoretical lens to explain the role of responsible production in achieving competitive advantages. Study 2 employs the natural resource-based view to emphasize the organization-resource relationship for financial performance. Study 3 also uses a resource-based view to elaborate on the importance of integrating gamification into green manufacturing policies.

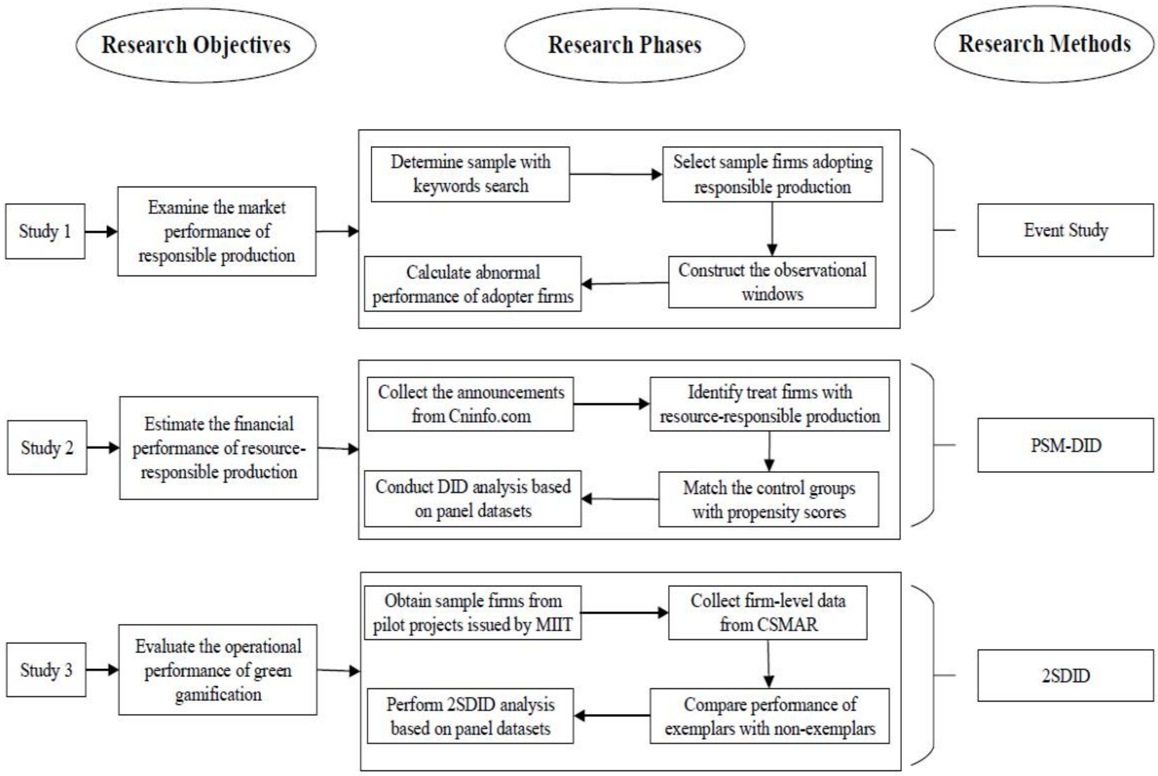

Figure 1.1 Research Framework of this thesis

Table 1.1 A summary of three interconnected studies in this thesis

	Study 1	Study 2	Study 3
Theoretical lens	Resource-based view and legitimacy theory	Natural resource-based view	Resource-based view
Dependent variables	Market value	Financial performance	Operational efficiency
Independent variables	Responsible production	Resource-responsible production	Green gamification
Moderators	Firm size and financial slack	Political connections and digital transformation	State ownership and R&D investment
Sample data	Cross-sectional data: 392 listed adopter firms	Panel data: 3,022 firm-year observations	Panel data: 18,297 firm-year observations
Research methods	Event study	PSM-DID	2SDID
Endogeneity tests	Heckman's two-step procedure and propensity score matching	Instrumental variable based on two-stage least squares (2SLS) model	Propensity score matching
Robustness test	Alternative methods of abnormal performance, alternative	Parallel trend test, placebo test, and alternative variable	Alternative DID methods (CSDID and TWFE), parallel trend test, placebo test,

	observational window, and alternative variable measurement	measurements	alternative variable measurements, alternative observational window, and alternative SFE
Additional analysis	The moderating role of COVID-19	/	The impact of green gamification on market and financial performance

1.5 Research Significance

Responsible production is a feasible way for manufacturers to achieve sustainability in terms of environmental, resource, and social responsibility during the production process. The contributions of this thesis are as follows.

Study 1 enriches the understanding of responsible production by revealing the role of responsible production as legitimate actions to be leveraged as variable resources for achieving competitive advantages. Drawing upon the resource-based view literature (Wernerfelt, 1984) and legitimate theory (Patten, 1992; Feng et al., 2020a), this study empirically and theoretically elucidates the positive correlation between responsible production, as a legitimate business practice, and market value. Extending the existing discourse on the practice-performance nexus from a resource-based view (Russo and Fouts, 1997; Liu et al., 2022a), this research highlights the pivotal role of resource abundance, manifested through firm size and financial slack, in bolstering the value creation potential of responsible production practices. Furthermore, in light of the resource dependency challenges posed by the COVID-19 pandemic (Chen et al., 2022), this study reveals the mitigating effect of the pandemic, as a form of resource scarcity, on the market value of adopting responsible production practices. Consequently, Study 1 underscores the significance of resource abundance, specifically firm size and financial slack, in fostering the positive market value of responsible production, in stark contrast to the adverse impact of resource shortages exemplified by the COVID-19 pandemic, from a resource-based view.

Study 2 advances the knowledge about responsible production by highlighting the role of resource responsibility in enhancing financial performance. Validating and Extending the literature on the natural-resource-based view (Andersen, 2021; Farooque et al., 2022), this study reveals the importance of the organization-resource relationship as well as the significance of external networks and internal capabilities in achieving product stewardship, pollution prevention, and sustainable development for competitive advantages. Echoing the literature on the practice-performance relationship (Lee et al., 2001; Li et al., 2019), Study 2 uncovers the strengthening role of political connections and digital transformation in affecting the influence of resource-responsible production on financial performance.

Study 3 adds new insights into the OM literature by shedding light on the importance of gamification in green manufacturing for enhancing operational efficiency. Enriching the literature on green gamification from the information systems perspectives (Yang et al., 2023; Behl et al., 2024), this study elaborates on the significance of green gamification in affecting a firm's business operations. Validating and Extending the literature on the resource-based view (Jabbour et al., 2022; Zhang et al., 2022), this study uncovers the positive relationship between green gamification and operational efficiency as well as the substitutive role of R&D investment and the complementary role of state ownership in resource allocation for green gamification.

1.6 Structure of the Thesis

This thesis comprises six chapters, namely: Introduction, Literature Review, Study 1, Study 2, Study 3, and Conclusions. The subsequent sections elaborate on the content of each of these chapters as follows.

Chapter 1 depicts research backgrounds, including practical and theoretical background, proposes research questions, summarizes research objectives, elaborates the research framework, elucidates research significance, and outlines the research structure of this thesis.

Chapter 2 elaborates on the definition of responsible production and clarifies the relevant concepts. This chapter reviews the related literature about the relationship between responsible production practices (i.e., environmental, social, and resource) and firm performance.

Chapter 3 examines the market value of responsible production practices adoption as well as the moderating role of firm-level characteristics (i.e., firm size and financial slack). This chapter introduces research motivations and questions, elaborates the related theories and literature, elucidates the justifications of hypotheses, describes data and methodology, presents the analyses and results, discusses research implications, and concludes Study 1.

Chapter 4 explores the impact of resource-responsible production on financial performance as well as the moderating role of external networks (i.e., political connections) and internal capabilities (i.e., digital transformation). Specifically, this chapter incorporates six parts, including an introduction, theoretical background, hypotheses development, data and methodology, analyses and results, and discussion and conclusion.

Chapter 5 explores the influence of green gamification on operational efficiency as well as the moderating role of organizational (i.e., state ownership) and technological (i.e., R&D investment) characteristics. In particular, this chapter introduces research motivations and questions, elucidates the literature review and theoretical background, proposes the hypotheses, describes data and methodology, displays the results, and discusses the research implications and limitations for future research.

Chapter 6 succinctly summarizes the key findings of the three studies conducted, delves into the implications of these findings for research and practice, acknowledges the limitations of the present work, outlines potential avenues for future research, and concludes with a reflective overview of this thesis.

Chapter 2: Literature Review

2.1 The definition of responsible production and similar concepts

Responsible production is a specific manifestation of corporate social responsibility (CSR) in a product's life cycle (McWilliams and Siegel, 2001). It refers to the production of goods or services in a responsible manner of achieving the sustainability goals of resource efficiency, environmental friendliness, and social well-being from procurement, design, and manufacturing, to waste disposal (Liu et al., 2021).

The concepts relevant to responsible production are presented in Table 1.1. Green production suggests the production of goods and services in an environmentally friendly way to minimize waste and emissions (Guo et al., 2015). Lean production refers to the production of using less resource input to generate more outputs (Wu et al., 2015). Beyond green production and lean production, responsible production requires a firm's process management for sustainability by bearing the responsibility of resource, environmental, and social aspects (Liu et al., 2021). Sustainable production depicts the creation of goods and services using the systems of environmental friendliness, economic viability, and social harmony (Bonvoisin et al., 2017). Unlike sustainable production highlights the outcome of sustainability, responsible production emphasizes the process of shouldering responsibility (Liu et al., 2021). The SDG12 suggests that responsible production is to ensure sustainable production patterns. Especially in manufacturing industries, responsibility awareness is the first step to prevent environmental pollution and waste of resources at the source (Flammer, 2013; Xia et al., 2018). To promote sustainability, responsible production is worthwhile to be disseminated and spread in a firm's production and operations management.

Table 2.1 The concepts similar to resource-responsible production

References	Key points	Definitions	Responsible production
(McWilliams and Siegel, 2001)	CSR	An action that appears to further some social good, beyond the interests of the firm and that law requirements.	Focusing on a product's life cycle.
(Lindhqvist, 2000)	Extended producer responsibility	Manufacturer responsibility extends to the take-back, recycling, and final disposal of the product.	Not limited to waste disposal
(Guo et al., 2015)	Green production	The product manufacturing and consumption processes aimed to	Highlighting the aim of environmental,

		reduce pollution.	social, and resource aspects
(Wu et al., 2015)	Lean production	A manufacturing approach used to achieve high-volume flexible production using minimal inventories of raw materials.	Not limited to resource efficiency
(Jabbour et al., 2022)	Circular economy	The activities to minimize natural resource use and the flow of waste.	Not limited to resource conservation
(Bonvoisin et al., 2017)	Sustainable production	The creation of manufactured products with manageable effects on the environment while delivering economic and societal value.	Highlighting a firm's proactive action in taking responsibility

2.2 The relationship between responsible production and firm performance

Table 2.2 depicts the related literature about the relationship between responsible production and firm performance. The literature has consistently supported the positive effects of responsible production on environmental and social performance (Baah et al., 2021a; Baah et al., 2021b; Xie et al., 2022). Specifically, green production (Baah et al., 2021a) and green process innovation (Xie et al., 2022) exert a significant and positive influence on environmental performance. In addition, resource-saving production practices, such as the use of energy-saving technologies (Pons et al., 2013) and leanness production (Shashi et al., 2019), contribute to environmental sustainability.

Prior literature regarding the economic returns of responsible production has yielded mixed results, ranging from negative (Baah et al., 2021b) and positive (O'Neill et al., 2016) to insignificant (Pons et al., 2013). Most of these studies have focused on environmental aspects based on survey questionnaires, lacking a perspective to identify the resource dimensions of responsible production. Additionally, scant literature investigates the long-term consequences of responsible production from an operational view. Against this background, this thesis aims to investigate the short-term and long-term effects of responsible production on market, financial, and operational performance.

Table 2.2 Related literature on responsible production

Dimensions	Sources	Key findings	Samples
Environment	(Baah et al., 2021a)	Green production positively influences firm reputation and environmental performance, but has a negative influence on financial	210 Ghanaian manufacturers

		performance	
Environment	(Baah et al., 2021b)	Proactive environmental production practices positively influence process and environmental performances but negatively affect financial performance. Reactive environmental production practices have a positive and significant influence on process, environmental, and financial performances.	278 Ghanaian manufacturers
Environment	(Chen et al., 2023a)	Manufacturers focusing on environmental responsibility are negatively associated with long-term performance. This effect depends on the conditions of the top management team composition and situation.	410 Chinese companies
Environment	(Xie et al., 2022)	Green process innovation has an insignificant influence on firms' financial performance significantly in the short term, but three-year-lagged green process innovation positively affects firms' financial performance.	172 pollution-intensive manufacturers
Social	(O'Neill et al., 2016)	Quality management orientation positively affects financial performance.	99 small Australian manufacturing firms
Resource	(Pons et al., 2013)	The use of energy-saving technologies has an insignificant effect on economic performance but positively influences environmental performance.	180 European manufacturers
Resource	(Shashi et al., 2019)	Leanness practice positively influences process innovation and product innovation, which thereby positively affects environmental and financial performance.	374 Indian manufacturers
Resource	(Fan et al., 2017)	Energy efficiency is positively associated with return on equity, return on assets, return on investment, and return on sales but has no significant influence on Tobin's q.	17 Chinese companies

Chapter 3: Unraveling the market reactions to the adoption of responsible production: An event study

3.1 Introduction

The United Nations (UN) underscores the significance of responsible production as a part of the twelfth sustainable development goal (SDG12) in enhancing sustainability (Tseng et al., 2018). Responsible production involves the ethical and sustainable production of goods and services with the aims of resource efficiency, environmental protection, and social well-being (Roy and Singh, 2017; Liu et al., 2021). For instance, Tesla decorated its vehicles with 100% renewable energy, minimized greenhouse gas emissions across the entire value chain, utilized solar panels to cover roof spaces, and leveraged artificial intelligence to improve energy efficiency[5]. There has been increasing pressure on enterprises to embrace responsible production to achieve sustainability over the past decades. As one of the world's largest carbon-emitting countries, China has encountered serious pollution and resource scarcity issues. The Chinese government has prioritized energy conservation and emission reduction in the 13th Five-Year Plan for industry upgrades, focusing on resource-efficiency operations. As a major contributor to environmental degradation, manufacturers should build market confidence by meeting societal expectations as responsible businesses.

Noteworthy, responsible production has become a key consideration for many investors, as environmental, social, and governance (ESG) performance plays a critical role in shaping their investment decisions (Calvo et al., 2015). Evidence indicates that consumers are willing to pay a premium for socially-responsible products (Tully and Winer, 2014). However, there is limited literature examining the value of responsible production practices among manufacturing industries. Previous research predominantly highlights the positive and significant impact of responsible production practices (e.g., environmental advertising and green supply chain management) on economic and environmental performance (Leonidou et al., 2014; Li et al., 2019). Nonetheless, some studies suggest that adopting responsible production practices, like green manufacturing and using environmental management systems, will require increased financial investment and lead to lowered energy efficiency (Mao and Wang, 2019; Jeong and Lee, 2022). These conflicting perspectives create uncertainty for firms regarding the value of responsible production, leading to hesitation in embracing responsible production practices. Nevertheless, engaging in responsible production is likely to enhance a

[5] https://www.tesla.com/ns_videos/2022-tesla-impact-report.pdf (accessed on November 22, 2023).

firm's reputation and market performance by increasing investor involvement, meeting stakeholder expectations, and supporting firm growth (Khodakarami et al., 2023). Despite this, little attention has been given to investigating the firm value of responsible production practices adoption.

Responsible production as a legitimate practice requires alignment with a firm's available resources, and the transition from normative legitimacy to pragmatic legitimacy needs resource support (Melnyk et al., 2023). The COVID-19 pandemic has exacerbated resource shortages for manufacturers due to supply chain disruption and limited access to financial capital (Chen et al., 2022). In this vein, resource availability plays a crucial role in promoting a firm's business growth. The resource-based view (RBV) suggests that a firm's sustained competitive advantage is derived from its valuable, rare, inimitable, and non-substitutable resources and capabilities (Wernerfelt, 1984). This theory posits that a firm's competitiveness is influenced by its resources and capabilities relative to its competitors. From the RBV, the market responses to responsible production practices adoption depend on a firm's ability to leverage its resources and capabilities. For example, large firms may benefit from their ability to survive in dynamic markets, their high level of corporate diversification, and their large economies of scale. These intangible capabilities and tangible resources allow them to effectively embrace responsible production practices. Yet, it remains unclear whether the market value of adopting responsible production practices is determined by firm size.

Furthermore, firms with high financial slack are likely to utilize surplus monetary resources to implement responsible actions (Chen et al., 2022). For instance, excessive financial resources can be allocated to introduce innovative technologies, organize human labor, and build new infrastructures, which are essential resource inputs for responsible production practices. Previous research indicates that resource slack enables firms to mitigate potential risks in the face of environmental threats but imposes a cost burden for allocating resources (Bradley et al., 2011). The divergent views on whether resource slack exacerbates or alleviates risks in organizational performance have yet to reach a consensus (Guo et al., 2020; Liang et al., 2023). To advance the literature, this study explores the role of financial slack in influencing the stock market valuation of adopting responsible production practices.

Thus, the following research questions guide our investigation into the market responses to responsible production practices adoption under varying conditions.

RQ1: Do responsible production practices influence firms' stock market valuation?

RQ2: How do firm size and financial slack affect the stock market valuation of adopting responsible production practices?

To address our research questions, this study examines the influence of responsible production on the market value as well as the moderating role of firm size and financial slack on the above relationship. Given that manufacturers encounter unprecedented challenges from resource shortages during the COVID-19 pandemic (Chen et al., 2022), we conduct additional analysis to explore whether the role of firm size and financial slack on the market responses to responsible production practices adoption is affected by the COVID-19 pandemic. Leveraging an event study approach based on corporate announcements, this study reveals the positive market performance of adopting responsible production practices. Drawing upon legitimacy theory and the RBV, the positive market performance of these practices is found to be stronger for large manufacturers or those with high financial slack, particularly during the COVID-19 pandemic. Additional analysis suggests that the COVID-19 pandemic weakens the positive market value of responsible production practices adoption. Consequently, this research contributes to the operations management (OM) literature in three key aspects. Firstly, it extends the application of legitimacy theory and the RBV to illustrate the firm value of adopting responsible production practices. Most of the existing RBV literature has predominantly investigated the impact of innovation and digital technologies as strategic resources on a firm's market performance (Son et al., 2014; Liu et al., 2022a). In this study, we consider firm size, an accumulated outcome of managerial decisions (Chuang et al., 2019), and financial slack, represented by excess cash holdings and monetary resources (Guo et al., 2020), to reflect a firm's resources and capabilities that can be input for responsible production. From the RBV, this study sheds light on the importance of resources in the practice-performance relationship. Secondly, this study uncovers the reinforcing role of firm size and financial slack in determining the value of adopting responsible production practices. The mixed results in previous research regarding the value of responsible production are explained by some contextual features within firms (Li et al., 2019; Mao and Wang, 2019). This study offers insights into when responsible production can bring more value to firms. Thirdly, the additional analysis sheds light on the weakening effect of the COVID-19 pandemic on the market value of responsible production practices adoption. This study also finds that the COVID-19 pandemic amplifies the importance of firm size and financial slack on the market valuation of adopting responsible production practices. These findings offer valuable insights into the negative impact of resource scarcity caused by the COVID-19 pandemic and the positive effect of resource support on the stock market valuation of the adoption of responsible production practices. Therefore, our findings provide guidance for practitioners on when to adopt responsible production.

3.2 Literature Review

3.2.1 Responsible production

Responsible production indicates the production of goods and services with the aim to minimize waste and pollution while optimizing resource utilization for improved profitability (Roy and Singh, 2017). It emphasizes a firm's commitment to achieving resource efficiency, environmental stewardship, and social responsibility throughout the production process (Liu et al., 2021). As a key element of corporate social responsibility (CSR), responsible production depicts that firms have the responsibility for their societal and environmental impacts beyond financial returns (McWilliams and Siegel 2001). Unlike CSR, which encompasses a broader scope including social philanthropy, responsible production specifically targets the processes involved in the production of goods and services (Liu et al., 2021). Moreover, green production aims to reduce environmental harm (Guo et al., 2015), whereas lean production focuses on maximizing resource efficiency (Wu et al., 2015). Responsible production, therefore, addresses the intertwined concerns of resource management, environmental impact, and social issues.

External pressures from stakeholder and regulatory policies have driven firms to increasingly adopt responsible production models (Tseng et al., 2018). Prior research about the performance effect of responsible production practices presents mixed results, with outcomes ranging from positive to negative and sometimes insignificant (Mao and Wang, 2019; Jeong and Lee, 2022). Much of the research has concentrated on the environmental and economic impacts of responsible production, with less attention given to the firm value derived from adopting such practices (Jacobs et al., 2010; Feng et al., 2020a). Firm value plays a crucial role in attracting investors and satisfying stakeholders, thereby supporting the sustainable development of the business (Calvo et al., 2015; Feng et al., 2020a). Given the trade-off between higher operational costs and environmental benefits (Li et al., 2019; Mao and Wang, 2019), companies still seek further assurance regarding the value of responsible production. This highlights the need for a deeper exploration of market reactions to the adoption of responsible production practices. To assist firms in understanding the value of embracing responsible production, we are motivated to explore whether and when these practices affect firm value.

3.2.2 Legitimacy theory

Legitimacy theory, grounded in the social contract, suggests that firms should mitigate the negative impacts of corporate expansion while enhancing their corporate social performance (CSP) (Patten, 1992). As an embodiment of institutional capital addressing social issues, legitimacy boosts an organization's status, reputation, and chances of survival by helping it achieve market acceptance and gain access to additional resources (Lounsbury and Glynn, 2001). This theory has been extensively applied in business and management research (Leonidou et al., 2014; Sila, 2018). Much of the current research explores the connection between legitimacy theory and sustainability disclosures, including environmental advertising and sustainable practices (Leonidou et al., 2014; L'Abate et al., 2023). In particular, scholars have used legitimacy theory to demonstrate that total quality management practices have a positive influence on CSP and market performance (Sila, 2018).

Importantly, the legitimate actions of adopting responsible production practices can help companies mitigate public concerns about their environmental impacts, enabling them to navigate trade barriers when expanding production and market activities internationally (Li et al., 2019). Since responsible production is voluntary, companies can demonstrate their legitimacy by complying with policy regulations (Feng et al., 2020a). Specifically, companies often adopt environmental and social standards, such as ISO 14001 and SA8000, as a legitimacy façade, showcasing their commitment to CSR within supply chains (Mueller et al., 2009). Building on the legitimacy theory, manufacturers that consistently govern their operations in line with societal norms can secure market acceptance and support (Crossley et al., 2021). This study utilizes legitimacy theory to explore the market value of responsible production practices adoption.

3.2.3 Resource-based view and responsible production

The resource-based view (RBV) asserts that firms can achieve sustained competitive advantages by leveraging resources that are valuable, rare, inimitable, and non-substitutable (Wernerfelt, 1984). This theory is extensively applied in operations management research to highlight the significance of technological innovation and green practices (Jabbour et al., 2022; Qader et al., 2022). From an RBV perspective, we contend that the market valuation of responsible production is contingent upon a firm's resources and capabilities in supporting this legitimate endeavor. Possessing valuable resources and capabilities positions firms advantageously in the practice-performance linkage, making it difficult for competitors to outdo them.

Drawing from the RBV, the value of a firm derived from adopting responsible production practices depends on the availability of substantial resources, which facilitate the transfer from normative legitimacy to pragmatic legitimacy (Melnyk et al., 2023). Resource support is crucial in enhancing human resource utilization and aiding organizations in complying with laws, regulations, and policies during the implementation of responsible production. For example, well-resourced firms are likely to establish management standards and best practices to ensure that responsible production practices are consistent and compatible with market expectations (Guo et al., 2020). This study identifies firm size and financial slack as indicators of resource availability. Specifically, large firms are better equipped to overcome financial constraints and technical challenges due to their diverse technical expertise, large economic scale, and dynamic capabilities to thrive in the uncertain market (Chuang et al., 2019). Additionally, firms with slack financial resources can allocate additional monetary investments and human resources to responsible production, effectively managing and improving their operations to meet or exceed policy requirements (Chen et al., 2022).

3.3 Hypotheses Development

The research framework for this study is depicted in Figure 3.1. Based on legitimacy theory, we propose that the adoption of responsible production practices generates a favorable reaction from the stock market. Utilizing the RBV, we posit that the market valuation of these responsible production practices is positively influenced by firm size and financial slack.

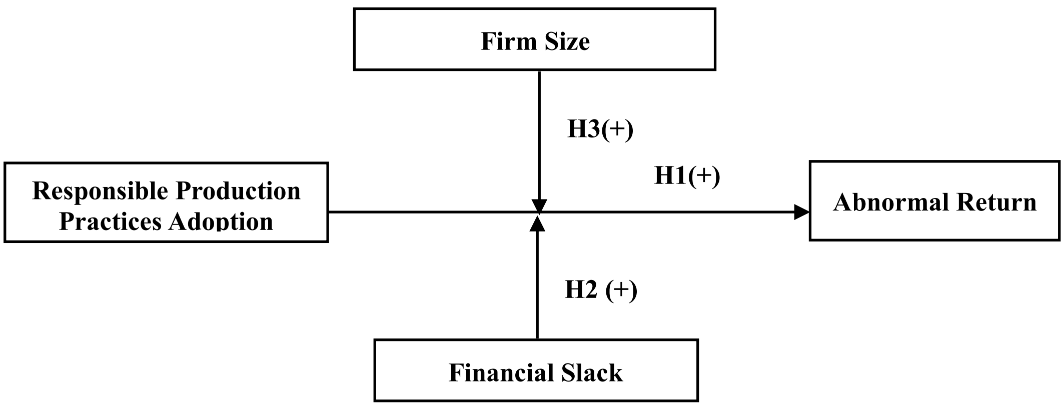

Figure 3.1 Research Framework of Study 1

3.3.1 The market value of responsible production practices adoption

By engaging in responsible production, firms can cultivate a positive social reputation by complying with the goals of SDG12, which seeks to decouple economic development from environmental harm while enhancing efficiency and promoting sustainable lifestyles (Liu et al., 2021). This improved environmental image can open up business opportunities, such as improved shareholder investments and sales growth (Jacobs et al., 2010). Echoing this viewpoint, research shows that publicizing sustainability certifications as a demonstration of CSR commitment enables firms to effectively communicate their responsible practices to investors, thereby positively impacting their stock price performance (Feng et al., 2020a).

Drawing from legitimacy theory, aligning with stakeholders' expectations can lead to significant performance benefits through the adoption of responsible production practices. For example, responsible production can help firms avoid penalties and reduce costs associated with environmental regulatory compliance (Gouda and Saranga, 2020). Additionally, the legitimate actions of responsible production contribute to fewer environmental accidents, including severe pollution and excessive emissions, which can lead to lower costs for end-of-pipe environment control (Jabbour et al., 2022). Furthermore, empirical evidence suggests that taking environmental responsibility provides firms with unique and competitive resources, positively affecting their stock price (Flammer, 2013). For example, companies that maintain environmental legitimacy experience reduced unsystematic stock market risk, especially when their environmental performance complies with stakeholders' expectations regarding the natural environment (Bansal and Clelland, 2004). On the other hand, environmental irresponsibility can result in declining shareholder wealth (Xu et al., 2016). Therefore, the legitimate action of adopting responsible production practices not only attracts market favor but also enhances firm value.

Hypothesis 1 (H1): The market responds positively to the adoption of responsible production practices.

3.3.2 The moderating role of financial slack

Drawing from the RBV, the implementation of responsible production practices requires substantial capital resources, including financial investments and human labor, which are essential for creating value through legitimate actions. A firm's financial resources include tangible and intangible assets that can be strategically utilized to improve efficiency and effectiveness in the marketplace (Chen et al., 2022). Adopting responsible production involves investing financial resources into planning, developing, and optimizing manufacturing processes to minimize hazardous waste, design recyclable products, and ensure safer operations (Zhu et al., 2021). Having ample financial slack provides firms with the funds needed to navigate economic challenges and sustain efficient business operations (Liang et al., 2023).

In the realm of responsible production, financial resources are crucial for supporting research and development (R&D) investments, which facilitate the successful execution of upstream activities, such as green procurement, and downstream activities, such as product recovery and recycling, all of which contribute to broader sustainability goals (Guo et al., 2020). Additionally, financial slack enables firms to maintain stable operations and buffer against market volatility, ensuring the continuous implementation of responsible production practices. Firms with substantial financial slack inspire greater investor confidence in their ability to achieve responsible production goals aligned with sustainability objectives (Mao and Wang, 2019; Chen et al., 2022). Therefore, we propose the following hypothesis

Hypothesis 2 (H2): The positive market value of adopting responsible production practices is more pronounced for firms with higher financial slack.

3.3.3 The moderating role of firm size

Large firms are more adept at aligning with market demands and achieving market acceptance through the transition from normative legitimacy to the practical implementation of responsible production practices (Cordeiro and Tewari, 2015). Research indicates that, compared to small and medium-sized enterprises (SMEs), larger firms are more likely to disclose extensive information on the environment and social matters, as this can enhance their visibility and economic impact (Dias et al., 2018). Large firms are better equipped to manage risks associated with market fluctuations and reduce uncertainties related to environmental changes (Chuang et al., 2019). Moreover, they often face fewer financial constraints when engaging in socially and environmentally responsible behaviors (Wu et al., 2016). As a result, these firms are more likely to gain market confidence through their commitment to environmentally friendly practices.

The superior human resources available to large firms also provide them with the capacity to allocate operational resources for additional corporate initiatives (Khodakarami et al., 2023). Large firms typically have more experience in addressing technical challenges and managing resource allocation to ensure consistent economic returns (Cordeiro and Tewari, 2015). Furthermore, their extensive resources support technical innovation and maintain core production operations, contributing to economic stability and health (Chuang et al., 2019). According to the RBV, large firms are positioned to gain greater benefits from implementing responsible production practices, thereby enhancing their market value.

Hypothesis 3 (H3): The positive market value of adopting responsible production practices is greater for large firms.

3.4 Data and Methodology

This study focuses on Chinese manufacturers that have implemented responsible production practices. China, as one of the leading contributors to global energy-related carbon emissions and a major player in international exports, faces significant environmental and resource consumption challenges. Adopting responsible production practices is a strategic and legitimate measure for manufacturers to address environmental concerns and overcome trade barriers, thereby improving market acceptance. Additionally, the Chinese government has been proactive in promoting corporate responsibility, including circular economy and low-carbon policies (Zhu et al., 2018). This context highlights the importance for Chinese manufacturers to adopt responsible production and adhere to evolving regulatory and environmental priorities.

3.4.1 Data collection

To examine the market value of responsible production practices adoption, we gathered sample announcements from Cninfo.com. This database, endorsed by the China Securities Regulatory Commission (CSRC), is a crucial resource for obtaining announcements from publicly listed Chinese companies (Liu et al., 2022b). The data spans from January 1, 2016, to July 18, 2023. This period was chosen because SDG12, which emphasizes responsible production, was introduced at a United Nations summit in September 2015. Firms need time to adapt to and set standards for responsible production. Consequently, we observe data from 2016 to 2023 for our dependent variables, and we use data from 2015 to 2022 for control variables related to firm characteristics and financial statements. In 2015, 2,827 companies disclosed their annual reports, reflecting a growth rate of 8.18% over 2014[6], which provides a robust dataset for our analysis.

Following prior research (Liu et al., 2021) and the objectives of SDG 12, we categorize responsible production into three aspects: resource management, environmental stewardship, and social responsibility in the production processes. Table 3.1 presents the keywords used to identify announcements related to responsible production practices from 2016 to 2023. The sample selection process, illustrated in Figure 3.2, involves four steps: Firstly, we collected

[6] https://www.gov.cn/xinwen/2016-09/10/content_5107189.htm (accessed on November 25, 2023)

1,830 announcements from publicly listed Chinese manufacturers. Secondly, we filtered out 5 duplicated entries and 1,038 irrelevant announcements, such as those concerning irresponsible production, mergers, acquisitions, and investments, leaving 787 announcements. Thirdly, we selected the earliest announcement date as the event date for each firm, reducing the dataset to 399 announcements. Finally, we excluded 7 announcements due to insufficient data during the estimation or event period, resulting in 392 announcements for further analysis.

Table 3.1 Keyword searching items

Searching Items	Searching keywords	Sources
Responsible production	**Social:** safety management, production management, safe production, ISO, quality management, technological innovation, product labeling	(Yadav et al., 2023)
	Environmental: clean, environmental protection, ecological design, reverse logistics, recycle and reuse, carbon reduction, low carbon, zero carbon, emission reduction, green product, green disposal, green supply chain, green technology, green manufacturing, green logistics, green production, green factory, eco-design, green transformation, green certificate, green material, green package, green operations, and green innovation	(Yadav et al., 2023)
	Resource: lean, resource-saving, resource conservation, circular, high efficiency, energy saving, renewable energy	(Jasti and Kodali, 2015)
Periods	From 2016-01-01 to 2023-7-18	

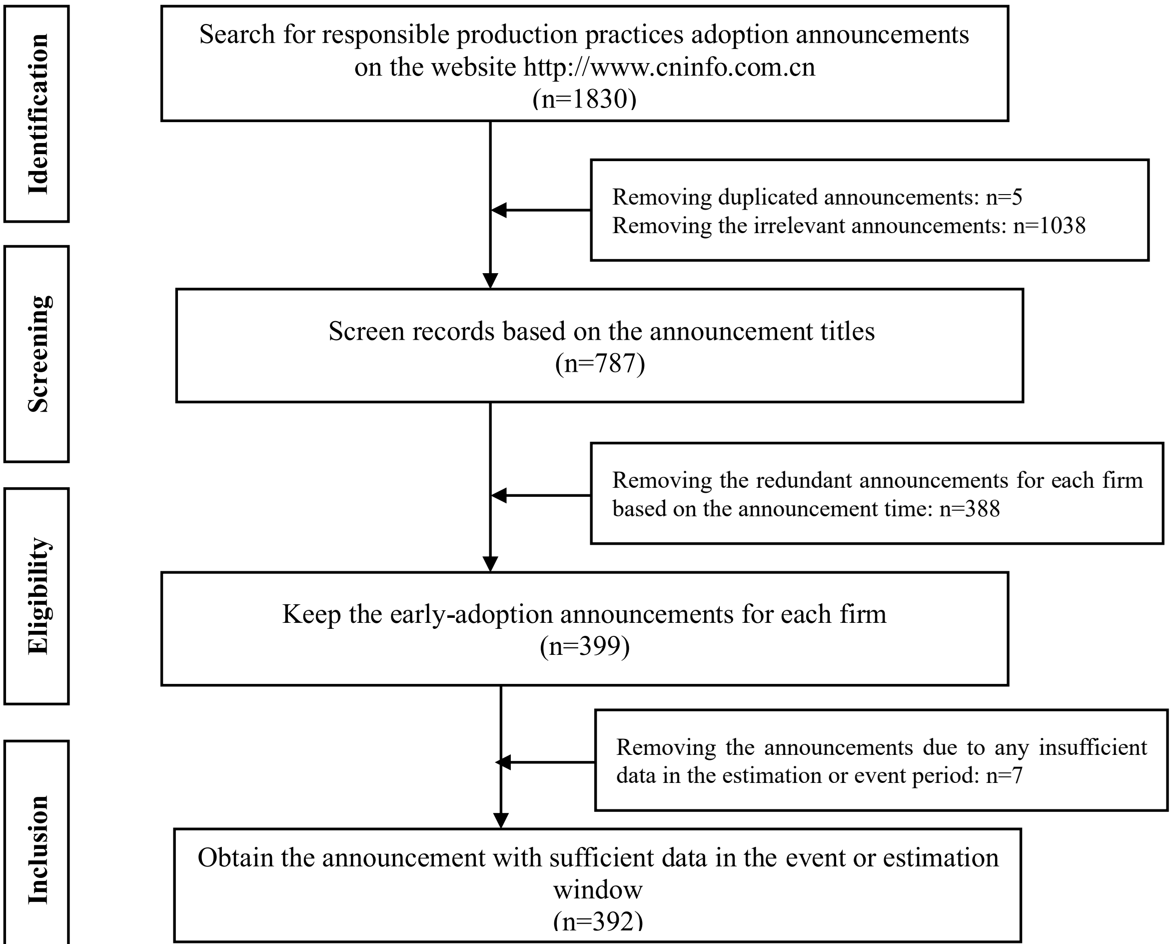

Figure 3.2 Selection of included event announcements

After finalizing the sample, we obtained firm-specific data from the China Stock Market and Accounting Research (CSMAR) database, a widely used source for insights into corporate performance in Chinese markets (Shou et al., 2021b; Shen et al., 2023). Panel A in Table 3.2 shows the distribution of announcements across years, and Panel B provides examples of responsible production practices.

Table 3.2 Descriptive statistics of included announcements

Panel A: distribution of selected announcements across years

Year	Frequency	Percent
2016	56	14.29
2017	45	11.48
2018	57	14.54
2019	50	12.76
2020	33	8.42
2021	58	14.80
2022	68	17.35
2023	25	6.38

Total	392		100.00
Panel B: The examples of selected announcements			
Stock name	Stock code	Time	Announcement title
NONFEMET	000060	2019-09-24	The investment and construction of the green upgrading and transformation project of zinc slag smelting in Danxia Smelter
Huading Nylon	601113	2016-12-14	The high-quality nylon 6 high-efficiency and low-consumption large-scale intelligent production integration technology project won the China Industry Award Nomination Award.
ZHENHUA CHEMICAL	603067	2021-03-30	The investment in the construction of chromium salt green and clean production core technology research and development and intelligent energy-saving and environmental protection technology integrated innovative application projects.
SHENWU ENERGY SAVING	000820	2017-08-09	The key technology and demonstration of the recycling of iron and zinc dust and sludge resources in the rotary hearth furnace has been evaluated as an internationally leading level.

3.4.2 Event study methodology

The event study methodology is employed to evaluate the short-term impact of significant events on a firm's market value, typically reflected in stock returns (Ding et al., 2018). This approach is commonly used in supply chain and operations management research to analyze the market value of corporate announcements (Lam et al., 2019; Liu et al., 2022b). The methodology involves three main steps: defining the event window, establishing the estimation window, and calculating abnormal market returns. Accordingly, this study employs the event study methodology to explore the market value of responsible production practices adoption.

Figure 3.3 depicts the event timeline used to observe the market reactions to adopting responsible production practices. Firstly, following established studies (Lam et al., 2019; Chen et al., 2022), the announcement date is designated as day 0, and the event window is set to (-1, 1), which includes the trading day before (=-1), during (=0), and after (=1) the announcement date. Secondly, we specify the estimation period to evaluate a firm's expected return without any responsible production announcements. Consistent with prior research (Chen et al., 2022), the estimation period of a 120-trading day interval ending 11 days before the announcement date, denoted as (-130, -11). Thirdly, in line with the prior literature (Chen et al., 2022; Liu et al., 2022b), we adopt the general market model to calculate abnormal returns (ARs) and derive cumulative abnormal returns (CARs). The estimation model is described by the following equation (1).

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \quad (1)$$

where R_{it} is the actual return of stock *i* on day *t*, and R_{mt} denotes the market return on day *t*. The parameters α_i and β_i suggest the intercept and slope of the relationship between actual returns and market returns for stock i, respectively. The term ε_{it} indicates the unobserved error.

By identifying the return rate of each stock during the designated estimation period, we can obtain the parameters $\widehat{\alpha_i}$ and $\widehat{\beta_i}$ to calculate the expected return. The abnormal return of stock *i* on day *t* (AR_{it}) refers to the difference between the actual return and the expected return, formulated as shown in equation (2):

$$AR_{it} = R_{it} - \left(\widehat{\alpha_i} + \widehat{\beta_i} R_{mt}\right) \quad (2)$$

The cumulative abnormal return (CAR) is defined as the sum of ARs over the event window. Its calculation is described in equation (3):

$$CAR_i = \sum_{t=-1}^{t=+1} AR_{it} \quad (3)$$

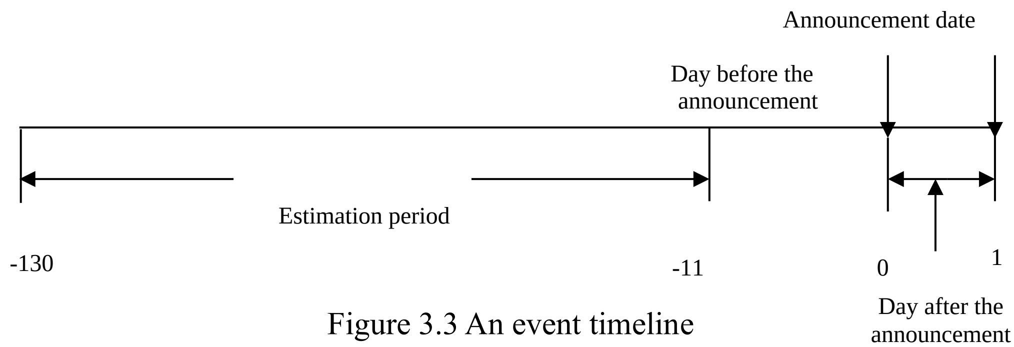

Figure 3.3 An event timeline

3.4.3 Cross-sectional regression model

To address research questions, we use CARs over a three-day window, denoted as (-1, 1), to evaluate the market impact of adopting responsible production practices. Financial slack is defined as the ratio of current assets to current liabilities, representing the availability of excess financial resources (Zhu et al., 2021). Additionally, we measure firm size using the logarithm of the total number of employees (Wiengarten et al., 2017). Moreover, we perform robustness checks by examining CARs over the two-day windows, namely (-1,0) and (0,1).

To address alternative explanations, we include firm-specific characteristics as control variables in our proposed model. Firstly, firm age and profitability are crucial determinants of corporate operations and financial performance (Liu et al., 2022a; Tong et al., 2022). Secondly, high financial leverage indicates that firms have the financial resources for internal growth but may face challenges in meeting debt obligations (Iqbal et al., 2020). Thirdly, we incorporate the inventory turnover ratio, calculated as the cost of goods sold divided by inventory (Chen et al., 2022). Fourthly, ownership structure reflects a firm's ability to access financial resources and human capital (Shou et al., 2021b). Fifthly, customer concentration can influence CSR, thereby positively affecting financial performance (Zhu et al., 2021; Chen et al., 2022). Sixthly, R&D intensity, representing a firm's capability for innovation, is also included as it affects firm performance (Shou et al., 2021b). Lastly, we include *City* as a control variable to account for the varying economic conditions across different locations.

Table 3.3 outlines the variables used in the analysis, while Table 3.4 shows the correlations among these variables, with the absolute correlation coefficients ranging from 0.002 to 0.509. We also conduct a variance inflation factor (VIF) test to assess multicollinearity in our regression analyses. The maximum of VIFs observed is 1.97, indicating that multicollinearity is not a significant concern.

Table 3.3 Variable description

Variable	Description	Mean	S. D.	Min	Max
$CAR_{(-1,1)}$	The cumulative abnormal returns during the event window (-1,1)	0.004	0.054	-0.377	0.240
$CAR_{(-1,0)}$	The cumulative abnormal returns during the event window (-1,0)	0.005	0.041	-0.225	0.202
$CAR_{(0,1)}$	The cumulative abnormal returns during the event window (0,1)	0.003	0.047	-0.276	0.218
Financial Slack	current assets divided by current liabilities	2.551	3.177	0.094	38.398
Firm Size	The log transformation of the total number of employees	7.266	1.940	0	11.250
Firm Age	The number of years since a manufacturer was established	18.523	5.396	6	44
Firm Profitability	net income divided by total assets	0.045	0.060	-0.210	0.382
Financial Leverage	total debts divided by total assets	0.398	0.196	0	1
State Ownership	A dummy variable of whether a manufacturer is state-owned (No=0, Yes=1)	0.202	0.402	0	1
R&D Intensity	The ratio of R&D expenses to sales	0.040	0.033	0	0.245
Inventory	The cost of goods divided by the inventory	4.991	5.474	0	55.784

Turnover Ratio					
Customer Concentration	The sales proportion of a manufacturer's five largest customers	0.280	0.221	0	1
City	A dummy variable of whether a manufacturer is located in first-tier cities (Yes=1, No=0)	0.199	0.400	0	1

Table 3.4 Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) CAR $_{(-1,1)}$	1.000										
(2) Financial Slack	0.087	1.000									
(3) Firm Size	0.170	-0.157	1.000								
(4) Firm Age	-0.010	-0.104	0.051	1.000							
(5) Firm Profitability	-0.008	0.199	-0.011	-0.002	1.000						
(6) Financial Leverage	0.078	-0.509	0.409	0.126	-0.359	1.000					
(7) State Ownership	0.088	-0.164	0.234	0.144	-0.158	0.293	1.000				
(8) R&D Intensity	-0.035	0.236	-0.010	-0.102	-0.028	-0.260	-0.140	1.000			
(9) Inventory Turnover Ratio	0.023	-0.074	0.041	0.050	0.096	0.107	0.094	-0.265	1.000		
(10) Customer Concentration	0.044	0.113	0.030	-0.082	-0.011	0.010	0.048	0.166	-0.013	1.000	
(11) City	0.006	0.003	0.055	0.031	-0.041	0.063	-0.043	0.146	-0.082	0.020	1.000

Note: The absolute correlation coefficient exceeds 0.096 at the significance level of 0.05.

We employ the ordinary least squares (OLS) regression to examine the effects of firm size and financial slack on the market value of adopting responsible production practices. The regression equation (4) is described below.

$$CAR_{i,t} = \alpha_0 + \alpha_1 Financial\ Slack_{i,t-1} + \alpha_2 Firm\ Size_{i,t-1} + \alpha_3 Inventory\ Turnover\ Ratio_{i,t-1} + \alpha_4 Firm\ Age_{i,t-1} + \alpha_5 Firm\ Profitability_{i,t-1} + \alpha_6 Financial\ Leverage_{i,t-1} + \alpha_7 R\&D\ Intensity_{i.t-1} + \alpha_8 State\ Ownership_{i,t-1} + \alpha_9 Customer\ Concentration_{i,t-1} + \alpha_{10} City_i + \varepsilon_i \quad (4)$$

Where $CAR_{i,t}$ denotes the cumulative abnormal return of a firm *i* at the event window of (-1,1). ε_i is the random error.

3.5 Analysis and Results

3.5.1 Main results

Table 3.5 shows the results of the market reaction test. Panel A displays the daily abnormal returns of the trading day before, during, and after the announcement date (=0). The mean AR on day 0 is 0.0046, which is positive and statistically significant at the 5% level. Of the 392 announcements, 202 (51.53%) had a positive reaction on day 0, though this result is not significantly different from a 50% baseline (*p*-value=0.579). The Corrado rank and generalized sign tests further support a positive market value of responsible production practices on the announcement day (p<0.01). The mean AR on day -1 is not statistically significant, indicating no information leakage before the announcement date. This supports Hypothesis 1, confirming a positive market reaction to responsible production practices adoption on the announcement date.

Panel B from Table 3.5 presents cumulative abnormal returns for two-day and three-day event windows. While the mean CARs over these periods are positive, they are not statistically insignificant, suggesting that the positive market reaction to the adoption of responsible production practices is not sustained over a longer period. This insignificant result can be explained by the efficient market assumption implied in the event study approach (Fama et al., 1969). Nevertheless, the Corrado rank and generalized sign tests reveal significant and positive CARs because these tests can mitigate the violation of normal distribution assumptions in the t-test (Agrawal and Kamakura, 1995). Overall, all the results suggest a positive market value attributed to the adoption of responsible production practices during two-day and three-day event windows (p<0.01).

Table 3.5 Market reaction results

Panel A: Daily abnormal returns						
Event day	N	Mean	%positive	T-test	Generalized Sign test	Corrado rank test
-1	392	0.0001 (0.952)	46.17% (0.143)	0.061	0.333	1.201
0	392	0.0046 (0.049)	51.53% (0.579)	1.993**	2.361**	3.544***
1	392	-0.0012 (0.608)	44.64% (0.038)	-0.514	-0.377	0.277
Panel B: Cumulative abnormal returns for three-day and two-day windows						
Event window	N	Mean	%positive	T-test	Generalized Sign test	Corrado rank test
(-1,1)	392	0.0036 (0.374)	51.28% (0.650)	0.892	2.259**	2.899***
(-1,0)	392	0.0047 (0.148)	52.30% (0.391)	1.457	2.665***	3.338***
(0,1)	392	0.0034 (0.296)	51.02% (0.724)	1.049	2.158**	2.714***

Note: *p*-value are displayed in parentheses, *p < 0.1, **p < 0.05, ***p<0.01.

Table 3.6 outlines the cross-sectional regression results. The results of evaluating CARs over the two-day and three-day windows consistently indicate the positive impact of financial slack on CARs ($p_{(max)}$ <0.05). Thus, Hypothesis 2, proposing that firms with high financial slack experience a more positive influence on the market value derived from the adoption of responsible production practices is consolidated. Moreover, large firms receive more positive market responses to the adoption of responsible production practices, as demonstrated in examining CARs over the two-day and three-day windows ($p_{(max)}$ <0.1). Therefore, Hypothesis 3 is supported.

Table 3.6 Cross-sectional regression results

	CAR $_{(-1,1)}$	CAR $_{(-1,0)}$	CAR $_{(0,1)}$
Financial Slack	0.003***(0.001)	0.002**(0.001)	0.002***(0.001)
Firm Size	0.004***(0.002)	0.004***(0.001)	0.002*(0.001)
Firm Age	-0.0002(0.001)	-0.0001(0.0003)	0.000(0.0004)
Firm Profitability	-0.008(0.050)	-0.015(0.038)	-0.034(0.043)
Financial Leverage	0.019(0.019)	0.001(0.015)	0.028*(0.017)
State Ownership	0.007(0.007)	0.001(0.006)	0.003(0.006)
R&D Intensity	-0.089(0.093)	-0.075(0.071)	0.031(0.080)
Inventory Turnover Ratio	0.00004(0.001)	0.0004(0.0004)	-0.0001(0.0004)
Customer Concentration	0.006(0.013)	0.003(0.010)	0.001(0.011)
City	0.0003(0.007)	0.001(0.005)	0.001(0.006)
Constant	-0.038**(0.016)	-0.023(0.012)	-0.023(0.014)
R^2	0.0536	0.0444	0.0447
Max VIF	1.97	1.97	1.97

Note: Sample N=392, *p < 0.1, **p < 0.05, ***p<0.01; Standard errors are outlined in parentheses.

3.5.2 Robustness check

3.5.2.1 Estimation of AR and CARs

To verify our findings, we employ different approaches to evaluate the AR and CARs of adopting responsible production practices, as illustrated in Table 3.7. Panels A and B extend the estimation periods to 21 and 31 days before the announcement date based on a 120-trading day interval, respectively. Panel C extends the period to 150 trading days, denoted as (-160, -11). Panel D uses the Fama-French three-factor model, while Panel E shows CARs over the three-day event window based on these different models. All results consistently indicate a positive market reaction to the adoption of responsible production practices.

Table 3.7 Robustness tests of an event study

Panel A: Daily AR based on 120 trading days window (-140, -21)					
Event day	N	Mean	T-test	Generalized sign test	Corrado rank test
-1	391	-0.0001	-0.026	0.174	1.296
0	391	0.0046	1.780*	2.307**	3.552***
1	391	-0.0012	-0.475	-0.333	0.296
Panel B: Daily AR based on 120 trading days window (-150, -31)					
Event day	N	Mean	T-test	Generalized sign test	Corrado rank test
-1	389	0.00003	0.014	0.382	1.310
0	389	0.0043	1.830*	2.317**	3.59 4***
1	389	-0.0009	-0.372	-0.229	0.190
Panel C: Daily AR based on 150 trading days window (-160, -11)					
Event day	N	Mean	T-test	Generalized sign test	Corrado rank test
-1	392	0.0001	0.027	0.383	1.299
0	392	0.0044	1.906*	2.411**	3.502***
1	392	-0.0014	-0.590	-0.936	0.251
Panel D: Daily AR based on the Fama-French three-factor model					
Event day	N	Mean	T-test	Generalized sign test	Corrado rank test
-1	392	-0.0007	-0.317	0.319	1.211
0	392	0.0032	1.381	2.759***	3.197***
1	392	-0.0016	-0.674	-0.291	0.345
Panel E: CARs for three-day window (-1,1)					

Event window	N	Mean	T-test	Generalized sign test	Corrado rank test
(-140, -21)	391	0.0032	0.743	2.611***	2.970***
(-150, -31)	389	0.0035	1.295	2.826***	2.941***
(-160, -11)	392	0.0031	0.778	2.411***	2.917***
Fama-French three-factor model	392	0.0009	0.227	2.251**	2.744***

Note: *p < 0.1, **p < 0.05, ***p<0.01

3.5.2.2 Estimation of cross-sectional analysis

We conduct robustness tests to ensure the validity of our cross-sectional analysis. In particular, we recalculate the AR based on different estimation methods from Section 5.2.1 and estimate CARs over the three-day window to test whether the market responses to adopting responsible production practices are affected by firm size and financial slack, as displayed in Table 3.8. Models 1 and 2 use alternative estimation periods, while Model 3 extends the estimation window, and Model 4 employs the Fama-French three-factor model. Results suggest that the positive market value of adopting responsible production practices is more pronounced for larger firms and those with higher financial slack.

Table 3.8 Robust tests based on various estimations

$CAR_{(-1,1)}$	Model 1: (-140, -21)	Model 2: (-150, -31)	Model 3: (-160, -11)	Model 4: Fama-French three-factor model
Financial Slack	0.002**(0.001)	0.003***(0.001)	0.003**(0.001)	0.003**(0.001)
Firm Size	0.004**(0.002)	0.005***(0.002)	0.005***(0.002)	0.005***(0.002)
Firm Age	-0.0001(0.001)	-0.0002(0.001)	-0.0002(0.001)	-0.0001(0.001)
Firm Profitability	-0.012(0.051)	-0.024(0.051)	-0.016(0.051)	0.037(0.052)
Financial Leverage	0.011(0.020)	0.027(0.020)	0.016(0.020)	0.026(0.020)
State Ownership	0.008(0.007)	0.006(0.007)	0.008(0.007)	0.007(0.008)
R&D Intensity	-0.140(0.094)	-0.135(0.095)	-0.091(0.094)	-0.043(0.097)
Inventory Turnover Ratio	0.00001(0.001)	-0.00004(0.001)	0.00003(0.001)	-0.0001(0.001)
Customer Concentration	0.007(0.013)	0.005(0.013)	0.006(0.013)	0.014(0.013)
City	0.001(0.007)	-0.001(0.007)	0.0003(0.007)	0.004(0.007)
Constant	-0.033*(0.017)	-0.045***(0.017)	-0.038**(0.016)	-0.057***(0.017)
R^2	0.0474	0.0701	0.0539	0.0666

Observations	391	389	392	392

Note: *p < 0.1, **p < 0.05, ***p<0.01; Standard errors are outlined in parentheses.

Furthermore, we conduct the cross-sectional analysis by using alternative variable measurements and including different control variables, as displayed in Table 3.9. Firstly, we use quick ratio, defined as current assets minus inventories scaled by current liabilities (Wiengarten et al., 2017), and cash ratio, defined as the ratio of cash and cash equivalents to current liabilities (Singh, 1986; Teirlinck, 2020), to measure financial slack. Models 1 and 2 replace the current ratio with quick and cash ratios, respectively. Secondly, in line with the previous literature (Yiu et al., 2020; Chen et al., 2022), we log-transform total assets and sales revenue as two alternative measures of firm size, as displayed in Models 3 and 4. Thirdly, we introduce year dummies into the model and explain any potential time-specific effects, as illustrated in Model 5. Fourthly, prior evidence suggests that industry competitiveness is crucial in influencing firm performance (Wiengarten et al., 2017). Thus, we include industry competitiveness (i.e., measured by 1 minus Herfindahl index), as displayed in Model 6. In sum, these results consolidate the robustness of the findings regarding the strengthening influence of firm size and financial slack on the market responses to the adoption of responsible production practices.

Table 3.9 Robustness tests based on alternative variable measurements

$CAR_{(-1,1)}$	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Financial Slack	0.003***	0.005***	0.002*	0.002**	0.003***	0.003***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.003)
Firm Size	0.004***	0.004***	0.004***	0.004***	0.004**	0.004***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Firm Age	-0.0002	-0.0002	-0.0003	-0.0003	0.0001	-0.0002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firm Profitability	-0.008	-0.008	-0.007	-0.020	0.019	-0.003
	(0.050)	(0.050)	(0.049)	(0.049)	(0.052)	(0.050)
Financial Leverage	0.018	0.013	-0.004	-0.003	0.022	0.020
	(0.019)	(0.018)	(0.020)	(0.020)	(0.020)	(0.020)
State Ownership	0.007	0.006	0.008	0.009	0.007	0.007
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
R&D Intensity	-0.090	-0.056	-0.072	-0.061	-0.064	-0.077
	(0.093)	(0.093)	(0.091)	(0.091)	(0.099)	(0.094)
Inventory Turnover Ratio	-0.00002	0.0001	-0.00005	-0.0002	0.0001	0.00005
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Customer	0.006	0.006	0.001	0.003	0.009	0.005

Concentration	(0.013)	(0.013)	(0.012)	(0.012)	(0.013)	(0.013)
City	0.0001	-0.001	0.0001	-0.0001	0.001	0.0004
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Year Dummies					Included	
Industry Competitiveness						-0.025
						(0.026)
Constant	-0.037**	-0.033**	-0.080***	-0.077***	-0.041**	-0.016
	(0.016)	(0.016)	(0.020)	(0.019)	(0.019)	(0.028)
R^2	0.0537	0.0599	0.0842	0.0831	0.0727	0.0560

Note: Sample N=392, *p < 0.1, **p < 0.05, ***p<0.01; Standard errors are displayed in parentheses.

3.5.3 Endogeneity concerns

Endogeneity appears when explanatory variables are associated with the error term (Weeks, 2002). The endogeneity issues are caused by omitted variables, self-selection bias, and reverse causality. Firstly, our proposed model incorporates firm-specific characteristics as control variables. In addition, we have introduced industry-specific factors and year dummies for robustness checks to reduce potential bias derived from omitted variables. Secondly, the explanatory variables are adopted in the previous fiscal year. Particularly, there is a year lag between the control and dependent variables. Thirdly, the self-selection bias emerges because the unobserved factors can affect the existence of included announcements. Besides, firms can adopt responsible production practices but opt not to announce them timely, leading to non-random and self-selection concerns.

To mitigate self-selection bias, we utilize propensity score matching (PSM) in selecting the control group consisting of non-adopter firms. This approach necessitates the identification of publicly listed manufacturers as potential control candidates. Drawing upon precedents from literature (Feng et al., 2020b; Zhu et al., 2021), we have selected various firm-level characteristics, including firm size, profitability, age, Tobin's Q, ISO14001 certification, financial leverage, ownership structure, customer concentration, and industry type, as predictive factors for the adoption of responsible production practices. Employing a logit regression model, we calculate the propensity score and then employ a closest-neighbor nonplacement matching method with a caliper of 0.05 to match the control group. Accordingly, the final dataset consists of 392 control firms with 392 treatment firms, which is chosen for further analysis. Subsequent difference tests indicate that there are no statistically significant disparities in any of the selected predictors between the control and treatment firms.

Due to the lack of complete security and market return data during the estimation or event period, the market reaction analysis was narrowed down to 337 control firms out of the initial 392. Table 3.10 presents the market responses to the adoption of responsible production practices for these matched control firms. Specifically, Panel A showcases the daily AR of the control samples, revealing no statistically significant impacts on any of the event days. Furthermore, Panel B depicts the CARs of the control firms, indicating insignificant CARs within both the three-day and two-day event windows. Collectively, these findings underscore notable distinctions in market reactions between the two groups of firms, thereby implying that self-selection bias may not pose a significant concern in this context.

Table 3.10 Market reaction results among control firms

Panel A: Daily abnormal returns of matched samples					
Event day	N	Mean	T-test	Corrado rank test	Generalized sign test
-1	337	-0.0002	-0.133	0.445	0.380
0	337	0.0001	0.028	0.231	0.380
1	337	0.0001	0.080	0.291	-0.495
Panel B: Cumulative abnormal returns of matched samples					
Event window	N	Mean	T-test	Corrado rank test	Generalized sign test
(-1,1)	337	-0.00004	-0.013	0.558	0.817
(-1,0)	337	-0.0002	-0.074	0.484	-0.276
(0,1)	337	0.0002	0.077	0.359	-0.495

To address potential self-selection bias in line with prior literature (Feng et al., 2020b), we utilize the Heckman two-step procedure. In the first step, we apply a probit model to estimate the probability of adopting responsible production practices, regressing it against the explanatory variables used in the PSM approach for both treatment and control firms. Following this, we derive the inverse Mills ratio from the probit regression. Subsequently, in the second step, we incorporate the inverse Mills ratio as a control variable and re-execute the cross-sectional regression model presented in Section 4.3. Table 3.11 displays the results of the second-step Heckman regression, with Models 1 through 4 estimating CARs over a three-day event window of (-1,1), utilizing various estimation windows ranging from (-130, -11), (-160, -11), (-150, -31), to (-140, -21). Model 5, specifically, evaluates CARs by using the Fama-French three-factor model. Across all models, the results indicate that the inverse Mills ratio does not exert a significant influence, reinforcing the robustness of our findings. Additionally, the primary effects remain congruent with those presented in Section 5.1, confirming that endogeneity does not undermine the validity of the proposed model.

Table 3.11 The tests of mitigating endogeneity concerns

	Model 1: (-130, -11)	Model 2: (-160, -11)	Model 3: (-150, -31)	Model 4: (-140, -21)	Model 5: Fama-French three-factor model
Financial Slack	0.003***	0.003**	0.003***	0.003**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firm Size	0.004**	0.004**	0.005***	0.004**	0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Firm Age	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firm Profitability	-0.001	-0.009	-0.022	-0.006	0.043
	(0.051)	(0.051)	(0.051)	(0.051)	(0.020)
Financial Leverage	0.017	0.013	0.027	0.008	0.025
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
State Ownership	0.007	0.008	0.006	0.008	0.007
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)
R&D intensity	-0.080	-0.083	-0.132	-0.132	-0.036
	(0.094)	(0.094)	(0.095)	(0.094)	(0.097)
Inventory Turnover Ratio	-0.00005	-0.0001	-0.0001	-0.0001	-0.0002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Customer Concentration	0.009	0.008	0.006	0.010	0.016
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
City	0.0002	0.0001	-0.002	0.001	0.004
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Inverse Mills ratio	-0.013	-0.013	-0.004	-0.011	-0.010
	(0.010)	(0.010)	(0.010)	(0.010)	(0.011)
Constant	-0.016	-0.015	-0.037	-0.012	-0.039
	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)
R^2	0.0573	0.0576	0.0705	0.0504	0.0688
Observations	392	392	389	391	392

Note: *p < 0.1, **p < 0.05, ***p<0.01; Standard errors are displayed in parentheses.

3.5.4 Additional analysis

We have conducted a thorough examination of the potential influence of the COVID-19 pandemic on the stock market valuation associated with responsible production practices. The findings are presented in Table 3.12, which includes an analysis considering the variable

COVID-19. Specifically, Model 1 incorporates a dummy variable, COVID-19, indicating the presence of the pandemic in year *t*, within our proposed model. For the purpose of this study, the pre-pandemic period spans from 2016 to 2019, while the COVID-19 pandemic is considered to have commenced in 2020. Models 2 and 3 further dissect the results, distinguishing between before and during the COVID-19 pandemic periods. Our analysis from Model 1 reveals a negative impact of the COVID-19 pandemic on the market valuation of adopting responsible production practices. Notably, Models 2 and 3 provide compelling evidence that the influence of firm size and financial slack on enhancing the market value of these practices is significantly more pronounced during the COVID-19 pandemic compared to the pre-pandemic period. This additional insight underscores the fact that the COVID-19 pandemic has exacerbated resource constraints for manufacturers, heightening their need for support in fostering the firm value associated with adopting responsible production practices.

Table 3.12 The moderating role of the COVID-19 pandemic

$CAR_{(-1,1)}$	Model 1	Model 2	Model 3
Financial Slack	0.003***(0.001)	-0.0001(0.001)	0.006***(0.002)
Firm Size	0.004**(0.002)	0.003(0.003)	0.004**(0.002)
COVID-19	-0.011*(0.006)		
Firm Age	-0.0001(0.001)	-0.000004(0.001)	0.0005(0.001)
Firm Profitability	0.004(0.050)	-0.047(0.069)	0.042(0.076)
Financial Leverage	0.022(0.019)	0.006(0.025)	0.039(0.032)
State Ownership	0.006(0.007)	0.003(0.009)	0.008(0.012)
R&D intensity	-0.086(0.093)	-0.021(0.123)	-0.109(0.146)
Inventory Turnover Ratio	0.0001(0.001)	-0.0002(0.001)	0.001(0.001)
Customer Concentration	0.005(0.013)	0.008(0.016)	0.00001(0.021)
City	0.001(0.007)	0.007(0.009)	-0.006(0.011)
Constant	-0.037**(0.016)	-0.013(0.023)	-0.074***(0.025)
Observations	392	208	184
R^2	0.0628	0.0263	0.1231

Note: *p < 0.1, **p < 0.05, ***p<0.01; Standard errors are outlined in parentheses.

3.6 Discussions

Utilizing an event study encompassing 392 corporate announcements, this research underscores the positive market valuation associated with the adoption of responsible production practices. This finding echoes prior research, which underscores the crucial role of legitimate sustainability initiatives, such as environmentally-friendly certifications, in fostering stakeholder and investor support due to their alignment with policy regulations (Feng et al., 2020a). Our cross-sectional analysis further solidifies the notion that financial slack positively affects market reactions to the adoption of responsible production practices. This aligns with existing literature (Wiengarten et al., 2017; Chen et al., 2022), emphasizing resource slack as a strategic tool for fostering self-development opportunities and resource accessibility, which are pivotal in supporting corporate endeavors. Furthermore, our findings reveal that larger firms experience more favorable market responses to the adoption of responsible production practices. This reinforces the notion that large firms derive greater benefits from adopting responsible practices due to their heightened visibility and abundant resources, which contribute to enhancing the market value of responsible production (Cordeiro and Tewari, 2015). Our additional analysis sheds light on the detrimental impact of the COVID-19 pandemic on the market valuation of responsible production practices adoption. Notably, the amplifying effect of firm size and financial slack on the market value of these practices during the pandemic underscores the heightened importance of resource support, particularly during this challenging period. These findings underscore the critical role of resource support in fostering the adoption of responsible production practices and creating firm value, especially amidst the COVID-19 pandemic (Chen et al., 2022).

Drawing from legitimacy theory and the RBV, this study elucidates the reinforcing influence of firm size and financial slack on the positive market performance emanating from the adoption of responsible production practices. Our research contributes to existing OM knowledge through three pivotal avenues. Firstly, by positioning responsible production as a legitimate strategic approach to aligning with stakeholder expectations and augmenting firm value, this study challenges the prevailing reluctance among manufacturers to integrate responsibility into their operational structures due to complex resource allocation concerns and substantial operating costs (Mao and Wang, 2019). Through empirical evidence, we demonstrate that responsible production practices positively influence stock market valuation, establishing them as genuine and effective initiatives. In harmony with prior literature (Feng et al., 2020a), our findings underscore how firms can enhance their reputations and strengthen investor confidence in their legitimate endeavors by adhering to responsible production policies. Consequently, this study contributes to the proliferation of responsible production practices by elucidating their legitimate actions as market-oriented advantages capable of attracting investors and stakeholders. By disentangling these underlying benefits, we facilitate a deeper understanding of the strategic significance of responsible production in contemporary business environments.

Secondly, this study sheds light on the pivotal role of financial slack and firm size as key enablers in the value-creation process stemming from the adoption of responsible production practices. The existing literature on the benefits or drawbacks of financial slack to the practice-performance relationship has produced mixed findings (Bradley et al., 2011; Liu et al., 2022a). Contrary to the prevalent view in the literature that resource slack exacerbates risks (Liang et al., 2023), our study reveals its risk-mitigating function in navigating the economic uncertainties and operational complexities associated with the implementation of responsible production practices. Building upon prior research (Cordeiro and Tewari, 2015; Chuang et al., 2019), we demonstrate that large firms, with their economies of scale, possess the advantage of robust human resources, extensive technical expertise, and superior organizational capabilities, which enable them to harness the benefits of adopting responsible production practices. These firms can leverage their financial slack and additional resources to engage in socially and environmentally responsible behaviors, surmounting potential financial constraints (Wu et al., 2016). In line with the insights of earlier studies (Chuang et al., 2019; Darby et al., 2020), this research underscores how financial slack and firm size function as a protective shield against the potential vulnerabilities that may arise from responsible production policies in an unpredictable business landscape.

Thirdly, this study contributes novel insights into the RBV by elucidating the pivotal role of resource support, rather than resource scarcity, in shaping the practice-performance linkage. Particularly, it emphasizes the crucial function of resource support, possessed by firms with large size or ample financial slack, in fostering favorable market reactions to the adoption of responsible production practices. Conversely, the resource scarcity induced by the COVID-19 pandemic poses obstacles to the value creation associated with the implementation of such practices. Despite this, under conditions of resource scarcity, the reinforcing effect of firm size and financial slack becomes particularly salient in influencing the positive market valuation of adopting responsible production practices. These findings reinforce the idea that manufacturers necessitate substantial financial and technical resources to integrate responsible production practices into their operational frameworks (Mao and Wang, 2019; Guo et al., 2020).

3.7 Conclusions

Building upon the legitimacy theory and the RBV, this study presents compelling evidence of positive market reactions to the adoption of responsible production practices, while also illustrating the reinforcing effect of firm size and financial slack on these dynamics. Employing an event-study methodology to analyze a dataset of 392 corporate announcements, our findings align with prior research, reinforcing the favorable link between responsible practices and enhanced firm value, achieved through the alignment of stakeholder interests (Harjoto and Laksmana, 2018). Furthermore, this study contributes novel insights into the RBV by highlighting the pivotal role of resources in shaping the practice-performance linkage, particularly in the context of the COVID-19 pandemic. Additionally, our analysis reveals the detrimental impact of the COVID-19 pandemic on the market valuation of adopting responsible production practices. Notably, our findings provide invaluable managerial implications by shedding light on the importance of resource support in facilitating the transformative shift towards legitimacy-driven initiatives. These insights underscore the critical role of strategic resource allocation and management in fostering positive market perceptions and enhancing firm value amid challenging economic conditions.

This study offers several pivotal managerial insights for seamlessly integrating responsible production practices into operations management strategies. Firstly, it highlights the positive market valuation that firms can accrue by adopting such practices, emphasizing the imperative for proactive embracement, aligning with prevailing market expectations. For example, prioritizing quality management and eco-design can strategically position firms to adhere to responsible production policies, thereby fostering market acceptance. These revelations serve as a valuable reference for policymakers seeking to devise informed strategies aimed at propagating responsible production practices. In the face of policy regulations and international trade pressures, Chinese manufacturers must comply with directives such as energy conservation and emission reduction to uphold their status as responsible enterprises. Secondly, this study provides invaluable guidance on the optimal timing for adopting responsible production practices. Successful implementation hinges crucially on the availability of robust financial, technical, and human resources availability. Large firms, with their substantial resources (including technical expertise and human capital), are expected to lead the way in adopting these practices. Concurrently, firms with high financial slack are better equipped to integrate responsible production practices seamlessly, ensuring uninterrupted business operations. Lastly, this research underscores the significance of tailoring policy support and funding allocation specifically for the adoption of responsible production practices. As China's primary manufacturing hub, it is imperative to establish responsible production standards to compensate for any shortcomings in high-end outputs and craftsmanship. Given the necessity of resource support for responsible production, policymakers must provide tailored resources to small firms or those with limited financial slack, facilitating their successful adoption of these practices.

Several limitations in interpreting the study's findings present avenues for future research endeavors. Firstly, there exists a potential to delve deeper into the categorization of responsible production practices, meticulously distinguishing actions across various lifecycle stages of a product (e.g., eco-design and waste disposal) or specific dimensions of responsibilities (e.g., resource and environmental stewardship). By doing so, scholars can investigate and contrast the differential impacts of these subdimensions on market valuation. Secondly, the current study primarily centers on the short-term market value of responsible production. To offer a more holistic view of long-term strategic planning, future research should broaden its scope to explore the enduring effects of adopting such practices. Furthermore, examining the broader performance outcomes, including their influence on supply chain resilience, as exemplified by prior research (Li et al., 2023), would enrich our understanding of the value proposition of responsible production. Thirdly, there is a need for further investigation into the mediating mechanisms that underlie the linkage between responsible production and market value. Particularly, unraveling how responsible production practices enhance customer satisfaction or amplify network attention can illuminate the pathways through which these practices influence market valuation. Lastly, it is crucial to consider other contingent factors that may moderate the market performance of adopting responsible production practices. For example, the motivations driving the adoption of these practices, whether altruistic or egoistic, warrant nuanced exploration for empirical validation. This nuanced approach can provide deeper insights into the complexities of this relationship.

Chapter 4: Does resource-responsible production enhance financial performance: The role of digital transformation and political connections

4.1 Introduction

Resource conservation, which reflects a firm's interaction with natural resources (hereafter referred to as the organization-resource relationship), has garnered increasing attention in both academic and industrial areas (Li et al., 2022a). The United Nations has warned that "our planet is running out of resources, but populations are continuing to grow"[7]. Additionally, responsible consumption and production as the twelfth sustainable development goal (SDG12) underscores the importance of resource conservation, advocating for the principle of "doing more and better with less" (Tseng et al., 2018). To advance resource conservation, academic literature highlights the concept of resource-responsible production, which involves a firm's commitment to minimizing the consumption of natural resources in the production process (Kalaitzi et al., 2019; Ahmad et al., 2023). This approach offers a viable path for manufacturers to pursue a sustainable future. However, developing markets face significant challenges due to resource scarcity exacerbated by uncontrolled consumption driven by the growing population. To address resource depletion, the Chinese government has introduced initiatives such as circular economy programs and energy conservation projects (Li et al., 2022a). Nonetheless, some firms are hesitant to embrace resource-responsible production due to economic uncertainties and substantial investment requirements (Mao and Wang, 2019). Hence, it is crucial to explore whether resource-responsible production positively or negatively affects financial performance.

The extant literature presents varied findings on the relationship between resource-responsible production and financial performance (Kalaitzi et al., 2019; Ahmad et al., 2023; Sun et al., 2023). Numerous studies have focused on the effects of corporate social responsibility (CSR) and corporate environmental responsibility (CER) on corporate financial performance (CFP) (Guo et al., 2015; Li et al., 2019; Li et al., 2021). As a key aspect of CSR and CER, resource-responsible production has not been extensively studied, resulting in mixed opinions (Jeong and Lee, 2022; Ahmad et al., 2023). Prior research has found a positive relationship between resource-responsible production and financial performance, suggesting it can offer a competitive edge (Demirel and Danisman, 2019; Jabbour et al., 2022). In contrast, other studies have found no significant connection between resource efficiency and financial

[7] https://www.un.org/sustainabledevelopment/sustainable-consumption-production/ (accessed on March 11, 2024)

performance (Kalaitzi et al., 2019). Moreover, some empirical research has shown mixed findings about the performance effects of resource-responsible production, including insignificant, positive, and negative outcomes (Ahmad et al., 2023). Much of this research has been concentrated in developed countries, with a limited focus on developing markets. This study aims to explore the influence of resource-responsible production on financial performance within these emerging contexts.

These mixed results suggest that the benefits of resource-responsible production may vary among firms. For instance, while Tesla has become a leading electric vehicle (EV) manufacturer, several promising EV start-ups have struggled due to inadequate implementation of resource-responsible production[8]. This indicates that certain factors might affect a firm's success in dynamic markets, warranting a further examination of the conditions under which resource-responsible production influences financial performance. Research has indicated that a firm's competitive advantage depends on internal capabilities and external networks (Lee et al., 2001), which are crucial for the adoption of resource-responsible production. For example, Tesla has used digital technologies to formulate precise maps and implement self-driving capabilities for novel, energy-efficient autonomous vehicles[9]. In line with this example, empirical evidence underscores that digital transformation empowers firms to innovate their existing business models, such as embracing resource-responsible production, thereby enhancing financial performance (Yang and Han, 2023; Zhao et al., 2023). Notably, in developing markets, governments serve as pivotal resource providers, exerting considerable influence over corporate operations (Sheng et al., 2011). Consequently, firms have increasingly forged political connections by appointing political officers to executive positions or engaging in political donations/lobbying efforts to shape policy (Li and Jin, 2021). An illustrative case is BYD, a preeminent EV manufacturer in China, which has fostered collaborative ties with government entities and research organizations to advance renewable energy solutions[10]. Through these political connections, BYD has garnered policy incentives, investment funding, and tax concessions. However, research investigating the moderating influence of digital transformation and political connections on the relationship between resource-responsible production and financial performance remains scarce. Accordingly, this study empirically addresses the following two research questions.

RQ1: Does resource-responsible production positively affect financial performance?

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[8] https://www.scmp.com/business/china-business/article/3237078/chinas-ev-war-only-strongest-will-survive-byd-xpengs-dominance-knock-out-15-pretenders-amid-supply (accessed on December 14, 2023)
[9] https://www.globaldata.com/store/report/tesla-inc-enterprise-tech-analysis/ (accessed on December 14, 2023)
[10] https://www.byd.com/us (accessed on August 24, 2023)

RQ2: How do digital transformation and political connections modulate the relationship between resource-responsible production and financial performance?

The nexus between resource-responsible production and financial performance is illuminated by the natural resource-based review (NRBV), which underscores competitive advantage rooted in a firm's relationship with the natural environment (Hart, 1995). Resource-responsible production, as a strategic endeavor, aims to conserve natural resources, thereby strengthening the organization-resource linkage (Li et al., 2022a). Furthermore, the contingent NRBV proposes that a firm's competitive advantage is shaped by both internal and external factors (Andersen, 2021; Farooque et al., 2022). In this study, we posit that digital transformation and political connections, representing a firm's internal capabilities and external networks, respectively, modulate the linkage between resource-responsible production and financial performance. Employing a difference-in-differences (DID) analysis coupled with the propensity score matching (PSM) method, our findings reveal a positive effect of resource-responsible production on financial performance. Notably, the heterogeneity test underscores the significance of this positive impact among firms with high digital transformation or politically connected firms, whereas the effect is less pronounced among those with low digital transformation or lacking political connections.

This study makes significant contributions to the existing literature in three key aspects. Firstly, this study reinforces and expands the NRBV literature by shedding light on the pivotal role of internal capabilities (i.e., digital transformation) and external networks (i.e., political connections) in transforming resource-responsible production into a competitive advantage for firms. Notably, this study fills a gap in the contingency perspective on the organization-resource relationship, which has been underrepresented in prior research (Mathiyazhagan et al., 2021; Sun et al., 2023). By empirically demonstrating the beneficial effects of digital transformation and political connections on pollution prevention, product stewardship, and sustainable development, this work pioneers a new path in advancing the NRBV framework. Secondly, this study enhances the scholarly understanding of resource-responsible production, by distinguishing it from traditional CSR and CER frameworks. While prior studies have extensively explored CSR and CER (Guo et al., 2015; Li et al., 2019; Li et al., 2021), there is a scarcity of research comprehensively examining the relationship between resource responsibility and financial performance, with conflicting results reported (Ahmad et al., 2023). This study offers robust empirical evidence, clarifying the nature of this relationship and enriching the literature on resource-responsible production. Lastly, this study addresses the critical question of when to adopt resource-responsible production for performance enhancement. Building upon prior research (Jabbour et al., 2022; Lin and Zhang, 2023), this study highlights the enabling role of digital transformation in fostering innovation and operational agility, thereby facilitating the positive impact of resource-responsible production on financial performance. Furthermore, it extends existing knowledge (Li et al., 2015; Tihanyi et al., 2019) by emphasizing the structural capital and network resource dimensions of political connections, which can be leveraged to create competitive advantages through government-driven initiatives. These findings carry practical implications, suggesting that firms with advanced digital capabilities or political connections should prioritize the adoption of resource-responsible production. Moreover, policymakers are encouraged to allocate resources such as policy support and training to firms lacking in these areas, fostering a broader adoption of resource-responsible practices.

4.2 Theoretical Background

4.2.1 Resource-responsible production

Resource-responsible production embodies a company's commitment to maximizing resource efficiency and minimizing resource consumption, as highlighted by prior research (Ahmad et al., 2023; Sun et al., 2023). A prime example is Apple's adoption of this approach, demonstrated through the use of recycled cobalt in batteries, encouraging suppliers to make clean energy commitments, and repurposing materials from outdated products. These initiatives have propelled Apple to attain the milestone of becoming the world's first trillion-dollar company[11]. While much research has centered on the implications of CSR and CER, as noted by the existing literature (Guo et al., 2015; Lin and Zhang, 2023), relatively few studies have delved into resource-responsible production. Distinguishing itself from CSR's broader focus on social philanthropy (McWilliams and Siegel, 2001), resource-responsible production underscores the significance of preserving natural resources throughout the production process, from input to output. This entails actions such as procuring renewable materials at the input stage, embracing resource-efficient innovations during production, and recycling end-of-life products. Furthermore, resource-responsible production can be seen as a concentrated aspect of CER, which emphasizes a company's dedication to mitigating environmental pollution, resource depletion, and ecological imbalance (Xu et al., 2020). Table 4.1 outlines the practices associated with resource-responsible production, CSR, and CER, facilitating the identification

[11] https://www.apple.com/hk/en/environment/ (accessed on December 14, 2023)

of their similarities and differences.

In light of the paramount significance of resource conservation and efficiency, scholars have exhibited a keen interest in resource-responsible production for performance enhancement (Jabbour et al., 2022; Guo and Tsinopoulos, 2023). The extant literature examining the impact of resource-responsible production on financial performance presents a mixed picture, spanning from positive (Sun et al., 2023) and negative findings (Ahmad et al., 2023) to instances of insignificance (Kalaitzi et al., 2019). Notably, several studies underscore a favorable correlation between resource-responsible production and financial performance (Farooque et al., 2022; Jabbour et al., 2022; Sun et al., 2023). For instance, empirical analysis based on data from seven countries spanning 2010 to 2021 highlights the positive influence of green innovation and resource efficiency on economic growth (Sun et al., 2023). Conversely, research involving 183 surveys indicates an inconsequential link between resource efficiency and financial performance in contexts of scarce natural resources (Kalaitzi et al., 2019). Additionally, there are instances where water conservation efforts have been found to adversely affect financial performance, as exemplified by data from 2018 (Ahmad et al., 2023). It is noteworthy that most of these investigations have relied on survey questionnaires, primarily focusing on developed markets, particularly European firms (Demirel and Danisman, 2019; Kalaitzi et al., 2019; Stekelorum et al., 2021). However, emerging countries, where rapid population growth and unchecked resource depletion pose pressing challenges due to resource scarcity, have received relatively limited attention (Zhao and Bai, 2021). Consequently, there is a compelling need to delve deeper into the influence of resource-responsible production on financial performance in emerging markets, along with an exploration of the boundary conditions that govern this relationship.

Table 4.1 The practices of resource-responsible production, CSR, and CER

Aspects	Resource-responsible production	CSR	CER
Charitable donation for vulnerable groups		√	
Pollutant discharge treatment		√	√
Employee safety and welfare		√	
Product quality and customer service		√	
The reduction of exhaust emissions		√	√
Energy-saving and consumption-reducing production equipment	√	√	√
The design of recyclable resources for products	√	√	√
Garbage classification and processing		√	√

Battery recycling and reuse	√	√	√
Fair competition and business		√	

Note: √ represents which practices belong to resource-responsible production, CSR, or CER.

4.2.2 Natural resource-based view

The natural resource-based view (NRBV) is a strategic management framework that underscores the pivotal role of a firm's rapport with the natural environment in shaping a firm's competitiveness (Hart, 1995). This theory recognizes environmentally sustainable economic capabilities and strategies as valuable and scarce resources that firms can harness to establish distinctive and advantageous market positions. The NRBV encompasses three interconnected strategies—pollution prevention, product stewardship, and sustainable development—which collectively contribute to a firm's competitive edge. Firstly, pollution prevention fosters cost savings by promoting efficient resource utilization and emission reduction, thereby mitigating waste disposal expenses and evading environmental regulatory penalties. Secondly, product stewardship enables firms to preempt competitors by pioneering new or eco-friendly product domains, enhancing their reputation and differentiating their offerings. Lastly, sustainable development necessitates a long-term perspective that decouples economic growth from environmental depletion, fostering stronger stakeholder engagement and positioning firms for a more promising future. In the academic realm, the NRBV offers a valuable lens for comprehending a firm's nexus with the natural environment and elucidating its competitive advantages, as evidenced by previous studies (Andersen, 2021; Farooque et al., 2022).

Substantial portions of prior research have leveraged the NRBV to elucidate the impact of CER and eco-friendly practices on organizational outcomes (Andersen, 2021; Farooque et al., 2022; Yi and Demirel, 2023). Notably, researchers have discerned that firms integrate natural environmental concerns into their strategic planning frameworks to enhance performance, as perceived through the NRBV lens (Farooque et al., 2022; Guo and Tsinopoulos, 2023). In the present study, we adopt the NRBV as our theoretical framework to expound on the intricate relationship between organizational resources and financial performance. For instance, embracing resource-responsible production necessitates firms to select recyclable raw materials, design adaptable products, and facilitate the reuse of end-of-pipe products. Drawing upon the NRBV, we posit that resource-responsible production embodies a cohesive set of resources and capabilities, aimed at fostering an organization-resource nexus that can bolster a firm's competitive edge.

4.2.3 Digital transformation and political connections

In the context of resource-responsible production, firms have progressively harnessed digital technologies to oversee resource utilization across procurement, design, manufacturing, and disposal stages (Garmulewicz et al., 2018; Stekelorum et al., 2021; Jabbour et al., 2022). Existing evidence underscores that digital transformation can alleviate corporate financing constraints, augment analyst attention, and enhance corporate ESG performance (Chen and Hao, 2022; Cai et al., 2023). Beyond internal capabilities, the successful implementation of resource-responsible production heavily relies on substantial investments backed by external networks (Lee et al., 2001; Zhao et al., 2018). Studies have shown that political connections serve as an efficacious means for firms to access diverse external resources and bolster their competitive edge (Li and Jin, 2021). Nonetheless, limited research has delved into the importance of internal capabilities (i.e., digital transformation) and external networks (i.e., political connections) in shaping the linkage between resource-responsible production and financial performance (Lee et al., 2001; Andersen, 2021). Building upon the NRBV, this study contends that digital transformation and political connections can empower firms with political acumen and digital prowess, enabling them to leverage resource-saving sustainable economic practices, such as resource-responsible production, to attain competitive advantages.

Digital transformation is imperative for firms to maintain a competitive edge in legitimate endeavors, such as resource-responsible production, thereby fostering economic returns (Chen and Hao, 2022; Yang and Han, 2023). This transformation encompasses the integration of advanced technologies, including cloud computing, big data analytics, artificial intelligence, and the Internet of Things, to revolutionize traditional processes. Previous research underscores the integration of digital technologies (i.e., industry 4.0 technologies) into circular economy practices, facilitating business operations (Jabbour et al., 2022). Consistent with this literature, scholars have observed that digital transformation endows firms with innovation prowess, organizational agility, and financing capabilities (Lu et al., 2023; Yang and Han, 2023; Zhao et al., 2023). These digital and dynamic competencies can be harnessed to address the challenges associated with adopting resource-responsible production. Consequently, firms that have undergone significant digital transformation are poised to possess innovative capabilities for product stewardship and pollution prevention, enabling them to meticulously manage resources throughout a product’s lifecycle.

Political connections confer privileges to firms, granting them preferential access to information, resources, and political assurances that bolster economic development, particularly in emerging markets (Sheng et al., 2011; Li et al., 2015; Tihanyi et al., 2019). The notion of political connection encompasses the existence of both informal and formal ties between businesses/individuals and political entities/figures (Tihanyi et al., 2019). Informal connections might manifest as personal relationships between corporate executives and government officials, whereas formal ties could involve political figures holding equity or occupying pivotal positions within a company. The academic discourse has delved into the dual nature of political connections, highlighting both their detrimental and beneficial effects on firm performance (Ling et al., 2016; Schweizer et al., 2019). On the negative spectrum, scholars contend that maintaining political ties imposes substantial costs on firms (Ling et al., 2016), potentially compromising operational efficiency (Shen et al., 2023). Conversely, proponents argue that in the long-term, politically connected firms can capitalize on government-led initiatives, aligning with stakeholder expectations (Li et al., 2015), and reap benefits such as policy advantages (e.g., additional tax incentives), enhanced market access, and preferential treatment from financing institutions (Li and Jin, 2021). Moreover, by fostering stakeholder engagement, politically connected firms leverage resource-responsible production strategies for sustainable development, ultimately enhancing their financial performance. This underscores the strategic value of political connections in enabling firms to navigate the complex landscape of economic development while promoting environmental and social responsibility.

4.3 Hypotheses Development

4.3.1 Resource-responsible production and financial performance

By engaging in resource-efficient economic endeavors, firms can propel a paradigm shift towards a more sustainable future, simultaneously reaping operational benefits as evidenced by prior research (Stekelorum et al., 2021; Li et al., 2022a). In contrast to these findings, some scholars contend that enhancing resource efficiency necessitates increased investment costs for process management, leaving firms vulnerable to supply chain disruption due to resource constraints (Modi and Mishra, 2011). However, this perspective overlooks the mitigating role of slack resources and the pivotal importance of a firm's relationship with natural resources. Instead, resource-responsible production underscores the legitimacy and regulatory compliance, which fosters stakeholder engagement and unlocks multiple benefits, including investor favor, policy funding, and market acceptance (Mathiyazhagan et al., 2021). Moreover, suppliers prefer firms adopting responsible practices (Stekelorum et al., 2021), while customers are willing to pay premiums for socially responsible products (Rousseau and Vranken, 2013; Tully and Winer, 2014). Given the abundance of research supporting the merits of legitimate actions (Feng et al., 2020a; Li et al., 2021), resource-responsible production emerges as a strategic pathway for manufacturers to enhance their performance.

Drawing from the NRBV, resource-responsible production outlines a firm's strategic approach and capabilities in managing its relationship with natural resources, empowering it to capitalize on market opportunities and secure competitive advantages. Firstly, this production model underscores the importance of continuous improvement in product innovation and process management, leading to cost reductions and quality enhancements (Gouda and Saranga, 2020). Particularly, firms can mitigate expenses related to end-of-pipe pollution control devices and environmental penalties, reinforcing their financing stability. Secondly, embracing resource-responsible production signifies a firm's adeptness in stakeholder integration (Gupta et al., 2019; Stekelorum et al., 2021), aligning with societal values and expectations to gain investor favor (Feng et al., 2020a). Thirdly, this model embodies a firm's ability to forge a shared vision for sustainability, meeting both policy requirements and market demands (Liagkouras et al., 2020), potentially yielding long-term economic benefits (Xu et al., 2020). Empirical evidence further suggests that resource-responsible production fosters employee loyalty and customer allegiance (Buell and Kalkanci, 2021). Based on these insights, we hypothesize that

Hypothesis 1: Resource-responsible production exerts a positive influence on financial performance.

4.3.2 The role of digital transformation

Firms have progressively integrated digital technologies into resource-responsible production strategies, aiming to secure economic returns (Li et al., 2019; Tian et al., 2023). Within the manufacturing sector, digital transformation unlocks valuable insights from big data, fostering innovation and quality enhancements (Zhao et al., 2023). Moreover, it bolsters organizational flexibility and competitiveness by reshaping and optimizing traditional production models (Chatterjee and Mariani, 2022). Firms that have embraced high levels of digital transformation tend to disclose their CER and CSR actions, thereby strengthening their financing capabilities and achieving superior performance (Yang and Han, 2023).

Building upon the NRBV, we argue that digital transformation amplifies the positive influence of resource-responsible production on financial performance. Prior research underscores the role of digital transformation in empowering firms with advantages in information and process management for product stewardship and pollution prevention (Stekelorum et al., 2021; Yang and Han, 2023). Firms can harness big data analytics to select optimal suppliers offering better renewable resources and utilize blockchain to trace resource consumption pathways, facilitating industry optimization (Stekelorum et al., 2021). Furthermore, digital transformation fosters innovation capabilities (Zhao et al., 2023) and organizational flexibility (Reuschl et al., 2022), enabling firms to refine their business model. For example, highly digitalized firms strive for recyclability and durability in product design, addressing operational complexities and driving economic returns (Lin and Zhang, 2023). Consequently, we hypothesize that

Hypothesis 2: Digital transformation reinforces the positive effect of resource-responsible production on financial performance.

4.3.3 The role of political connections

Firms have increasingly cultivated political connections to tap into a diverse array of external resources, including financial leverage (Tihanyi et al., 2019), policy support (Sheng et al., 2011), and stakeholder engagement (Yi and Demirel, 2023). In emerging markets, the government's regulatory influence is heightened, acting as a pivotal source of essential resources for firm growth (Li et al., 2015). Politically connected firms thus gain access to substantial resources and enhanced resilience against political uncertainties, bolstering the transformation of resource-responsible production into superior performance.

These connections facilitate access to state backing and preferential financial policies (Li et al., 2015; Tihanyi et al., 2019), enabling firms to secure debt financing for investments in resource-responsible production, ultimately generating economic returns (Faccio et al., 2006). Additionally, politically connected firms can swiftly adapt to market shifts and mitigate external uncertainties through legal and institutional support derived from stakeholder engagement (Tihanyi et al., 2019; Li and Jin, 2021). They tend to engage in collaborative activities centered on information sharing, product development, and technological collaboration (Kotabe et al., 2017), capitalizing on financial support and mitigating risks associated with political uncertainties in resource-responsible production. Given the above, we posit that

Hypothesis 3: Political connections reinforce the positive influence of resource-responsible production on financial performance.

4.4 Data and Methodology

4.4.1 Data and sample

In light of the paramount significance of emerging markets within the global economic landscape, our study concentrates onn publicly listed Chinese manufacturers as a representative cohort to validate our hypotheses. Firstly, China stands as a pivotal global manufacturing epicenter, confronting formidable challenges stemming from resource depletion (Zhao and Bai, 2021). Secondly, the Chinese government has underscored the importance of promoting energy-efficient and circular economy policies. By assessing the influence of resource-responsible production on financial performance in China, our research offers valuable insights that could inform resource-responsible production practices in other emerging economies grappling with analogous resource scarcity issues.

Table 4.2 encapsulates the search criteria (panel A), distribution patterns (Panel B), and illustrative examples (Panel C) of announcements on resource-responsible production. Drawing upon the extant literature (Jasti and Kodali, 2015), we used the keywords to screen announcements by title, focusing specifically on the manufacturing sector from 1 January 2013 to 31 December 2019. Manufacturers, being substantial contributors to resource consumption, are poised to shoulder resource responsibility for fostering sustainability. This timeframe was chosen deliberately, coinciding with the Chinese government's launch of the "Twelfth Five-Year Plan" for circular economy development in December 2012[12], and terminated in 2019 to preclude the confounding effects of the COVID-19 pandemic. Our initial data collection yielded a total of 904 announcements sourced from the Shenzhen Stock Exchange (336), Shanghai Stock Exchange (141), and Cninfo.com (427). Following the removal of duplicates, we retained 582 announcements. Subsequent title-based screening eliminated announcements unrelated to resource-responsible production practices, including those addressing irresponsible resource utilization or investments/mergers, resulting in a refined set of 328 announcements. Ultimately, we identified the earliest announcement of each firm, curating a dataset of 135 adopter firms for in-depth analysis.

To enrich our understanding, we sourced firm-specific data from the China Stock Market & Accounting Research (CSMAR) database, a comprehensive repository of financial statements for Chinese-listed companies (Shou et al., 2021b; Liu et al., 2022a). This facilitated the collection of panel data for subsequent empirical examinations. Figure 4.1 outlines the

[12] https://www.ndrc.gov.cn/fzggw/jgsj/hzs/sjdt/201212/t20121218_1130808.html (accessed on December 8, 2023)

methodological sequence, encompassing data selection, propensity score matching (PSM), difference-in-differences (DID) analysis, robustness checks, and heterogeneity assessments. The subsequent sections will delve into these analytical steps in detail.

Table 4.2 Descriptive statistic of selected announcements

Panel A: Search items for resource-responsible production

Dimensions	**Items**	**Source**
Keywords	Circular economy, recycle, reuse, energy saving, efficiency, renewable energy, efficient, technology improvement, resource-saving	(Jasti and Kodali, 2015)
Industry	Manufacturing sector	
Time Periods	from 1 January 2013 to 31 December 2019	

Panel B: Distribution of included sample firms across years

Year	**Frequency**	**Percent**
2013	33	24.44%
2014	19	14.07%
2015	12	8.89%
2016	21	15.56%
2017	15	11.11%
2018	19	14.07%
2019	16	11.85%
Total	135	100%

Panel C: Examples of resource-responsible production announcements

Stock name	**Stock code**	**Announcement title**	**Time**
ADAMA Ltd.	000553	Investment and construction of 300,000 tons/year caustic soda plant energy-saving and emission reduction technical transformation project	May 28, 2023
YBTY	002386	The recognition of the National Circular Economy Pilot Demonstration Unit	November 21, 2014
ZJDFDR	300217	The "Industrialization of PTC Electric Heater for High-Efficiency and Energy-Saving Electric Vehicles" project was included in the "2015 National Torch Plan" project	December 29, 2015
SNS	300470	The project "Development of 20MPa dry gas seal for circulating hydrogen compressor" passed the achievement appraisal of China Machinery Industry Federation and China General Machinery Industry Association	November 23, 2017

HUAMAO SHARE	000850	Investment in high-quality and efficient full-process intelligent spinning upgrade and transformation project	January 5, 2019

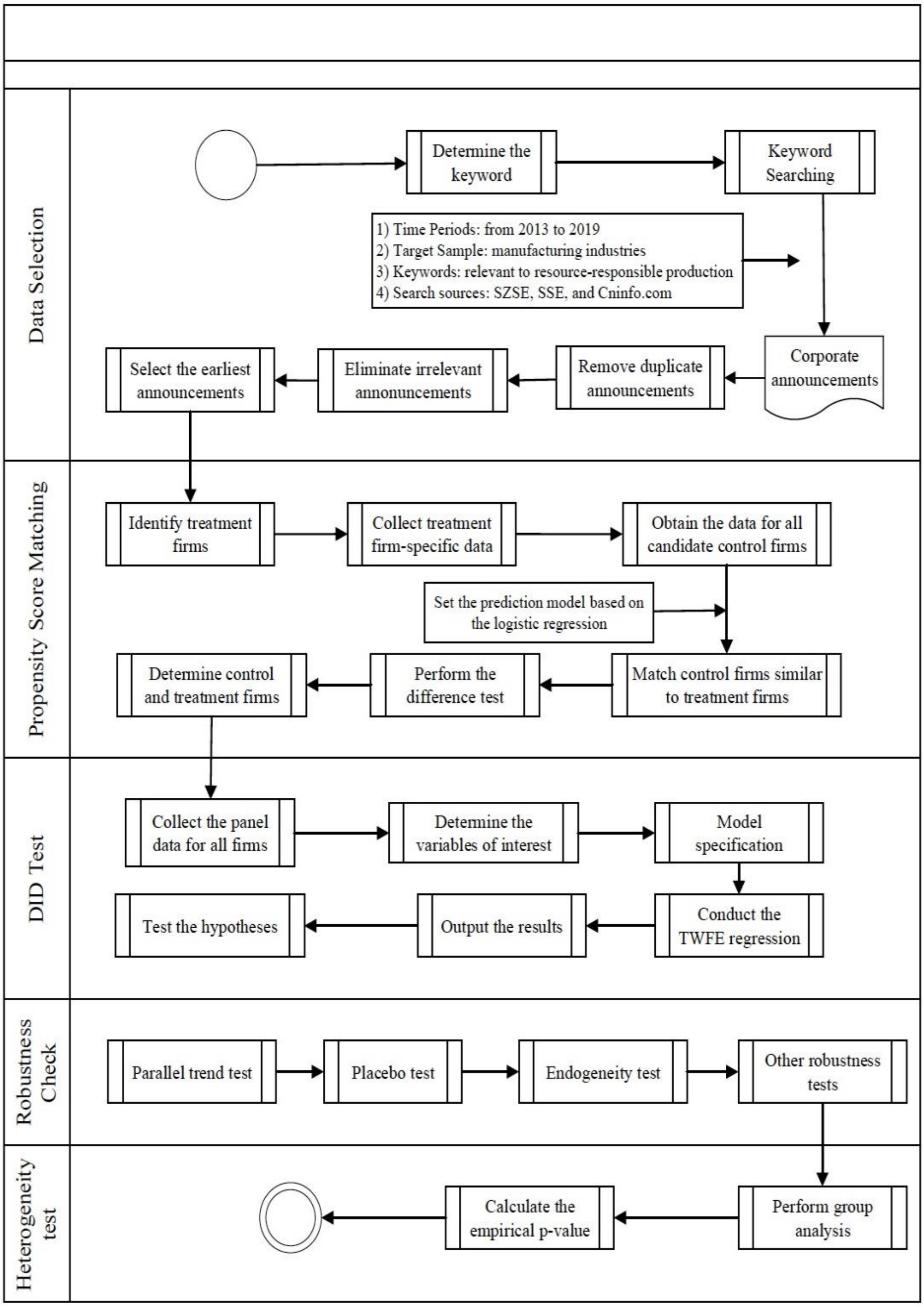


Figure 4.1 Procedures of data analysis

4.4.2 Propensity score matching

We adopted the propensity score matching (PSM) methodology to identify a control group of firms based on their propensity to be selected for the treatment group, which was determined by calculating their propensity scores. In deriving these scores, we incorporated a comprehensive set of observable covariates, namely *Firm Size*, *Firm Age*, *Firm Profitability*, *Financial Leverage*, *Innovation Capability*, *State Ownership*, and *Tobin's Q*. The choice of these covariates was grounded in previous research that underscores their pivotal roles in shaping a firm's practices (Feng et al., 2020a; Shou et al., 2021b; Zhu et al., 2021). In particular, firm size, age, profitability, and financial leverage are paramount in determining a firm's operational dynamics (Zhu et al., 2021). Furthermore, state ownership and Tobin's Q significantly influence a firm's legitimate strategic actions (Feng et al., 2020a), while innovation capability is crucial for overcoming technological barriers and fostering knowledge dissemination within a firm's practices (Shou et al., 2021b). Utilizing a logistic regression model, we estimated these propensity scores, as outlined in the subsequent equation. This rigorous approach ensures the creation of a well-balanced control group, thereby enhancing the precision and credibility of our findings.

$$\begin{aligned} Logit\big(P(Treat_i = 1)\big) &= \beta_0 + \beta_1 Firm\ Size_i + \beta_2 Firm\ Age_i + \beta_3 Firm\ Profitability_i \\ &+ \beta_4 Financial\ Leverage_i + \beta_5 Innovation\ Capability_i \\ &+ \beta_6 State\ Ownership_i + \beta_7 Tobin's\ Q_i + \epsilon_i \end{aligned}$$

Where *Treat* denotes the likelihood for firm *i* being assigned to the treatment group, it is crucial to note that the adoption of resource-responsible production practices occurred in or after 2013. To maintain consistency with the existing literature (Son et al., 2020), we utilized predictor variables from the pre-adoption year (i.e., 2012) in our calculations.

For the PSM process, we implemented the closest-neighbor method without replacement, utilizing a caliper of 0.05. The application of this method reveals that one treatment firm could not be successfully matched. Consequently, 134 treatment firms are successfully paired with 134 control firms, based on their respective propensity scores. As evidenced in Table 4.3, our findings indicate that there are no statistically significant differences between the treatment and control group firms after PSM (p>0.1), suggesting a well-balanced sample for further analysis.

Table 4.3 Summary statistics of two groups before and after PSM

Variable	Unmatched	Mean			t-test
	Matched	Treat	Control	%bias	t (p-value)

Firm Size	U	6.717	3.378	98.5	10.02(0.000)
	M	6.710	6.620	2.7	0.25(0.799)
Firm Age	U	13.756	11.601	36.5	3.96(0.000)
	M	13.716	14.187	-8	-0.68(0.498)
Firm Profitability	U	0.060	0.029	19.8	4.22(0.000)
	M	0.053	0.056	-1.8	-0.14(0.887)
Financial Leverage	U	0.382	0.183	78.9	9.02(0.000)
	M	0.379	0.368	4.4	0.36(0.716)
Innovation Capability	U	0.026	0.017	31.7	3.17(0.002)
	M	0.026	0.031	-16.7	-1.11(0.269)
State Ownership	U	0.319	0.156	38.8	5.04(0.000)
	M	0.321	0.306	3.6	0.26(0.793)
Tobin's Q	U	1.242	0.759	43.7	4.7(0.000)
	M	1.251	1.171	7.2	0.73(0.464)

4.4.3 Difference-in-differences analysis

Following the application of the PSM method, we conducted a difference-in-differences (DID) analysis, a statistical technique aimed at estimating causal effects by contrasting temporal changes between treatment and control groups (Goodman-Bacon, 2021). Our analysis centers on the announcement year as the adoption year, spanning from 2013 to 2019, and employs a 13-year window to observe dynamic changes, encompassing a three-year pre-adoption and a three-year post-adoption period (i.e., from 2010 to 2022).

Table 4.4 outlines the variables examined in this study. To evaluate financial performance, we utilize the return on assets (ROA) metric, calculated as the ratio of net income to total assets (Xu et al., 2020). Additionally, we explore the interaction between two binary variables: *Treat*, which signifies whether a firm adopts resource-responsible production practices, and *Post*, indicating whether the observational year falls before or after/on the adoption year. Our DID analysis also incorporates a suite of control variables, including *Firm Size*, which reflects a firm's economic scale and resource allocation capabilities (Shou et al., 2021a); *Firm Profitability*, an indicator of past financial performance (Schwieterman et al., 2018; Zhu et al., 2021); *Financial Leverage* and *Financial Slack*, which measure a firm's debt financing abilities and monetary resource slack, respectively, influencing firm practices (Zhu et al., 2021); *State Ownership*, which can facilitate access to resources but potentially hinder operational efficiency (Tihanyi et al., 2019; Feng et al., 2020a); and *Supply Chain Concentration* and *Industry Competitiveness*, which reflect a firm's supply chain and operational environments, impacting business performance (Lo et al., 2013; Chen et al., 2023b). Due to data limitations, our final dataset comprises 3,022 observations across 265 firms. Table 4.5 displays the correlations among these variables, revealing absolute correlation coefficients ranging from 0.002 to 0.374. Notably, the maximum value of variance inflation factors (VIFs) is 3.77, which falls below the threshold of 10, indicating that multicollinearity is not a significant concern in our analysis.

Table 4.4 Variable description

Variable	Description	Mean	S. D.	Min	Max
Financial Performance	ROA in the year t	0.027	0.110	-2.871	0.644
Treat	A dummy variable depicting whether a firm is in the treatment (=1) or control group (=0)	0.505	0.500	0	1
Post	A dummy variable of whether the year is after (=1) or before/on (=0) the adoption year	0.631	0.483	0	1
Firm Size	The log-transformed total number of employees	7.875	1.205	0	12.338
Firm Profitability	ROA in the year t-1	0.034	0.089	-0.854	2.163
Financial Leverage	The ratio of total debt to total assets	0.443	0.202	0	0.996
Financial Slack	The ratio of current assets to current liabilities	2.299	4.695	0	190.869
State Ownership	Dummy variable of whether a firm is state-owned (=1) or non-state-owned (=0)	0.363	0.481	0	1
Supply Chain Concentration	The average of the purchases and sales ratios of the top five suppliers and customers	0.267	0.173	0	0.9208
Industry Competitiveness	1 minus Herfindahl-Hirschman Index of total sales based on industry types	0.896	0.103	0	1
Digital Transformation	A time-invariant variable is equal to 1 if the frequency of “big data, cloud, blockchain, artificial intelligence, and digital technology application-related words” is larger than the median frequency of all the observations at the adoption year, otherwise 0	0.455	0.498	0	1
Political Connections	A time-invariant variable is equal to 1 if a top management team member was currently or previously an official of the central or local government at the adoption year, otherwise 0	0.378	0.485	0	1
Year	The observational year from 2010 to 2022	2016.44	3.589	2010	2022

Note: Sample N=3,022

Table 4.5 Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Financial Performance	1.000											
(2) Treat	0.015	1.000										
(3) Post	-0.055	0.016	1.000									
(4) Firm Size	0.078	0.049	0.065	1.000								
(5) Firm Profitability	0.367	-0.002	-0.056	0.055	1.000							
(6) Financial Leverage	-0.199	0.010	0.007	0.346	-0.257	1.000						
(7) Financial Slack	0.057	-0.075	-0.077	-0.193	0.088	-0.374	1.000					
(8) State Ownership	-0.032	0.047	-0.038	0.226	-0.051	0.294	-0.121	1.000				
(9) Supply Chain Concentration	-0.079	0.005	0.260	-0.316	-0.039	-0.144	0.082	-0.122	1.000			
(10)Industry Competitiveness	0.003	0.003	-0.059	-0.011	-0.002	0.004	0.035	0.115	-0.108	1.000		
(11)Digital Transformation	0.013	-0.229	-0.088	0.039	0.030	-0.047	0.023	-0.108	-0.090	-0.082	1.000	
(12)Political Connections	-0.033	-0.007	0.044	-0.038	-0.029	0.032	-0.042	-0.147	-0.054	0.057	-0.023	1.000

Note: The absolute correlation coefficient is larger than 0.035 at the significance level of 0.05.

We employed a two-way fixed effect (TWFE) model with robust standard error to test our hypotheses. This model has been extensively utilized in previous literature for conducting DID analyses (Beck et al., 2010; Goodman-Bacon, 2021). The estimation equation adopted in our analysis is presented as follows.

$$
\begin{aligned}
&Financial\ Performance_{it} \\
&\quad = \alpha_0 + \alpha_1 Treat_i + \alpha_2 Post_t + \alpha_3 Treat_i \times Post_t + \alpha_4 Firm\ Size_{it-1} \\
&\quad + \alpha_5 Firm\ Profitability_{it-1} + \alpha_6 Financial\ Leverage_{it-1} \\
&\quad + \alpha_7 Financial\ Slack_{it-1} + \alpha_8 Supply\ Chain\ Concentration\ _{it-1} \\
&\quad + \alpha_9 State\ Ownership_{it-1} + \alpha_{10} Industry\ Competitiveness_{it-1} + Year_t \\
&\quad + \mu_i + \varepsilon_{it}
\end{aligned}
$$

Where the coefficient α_3 of the interaction term $Treat_i \times Post_t$ quantifies the extent to which a firm's financial performance in the treatment group varies, relative to firms in the control group, across our observation period. To account for unobserved, time-invariant firm characteristics, we incorporate firm-level fixed effects (i.e., μ_i). Additionally, we control for time-specific effects by including year dummies $Year_t$ in our model.

4.5 Analyses and Results

4.5.1 Main effects

Table 4.6 presents the results of the PSM-DID analysis. Specifically, regarding the estimation of financial performance, as measured by ROA, Model 1 showcases the results obtained from the TWFE model, while Model 2 exhibits the findings from the random effects model. To reinforce our conclusions, we employed cost efficiency, defined as the ratio of sales to costs, as an alternative proxy for financial performance (Shou et al., 2021b). Model 3 estimates financial performance based on cost efficiency utilizing the TWFE model, and Model 4 reflects the random effects model with cost efficiency as the dependent variable. Notably, in all models, the interaction term between *Treat* and *Post* is positive and statistically significant (p<0.05), indicating that the adoption of resource-responsible production practices has a significant and positive impact on financial performance. This observation lends support to Hypothesis 1, suggesting that embracing such practices enhances financial performance.

Table 4.6 The main results of PSM-DID analysis

	Model 1	**Model 2**	**Model 3**	**Model 4**
Post	-0.010	-0.015**	-0.028**	-0.028**
	(0.007)	(0.006)	(0.012)	(0.011)
Treat × Post	0.019**	0.017**	0.041***	0.041***
	(0.009)	(0.007)	(0.015)	(0.015)
Firm Size	0.002	0.009***	-0.002	0.008
	(0.008)	(0.003)	(0.009)	(0.008)

Firm Profitability	0.247***	0.395***	0.481***	0.540***
	(0.078)	(0.092)	(0.138)	(0.151)
Financial Leverage	-0.088***	-0.090***	-0.125***	-0.156***
	(0.027)	(0.019)	(0.034)	(0.037)
Financial Slack	-0.0003	-0.0003	0.004***	0.004***
	(0.0003)	(0.0002)	(0.001)	(0.001)
State Ownership	-0.032**	-0.0004	0.001	0.015
	(0.013)	(0.004)	(0.022)	(0.018)
Supply Chain Concentration	-0.049	-0.028*	0.010	0.005
	(0.038)	(0.016)	(0.059)	(0.053)
Industry Competitiveness	0.059	0.004	0.016	-0.016
	(0.055)	(0.025)	(0.037)	(0.036)
Constant	0.023	-0.002	1.096***	1.064***
	(0.055)	(0.023)	(0.073)	(0.055)
Firm fixed effect	Yes		Yes	
Firm random effect		Yes		Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	3022	3022	3022	3022
Groups	265	265	265	265
Overall R-squared	0.1262	0.1710	0.1931	0.2334
F statistics	4.47***		7.91***	
Wald Chi2		191.73***		218.91***
Max VIF	3.77	3.77	3.77	3.77

Note: Robust standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

4.5.2 Robustness check

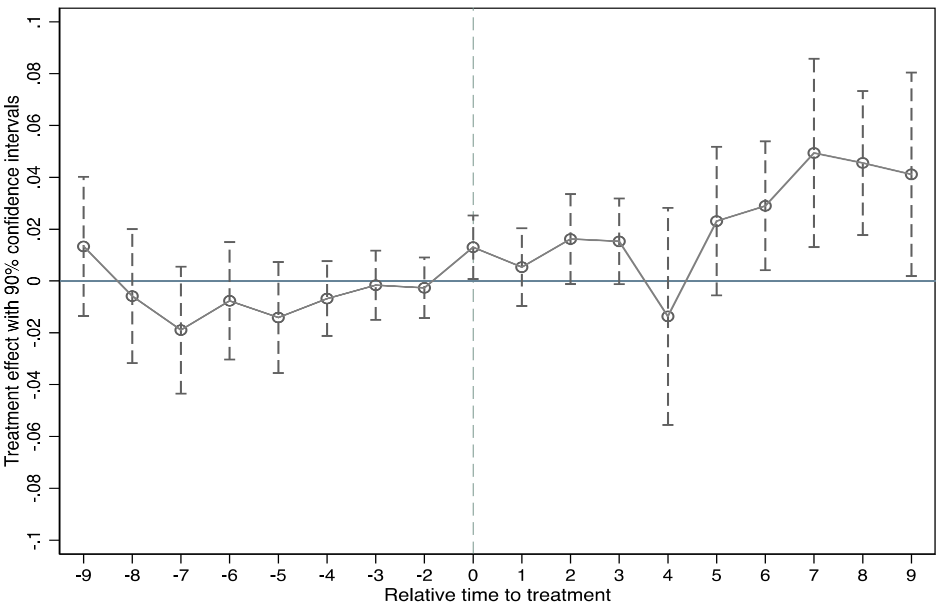
4.5.2.1 Parallel trend assumption with relative time model

The parallel trend assumption is paramount in DID analysis to uphold the reliability of the findings (Beck et al., 2010). This assumption presupposes that the treatment and control groups follow similar performance trends prior to the implementation of resource-responsible production practices. Its objective is to ensure that any discernible differences in outcomes are solely attributable to the treatment effect, as opposed to preexisting trends differing between the two groups (Goodman-Bacon, 2021). To verify this assumption, we conducted a common trend analysis using a relative time model, as detailed below.

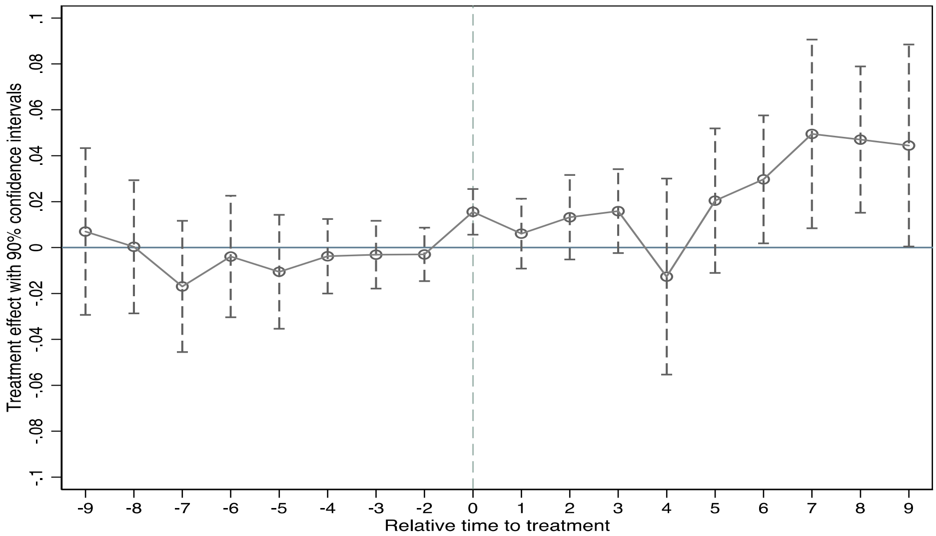
$$Financial\ Performance_{i,t} = \zeta_0 + \zeta_1 Pre^{-9} + \zeta_2 Pre^{-8} + \cdots \zeta_9 Pre^{-1} + \zeta_{10} Current^0 + \zeta_{11} Post^1 + \cdots + \zeta_{19} Post^9 + \zeta_{20} Control\ \ Variables + Year_i + \xi_{i,t-1}$$

Here, Pre^{-k} denotes the performance in the *k*th year preceding the adoption of responsible production practices, whereas $Post^k$ signifies the performance in the *k*th year following the adoption. $Current^0$ represents the performance in the year of adoption. Notably, we exclude the dummy variable for Pre^{-1} as it serves as the reference group.

Figures 4.2(a) and 4.2(b) depict the estimated coefficients and their respective 90% confidence intervals across different time periods, with and without control variables, respectively. The results indicate that, prior to the adoption year, all confidence intervals include zero, indicating no statistically significant differences between the treatment and control groups during the pre-treatment periods. This observation upholds the validity of the parallel-trends assumption underlying our DID analysis.



(a) Relative time model with control variables



(b) Relative time model without control variables

Figure 4.2 Relative time models with or without control variables

4.5.2.2 Placebo test

To bolster the robustness of our DID analysis, we conducted a placebo test by artificially constructing a fictitious independent variable (Treat×Post). In this test, we randomly permuted the values of this interaction item 300 times and reran our proposed models, repeating this process a total of 500 iterations. The aim is to ascertain whether the coefficient associated with this "false independent variable" would attain statistical significance.

As shown in Figure 4.3, the distribution of *p*-values obtained from these placebo tests, pertaining to the relationship between resource-responsible production and financial performance, reveals that 90.6% of the "false" *p*-values exceed 0.1. Furthermore, the beta coefficient of the "false independent variable" consistently varies from the estimation coefficients derived from our proposed model. These findings underscore the robustness of our DID analysis, suggesting that our results are not spurious or established by chance.

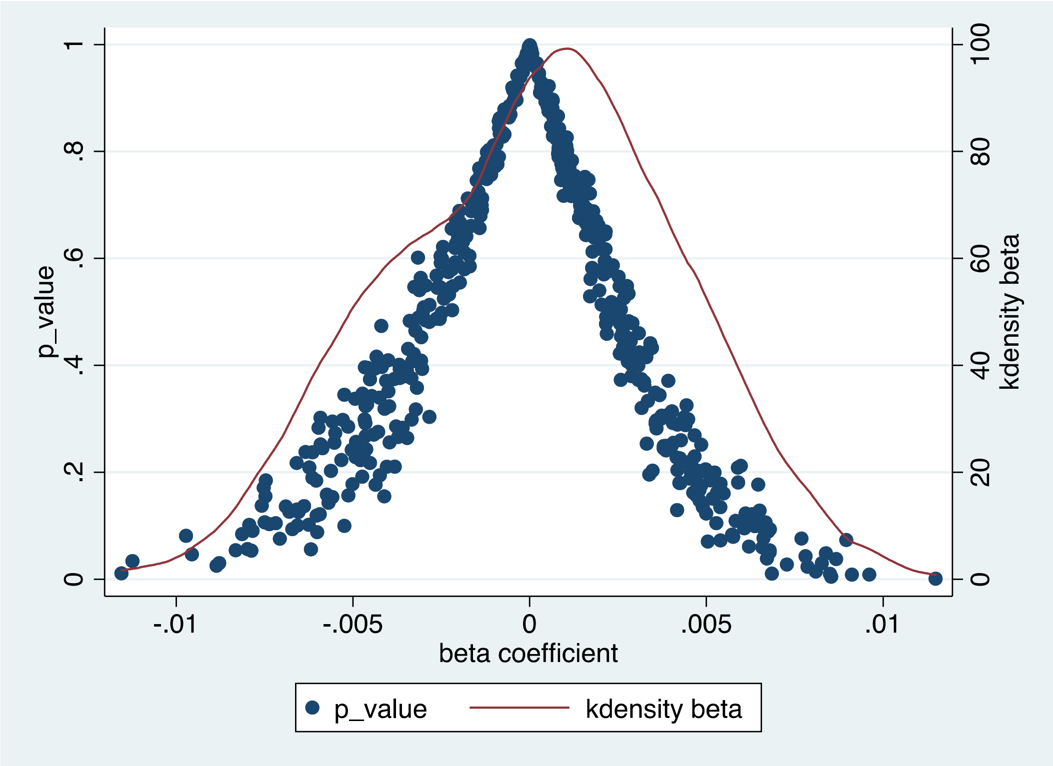


Figure 4.3 Placebo tests for the DID analysis

4.5.2.3 Endogeneity test

The PSM-DID analysis may be vulnerable to endogeneity concerns arising from omitted variables. To mitigate this issue, we used the instrumental variable (IV) approach within a two-stage least squares (2SLS) framework. In particular, we define *Resource Responsible Production*, represented by the interaction term $Treat \times Post$, as a dummy variable depicting whether a firm *i* adopts resource-responsible production practices in a given year *t*. We utilized the average resource-responsible production at both the industry and province levels as the IVs, which are correlated with the independent variable but theoretically unrelated to the dependent variable. Table 4.7 showcases the results of our endogeneity test. In the first stage, we regressed the independent variable (i.e., *Resource Responsible Production*) on the IVs and control variables to derive predicted values, as presented in Model 1. Subsequently, in the second stage, we regressed financial performance on these predicted values, detailed in Model 2. The Kleibergen-Paap rk LM statistic significantly rejects the null hypothesis, supporting the validity of our IVs (p=0.000). Additionally, the Cragg-Donald and Kleibergen-Paap rk Wald F statistics surpass the critical value of 10% maximal IV size in the Stock-Yogo test (474.092>19.93, 166.908>19.93), suggesting that our IVs are not weak. Moreover, the Hansen J statistic fails to reject the null hypothesis that all IVs are exogenous, suggesting that endogeneity is not a serious issue in this study. Notably, our findings remain consistent even after addressing these endogeneity concerns.

Table 4.7 The results of the endogeneity test

	Model 1: Resource Responsible Production	Model 2: Financial Performance
Resource Responsible Production		0.027**(0.012)
Resource Responsible Production $_{province}$	0.786***(0.072)	
Resource Responsible Production $_{industry}$	0.886***(0.092)	
Firm Size	0.014(0.013)	0.002(0.008)
Firm Profitability	0.077(0.073)	0.245***(0.079)
Financial Leverage	0.080(0.076)	-0.089***(0.028)
Financial Slack	0.001(0.001)	-0.0003(0.0003)
State Ownership	0.151***(0.049)	-0.032**(0.013)
Supply Chain Concentration	-0.034(0.069)	-0.049(0.038)
Industry Competitiveness	-0.063(0.141)	0.063(0.054)
Kleibergen-Paap rk LM statistic	90.074 (*p*=0.000)	
Cragg-Donald Wald F statistic	474.092	
Kleibergen-Paap rk Wald F statistic	166.908	
Stock-Yogo weak ID test critical values	10% maximal IV size= 19.93	
Hansen J statistic	2.183 (*p*=0.1396)	

Note: Robust standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

4.5.2.4 Other robustness tests

We conducted a series of additional robustness checks, as detailed in Table 4.8, to further validate our findings. Firstly, the observational period spans from 2010 to 2022, which offers a relative time frame of [-9, 9]. However, for firms adopting resource-responsible production in 2013 or 2019, the observational relative time is [-3, 9] or [-9, 3]. Specifically, we observe the dynamic evolution of their financial performance within a more symmetric relative time window of [-3, 3], as presented in Model 1. This approach ensures that each firm is evaluated over an equal duration before and after the adoption year. Secondly, to ensure the robustness of variable measurements, we substituted the number of employees with total assets to measure firm size (Zhu et al., 2021). In particular, we log-transformed total assets as an alternative indicator of firm size, and the results are presented in Model 2. Thirdly, we augmented our proposed model by incorporating Tobin's Q as an additional control variable, as displayed in Model 3, to account for potential variations in market valuation. Fourthly, we conducted a sensitivity analysis by adjusting the adoption year to one year prior to the official announcement date, as depicted in Model 4, to examine the impact of this alternative definition on our findings. Lastly, given the potential disruption caused by the COVID-19 pandemic since 2019, we restricted our observation window to 2010—2018 to isolate the effects of the pandemic. The results from this analysis, presented in Model 5, demonstrate the consistency of our findings even when excluding the post-pandemic period. In summary, the outcomes of these robustness tests reinforce the validity and reliability of our previous findings.

Table 4.8 The results of robustness tests

	Model 1	Model 2	Model 3	Model 4	Model 5
Post	-0.001	-0.011	-0.011	-0.008	-0.005
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)
Treat × Post	0.016*	0.020**	0.019**	0.017**	0.025**
	(0.009)	(0.009)	(0.009)	(0.008)	(0.013)
Firm Size	0.008	-0.007	0.002	0.002	0.004
	(0.015)	(0.004)	(0.008)	(0.008)	(0.010)
Firm Profitability	0.250**	0.253***	0.243***	0.247***	0.230**
	(0.115)	(0.082)	(0.079)	(0.078)	(0.110)
Financial Leverage	-0.078	-0.075***	-0.084***	-0.088***	-0.079*
	(0.066)	(0.024)	(0.029)	(0.028)	(0.041)
Financial Slack	-0.00001	-0.0002	-0.0002	-0.0003	-0.0001
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
State Ownership	-0.020	-0.032**	-0.027**	-0.031**	-0.007
	(0.021)	(0.014)	(0.014)	(0.014)	(0.023)
Supply Chain	-0.039	-0.054	-0.051	-0.049	-0.075
Concentration	(0.028)	(0.038)	(0.038)	(0.038)	(0.050)
Industry Competitiveness	-0.015	0.059	0.061	0.057	0.090
	(0.025)	(0.056)	(0.055)	(0.055)	(0.090)
Tobin's Q			0.009**		
			(0.003)		
Constant	0.034	0.177**	-0.001	0.024	-0.028
	(0.090)	(0.083)	(0.056)	(0.055)	(0.077)
Firm fixed effect	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	1720	3022	3022	3022	2003
Groups	261	265	265	265	259
Overall R-squared	0.2629	0.1066	0.1404	0.1267	0.1408
F statistics	3.02***	4.44***	6.18***	4.27***	3.10***

Max VIF	3.77	3.77	3.77	4.54	3.31

Note: Robust standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

4.5.3 Heterogeneity test

We conducted a group analysis, as outlined in Table 4.9, to address our second research question. Drawing upon the established literature (Cleary, 1999), we employed a bootstrapping method with 1000 iterations to compare the coefficient differences between two distinct groups, thereby calculating the empirical *p*-values. Models 1 and 2 showcase the results when firms were stratified into those with low and high levels of digital transformation, respectively. Our findings reveal that resource-responsible production exerts a statistically significant and positive influence on financial performance among firms with high digital transformation ($p<0.05$), whereas this effect is not evident among firms with low digital transformation ($p>0.1$). Notably, the significant empirical *p*-value (<0.1) underscores a substantial disparity between these two groups, indicating that digital transformation acts as a catalyst, amplifying the beneficial effects of resource-responsible production on financial performance. This observation lends support to Hypothesis 2.

Furthermore, Models 3 and 4 display the results pertaining to firms without and with political connections, respectively. Our analysis suggests that politically connected firms experience a significant and positive financial return as a result of the adoption of resource-responsible production practices ($p<0.05$). In contrast, firms lacking political connections do not reap similar benefits from such practices ($p>0.1$). The empirical *p*-value, which is less than 0.1, underscores a marked difference between these two subsets of firms, suggesting that political connections serve to enhance the positive impact of resource-responsible production on financial performance. This finding provides empirical evidence in favor of Hypothesis 3.

Table 4.9 The results of the heterogeneity test

	Model 1: Low digital transformation	**Model 2: High digital transformation**	**Model 3: Without political connections**	**Model 4: With political connections**
Post	-0.003	-0.012	0.005	-0.032**
	(0.009)	(0.010)	(0.007)	(0.014)
Treat × Post	0.005	0.031**	0.010	0.038**
	(0.010)	(0.012)	(0.010)	(0.016)
Firm Size	-0.011	0.008	-0.004	0.006
	(0.009)	(0.009)	(0.010)	(0.012)

Firm Profitability	0.170***	0.389***	0.335***	0.189*
	(0.063)	(0.141)	(0.074)	(0.102)
Financial Leverage	-0.068***	-0.088*	-0.059*	-0.112**
	(0.020)	(0.051)	(0.031)	(0.052)
Financial Slack	-0.0001	-0.002	-0.0002	0.00001
	(0.0001)	(0.002)	(0.0003)	(0.002)
State Ownership	-0.031	-0.023	-0.022	-0.054**
	(0.019)	(0.021)	(0.015)	(0.023)
Supply Chain Concentration	0.019	-0.135*	-0.053	-0.043
	(0.021)	(0.073)	(0.053)	(0.036)
Industry Competitiveness	0.034	0.066	0.083	-0.054
	(0.054)	(0.080)	(0.070)	(0.069)
Constant	0.118	-0.019	0.034	0.096
	(0.087)	(0.021)	(0.073)	(0.092)
Firm fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Observations	1647	1375	1880	1142
Groups	145	120	168	97
Overall R-squared	0.0673	0.2097	0.1167	0.1359
F statistics	5.43***	3.50***	3.30***	3.72***
Max VIF	4.67	3.74	3.63	4.13
Empirical *p*-value	0.097		0.087	

Note: Robust standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

4.6 Discussion and Conclusion

4.6.1 Key findings

Building upon the NRBV, this study establishes a foundational pathway to comprehend the vitality of resource-responsible production, which stands apart from CER and CSR. Through a PSM-DID analysis encompassing 3,022 year-firm observations, we uncover a robust positive relationship between resource-responsible production and financial performance. Drawing from the CSR and CER literature ((Liagkouras et al., 2020; Li et al., 2021), our study uniquely shines a light on the paramount significance of resource responsibility for sustainability by distinctly differentiating it from CSR and CER.

From a contingency view, our study reveals the reinforcing effect of digital transformation and political connections in the nexus between resource-responsible production and financial performance. Consistent with NRBV research (Andersen, 2021), this study emphasizes the pivotal role of internal capabilities (such as digital transformation) and external networks (like political connections) as contingency factors that elucidate the intricate organization-environment relationship, ultimately fostering a firm's competitive advantages. Particularly, these factors endow firms with distinct digital and political competencies, which can be harnessed to execute resource-responsible production strategies, thereby achieving competitive superiority. In harmony with prior studies (Jabbour et al., 2022), this study affirms that digital transformation is a pivotal catalyst in augmenting responsible practices for performance enhancement. Conversely, while contrasting with literature highlighting the potential negative influence of political connections on business operations (Shou et al., 2021a; Shen et al., 2023), our findings align with research emphasizing the advantageous role of political connections in driving superior performance (Li et al., 2015; Tihanyi et al., 2019). The implications garnered from these findings offer invaluable managerial insights and guidance for enterprises and policymakers alike. They underscore the need for comprehensive frameworks and policies that facilitate the widespread adoption and implementation of resource-responsible production practices, thereby advancing sustainability goals.

4.6.2 Theoretical implications

Resource-responsible production emerges as a viable strategy for manufacturers to address resource depletion and drive sustainable development (Tseng et al., 2018). Amidst dynamic market forces and evolving regulatory landscapes, manufacturers are increasingly compelled to adopt such practices for sustainability (Li et al., 2019). This study significantly advances our comprehension of resource-responsible production in three pivotal aspects. Firstly, this study validates and extends the NRBV literature by elucidating how resource-responsible production, in its interactions with internal capabilities (i.e., digital transformation) and external networks (i.e., political connections), affects financial performance. Contrasting the prevalent use of the NRBV framework to emphasize the impact of CER on financial performance, with mixed results (Andersen, 2021; Farooque et al., 2022; Yi and Demirel, 2023), this research uniquely focuses on resource-responsible production as a subset of CER, elucidating the intricate organization-resource relationship. Consolidating and extending the NRBV theory (Hart, 1995), our empirical findings underscore the beneficial relationship between a firm's stewardship of natural resources and its financial performance. Furthermore, extending the NRBV literature (Andersen, 2021), this study reveals the pivotal roles of digital transformation and political connections as internal capabilities and external networks, respectively, in enhancing this relationship for performance enhancement. Notably, our study underscores that these factors are crucial in realizing the interconnected strategies outlined in the NRBV literature, advancing prior research (Jabbour et al., 2022; Cai et al., 2023). Specifically, digital transformation fosters innovation in product design and waste management, while political connections confer advantages in financial leverage, policy support, information resources, and stakeholder engagement, enabling firms to adopt long-term, sustainable development strategies for performance optimization. Enriching the literature (Tihanyi et al., 2019; Li and Jin, 2021), this study affirms that politically connected firms reap greater benefits from legitimate actions owing to their advantages in financial leverage, policy support, access to information resources, and stakeholder engagement. These advantages empower firms to adopt a long-term perspective, enabling them to position themselves favorably for sustainable development and attain superior performance through resource-responsible production practices. Consequently, this research not only consolidates but also expands the NRBV literature by illuminating the significance of digital transformation and political connections in shaping the organization-resource nexus for enhanced performance outcomes.

Secondly, this study contributes fresh insights into responsible production by empirically demonstrating that integrating resource conservation into production processes can lead to superior financial performance. While prior research in developed contexts has documented the positive effects of CSR and CER on CFP (Dixon-Fowler et al., 2013; Guo et al., 2015; Xu et al., 2020), few studies have explored the importance of resource responsibility on financial performance in emerging markets. The literature on the linkage between resource-responsible production and financial performance has generated mixed results, ranging from positive to negative (Ahmad et al., 2023; Sun et al., 2023). Our findings resolve the existing paradox by revealing a robust positive correlation between resource-responsible production and financial performance, distinguishing it from CSR and CER and emphasizing its superiority in driving financial success.

Thirdly, this study is the first to elucidate the reinforcing effect of digital transformation and political connections on the relationship between resource-responsible production and financial performance. On one hand, we uncover the synergistic impact of resource-responsible production and digital transformation on financial outcomes. While the benefits of digital transformation in enhancing supply chain resilience and operational efficiency are widely acknowledged (Reuschl et al., 2022; Tian et al., 2023), our research fills a gap by exploring their combined effect on financial performance in emerging markets. Drawing from existing literature (Chatterjee and Mariani, 2022; Zhao et al., 2023), we emphasize that digital transformation empowers firms with innovative, financing, and organizational agility capabilities, crucial for resource-efficient production systems. On the other hand, we advance the discourse on political connections by demonstrating their positive moderating role in the organization-resource relationship. While prior studies have highlighted the negative aspects of political connections (Shou et al., 2021a; Shen et al., 2023), we contribute by elucidating their beneficial influence of adopting resource-responsible production, particularly in emerging markets where government involvement is paramount. Notwithstanding this, several studies have outlined the favorable impact of political connections on various aspects such as innovation intensity, debt financing, international expansion endeavors, and societal contributions (Li et al., 2015; Tihanyi et al., 2019). To further enrich our understanding, this research endeavors to demonstrate that politically connected enterprises are poised to capitalize on the adoption of resource-responsible production practices. In line with the existing literature (Tihanyi et al., 2019), our findings reveal that political connections facilitate the adoption of resource-responsible production strategies, ultimately contributing to economic gains. This phenomenon is particularly pronounced in emerging markets, where the government's prominent role in shaping corporate business models underscores the pivotal role of political connections in fostering firm growth (Li et al., 2015). Essentially, this study uncovers that political connections serve as a form of structural capital derived from external networks, offering crucial resources and capabilities that empower firms to adopt resource-responsible production for enhanced financial performance.

4.6.3 Managerial implications

This research offers valuable insights for managers and policymakers aiming to integrate resource-responsible production strategies for improved performance. The adoption of such practices presents a viable avenue for manufacturers to reap economic benefits. Firstly, manufacturers ought to prioritize resource conservation and efficiency throughout a product's lifecycle. Strategies like embracing renewable energy sources, designing products for recyclability, and implementing resource-efficient infrastructure can create a mutually beneficial scenario for both manufacturers and natural resources. Secondly, manufacturers must discern the optimal timing to fully leverage resource-responsible production for heightened economic returns. The integration of resource-responsible production with digital transformation can bolster firm growth. Hence, it is advisable for firms to harness digital technologies, such as big data analytics and cloud computing, to oversee and optimize natural resource usage. Attending workshops on the digital economy can help firms stay abreast of market trends, facilitating the integration of digital technologies into resource-responsible production. Firms with advanced digital transformation capabilities can navigate operational complexities and foster organizational agility within a resource-responsible production framework. Those with lower digital maturity should carefully assess their readiness to adopt resource-responsible practices or focus on enhancing their digital literacy to pave the way. Thirdly, firms can forge political connections to access external resources that support the adoption of resource-responsible production. Politically connected firms are encouraged to adhere to regulations and assume additional responsibilities, including resource-responsible production, to meet stakeholder expectations and secure greater economic rewards. Non-politically connected firms should meticulously evaluate their resource capabilities and consider alternative routes, such as inter-organizational collaboration, to access technical expertise and financial resources necessary for resource-responsible production.

Furthermore, it is undeniable that policymakers must disseminate the knowledge and significance of resource-responsible production for sustainability. This imperative transcends national borders, with both developing and developed countries alike encouraged to prioritize resource responsibility in their production processes. To this end, policymakers should establish clear and standardized guidelines for manufacturers to follow in implementing resource-responsible practices. One such metric could be the volume of renewable and non-renewable resources utilized, which can serve as a benchmark for assessing a manufacturer's commitment to natural resource stewardship. Recognizing the varying levels of adoption among firms, policymakers should offer substantial support to those with lower digital transformation capabilities or lacking political connections, incentivizing their responsible actions. By doing so, policymakers can contribute to the achievement of SDG12 by broadening the scope of firms engaged in resource-responsible production.

4.6.4 Limitations and future directions

This research presents several limitations that necessitate further examination through future studies. Firstly, a more profound exploration of the mediating and moderating mechanisms that govern the influence of resource-responsible production on financial performance could yield insightful results. Specifically, investigating whether resource-responsible production practices contribute to enhancing a firm's operational efficiency may offer a deeper understanding of the observed effects. Additionally, resource-responsible production encompasses a diverse array of practices, including material substitution, eco-design, and circular economy principles (e.g., recycling and reuse). Consequently, categorizing these practices into distinct phases and evaluating their differential impacts on financial performance would be beneficial. Secondly, to ensure a more comprehensive analysis and enhance the generalizability of the research findings, the sample size of observational data could be expanded by incorporating announcements from a wider range of information sources. Future studies may consider integrating data from various platforms, such as Google, Baidu, and other social media channels. Lastly, as resource-responsible production is a fundamental component of CSR and CER, which inherently encompass social and environmental considerations, future research can classify resource-responsible production into pure or mixed categories based on whether it incorporates social and environmental aspects. Furthermore, scholars can explore the impact of resource-responsible production on social performance (e.g., customer satisfaction) and environmental performance (e.g., emission reduction) by utilizing field investigations and survey questionnaires to collect primary data that can complement the secondary datasets employed in this study.

Chapter 5: Being greener makes firms better: How green gamification influences operational efficiency

5.1 Introduction

Gamification has become an essential way for enterprises to perform responsible and forward-thinking manufacturing operations (Hsu, 2022; Behl et al., 2024). Specifically, green gamification refers to the design of gamified elements in non-game situations to achieve environmental sustainability (Yang et al., 2023). In particular, ISO 14001 certification, corporate social responsibility (CSR) ratings, and environmental, social, and governance (ESG) scores can serve as gamified elements of green practices because these goals can induce engagement in certain activities by creating and increasing motivation (Warmelink et al., 2020). Evidence suggests that gamification is a strategic way to invoke green awareness and encourage environmentally responsible behavior (Zhang and Anwar, 2023; Behl et al., 2024). To promote green manufacturing, the Ministry of Industry and Information Technology has announced the "National Green Manufacturing Demonstration Enterprise" to award firms excelling in resource efficiency, emission reduction, and environmental management practices. Such a gamification strategy has motivated many manufacturers to engage in green activities, but some firms are hesitating about deciding whether to engage in green gamification (Mao and Wang, 2019). In the literature, scholars have found that the adoption of environmental management systems results in approximately 6%-12% lower energy efficiency than nonadopters (Jeong and Lee, 2022). In addition, the investment in low-carbon initiatives can lead to a 1.8% decrease in labor productivity (Sartal et al., 2020). Accordingly, it remains unclear whether engagement in green gamification can improve a firm's business operations.

Despite the consensus behind green gamification for improving sustainability, green gamification may be at odds with firms' goals of enhancing operational efficiency. The firm-level heterogeneity may allow for the varying effectiveness of green gamification. Engagement in green gamification requires substantial resources and dynamic capabilities to cope with the operational complexity caused by the integration of green practices into traditional business models (Yang et al., 2023; Behl et al., 2024). Most of the previous studies have proposed that state-owned enterprises (SOE) benefit from government-initiate responsible actions, like green gamification because these firms tend to meet stakeholders' expectations and attach great importance to their reputation (Chang et al., 2019; Shen et al., 2023). Notably, numerous studies have suggested the synthetic effect of green practices and innovation capability

(Garmulewicz et al., 2018; Jabbour et al., 2022), but some evidence shows that innovation-intensive firms obtain reduced benefits from responsible actions because innovation and responsible practices may substitute each other in terms of differentiation strategies to compete for managerial attention (Li et al., 2021). To date, little is relatively known about the boundary conditions of the relationship between green gamification and operational efficiency. Against this backdrop, this study is motivated to address the following two research questions.

RQ1: Does green gamification enhance operational efficiency?

RQ2: How do state ownership and R&D investment affect the relationship between green gamification and operational efficiency?

Building upon the resource-based view (RBV), this study gauges the effect on operational efficiency of green gamification, with a particular emphasis on its interaction effects with state ownership and R&D investment. Specifically, we first employ the stochastic frontier estimation (SFE) approach to measure operational efficiency. Then, we use a staggered two-stage difference-in-differences (DID) approach to analyze a panel dataset of 18,297 firm-year observations. Our analyses reveal that green gamification overall enhances operational efficiency. More notably, we demonstrate that state ownership strengthens but R&D investment weakens the positive impact of green gamification on operational efficiency. We also analyze the long-term effects of green gamification on market and financial performance. Our analyses are also robust to various alternative tests and estimation approaches, including parallel trend tests, placebo tests, and propensity score matching, indicating the robustness of the findings.

Our research contributes to the operations management (OM) literature in several important ways. First, this study validates and extends the RBV literature in operations management by shedding light on the importance of green gamification as a valuable asset owned by firms to achieve competitive advantages. Numerous studies have employed RBV to highlight the importance of strategic practices, digital technologies, and financial innovations in improving operational performance (Kortmann et al., 2014; Lam et al., 2016; Qiu et al., 2022). However, scant literature uses the RBV as a theoretical lens to explore the impact of green gamification on operational efficiency. Extending the RBV literature, this study answers what and how is the relationship between green gamification and operational efficiency. Echoing the resource-based opinions in the literature (Li et al., 2021; Chen et al., 2022), this study helps understand how firms strategically utilize resources to gain a competitive advantage within the internal dynamics of the firm from a complementarity and substitution perspective. Second, to the best of our knowledge, this is the first empirical study to reveal the importance of green gamification from an operational perspective. The gamification design has been widely investigated in the information systems literature, lacking substantial empirical evidence on its role in a firm's business operations (Warmelink et al., 2020; Hsu, 2022). Advancing extant research, this study uncovers a positive association between green gamification and operational efficiency by estimating two-stage DID models on an SFE-based operational efficiency measure, with a unique panel dataset that covers a wide range of firms. Third, this study reveals the strengthening role of state ownership and the weakening role of R&D investment in the relationship between green gamification and operational efficiency. Responding to the conflicting viewpoints existing in the literature (Li et al., 2021; Jabbour et al., 2022), this study unveils that innovation intensity may substitute corporate social responsibility, like green gamification, to influence operational efficiency because they can compete for managerial attention. Extending the literature (Tihanyi et al., 2019; Hsu et al., 2021), this study confirms that SOEs benefit from green gamification because they own the advantage of information sharing, resource availability, and policy support. Fourth, this study offers a long-term and dynamic perspective on the effects of green gamification on market and financial performance. Notably, our findings reveal that green gamification has a more sustained effect on the internality (i.e., operational efficiency and return on assets) than the externality (i.e., Tobin's Q). Most of the current studies have focused on the influence of green practices on economic, market, and operational performance (Li et al., 2019; Jeong and Lee, 2022), lacking a long-term view on identifying subtle differences between market and financial/operational performances caused by green practices (Modi and Mishra, 2011). Accordingly, this study provides practical guidance for managers and policymakers to enhance the efficiency gains of green gamification. By considering firm-level heterogeneity, firms can unlock the full potential of green gamification and achieve sustainable operational excellence.

5.2 Literature Review and Theoretical Background

5.2.1 Gamification in promoting environmental responsibility

Gamification refers to the use of game elements in non-game contexts to create a "game-like" experience of in-game contexts (Deterding et al., 2011). It consists of three major elements: motivational affordance, psychological outcomes, and behavioral outcomes (Hamari et al., 2014). The motivational affordances of the gamification design are presented in the form of points, leaderboards, achievements/badges, levels, and rewards (Liu et al., 2020). These motivational affordances can engender psychological outcomes, like motivation and attitude, and behavioral outcomes (Hamari et al., 2014; Cheng and Cao, 2024). The gamification design has been widely investigated in the information systems literature to explain personal motivations (Cheng and Cao, 2024), users' awareness (Yang et al., 2023), and individuals' engagement and behavior (Liu et al., 2020; Hsu, 2022). These studies have consistently argued that gamification can catalyze stimulating individual behavior or corporate practices (Zhang and Anwar, 2023). Extending the gamification literature, this study focuses on the integration of gamification into green manufacturing practices (thereafter, green gamification) from an operational view.

Green gamification refers to the application of gamification in the context of environmental issues, which can create a powerful mechanism to improve individual behavior and organizational performance (Yang et al., 2023; Behl et al., 2024). According to the definition and constituting elements (Deterding et al., 2011; Hamari et al., 2014), ISO14001 certification, ISO9001 certification, ESG scores, and CSR ratings can be considered as the motivation affordances because they can invoke corporate attitude and affect their behavioral outcomes. The existing literature has delved into green gamification, showing that gamification can increase green awareness and promote sustainable performance (Oppong-Tawiah et al., 2020; Yang et al., 2023; Zhang and Anwar, 2023). Specifically, the use of Ant Forest, a gamified initiative launched by a Chinese fintech company, can enhance environmentally responsible behavior through increasing psychological need satisfaction and belief or attitude persuasion (Zhang and Anwar, 2023). In addition, evidence shows that gamification positively influences green supply chain management, thereby leading to improved sustainable performance (Behl et al., 2024). Nowadays, policymakers have leveraged gamification mechanisms, such as demonstration lists and certifications, to promote green manufacturing for sustainability. Accordingly, firms are increasingly motivated to integrate green actions into their business operations. Notwithstanding, it leaves the questions over whether and how green gamification influences operational efficiency.

5.2.2 Operational efficiency and environmental-friendly actions

Operational efficiency refers to the extent to which a firm can effectively harness its organizational resources to generate business profits, in comparison to its industry counterparts (Chuang et al., 2019). These resources encompass tangible assets such as financial investments, as well as intangible assets like innovative and technological capabilities (Qiu et al., 2022). Traditional metrics for measuring operational performance include inventory turnover and cycle time (Fan et al., 2022), cost efficiency (e.g., the ratio of sales to operating costs), and profitability (return on assets) (Shou et al., 2021b). These metrics lack a comprehensive perspective on inputs related to operating resources; however, stochastic frontier estimation (SFE) offers a robust approach to evaluating operational efficiency (Kao et al., 2023; Shen et al., 2023). This approach takes into account three continuous operational improvement factors as resource inputs: human (e.g., the number of employees), financial (e.g., capital expenditure), and physical resources (e.g., inventory or the cost of goods sold) (Shen et al., 2023). The SFE model has been extensively utilized in operations management research to gauge operational performance (Yiu et al., 2020; Li et al., 2022b; Qiu et al., 2022).

Empirical evidence investigating the efficiency gains (or losses) of environmental-friendly actions is scarce and inconclusive, oftening reporting contradictory findings (Garmulewicz et al., 2018; Gouda and Saranga, 2020). While some survey-based research has demonstrated a positive relationship between green practices (e.g., green procurement and green process innovation) and firms' operational performance (Song et al., 2017; Gouda and Saranga, 2020; Bhatia, 2021), another stream of this literature reported that environmental management practices (e.g., green manufacturing) have negligible influence on operational performance (Inman and Green, 2018; Henao and Sarache, 2022; Arda et al., 2023). Specifically, scholars have proposed a "sand-cone" model with an operational performance at the base and environmental and social on top (Henao and Sarache, 2022). Furthermore, evidence suggests that green practices increase operating costs (Mao and Wang, 2019), lower resource efficiency (Jeong and Lee, 2022), decrease labor productivity (Sartal et al., 2020), and reduce profitability (Yang et al., 2011). These fragmented and contradictory results motivate us to further investigate the impact of environmental-friendly actions integrated by the gamification design, on operational efficiency.

5.2.3 Theoretical framework from a resource-based view

The resource-based view (RBV) posits that firms can gain a competitive advantage by leveraging resources that are valuable, rare, inimitable, and non-substitutive (Barney, 1991). These resources include tangible assets, such as capital expenditure, as well as intangible assets, including technological resources and innovation capabilities (Aragon-Correa and Sharma, 2003; Liu et al., 2022a). The RBV emphasizes that competitive advantage stems not only from resource ownership but also from a firm's ability to adeptly convert these resources into superior value (Barney, 2001). The RBV framework is widely utilized in the literature to clarify how technological innovation and green practices contribute to achieving superior performance (Jabbour et al., 2022; Zhang et al., 2022).

The RBV offers a framework for comprehending the relationship between green gamification and operational efficiency, as explored by previous research (Barney, 2001; Gavronski et al., 2011). Green gamification, demonstrating that firms excel in green practices, can be considered as valuable resources and capabilities that enable firms to mitigate adverse environmental impacts while concurrently enhancing resource efficiency. First, the integration of gamification into green practices enables firms to develop excellent capabilities, which are challenging for competitors to replicate due to the requirement for technical creativity and substantial resources. The adoption of green practices demands innovative approaches and specialized expertise that remain less accessible to other firms (Mao and Wang, 2019; Jeong and Lee, 2022). Second, green gamification can help firms build favorable reputations if they are awarded the badge of green manufacturing demonstration enterprises. A strong reputation for environmental responsibility has the potential to amplify a firm's competitive advantage and stakeholder perception, fostering increased customer loyalty, trust, and market share (Song et al., 2017; Buell and Kalkanci, 2021). Third, green gamification showcases a firm's prowess in embracing innovative pollution prevention and emission reduction strategies. By standing out with superior environmental-friendly actions, firms demonstrate their dedication to environmental sustainability and their capacity to adapt their existing business model to harmonize with evolving market requisites (Gavronski et al., 2011).

5.3 Hypotheses Development

Drawing from the RBV theory, we conceptualize green gamification as a collection of valuable resources and capabilities owned by firms to enhance their operational efficiency. Specifically, we argue that the positive impact of green manufacturing on operational efficiency is particularly prominent for state-owned enterprises (SOEs). Conversely, we assert that the positive efficiency gains of green manufacturing will be diminished for firms excelling in R&D activities. Figure 5.1 illustrates the research framework that governs this study.

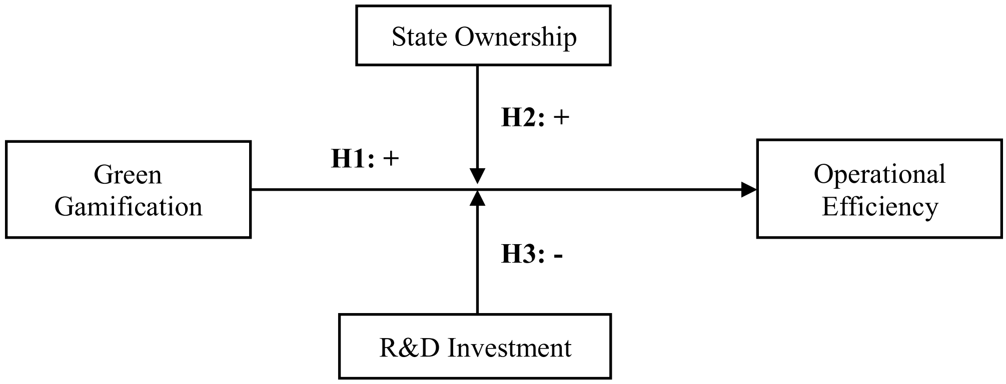


Figure 5.1 Research Framework of Study 3

5.3.1 Green gamification and operational efficiency

The rapid development of digitalization and globalization heightens manufacturers' awareness of the significance of green practices (Garmulewicz et al., 2018; Jabbour et al., 2022). The government has increasingly integrated gamification into the policy for promoting green manufacturing by rewarding and listing firms with excellent green actions as demonstration units. A notable illustration can be observed with Tesla, where managers utilize recyclable and biodegradable packaging materials in their products to minimize their environmental impact. By standing out with its environmentally friendly actions throughout its operations, Tesla has established itself as a pioneer in the automotive industry. Evidence has suggested that firms performing better in green practices are likely to gain a reputation and attract new customers (Song et al., 2017; Bhatia, 2021). As for green firms recognized by the government, they own the advantages of dynamic capability, cost reduction, and resource support to optimize their business operations.

Building upon the RBV, we argue that green gamification can enhance operational efficiency. First, firms that excel in green manufacturing are expected to own dynamic capabilities in coping with eco-design and waste disposal (Gouda and Saranga, 2020). If so, they can leverage increased dynamic capabilities to regulate business models and improve work efficiency (Bhatia, 2021). Second, firms with excellent green practices can reduce their costs in terms of product procurement and marketing promotions (Jabbour et al., 2022). The suppliers may give a price discount to a focal firm that is awarded for excellent environmentally responsible behavior, which lowers procurement costs. Additionally, green practices like material recycling and reusing can make firms reduce the necessity for raw material extraction and subsequently lower costs. Furthermore, evidence shows that customers tend to purchase products from responsible firms (Buell and Kalkanci, 2021). Third, firms with the recognition of green manufacturing can gain reputational benefits (Li et al., 2019) and enhance stakeholder satisfaction (Song et al., 2017). Accordingly, such firms can access external resources and policy support conducive to their business operations because of increased stakeholder engagement.

Hypothesis 1: Green gamification exerts a positive impact on operational efficiency.

5.3.2 The moderating role of state ownership

Green gamification is a critical approach to encouraging environmental management practices, which stimulates firms to comply with policy regulations (Yang et al., 2023; Behl et al., 2024). Stimulated by the motivation affordance of green gamification, such as awards and titles, SOEs are likely to exhibit a higher level of responsiveness to environmental concerns and actively integrate green practices into their business operations (Hsu et al., 2021).

On the one hand, SOEs can arrive at stakeholders' expectations by putting great effort into green gamification, which enables them to obtain more financial investments and policy support than non-SOEs (Wang et al., 2018; Tihanyi et al., 2019; Hsu et al., 2021). Evidence has suggested that SOEs benefit more from government-initiated responsible actions because they hold a long-term perspective to put a concentrated focus on environmental stewardship (Tihanyi et al., 2019). On the other hand, green gamification can induce cooperation or competition, which can motivate firms to develop innovation and dynamic capabilities. Such capabilities have the potential to invigorate the business operations of SOEs lacking an entrepreneurial orientation and competitive edge in innovation (Chang et al., 2019; Tihanyi et al., 2019). Based on the above, we hypothesize that

Hypothesis 2b: State ownership strengthens the positive impact of green gamification on operational efficiency.

5.3.3 The moderating role of R&D investment

Green gamification gives the gamified elements to green manufacturing practices, which enable firms' participation and stimulate them to make progress for fierce competition. The gamified design is instrumental in stimulating the adoption of innovative technologies to reduce environmental footprints and enhance resource efficiency. As for firms with more R&D investments, they are likely to develop innovative technology for core competitiveness and lack managerial attention supporting green gamification that demands substantial resources. Despite numerous studies supporting the synthetic effect of green practices and innovation technology (Li et al., 2019; Jabbour et al., 2022), the literature proposes that green practices and innovation exhibit substitutive effects on firm performance because both practices serve as differentiation strategies to attain competitive advantage (Li et al., 2021). In this study, we argue that R&D investment weakens the positive impact of green gamification on operational efficiency.

First, the existing literature illustrates that firms with higher R&D investment might encounter financial constraints and resource limitations (Lee et al., 2019; Yiu et al., 2020). If so, firms may need to find an equilibrium between green initiatives and innovation projects, which could divert substantial resources away from optimizing existing business models. This constraint on resource allocation could undermine the operational efficiency gains derived from green gamification. Second, both green gamification and innovations can bestow competitive advantages in attracting customers (Zhang et al., 2022; Arda et al., 2023). In other words, they have the overlapping capabilities and resources to arrive at a competitive advantage (Arda et al., 2023). However, firms with stronger innovation capabilities may opt for alternative complementary resources, such as financial support, to bring about a notable transformation in business operations. Third, both innovation and green gamification activities can introduce complexity and uncertainty as they experiment with novel technologies and processes (Mao and Wang, 2019; Yiu et al., 2020). Such complexity in these activities could potentially disrupt existing manufacturing processes and elevate operating costs (Mao and Wang, 2019). Thus, we hypothesize that

Hypothesis 3a: R&D investment weakens the positive influence of green gamification on operational efficiency.

5.4 Data and Methodology

5.4.1 Data and sample

The data for this study were collected from two primary sources of information. First, the selection process for green manufacturing demonstration enterprises involves identifying candidates through public announcements made on the official website (https://www.miit.gov.cn/) by the Ministry of Industry and Information Technology (MIIT) in China. The website offers information including the firm's name and address, along with details about the third-party evaluation agency involved. Since 2015, the Chinese government has placed substantial emphasis on green manufacturing as a pivotal objective within the "Made in China 2025" initiative.[13] Since 2017, the Chinese government has been selecting a cohort of demonstration enterprises that embrace green manufacturing practices, as part of their commitment to furthering this policy. Second, firm-level data were obtained from the China Stock Market and Accounting Research (CSMAR) database. This database has garnered considerable attention in previous academic research due to its comprehensive coverage of information concerning publicly listed Chinese firms (Shou et al., 2021b; Shen et al., 2023).

From the available list of green manufacturing demonstration enterprises on the MIIT platform, we extracted 18 documents covering three distinct firm-specific projects: green factories, green design, and green supply chain management. These documents were acquired from six batches between 2017 and 2021.[14] It is important to note that the entire process, starting from implementation and application to announcement reporting, generally spans a duration of 1 to 3 years (Hendricks et al., 2007). In consideration of the rapid advancements in digitalization, we have chosen a one-year implementation period as the criteria for delineating the event window of green gamification. As a result, the implementation periods considered in this study range from 2016 to 2020. Moreover, our focus is on publicly listed Chinese firms that operate within the manufacturing industries. This emphasis is underscored by the fact that these firms serve as the primary contributors to environmental hazards, and their data is readily accessible for comprehensive analysis (Li, 2018; Mao and Wang, 2019).

To build our panel dataset, we analyze the selected firms across a nine-year timeframe, including the period from 2014 to 2022. This timeframe comprises a two-year period before implementation and a two-year period after implementation. Upon the removal of observations with missing values, our ultimate sample comprises a total of 18,297 firm-year observations. Figure 5.2 depicts the time window of the observational samples. This sample includes 325 treatment firms and 2,776 control firms. Table 5.1 presents the descriptive statistics about the treatment firms included in the analysis. Panel A illustrates the distribution of treatment firms across different years. Panel B showcases the distribution of treatment firms categorized by industry types, using the three-digit China Securities Regulatory Commission (CSRC) codes.

[13] https://www.uschamber.com/assets/archived/images/final_made_in_china_2025_report_full.pdf (accessed on 1 July 2023)

[14] The sixth batch of green manufacturing was announced on 15 January 2022, but it was supposed to be released in 2021. In this study, we consider the announcement year of the sixth batch list as 2021.

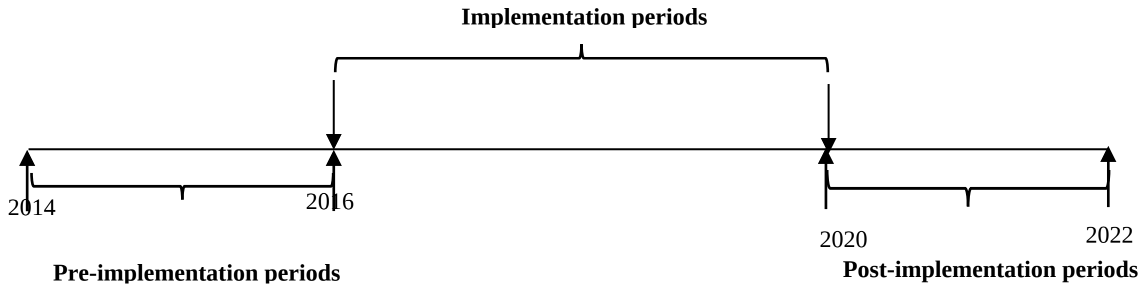


Figure 5.2 A nine-year window

Table 5.1 Descriptive statistics of included treatment firms

Panel A: The distribution of treatment firms by implementation year

Year	Frequency	Percentage
2016	35	10.769
2017	73	22.462
2018	76	23.385
2019	79	24.308
2020	62	19.077
Total	325	100

Panel B: The distribution of treatment firms by industry

Code	Industry	Count	Percent
C13	Farm products processing	8	2.462
C14	Food manufacturing	10	3.077
C15	Manufacture of wine, drinks, and refined tea	12	3.692
C17	Textile	11	3.385
C18	Textiles, garments, and apparel industry	5	1.538
C20	Wood processing and wood, palm, and grass products	2	0.615
C21	Furniture manufacturing	7	2.154
C22	Manufacture of paper and paper products	10	3.077
C23	Printing and reproduction of recorded media	2	0.615
C26	Manufacture of chemicals and chemical products	27	8.308
C27	Manufacture of basic pharmaceutical products	33	10.154
C28	Manufacture of chemical fiber	3	0.923
C29	Manufacture of rubber and plastic products	12	3.692
C30	Manufacture of non-metallic mineral products	7	2.154
C31	Ferrous metal smelting and pressing	13	4.000
C32	Non-ferrous metal smelting and pressing	18	5.538
C33	Manufacture of basic metals	7	2.154
C34	Manufacture of general equipment	16	4.923
C35	Manufacture of special equipment	23	7.077

C36	Manufacture of automobile	23	7.077
C37	Manufacture of transport equipment	2	0.615
C38	Manufacture of electrical equipment	40	12.308
C39	Manufacture of computer, electronic, and optical products	29	8.923
C40	Instrument and meter	4	1.231
C41	Other manufacturing	1	0.308
Total		325	100

5.4.2 Measures

5.4.2.1 Dependent variable

Following the literature (Fan et al., 2022), we employ a state-of-the-art approach with stochastic frontier estimation (SFE) to gauge operational efficiency. The SFE approach is commonly utilized in operations and supply chain management to evaluate a firm's operational performance (Li et al., 2022b; Qiu et al., 2022; Shen et al., 2023). In alignment with prior research (Qiu et al., 2022; Shen et al., 2023), we employ input resources such as the number of employees, cost of goods sold, and capital expenditure to generate operating income as output. Specifically, we utilize a time-varying decay model in conjunction with panel data for the application of the SFE method (Battese and Coelli, 1995). This model incorporates industry-fixed effects based on three-digit CSRC codes. Moreover, the SFE model is estimated through the utilization of the maximum likelihood estimation approach, as shown in the following equation.

$$Ln(Operating\ Income)_{ij\,t} = \eta_0 + \eta_1 Ln(Number\ of\ Employees)_{ijt} + \eta_2 Ln(Cost\ of\ Goods\ Sold)_{ijt} + \eta_3 Ln(Capital\ Expenditure)_{ijt} + V_{ijt} - U_{ijt}$$

Where V_{ijt} denotes the purely stochastic random error term influencing operating income, and U_{ijt} signifies the efficiency loss of firm *i* compared to industry *j* in year *t*. The value of U_{ijt} ranges between 0 and 1, with 0 indicating no loss of operational efficiency relative to the industry. In line with prior literature (Yiu et al., 2020; Qiu et al., 2022), operational efficiency (represented as 1-$\widehat{U_{ij,t}}$) is computed as the difference between 1 and the estimated value of U_{ijt}.

5.4.2.2 Independent variable

The primary objective of this study is to investigate the influence of green gamification on operational efficiency. Accordingly, we utilize a dataset of publicly listed firms derived from the green manufacturing demonstration list issued by MIIT. Specifically, we define the explanatory variable "$Green\ Gamification$" as a dummy variable denoting whether a firm is acknowledged as a green manufacturing demonstration exemplar at the observational periods.

5.4.2.3 Moderators

The extent of efficiency gains attributed to green gamification is contingent upon firm characteristics, such as state ownership and R&D investment. Importantly, SOEs have greater access to financial resources through government funding, subsidies, or preferential loans (Wang et al., 2018). The resources owned by these firms play a crucial role in facilitating the implementation of green manufacturing for gamification, which demands significant resource allocation (Mao and Wang, 2019; Jeong and Lee, 2022). Furthermore, innovation capabilities arising from green manufacturing adoption serve as complementary assets for SOEs, allowing them to exert a substantial influence on their business operations (Chang et al., 2019; Yiu et al., 2020). Following the prior literature (Wang et al., 2018), we consider state ownership as a binary variable, indicating whether a firm is state-owned (=1) or non-state-owned (=0).

Green gamification involves the utilization of an innovative green ecosystem to optimize operations through smarter strategies, including human-robot collaboration and intelligent manufacturing techniques (Mukherjee et al., 2023; Tian et al., 2023). Firms with more R&D investment might experience comparatively reduced benefits from green gamification, given that green gamification itself can cultivate sustainability and innovative capacities as strategies for differentiation (Li et al., 2021). In line with prior work (Yiu et al., 2020; Shou et al., 2021b), we measure R&D investment by calculating the ratio of R&D expenses to sales.

5.4.2.4 Control variables

In this research, we incorporate a set of control variables to account for various factors that could potentially impact operational efficiency. These control variables include firm size, age, profitability, financial leverage, financial slack, and customer concentration. Firm size signifies the extent of economic scale, affording resource advantages and exerting a positive influence on operational efficiency (Shou et al., 2021b). We quantify firm size as the natural logarithm of the total number of employees (Chuang et al., 2019). Older firms tend to exhibit greater resistance to the adoption of innovative practices, and firm age is measured by the natural logarithm of the number of years since the date of incorporation (Yiu et al., 2020). Firm profitability is evaluated through the ratio of net income to total assets, denoting the return on assets (Li et al., 2022b). A firm with significant financial leverage is susceptible to economic uncertainties, yet it also holds the potential for investing in and advancing its business operations (Liu et al., 2022a). Financial leverage is measured by the ratio of total debt to total assets (Shou et al., 2021b). Financial slack signifies surplus resources that aid a firm in navigating financial instability arising from market crises and sustaining economic equilibrium (Chen et al., 2022). Drawing from previous work (Zhu et al., 2021), financial slack is quantified as the ratio of current assets to current liabilities. Customer concentration plays a pivotal role in shaping CSR adoption and operational efficiency (Zhu et al., 2021; Shen et al., 2023). In accordance with the prior literature (Zhu et al., 2021), customer concentration is evaluated through the utilization of the Herfindahl-Hirschman index, which is derived from sales to the supplier's five largest customers.

Table 5.2 provides descriptions of the variables included in the analysis, whereas Table 5.3 displays the correlations among these variables. The results suggest substantial significant correlation coefficients among the variables. Notably, the absolute values of the correlation coefficients range from 0.006 to 0.540, indicating the absence of severe multicollinearity.

Table 5.2 Variable description

Variables	Description	Mean	S. D.	Min	Max
Operational Efficiency	A firm’s efficiency in transferring operational inputs into operational output among its industry peers	0.978	0.099	0.007	1.000
Green Gamification	A dummy variable of whether a firm being selected as the example of green manufacturing enters into the experimental periods (1=Yes, 0=No)	0.080	0.272	0	1
Firm Age	The natural logarithm of the number of years since a firm was established	2.906	0.309	1.386	4.143
Firm Size	The natural logarithm of the number of employees	7.624	1.180	0	12.571
Firm Profitability	Return on assets	0.039	0.119	-3.994	10.401
Financial Leverage	The ratio of total debt to total assets	0.391	0.197	0.008	0.999

Financial Slack	The ratio of current assets to current debts	2.798	3.617	0.032	144
Customer Concentration	a Herfindahl-Hirschman index of sales to the supplier's five largest customers	0.040	0.086	0	1
State Ownership	The equity nature of a firm (state-owned firms=1, non-state-owned firms=2)	0.248	0.432	0	1
R&D Investment	The ratio of R&D expenses to sales	0.047	0.104	0	5.052
Year	The year of observational samples	2018.393	2.528	2014	2022

Note: Sample N=18,297

Table 5.3 Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(10)	(11)
Operational Efficiency	1.000									
Green Gamification	-0.011	1.000								
Firm Age	-0.025	0.125	1.000							
Firm Size	-0.071	0.224	0.114	1.000						
Firm Profitability	0.022	0.020	-0.034	0.016	1.000					
Financial Leverage	-0.096	0.087	0.138	0.418	-0.226	1.000				
Financial Slack	0.056	-0.072	-0.090	-0.326	0.109	-0.540	1.000			
Customer Concentration	0.011	-0.052	-0.045	-0.135	-0.006	-0.032	0.097	1.000		
State Ownership	-0.106	0.053	0.208	0.313	-0.045	0.257	-0.128	-0.045	1.000	
R&D investment	0.049	-0.031	-0.082	-0.091	-0.023	-0.100	0.135	0.128	-0.056	1.000

Note: The absolute correlation coefficient is equal to or larger than 0.0158 at the significant level of 0.05.

5.4.3 Model specification

The two-stage DID (2SDID) approach is a statistical technique designed to tackle treatment-effect heterogeneity in situations involving staggered adoption (Gardner, 2022). This method enables a comparison between the periods before and after the implementation of green manufacturing initiatives, while effectively controlling for temporal heterogeneity. In this study, the staggered adoption of green manufacturing has engendered diverse average treatment effects across distinct groups and temporal periods (Goodman-Bacon, 2021). Given the staggered nature of green manufacturing adoption, we employ the 2SDID approach to examine the impact of green manufacturing adoption on operational efficiency. The first stage of the 2SDID approach involves establishing fixed effects for individual units (i.e., firms) and time periods (i.e., years) using the untreated observation samples. Importantly, only considering untreated observation samples at this step is vital for mitigating potential sample-selection bias (Gardner, 2022). Through the removal of fixed effects for individual units and periods, the second stage estimates average treatment effects by juxtaposing the outcomes of treated and untreated groups across the entire spectrum of observation samples. The two-stage estimation procedures are outlined as follows.

Stage 1: Estimating firm and time-fixed effects

$$Y_{i,t} = \gamma_i + \lambda_t + \alpha Controls_{i,t-1} + \varepsilon_{i,t}$$

Where $Controls_{i,t-1}$ signifies a series of control variables for each firm i in year t-1. Furthermore, the estimated fixed effects for individual units $\hat{\gamma}_i$ and time periods $\widehat{\lambda_t}$ are retained by using only untreated or not-yet-treated observations.

Stage 2: Estimating the overall average treatment effect on the treated (ATT)

$$Y_{i,t} - \hat{\gamma}_i - \widehat{\lambda_t} - \alpha \widehat{Controls}_{i,t-1} = \beta_1 D_{i,t} + \beta_2 D_{i,t} \times Moderator_i + \beta_3 Moderator_i + \varepsilon_{i,t}$$

Where $Y_{i,t}$ denotes the observed value of operational efficiency of firm i in year t. $D_{i,t}$ signifies a dummy variable (i.e., $Green\ Gamification$) of whether a treatment firm enters the experimental period. Following the prior literature (Doshi et al., 2013), we construct time-invariant moderators in the year before the implementation of green gamification, thus preemptively addressing potential endogeneity concerns arising from our DID identification.

5.5 Results

5.5.1 Main effects

Table 5.4 displays the results of the 2SDID regression analysis. Models 1 and 3 depict the estimations using the 2SDID approach, with and without control variables, respectively. Model 2 represents the relative time model without including control variables, whereas Model 4 incorporates control variables in the relative time model.

In Models 1 and 3, the coefficient of green gamification exhibits a positive and statistically significant relationship (p<0.05), providing evidence that green gamification enhances operational efficiency. This finding substantiates Hypothesis 1, positing a favorable correlation between green gamification and operational efficiency. Models 2 and 4 reveal that the positive influence of green gamification on operational efficiency strengthens progressively over time during the post-adoption periods. This finding implies that the efficiency gains derived from green gamification become pronounced as time progresses.

Table 5.4 The results of 2SDID regression

	Model 1	Model 2	Model 3	Model 4
Green Gamification	0.007** (0.003)		0.008** (0.003)	
Control Groups		Baseline (Omitted)		
$Treat*Pre_{t-6}$		-0.010(0.009)		-0.011(0.009)
$Treat*Pre_{t-5}$		-0.005(0.004)		-0.005(0.004)
$Treat*Pre_{t-4}$		-0.001(0.002)		-0.001(0.002)
$Treat*Pre_{t-3}$		0.0004(0.002)		0.0004(0.002)
$Treat*Pre_{t-2}$		0.001(0.001)		0.001(0.001)
$Treat*Pre_{t-1}$		0.002(0.001)		0.002(0.001)
$Treat*Post_{t+0}$		0.004*(0.002)		0.005**(0.002)
$Treat*Post_{t+1}$		0.007**(0.003)		0.007**(0.003)
$Treat*Post_{t+2}$		0.007**(0.003)		0.007**(0.003)
$Treat*Post_{t+3}$		0.005(0.004)		0.005(0.003)
$Treat*Post_{t+4}$		0.010(0.006)		0.010(0.006)
$Treat*Post_{t+5}$		0.021**(0.010)		0.020**(0.010)
$Treat*Post_{t+6}$		0.026*(0.016)		0.025*(0.015)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Control variables	No	No	Yes	Yes
Observations	18,297	18,297	18,297	18,297

Note: Standard errors are clustered at the firm level and reported in parentheses. *** p < 0.01; ** p < 0.05; * p < 0.1.

5.5.2 Robustness test

5.5.2.1 Parallel Trend Test

The DID method relies on the assumption of parallel trends in the evolution of both treatment and control firms before the year of green gamification. Following the prior literature

(Beck et al., 2010), we conduct a parallel trend test to examine operational efficiency changes before and after the implementation of green gamification.

Specifically, we utilize a relative time model and apply three different DID methods, including the two-way fixed effect (TWFE), CSDID, and 2SDID approaches, for a common trend analysis (Goodman-Bacon, 2021). The results of our analysis, depicted in Figure 5.3, showcase the estimated coefficients and their corresponding 90% confidence intervals, elucidating the assessment of operational performance related to green gamification across different periods. Across all scenarios, a notable and positive main effect is discernible. Importantly, the 90% confidence intervals before the implementation of green gamification consistently include zero, signifying the absence of any significant pre-treatment trend in our estimations. Hence, these findings corroborate the validity of the parallel-trends assumption underlying the DID analysis.

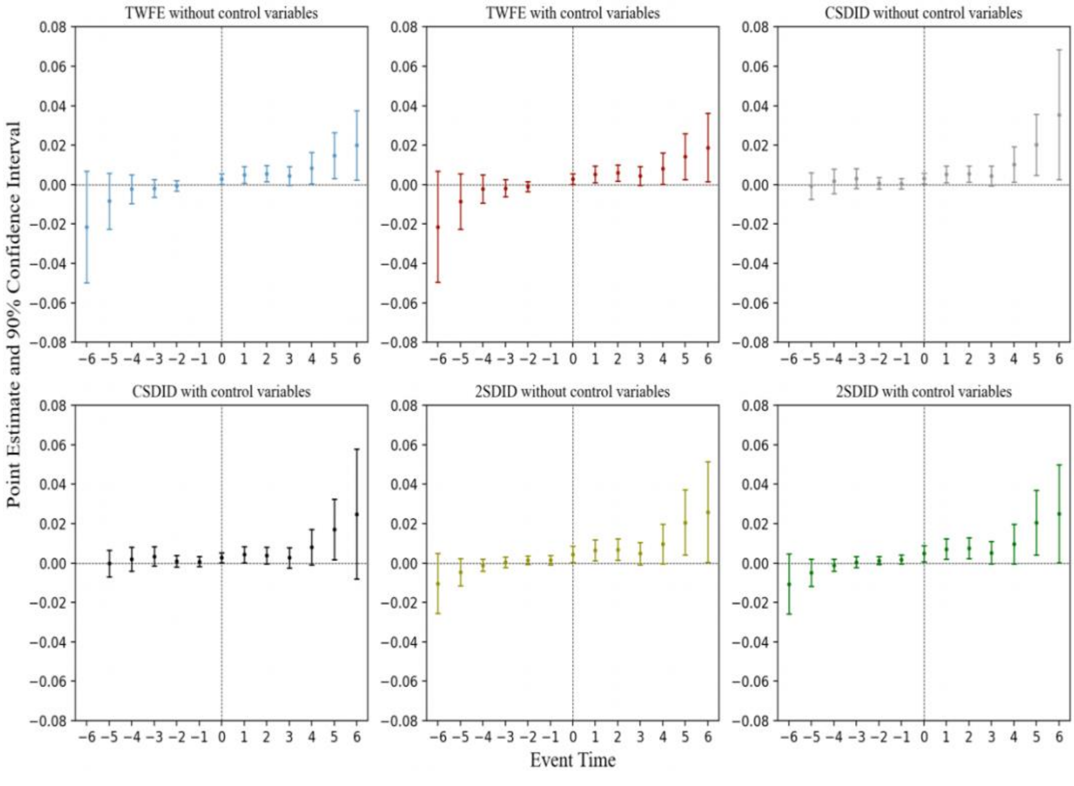


Figure 5.3 Temporal dynamics of average treatment effects

5.5.2.2 Alternative DID methods

Table 5.5 displays the results of the alternative DID strategies employed in this study. Specifically, we adopt the TWFE and CSDID methods to reevaluate our proposed model. Across Models 1 to 4, the coefficients of green gamification consistently exhibit significant and positive. These findings provide substantiation for Hypothesis 1, which postulates a favorable association between green gamification and operational efficiency.

Table 5.5 The results of alternative DID methods

	Model 1: TWFE	Model 2: TWFE	Model 3: CSDID	Model 4: CSDID
Green Gamification	0.007***	0.007***	0.007**	0.005*
	(0.001)	(0.001)	(0.003)	(0.003)
Control variables	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	18,297	18,297	17,027	17,027

Note: Standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. The sample size using the CSDID approach is 17,027 because the effective sample size with CSDID is smaller than for the standard model.

5.5.2.3 Alternative variable measurements

As highlighted in prior research (Chuang et al., 2019; Li et al., 2022b), firm size is a crucial factor that positively influences operational efficiency. The standard measurements of firm size include log-transformed total sales and log-transformed total assets (Yiu et al., 2020; Chen et al., 2022). In this analysis, we substitute the number of employees with total assets and total sales as the control variable to measure firm size. Furthermore, firm profitability can be measured using different metrics such as return on equity (ROE) and return on investment (ROI) (Lee et al., 2019; Tihanyi et al., 2019). Subsequently, we employ these two indicators of firm profitability to reevaluate our proposed model, respectively. Table 5.6 displays the results of the alternative measurements for firm size and firm profitability. In general, the results remain in alignment with our primary findings.

Table 5.6 The results of alternative variable measurements

	Firm Size		Firm Profitability	
	Log (Total Asset)	Log (Total Sales)	ROE	ROI
Green Gamification	0.007**(0.003)	0.007**(0.003)	0.008**(0.003)	0.008**(0.003)
Control Variables	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	18,297	18,297	18,297	18,297

Note: Standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

5.5.2.4 Changing implementation year and observational window

Drawing upon prior literature (Hendricks et al., 2007), the process of implementing green gamification practices is typically observed to extend for one to three years. In the literature (Chen et al., 2022), researchers also consider the announcement date as the implementation date. Accordingly, we define three-time points for implementation: the year of the announcement, two years preceding the announcement date, and three years preceding the announcement date. Panel A in Table 5.7 showcases the outcomes resulting from the redefinition of the implementation year. Furthermore, we adjust the observation window for treated firms to [t-6, t+5], [t-5, t+4], and [t-4, t+3], respectively. Panel B in Table 5.7 displays the results after altering the observational window. The overall results remain consistent and unchanged after redefining the implementation year and the observational window for treated firms.

Table 5.7 The results of redefining time windows

Panel A: The results by implementation year			
	0-year implementation	2-year implementation	3-year implementation
Green Gamification	0.008**(0.003)	0.007**(0.003)	0.007**(0.003)
Control Variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	18,297	18,205	17,775
Panel B: The results by an observational window			
	[t-6, t+5]	[t-5, t+4]	[t-4, t+3]
Green Gamification	0.007**(0.003)	0.006**(0.003)	0.006**(0.003)
Control Variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	18,270	18,142	17,882

Note: Standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

5.5.2.5 Placebo test

To further assess the robustness of our 2SDID analysis, we perform a placebo test involving the creation of fictitious treatment groups. In this examination, we randomly shuffle the value of the variable $Green\ Gamification$ for approximately 10 percent (1800) of observations and proceed to estimate our proposed model. This procedure is reiterated 500 times to evaluate the significance of the coefficient linked to the “false independent variable”.

Figure 5.4 illustrates the distribution of *p*-values derived from the placebo test. The analysis reveals that 89.4% (=447/500) of the “false” p-values are not statistically significant (*p*>0.1). Furthermore, the beta coefficient associated with the "false independent variable" in each iteration deviates from the estimated coefficients obtained from our proposed model. These results strongly indicate that the finding drawn from our 2SDID analysis is not a result of chance or random variation.

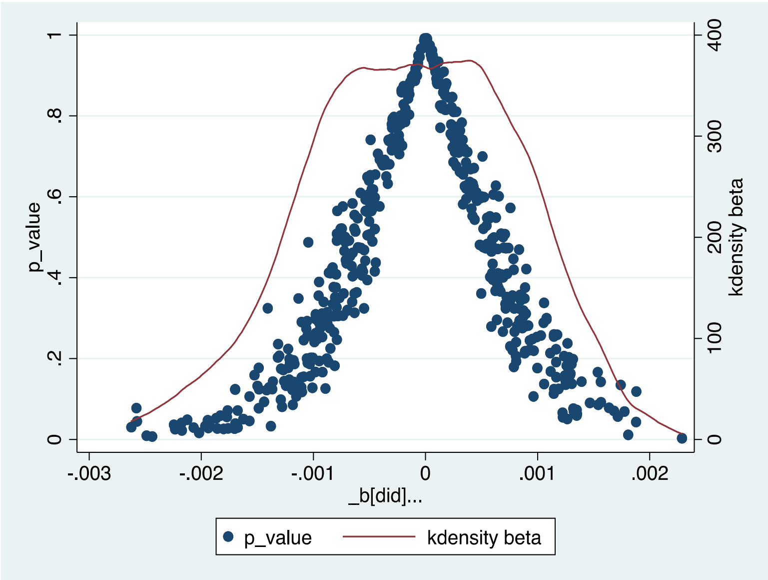


Figure 5.4 Distribution of *p*-values for estimating operational efficiency

5.5.2.6 Other robustness tests

We conducted additional robustness tests, as shown in Table 5.8, to further validate our findings. First, despite the announcement of the sixth-batch green manufacturing demonstration list in January 2022, we consider the year as 2021. To mitigate the interference of confounding events, we focus on the sample firms announced between 2017 and 2020, as depicted in Model 1. Second, incorporating sales growth as a control variable, we present the result in Model 2. Third, to evaluate the sensitivity of our results to choices in the observational window, we narrow down the window from [2014, 2022] to [2015, 2021]. The results of this adjustment are illustrated in Model 3. Fourth, no treatment groups exist within three specific manufacturing types (C24, C25, and C42). To ensure comparability between treatment and control groups, we exclude control samples from these industries in our analysis. Model 4 showcases the results following this exclusion. Overall, the results align with our main findings.

Table 5.8 The results of other robustness tests

	Model 1	Model 2	Model 3	Model 4
Green Gamification	0.007*(0.004)	0.008**(0.003)	0.008**(0.003)	0.008**(0.003)
Control variables	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	17,827	18,297	14,429	18,011

Note: Standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

5.5.3 Endogeneity and measurement bias

5.5.3.1 PSM-DID

The potential for sample selection bias is a valid concern in this model, given that selecting firms as exemplars in green manufacturing is not random. First, governmental agencies might opt for firms with stronger sustainability orientations to promote green manufacturing. Second, firms could selectively seek recognition as green manufacturing exemplars to boost their reputation and elicit additional investments. These factors introduce the possibility of sample selection bias, which could influence the results of subsequent DID analysis.

To mitigate the potential impact of sample selection bias, we utilize the propensity score matching (PSM) method to identify control groups that share similar industry-year characteristics with the treatment groups (Qiu et al., 2022). Specifically, we execute a logistic regression to calculate the propensity scores, which indicate the likelihood of a firm being chosen as a green manufacturing exemplar. The predictors used in the regression include ROA, ISO4001, Firm Age, and Firm Size. Using a one-to-one nearest neighbor and no-replacement matching approach with a caliper of 0.05 for the matching process, we identify 294 control firms that are comparable to 294 treatment firms before the event periods. Table 5.9 presents the summary statistics of control and treatment groups before and after PSM. The results reveal no significant difference in firm characteristics between the treatment and control firms after PSM.

Table 5.9 Summary statistics of two groups before and after PSM

Variable	Unmatched	Mean			t-test
	Matched	Treated	Control	%bias	t (p-value)
ROA	U	0.043	0.032	16.8	2.40(0.017)
	M	0.042	0.042	1	0.14(0.887)

Firm Age	U	2.776	2.744	10.4	1.57(0.118)
	M	2.776	2.766	3.1	0.37(0.711)
Firm Size	U	8.303	7.585	62.9	9.87(0.000)
	M	8.278	8.330	-4.6	-0.56(0.579
ISO4001	U	0.38398	0.27144	24.1	4.7(0.000)
	M	0.37709	0.38268	-1.2	-0.15(0.878)

After excluding observations with missing values, our final dataset comprises 4,745 firm-year observations. The results of the 2SDID analysis after PSM are presented in Table 5.10. In Models 1 and 3, a positive association between green gamification and operational efficiency is evident ($p<0.05$). Moreover, the relative time models from Models 2 and 4 support the parallel-trends assumption, highlighting no significant difference in operational efficiency between control and treatment groups before green gamification ($p>0.1$). Furthermore, we employ two alternative DID methods (i.e., CSDID and TWFE) to execute the relative time model, validating the results of PSM-2SDID. Collectively, all the results corroborate the parallel-trends assumption of DID analysis and remain consistent with our main findings.

Table 5.10 The results of two-stage DID after PSM

	Model 1	Model 2	Model 3	Model 4
Green Gamification	0.014**(0.006)		0.014**(0.006)	
Control Groups		Baseline (Omitted)		
Treat*Pre$_{t-6}$		-0.008(0.011)		-0.007(0.011)
Treat*Pre$_{t-5}$		-0.006(0.004)		-0.006(0.004)
Treat*Pre$_{t-4}$		-0.001(0.002)		-0.001(0.002)
Treat*Pre$_{t-3}$		0.001(0.002)		0.001(0.002)
Treat*Pre$_{t-2}$		0.002(0.001)		0.002(0.001)
Treat*Pre$_{t-1}$		0.001(0.002)		0.001(0.002)
Treat*Post$_{t+0}$		0.008**(0.004)		0.008**(0.004)
Treat*Post$_{t+1}$		0.010*(0.005)		0.010*(0.005)
Treat*Post$_{t+2}$		0.016**(0.007)		0.017**(0.007)
Treat*Post$_{t+3}$		0.011(0.008)		0.012(0.008)
Treat*Post$_{t+4}$		0.018*(0.011)		0.018*(0.010)
Treat*Post$_{t+5}$		0.020(0.015)		0.019(0.015)
Treat*Post$_{t+6}$		0.056*(0.033)		0.055*(0.032)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Control variables	No	No	Yes	Yes
Observations	4,745	4,745	4,745	4,745

Note: Standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

5.5.3.2 Measurement bias

This study employs the SFE approach to measure operational efficiency, determined by input and output variables associated with operational resources (Kao et al., 2023; Shen et al., 2023). The measurement of input variables, particularly the cost of goods sold, has sparked discussion in the literature. Following the existing literature (Yiu et al., 2020; Li et al., 2021), we measure a firm's operational efficiency by replacing the cost of goods sold with inventory. Table 5.11 displays the results of the 2SDID regression when considering inventory as the input resource. In Models 1 and 3, a positive and significant impact of green gamification on operational efficiency is found ($p<0.01$). Models 2 and 4 present corresponding relative time models, supporting the parallel-trends assumption. To validate this result, we also utilize the TWFE and CSDID methods to conduct the relative time model and gauge the influence of green gamification on operational efficiency. In general, these results affirm the validity of the parallel-trends assumption and lend support to our main findings.

Table 5.11 The results of the two-stage DID regression

	Model 1	Model 2	Model 3	Model 4
Green Gamification	0.008***(0.003)		0.008***(0.003)	
Control Groups		Baseline (Omitted)		
Treat*Pre$_{t-6}$		-0.002(0.004)		-0.002(0.004)
Treat*Pre$_{t-5}$		0.0001(0.003)		-0.0001(0.003)
Treat*Pre$_{t-4}$		-0.001(0.001)		-0.001(0.001)
Treat*Pre$_{t-3}$		-0.002(0.002)		-0.002(0.002)
Treat*Pre$_{t-2}$		0.001(0.001)		0.001(0.001)
Treat*Pre$_{t-1}$		0.002(0.001)		0.002(0.001)
Treat*Post$_{t+0}$		0.004**(0.002)		0.004**(0.002)
Treat*Post$_{t+1}$		0.007**(0.003)		0.008***(0.003)
Treat*Post$_{t+2}$		0.009***(0.003)		0.009***(0.003)
Treat*Post$_{t+3}$		0.007**(0.004)		0.007**(0.004)
Treat*Post$_{t+4}$		0.009*(0.005)		0.009*(0.005)
Treat*Post$_{t+5}$		0.019**(0.009)		0.019**(0.009)
Treat*Post$_{t+6}$		0.033*(0.019)		0.032*(0.019)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Control variables	No	No	Yes	Yes
Observations	16,407	16,407	16,407	16,407

Note: Standard errors are clustered at the firm level and reported in parentheses. *** p < 0.01; ** p < 0.05; * p < 0.1.

5.5.4 Mechanism analyses

5.5.4.1 Complementary and substitutive effects

We also investigate the circumstances that amplify or attenuate the impact of green gamification on operational efficiency. From a complementary view, we examine whether state ownership strengthens the efficiency gains derived from green gamification. From a substitutive view, we explore whether R&D investment weakens the influence of green gamification on operational efficiency. Table 5.12 displays the results of the moderation effects. Model 1 displays the results of the 2SDID analysis to estimate cost-related operational efficiency. Model 2, as the extension of Model 1, presents the results of PSM-2SDID. Model 3 focuses on the 2SDID analysis for evaluating inventory-related operational efficiency. Panel A estimates the moderating role of state ownership. Panel B gauges the moderating influence of R&D investment.

In Panel A, the results from Model 1 to Model 3 consistently reveal a positive and significant interaction between green gamification and state ownership ($p<0.1$). This finding implies that the efficiency gains of green gamification are more pronounced for SOEs, lending credence to Hypothesis 2. In Panel B, the results consistently reveal that the interaction between green gamification and R&D investment is statistically significant and negative across Model 1 to Model 3 ($p<0.01$). These results imply that R&D investment weakens the positive influence of green gamification on operational efficiency, thus supporting Hypothesis 3.

Table 5.12 The complementary and substitutive effects

	Model 1	Model 2	Model 3
Control Variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	18,297	4,745	16,407
Panel A: The moderating role of state ownership			
Green Gamification	0.003(0.003)	0.003(0.006)	0.003(0.003)
State Ownership	$-3.46e^{-11}(1.46e^{-11})$	$-1.77e^{-09}(1.34e^{-09})$	$-4.31e^{-11}$*$(2.44e^{-11})$
Green Gamification * State Ownership	0.014*(0.009)	0.030**(0.013)	0.017**(0.008)

Panel B: The moderating role of R&D Investment			
Green Gamification	0.020***(0.007)	0.042***(0.011)	0.020***(0.006)
R&D investment	$1.84e^{-11}$($1.08e^{-10}$)	$-1.37e^{-10}$($1.17e^{-09}$)	$-2.86e^{-09}$($5.92e^{-09}$)
Green Gamification *R&D investment	-0.337***(0.123)	-0.820***(0.193)	-0.332***(0.099)

Note: Standard errors are clustered at the firm level and reported in parentheses. *** p < 0.01; ** p < 0.05; * p < 0.1.

5.5.4.2 Market and financial performance

In this study, we extend our analysis to explore the long-term effects of green gamification on both market performance, measured by Tobin's Q (Yiu et al., 2020), and financial performance, measured by ROA (Yang et al., 2021). Table 5.13 presents the results concerning the impact of green gamification on market and financial performance. Model 1 examines the market reactions to green gamification, and Model 2 demonstrates the corresponding relative time model. Model 3 evaluates the financial returns of green gamification, and Model 4 displays the relative time model.

The coefficient of green gamification in Model 1 exhibits statistical significance and a positive trend, implying a positive association between green gamification and market value ($p<0.01$). Furthermore, the coefficient of green gamification in Model 3 is positive with statistical significance ($p<0.05$). These findings indicate that green gamification exerts a positive and significant influence on both market and financial performance. Additionally, all the relative time models align with the parallel-trends assumption of the DID analysis. Notably, the results of Model 3 display a pattern in which the positive market response to green gamification initially grows, and then gradually decreases over time. Moreover, the results of Model 4 indicate a growing and significant financial return stemming from green gamification in the long term.

Table 5.13 Market and financial returns of green gamification

	Market Performance		Financial Performance	
	Model 1	Model 2	Model 3	Model 4
Green Gamification	0.163**(0.052)		0.006**(0.002)	
Control Groups		Baseline (Omitted)		
Treat*Pre_{t-6}		-0.107(0.069)		-0.006(0.005)
Treat*Pre_{t-5}		-0.063(0.060)		-0.005(0.003)
Treat*Pre_{t-4}		-0.040(0.044)		-0.001(0.002)
Treat*Pre_{t-3}		-0.013(0.031)		-0.001(0.002)
Treat*Pre_{t-2}		0.026(0.025)		0.001(0.001)

$Treat*Pre_{t-1}$		0.039(0.025)		0.003(0.002)
$Treat*Post_{t+0}$		0.134***(0.042)		0.003(0.002)
$Treat*Post_{t+1}$		0.174***(0.055)		0.004(0.003)
$Treat*Post_{t+2}$		0.231***(0.069)		0.004(0.003)
$Treat*Post_{t+3}$		0.152**(0.071)		0.006*(0.004)
$Treat*Post_{t+4}$		0.122(0.084)		0.009**(0.005)
$Treat*Post_{t+5}$		0.079(0.107)		0.015**(0.006)
$Treat*Post_{t+6}$		0.242*(0.128)		0.019*(0.010)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes
Observations	18,910	18,910	18,898	18,898

Note: Standard errors are clustered at the firm level and reported in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

5.6 Discussion

The trade-off between environmental friendliness and operational advantages remains an ongoing inquiry (Henao and Sarache, 2022; Jeong and Lee, 2022). This study employs the resource-based view to elucidate the importance of green gamification in enhancing operational efficiency. The integration of gamification into green manufacturing aligns with the objective of resource efficiency and emission reduction, which prove advantageous for a firm's operational effectiveness (Li et al., 2019; Bhatia, 2021).

In terms of moderation effects, this study reveals that state ownership strengthens the positive influence of green gamification on operational efficiency. Consistent with previous studies (Chang et al., 2019; Shen et al., 2023), SOEs benefit more from government-initiated responsible actions, like green gamification, because they own greater access to financial and technical resources for green gamification (Chang et al., 2019; Shen et al., 2023). Moreover, innovation capacity developed from green gamification plays a pivotal role for SOEs in identifying novel operation techniques and enhancing their operational efficiency (Chang et al., 2019; Tihanyi et al., 2019). Viewed from a substitutive standpoint, our findings indicate that R&D investment weakens the positive influence of green gamification on operational efficiency. In line with prior literature (Li et al., 2021), green gamification as a form of CSR activity competes with innovation as a valuable resource to function as distinct strategies for differentiation, each contributing to maintaining competitive advantages. These findings provide insightful suggestions for managers and policymakers to effectively promote green gamification for sustainability.

5.6.1 Theoretical implications

In the pursuit of sustainability objectives, policymakers leverage green gamification to diminish carbon footprint and enhance resource efficiency. This study offers empirical evidence to answer the relationship between green gamification and operational efficiency by using a staggered DID method with panel datasets. Despite the improvement of green gamification for sustainability, the operational efficiency of green gamification remains under-explored (Jeong and Lee, 2022; Arda et al., 2023). While green manufacturing has the potential to ignite innovative business models, its implementation can entail substantial resource investments, potentially leading to organizational inertia and uncertain financial outcomes (Mao and Wang, 2019; Jeong and Lee, 2022). Extending the current body of research (Song et al., 2017; Inman and Green, 2018), we unveil that, contrary to the “sand-cone” and “trade-offs” models (Henao and Sarache, 2022), green gamification enhances operational efficiency, as measured through the SFE approach, in the long run.

This study offers new insight into the RBV literature by revealing the significance of resource complementarity in fostering a mutually beneficial scenario, both externally and internally within a firm. The synergistic interplay between green gamification and state ownership underscores how adopting innovative and responsible practices can invigorate established business models and optimize the operations of SOEs (Chang et al., 2019). The current literature suggests that the resource advantages gained from political ties could potentially hinder operational efficiency due to a reluctance to challenge the comfort of the status quo (Shen et al., 2023). As an extension of this work, our study indicates that green gamification can empower SOEs to embrace novel techniques and transformative business models, leading to heightened operational efficiency. Concurrently, SOEs contribute available resources (e.g., funding investment and policy support) that are crucial for the effectiveness of green gamification (Wang et al., 2018; Tihanyi et al., 2019).

This research uncovers a noteworthy revelation that R&D investment exerts a dampening effect on the efficiency gains of green gamification. Traditionally, R&D investments have been perceived as enhancers of a firm’s innovation and sustainability capabilities, contributing to the adoption of green initiatives and driving superior financial performance (Garmulewicz et al., 2018; Jabbour et al., 2022). However, when viewed from an operational standpoint, these two activities, which compete for resources with green practices, can introduce operational complexity and uncertainties to economic gains (Liu et al., 2022a; Tian et al., 2023). Analogous to green gamification, R&D investment involves a multitude of innovative activities that demand significant financial and human resources (Seth and Rehman, 2022; Mukherjee et al., 2023). In line with previous work (Li et al., 2021), innovation capability exhibits a certain substitutive effect on green practices, as they function as distinct strategies to maximize resource utilization. Drawing on a resource substitution theory, this study provides insights into the dynamics of resource allocation by revealing the suppressive phenomenon of green gamification alongside certain practices, such as R&D investment.

Last but not least, this study delves into the long-term implications of green gamification on market, financial, and operational performance. While current literature largely concurs with the positive correlation between green practices and TBL performance (Li et al., 2019; Arda et al., 2023), it tends to lack a comprehensive view of the dynamic evolution of the role of green gamification. Addressing this gap, our study employs a relative time model to unveil a spectrum of trends that vary from economic and operational performance to market performance caused by green gamification. More importantly, our findings underscore that the impact of green gamification resonates over the long term, profoundly influencing a firm's internality—captured by metrics like ROA and operational efficiency—while gradually diminishing its external impact, as evident in Tobin's Q. Ultimately, our investigation reveals that green gamification serves as a strategic avenue for firms to cultivate competitive advantages. This finding extends not only to heightening external market responsiveness but also to enhancing the internal facets of operational and financial performance, in evaluating the role of green gamification.

5.6.2 Managerial implications

Our findings provide manufacturers with valuable insights to harmonize their business operations with environmental sustainability. Considering both the substitutive and complementary effects highlighted in our study, firms are encouraged to adapt their strategies in accordance with their unique contexts, thereby setting practical and attainable objectives for sustainable manufacturing. To elaborate, firms can confidently navigate the decision-making process concerning their alignment with green manufacturing standards for gamification in their operations. To foster operational excellence, a noteworthy approach involves the incorporation of sustainable practices, such as eco-design, reverse logistics, and effective waste disposal methods, into their day-to-day operations.

Second, achieving exceptional operational performance requires more than just cultivating sustainability capabilities through green practices. It is worth noting that SOEs possess distinct advantages, including access to policy support like technical expertise and financial resources. Such firms can leverage green gamification to foster a situation characterized by efficiency-driven operations and innovation-oriented endeavors. By harnessing the potential of a motivated workforce for gamification, firms can maximize the full potential of green gamification, resulting in heightened operational efficiency gains.

Third, the substitutive effects underscore the necessity of prudent trade-off management and careful consideration of the implications of substitution, thus ensuring that desired outcomes are realized. The negative interaction of green gamification and innovation intensity serves as a guide for firms in regulating their operational strategies. As for firms with more R&D investment, the simultaneous pursuit of green gamification and innovation technology is not advisable due to the constraints on resource allocation. Specifically, firms are suggested to select either green practices or innovative activities, thereby ensuring a steady trajectory for business operations. As for firms with less R&D investment, they can consider the integration of green gamification to tap into their acquired capacities and seamlessly align them with their business operations. Striking a balance in the allocation of resources between green practices and innovative activities is imperative to avoid counterproductive outcomes.

5.6.3 Policy implications

Our findings further bolster the rationale behind advocating for the integration of gamification into green manufacturing policies in achieving the goals of carbon peak and carbon neutrality. First, policymakers can effectively encourage green gamification for improving firms' business operations by fostering and strengthening green awareness in a game-like context. Second, manufacturers are in pressing need of resources to enhance the efficacy of their green practices. Consequently, policymakers are strongly recommended to extend technical and financial support to those who choose to adopt green manufacturing for gamification. As an example, policymakers could prioritize offering project funding and specialized technical training in green operations to manufacturers committed to implementing green manufacturing initiatives. Third, policymakers should actively encourage firms that may lack innovation capabilities to convert existing business operations towards green manufacturing for gamification. By doing so, these firms can cultivate sustainability and innovation capabilities that are instrumental in managing manufacturing operations and elevating their operational competitiveness.

5.6.4 Limitations and future research

Several limitations provide opportunities for future research. First, the extent of efficiency gains from green gamification might differ across various aspects, ranging from eco-design and green factories to green supply chain management. However, the majority of our observational samples are firms recognized as exemplars of green factories. Scholars could gather more data from firms adopting different green processes and analyze the efficiency gains of distinct green practices. Second, the treatment samples only include the firms available on the demonstration lists acknowledged by MIIT, but some firms applying for green gamification but getting failure from gamification are not considered. A future avenue could involve expanding the sample to include firms that applying for green gamification but may not stand out in the selection of green manufacturing demonstration lists. This would enable a comparison in operational performance between non-adopters and adopters, as well as between high-performing and average-performing adopters. Lastly, more caution should be extended to investigate the mechanisms influencing the relationship between green gamification and operational efficiency. Specifically, green gamification may result in inter-organizational cooperation and competition, which increase employees' work efficiency and foster their innovation capabilities. By conducting field investigations or survey questionnaires, scholars may understand psychological and behavioral outcomes responding to green gamification. If so, scholars can find a mechanism explaining the relationship between green gamification and operational efficiency.

Chapter 6 Conclusions

6.1 Summary of Study Findings

This thesis consists of three interrelated studies to deepen the understanding of responsible production for performance. Specifically, we summarize the main findings of these three studies as follows.

(1) Major findings of Study 1

Using a dataset comprising 392 manufacturers that adopted responsible production practices between 2016 and 2023; this study employs a short-term event study approach to unveil the positive market value of responsible production practices adoption. Through cross-sectional regression analysis, we discern that firm size and financial slack can strengthen the market value of adopting responsible production practices, especially during the COVID-19 pandemic. The findings offer managerial insights for assisting firms in navigating their journey toward responsible production while safeguarding their firm value.

(2) Major findings of Study 2

Using propensity score matching and difference-in-differences analysis on 3,022 firm-year observations, we demonstrate the positive impact of resource-responsible production on financial performance. Notably, our findings also reveal that digital transformation and political connections strengthen the positive influence of resource-responsible production on financial performance. This study extends the NRBV literature by underscoring the role of digital transformation and political connections in enhancing the organization-resource relationship for financial performance. These insights offer valuable suggestions for managers to effectively embrace resource-responsible production practices and for policymakers to achieve sustainability goals.

(3) Major findings of Study 3

Based on a two-stage difference-in-differences analysis on 18,297 firm-year observations, we first observe that, on average, firms awarded as green manufacturing demonstration exemplars are likely to achieve higher operational efficiency, particularly in the long run. Notably, state ownership strengthens but R&D investment weakens the positive impact of green gamification on operational efficiency. This research adds new insights into the operations management (OM) literature by revealing the significance of green gamification in improving operational efficiency as well as uncovering the substitutive role of R&D investment and the complementary role of state ownership on the above relationship. These findings can provide suggestions for policymakers and manufacturers to leverage green gamification to improve efficiency gains.

6.2 Research Implications

6.2.1 Theoretical Implications

This thesis contributes to the existing literature in several important aspects. Specifically, the theoretical implications of the three studies are as follows.

Building upon legitimacy theory, Study 1 theoretically and empirically reveals the role of responsible production as a legitimate action to achieve competitive advantages. Extending the RBV literature, this study uncovers the strengthening role of resource abundance (i.e., firm size and financial slack) and the weakening role of resource shortage (i.e., COVID-19) on the market value of responsible production practices adoption. Accordingly, Study 1 lays the foundation for the understanding of responsible production by identifying the boundary conditions of firm size and financial slack on the market value of responsible production practices adoption.

Drawing from the natural resource-based view, Study 2 unveils the significance of resource-responsible production in explaining the organization-resource relationship for financial performance. Extending the NRBV literature, this study highlights the role of external networks (i.e., political connections) and internal capabilities (i.e., digital transformation) in supporting the implementation of resource-responsible production for economic returns. More importantly, this study confirms that political connections are crucial in enhancing stakeholder engagement for achieving sustainable development, and digital transformation is beneficial for product stewardship and pollution prevention. Therefore, this study enriches the NRBV literature by emphasizing the role of political connections and digital transformation in the organization-resource relationship built by resource-responsible production practices.

Drawing upon the resource-based view, Study 3 sheds light on the importance of green gamification in enhancing operational efficiency. Extending the OM literature, this study highlights the integration of gamification design into green manufacturing. More importantly, this study advances the knowledge about the RBV literature by revealing the strengthening role of state ownership and the weakening role of R&D investment in the integration of gamification into green manufacturing for operational efficiency. Consequently, Study 3 adds new insights into OM research by emphasizing the moderating role of R&D investment and state ownership in influencing the relationship between green gamification and operational efficiency from a resource-based view.

6.2.2 Managerial Implications

The research findings of this thesis can provide managerial implications for promoting responsible production in emerging markets. Specifically, the managerial implications are outlined as follows.

Study 1 provides suggestions for managers to make informed decisions in adopting responsible production practices. To create more value, managers should make a deliberate consideration about whether abundant resources can be leveraged for the implementation of responsible production. Big firms are suggested to embrace responsible production because they own substantial resources supporting responsible production and exert a more powerful influence over the market reaction. In contrast, small firms can enlarge external network resources to make up for the limitations of insufficient resources. On the other hand, it is desirable for firms with more financial slack to participate in responsible production practices. Firms with less financial slack should be cautious about whether to adopt responsible production. Accordingly, managers should rely on specific situations to determine whether and when to embrace responsible production practices for value creation.

Study 2 gives some insights about resource-responsible productions for managers to pursue superior performance. In particular, the integration of resource conservation and energy saving into the production process is beneficial for manufacturers to obtain higher economic returns. However, it is reasonable for manufacturers to consider their external networks and internal capabilities in inputting responsible production practices. Specifically, politically connected firms are suggested to implement resource-responsible production. As for firms without political connections, they should be cautious about whether to embrace resource-responsible production. Moreover, firms with high digital transformation can actively take part in resource-responsible production practices for economic returns. In contrast, firms with low digital transformation are suggested to evaluate whether they have the capabilities to cope with the difficulties of implementing resource-responsible production. Therefore, firms are suggested to make a deliberate consideration over whether or when to embrace resource-responsible production.

Study 3 offers insightful suggestions for managers to effectively undertake green gamification to improve their operational efficiency. Specifically, the integration of gamification design into green manufacturing is crucial for enhancing a firm’s business operations. In particular, SOEs are suggested to actively participate in green gamification for the enhancement of operational efficiency. On the contrary, non-SOEs can be considerate about whether to join in green gamification activities. Furthermore, it is not favorable for firms with more R&D investment to put great effort into green gamification. In contrast, firms with less R&D investment can try to attend green gamification activities to improve their operational performance. Consequently, firms need to consider their specific conditions to determine whether or when to participate in green gamification activities.

6.2.3 Policy Implications

This thesis offers several policy implications as follows. First, Study 1 encourages the policymakers are suggested to diffuse and promote the adoption of responsible production for value creation as well as provide policy support for firms facing the challenges from resource shortage in adopting responsible production. Second, Study 2 suggests that policymakers should emphasize resource responsibility in a firm's business operations as well as offer policy support for firms that are disadvantageous in seeking and transforming resources. Third, Study 3 informs that policymakers can integrate gamification into green manufacturing policies for enhancing a firm's business operations as well as encourage firms to pay attention to resource allocation of different business activities.

6.3 Limitations and Future Research Directions

Undoubtedly, the limitations of this thesis pave the way for future research. First, in Studies 1, 2, and 3, cautions can be generalized to other countries. For example, the sample data should be extended to other regions, which can capture cultural differences in the outcomes and effectiveness of implementing responsible production practices. Second, in Studies 1, 2, and 3, an in-depth investigation can be applied into the mediating mechanisms that can better explain the influence of responsible production practices on firm performance. For Study 1, scholars can examine whether firm reputation and stakeholder satisfaction mediate the relationship between responsible production and market value. For Study 2, resource-responsible production may influence financial performance through improving cost and efficiency performance. For Study 3, green gamification may stimulate inter-organizational cooperation and competition, which can be conducted in future research. Third, in Studies 1, 2, and 3, scholars can consider the linkage between responsible production practice and supply chain structure/performance in direct and moderating ways. For example, the market, financial, and operational performance of adopting responsible production practices may be determined by a firm's different supply chain structure, including supply chain network and dependence. Furthermore, responsible production practices can influence supply chain performance, such as supply chain resilience and sustainability.

6.4 Concluding Remarks

With the market and policy requirements, responsible production becomes prominent as a strategic way for manufacturers to maintain sustainability. This thesis provides a comprehensive picture to understand the significance of responsible production practices in influencing firm-level performance in terms of market, financial, and operational aspects. Accordingly, firms are suggested to proactively engage in responsible production practices for performance improvement. Despite this, the dark side of responsible production practices, such as operational complexity and cost investment, should be further examined in future research. Thus, firms need to consider whether and when to embrace responsible production practices based on their specific contexts.

This thesis provides empirical evidence to understand responsible production as a part of SDG12 for performance as well as reveal the boundary conditions of firm-level characteristics. The results provide theoretical and managerial implications for the adoption of responsible production. More importantly, this thesis also offers insightful references for policymakers to enhance responsible production for sustainability. In particular, this thesis sheds light on the importance of resource responsibility and green gamification in enhancing firm growth. Therefore, this thesis paves the way for future research to enrich the understanding of responsible production, which differs from CSR and CER.

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