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Article

Challenges and impact of the gig economy

Amit Joshi[1,*], Saharsh Jain[1], Puneet Kumar Gupta[2]

[1] Gandhi Memorial Intercontinental School, Jakarta 10630, Indonesia
[2] The ICFAI University, Dehradun 248011, India
*** Corresponding author:** Amit Joshi, ihsojtima@gmail.com

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Abstract: The dynamic landscape of global business, fueled by technological innovations, intense competition, and evolving consumer expectations, has prompted businesses to undergo significant restructuring. In response to these challenges, innovative business structures, particularly the gig economy, have emerged as a transformative force. The gig economy, facilitated by digital platforms, has redefined traditional work models, allowing individuals to engage in temporary and flexible jobs across various industries. While providing flexibility for workers and cost-effectiveness for businesses, the gig economy has uncertainty about jobs for workers, their rights, and the need for regulatory frameworks. This paper explores the evolution of the gig economy and its effect on the job environment, labour policies, and regulations. It highlights the advantages of gig work, such as flexibility and job expansion, while also addressing the challenges, including job insecurity and the potential for social and ethical dumping. The role of gig platforms in reshaping labour markets, particularly in empowering women in certain regions, is discussed. The paper emphasizes the necessity of adapting employment laws to accommodate the unique nature of gig work, considering factors like control exertion and triangular relationships. Moreover, the paper delves into issues of discrimination faced by gig workers based on gender or race, both domestically and internationally. It recognizes the potential benefits of outsourcing gig work in developing countries but underscores the ethical concerns of "ethics dumping" and the need for safeguards. The impact on workers' well-being, social integration, and the lack of protection under employment laws are discussed as challenges arising from the detachment of gig workers from conventional work environments. In response to these challenges, the paper examines existing policy initiatives, such as the European Union's efforts to regulate gig work, emphasizing the importance of building a skilled workforce and addressing concerns related to platform work. However, it identifies gaps in addressing ethical challenges, particularly in the realm of algorithmic systems, and the need for comprehensive measures to protect gig workers' rights, thus focusing on their welfare. The paper advocates for a holistic approach to address the ethical challenges posed by the expanding gig economy. It calls for a balance between flexibility and ethical considerations, envisioning a gig economy that not only meets market demands but also prioritizes fairness, equity, and the well-being of its workforce.

Keywords: employment; exploitation; gig economy; workers

1. Introduction

The global business landscape is going through a profound transition driven by innovative technologies, heightened competition, and consumers' raised expectations [1]. Due to the continuously changing economic environment, businesses are forced to reevaluate and restructure their operational models to remain competitive and adaptable to the continuously shifting landscapes. Central to this transformative paradigm is the evolution and proliferation of the gig economy, a phenomenon shaped

by digital advancements and characterized by flexible, temporary work arrangements [2]. The gig economy showcases a transformation from traditional employment structures, offering individuals the freedom to engage in short-term, task-based work across diverse industries [3]. Enabled by digital platforms, this evolution in work models has redefined the employer-employee relationship, with gig workers, often freelancers or independent contractors, enjoying autonomy in choosing when, where, and how much they work. While the gig economy provides unprecedented flexibility for workers and cost-efficiency for businesses, it has given rise to multifaceted challenges, ranging from job security concerns to the ethical implications of the shifting dynamics in labour markets. This paper delves into the multifaceted landscape of the gig economy, exploring its origins, evolution, and the various dimensions it introduces to the job market. It focuses on the advantages and disadvantages associated with gig work, emphasizing the need for nuanced regulatory frameworks to ensure fair treatment and protection of gig workers. Additionally, the paper addresses the effect of gig platforms on labour markets, with a focus on the empowerment of certain demographics, such as women, in specific regions. Furthermore, the paper navigates through the ethical considerations arising from the gig economy, including issues of discrimination, outsourcing practices, and the potential for social and ethical dumping. It analyses existing policy initiatives and proposes comprehensive measures to bridge gaps in protecting gig workers' rights, well-being, and fair treatment. As the expansion of the gig economy continues and reshapes the traditional contours of employment, a holistic understanding of its implications becomes imperative. The article seeks to contribute to this understanding by exploring the nuances of the gig economy, offering insights into its benefits, challenges, and ethical dimensions, and advocating for an approach that ensures both flexibility and ethical considerations in the evolving market economy.

2. Literature review

The advent of innovative technologies, competition around the world, and evolving customer expectations have compelled businesses to restructure their working models to thrive in existing fiercely competitive and continuously changing landscapes. In response to these challenges, innovations in business structures have emerged as a means of delivering diverse positions to the market [4,5]. This transformation expanded traditional freelance work, commonly referred to as the gig economy [6]. The gig economy's expansion is predominantly driven by digital applications, facilitating direct connections between service providers and customers [7]. In contrast to earlier applications of digital platforms for procuring project work, where information technology supports competition dissemination, gig economy platforms revolutionize the fundamental work model [8]. In the gig economy, individuals, often referred to as gig workers or freelancers, engage in temporary and flexible jobs rather than traditional full-time employment [9]. This form of work spans various industries, encompassing activities such as freelance writing, graphic design, ride-sharing, food delivery, and other on-demand services. Gig workers enjoy the freedom to choose when, where, and how much they work, making this flexibility appealing to those seeking a balance between work and other commitments. Many gig

workers discover opportunities through online platforms and apps that link them with clients or customers. Typically, gig work entails completing specific tasks or projects for a short period of time rather than committing to long-term employment. The surge in demand for temporary, contractual labour was notably influenced by the pressure of reduced costs due to the 2008 global financial crisis, contributing to the gig economy's expansion [10,11]. Gig workers, instead of being referred to as employees, are classified as contractors who are not dependent on their employers. This means they take care of taxes, insurance, medical care, and other benefits. While the gig economy offers flexibility for workers and cost-effectiveness for businesses, it has also raised concerns about job security, workers' rights, and the need for regulatory frameworks to ensure fair behaviour towards gig workers. The dynamics of the gig economy continue to evolve, influencing both the job market and discussions around labour policy and regulation. In certain aspects, these on-demand gigs prove advantageous for both workers and the economy, contributing to job expansion and supporting household incomes. These gigs typically offer flexible hours, minimal or no training expenses, and generally have low barriers to worker entry. These characteristics empower gig economy workers, even those with additional employment, to generate additional income or supplement their primary earnings, especially in challenging periods within a strained job market. Additionally, consumers availing themselves of on-demand services benefit from the convenience, accessibility, and often lower costs associated with these services [12]. Aligning with Adam Smith's concept of economic specialization, companies can opt for a model where tasks are assigned to different freelancers specializing in specific areas rather than hiring a generalist for all tasks. This approach promotes greater accountability among workers, as performance standards directly impact future income. The resulting boost in productivity growth generates rational exuberance, fostering increased confidence among consumers and businesses, leading to higher spending and investment, thereby creating more job opportunities, and resulting in higher per capita income [13]. Participation in the gig economy has seen diverse contributors, notably benefiting women's involvement in the workforce. For example, in the West Bank and Gaza region, over 3rd out of 15,000 users on the Souktel are women, while women constitute only 19% of the overall labour force in that area [14]. Online labour markets like Freelancer and Upwork are expected to serve as alternatives to traditional physical labour migration, resulting in increased job opportunities within digital platforms [15]. The shift in labour markets brought about by gig platforms, particularly the increased potential for outsourcing production and assigning responsibilities to workers, requires a reconfiguration of risks, protections, and liabilities in the value chain of production [16]. This restructuring may give rise to social dumping, pushing industries to increasingly rely on gig workers to cut the cost of operation and maintain competitiveness. The pressures for cost reduction, heightened by the financial crisis during 2008 and the recent economic decline owing to the pandemic due to COVID-19, elevate the social risk and ethical impacts on gig workers [17–19].

Due to the distinctive nature of gig work, it poses challenges to fitting into the existing laws of employment. The substantial flexibility inherent in gig work, coupled with the widespread geographic dispersion of workers on gig platforms, complicates the enforcement of existing labour laws, such as minimum wages, and makes

facilitating collective bargaining more challenging. Recommendations stemming from this perspective include suggesting the establishment of a specific law for labour [17] or introducing a specific division for gig workers with a constrained set of labour rights, like 'independent workers' [20] or 'dependent contractors' [21,22]. The crucial factors for the welfare of gig workers include effectively enforcing employment laws through regulatory measures and educating them about their rights [23]. To support dimensions of enforcement and education, platforms like the Turkopticon may be employed to empower gig workers through collective bargaining [24].

Expanding the range of employment law categories, selection tests, and protective measures to encompass gig work is recommended [18,20,21,25]. Rather than solely focusing on the extent of control exerted by an employer, the analysis should also consider the extent of the right of an employer to exercise control [17]. In the gig economy, many platforms exert control over various aspects, including work allocation, pricing, worker appearance, work quality supervision, and worker termination. This gives rise to triangular relationships that may necessitate a more distributed concept of employment, with shared responsibilities among the platform intermediary, gig workers, and end-users [10,22,23].

Another concern pertains is discrimination experienced by gig workers based on gender or race. Additionally, there is evidence of the maltreatment of gig workers in less developed countries where their pregig work is frequently outsourced [26]. On a positive note, outsourcing gig work can benefit the local economy by creating employment opportunities and offering better wages. Various international organizations have recognized the potential of the rapid growth of online labour platforms in low- and middle-income countries to increase employment and contribute to poverty reduction efforts [27–29]. Additionally, workers sometimes utilize digital labour platforms to access overseas markets that are less discriminatory or as an alternative means to access local markets, given that digital platforms can conceal characteristics likely to result in discrimination [30].

Nevertheless, the cost of communication and setup diminishes the advantages for workers in less developed countries [31]. Moreover, there exists a potential for wage convergence and racial discrimination, adding to the challenges [32]. Differences in bargaining power are evident among various groups of workers; in Southeast Asia, workers enjoy higher bargaining power due to increased demand compared to their Sub-Saharan African counterparts [26]. The outsourcing of gig work to jurisdictions with lower rights and wages also raises ethical concerns, often referred to as ethics dumping. As gig workers become increasingly detached from conventional work environments and professional affiliations, they confront challenges that are related to their well-being and social integration [33]. Many gig workers currently lack protection under employment law, including safeguards against unfair discrimination, primarily because they are frequently misclassified as non-employees.

The challenges arising from this shift underscore the need for reform, a sentiment reflected in various policy initiatives at both national and supranational levels. In 2019, the European Union commissioned the High-Level Expert Group (HLG) to regulate gig workers. To address this, they proposed a focus on building a skilled workforce to support digital work by certifying workers with a "Digital Skills Personal Learning Account". This approach aims to mitigate concerns related to the lock-in effect of

platform work, empowering workers to navigate the implicit algorithms guiding their tasks. In the gig economy, it is crucial to highlight occupational safety, mental health, and stress mitigation by updating labour laws to ensure equal treatment across standard and non-standard work arrangements. Additionally, it is imperative to address labour market social and economic polarization by establishing a "Digital Single Window" for managing employment contributions and taxes while redistributing the value of digital ownership.

While these proposals are coherent and reasonable, there are gaps in addressing certain ethical challenges. The increased use of algorithmic systems lacks caution and fails to emphasize safeguards for transparency and accountability. Discrimination, exclusion, and disconnectedness faced by gig workers, especially concerning race, gender, nationality/citizenship, and other personal characteristics, are undervalued. The predominant focus on mental health conditions, overlooking broader issues of discrimination and exclusion, is a concern. A comprehensive approach is necessary to safeguard the rights and well-being of gig workers. As the gig economy expands, it is essential to address the entire spectrum of ethical challenges it presents thoroughly. This comprehensive approach is crucial to ensuring that this evolving mode of work goes beyond mere tolerability, aspiring to become an ethically preferable development within the market economy that upholds principles of fairness and equity. In this context, the gig economy should not only offer flexible labour but also strive to provide labour that is both flexible and ethically preferable.

3. Analysis

The emergence and growth of the gig economy have prompted a comprehensive analysis of its various facets, ranging from economic implications to social and ethical considerations. This analysis seeks to delve deeper into key aspects, providing insights into the impact and challenges associated with the gig economy.

The gig economy contributes to job expansion, providing opportunities for income generation, especially in challenging economic periods. The flexibility it offers benefits workers seeking supplemental income. However, the gig economy's reliance on short-term, contractual labour may contribute to job insecurity and challenges in ensuring stable income for gig workers. Gig platforms allow for economic specialization, enabling companies to leverage the expertise of freelancers in specific areas. This can lead to productivity growth and increased job opportunities. The restructuring of labour markets may result in social and ethical dumping, where gig workers bear the brunt of cost-cutting pressures, especially during economic downturns. Adapting regulatory frameworks can facilitate the coexistence of traditional and gig employment models, promoting flexibility in the workforce. Enforcing existing employment laws, such as minimum wages and collective bargaining, poses challenges due to the dispersed nature of gig workers and the unique characteristics of gig work. Positive Aspects: The gig economy has the potential to empower underrepresented groups, including women, by providing opportunities for participation and income generation. Discrimination based on gender, race, or nationality may persist, highlighting the need for measures to ensure equal opportunities and fair treatment. Outsourcing gig work to low-income countries can

contribute to poverty reduction and employment opportunities. “Ethics dumping” raises ethical concerns, as companies may exploit lower rights and wages in certain jurisdictions. Gig workers may face challenges in terms of well-being and social integration. Policy initiatives, such as those proposed by the European Union, aim to regulate gig work, protect workers’ rights, and ensure fair treatment. The effectiveness of these policies relies on achieving a delicate balance between encouraging innovation and flexibility while safeguarding the rights and well-being of gig workers. Technology enhances efficiency in gig work by facilitating better matchmaking between workers and jobs. Lack of transparency in algorithmic systems used by gig platforms may lead to biased decision-making and challenges related to accountability.

In summary, the analysis underscores the need for a nuanced approach to navigating the gig economy. While recognizing its potential benefits in terms of flexibility, job opportunities, and economic empowerment, addressing concerns such as job insecurity, discrimination, and ethical considerations is crucial. Striking a balance between innovation, flexibility, and ethical considerations is imperative to ensure the gig economy evolves into a sustainable and equitable mode of work.

4. Practical implications

The proliferation of the gig economy brings forth a myriad of practical implications that span across various stakeholders, including workers, businesses, policymakers, and society at large. Understanding and addressing these implications is essential for effectively navigating the evolving landscape of work. Gig work provides individuals with the flexibility to choose their working hours, locations, and the types of tasks they undertake. This can be advantageous for those seeking to balance work with other commitments, such as education or caregiving responsibilities. However, the same flexibility may lead to challenges such as income instability and a lack of access to traditional employment benefits like health insurance and retirement plans. Companies can benefit from the cost-effectiveness of gig work, as they can engage freelancers for specific tasks without the overhead costs associated with full-time employees. The reliance on gig workers may pose challenges in maintaining a cohesive company culture, and businesses may face reputational risks if not perceived as treating gig workers fairly.

Gig work introduces opportunities for labour market expansion and entrepreneurship. Adapting regulatory frameworks can facilitate the coexistence of traditional and gig employment models. Existing labour laws may struggle to adequately address the unique nature of gig work, leading to difficulties in enforcing protections such as minimum wages and collective bargaining rights.

The gig economy can empower underrepresented groups, including women, in regions where they face workforce challenges. Online platforms may offer new opportunities for participation and income generation. Discrimination based on gender, race, or nationality can persist in gig work, and ensuring equal opportunities and fair treatment remains a critical challenge.

Outsourcing gig work to low-income countries can create employment opportunities and contribute to poverty reduction. The practice of “ethics dumping”, where companies exploit lower rights and wages in certain jurisdictions, raises ethical

concerns. Gig workers may face challenges related to well-being and social integration. Policy initiatives, such as those proposed by the European Union, aim to regulate gig work, protect workers' rights, and ensure fair treatment. Implementing effective policies requires a delicate balance to encourage innovation and flexibility while safeguarding the well-being and rights of gig workers. Embracing technology can enhance efficiency and matchmaking between gig workers and jobs. Lack of transparency in algorithmic systems used by gig platforms may lead to issues such as biased decision-making and lack of accountability, necessitating a focus on transparency and fairness.

The practical implications of the gig economy are diverse and multifaceted, requiring a nuanced approach from various stakeholders to harness the benefits while addressing the challenges. Policymakers, businesses, and workers need to collaboratively navigate this evolving landscape to create a sustainable and equitable future of work.

5. Conclusion

In conclusion, the study provides a comprehensive exploration of the gig economy, unraveling its multifaceted impact on the global workforce, businesses, and societal structures. While recognizing the potential benefits associated with flexibility, job expansion, and economic empowerment, the study also highlights critical challenges and ethical considerations that demand thoughtful attention. The gig economy's transformative force in reshaping traditional employment structures is evident, driven by digital innovations and the evolving preferences of both workers and businesses. However, the implications are not unilaterally positive, as the flexibility provided to gig workers coexists with concerns over job security, the absence of traditional employment benefits, and the potential for exploitation in the form of social and ethical dumping. Legal and regulatory frameworks, designed for a different era of work, face challenges in adapting to the distinctive characteristics of gig employment. The study underscores the need for nuanced approaches, such as the establishment of specialized labour laws or the creation of new gig worker categories, to ensure the protection of workers' rights and fair treatment. Ethical considerations loom large in the gig economy, with issues of discrimination, especially based on gender and race, taking centre stage. The study acknowledges the positive potential of outsourcing gig work to low-income countries but emphasizes the ethical imperative of avoiding "ethics dumping" and safeguarding the well-being and integration of gig workers into the broader workforce. Policy initiatives, exemplified by the European Union's efforts, demonstrate a recognition of the need for regulation. However, the study highlights the importance of balancing innovation with safeguards for workers, advocating for comprehensive measures that address algorithmic transparency, discrimination, and the broader spectrum of gig workers' well-being. The temporal and geographical limitations of the study are acknowledged, and it calls for ongoing research to keep pace with the dynamic nature of the gig economy. The evolving role of technology, coupled with the intersectionality of social and cultural factors, demands continuous examination to inform policies and practices that uphold fairness, equity, and the well-being of gig workers. In essence, the gig economy represents a

paradigm shift in the world of work, demanding a delicate balance between flexibility and ethical considerations. As the gig economy continues to expand, the study concludes with a call to action—a collective endeavour to shape its trajectory into an ethically preferable development within the market economy, one that upholds principles of fairness, equity, and the holistic well-being of all those engaged in this evolving mode of work.

6. Limitations of the study

While this analysis aims to provide a comprehensive understanding of the gig economy and its implications, it is essential to acknowledge the inherent limitations of the study. These limitations may impact the generalizability and depth of the findings, and they include: Temporal Constraints: The gig economy is a rapidly evolving phenomenon influenced by technological advancements, economic shifts, and societal changes. The study's findings may be limited by the temporal context, as developments in the gig economy may have occurred since the last available data.

Geographical Scope: The study may have a specific focus on certain regions or countries, potentially limiting the generalizability of findings to a global context. The gig economy experiences variations in its impact and challenges across different regions with distinct economic, cultural, and regulatory landscapes.

Data Sources and Bias: The analysis heavily relies on existing literature, research studies, and policy documents. The limitations of these sources, including potential biases, inaccuracies, or omissions, could impact the comprehensiveness and accuracy of the study.

Varied Definitions of Gig Work: Different studies and regions may use varied definitions and classifications for gig work, freelance, and independent contracting. This lack of uniformity in terminology could lead to variations in the interpretation of findings and comparability across studies.

Diversity of Gig Workers: The gig economy encompasses a diverse range of workers engaged in various types of work, from freelance writing to ride-sharing. The study might not capture the nuanced experiences and challenges specific to different sectors or occupations within the gig economy.

Limited Stakeholder Perspectives: The perspectives considered in the study may be predominantly from the viewpoint of workers, policymakers, and researchers. The inclusion of perspectives from businesses, gig platform operators, and consumers could provide a more holistic understanding of the gig economy.

Unexplored Social and Cultural Factors: Social and cultural factors play a significant role in shaping the dynamics of the gig economy. The study might not thoroughly explore how societal norms, values, and cultural contexts influence gig work and its implications.

Dynamic Nature of Technology: The study may not fully capture the continuous evolution of technology, including advancements in gig platforms, algorithmic systems, and their impact on the nature of gig work. Technological developments could introduce new dynamics not covered in the study.

Limited Longitudinal Perspective: The study's focus on the current state of the gig economy may limit its ability to provide insights into long-term trends, changes, or adaptations in response to challenges over an extended period.

Unexplored Intersectionality: The study may not thoroughly explore how factors such as gender, race, age, or socioeconomic status intersect with gig work experiences. An intersectional analysis could reveal nuanced challenges faced by specific demographic groups. Acknowledging these limitations is crucial for interpreting the findings in a context-aware manner. Future research endeavours may address these limitations to further refine our understanding of the gig economy and its multifaceted implications.

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Article

Artificial intelligence for SDG 4 of the 2030 agenda: Transforming education to achieve quality, equality, and inclusion

Eucidio Pimenta Arruda*, Durcelina Pimenta Arruda*

Faculty of Education, Federal University of Minas Gerais, Belo Horizonte 31270-180, Brazil
*** Corresponding authors:** Eucidio Pimenta Arruda, eucidio@ufmg.br; Durcelina Pimenta Arruda, durcelina@gmail.com

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Abstract: The objective of this article is to discuss the possibility of using generative artificial intelligence (AI) to enhance teaching practices and pedagogical support to improve the quality of education provided to young people in elementary and secondary schooling. This issue is linked to the global perspective of a shortage of teachers, which directly affects Sustainable Development Goal 4 (SDG 4), concerning the enhancement of education quality as a target for global sustainable development. From this viewpoint, the potential use of AI may also relate to the improvement of educational quality and the reduction of social inequalities, yielding indirect effects on other sustainable development goals. As a method, we intend to conduct an extensive theoretical discussion addressing the challenges for teacher education and work worldwide, utilizing existing data from databases such as UNESCO, the UN, and the OECD, among others. In addition to data on teachers, we plan to analyze the potential for creating artificial intelligence based on existing ones but trained for the specific contexts of each country's educational system. The goal is to examine the potential for formatting artificial intelligence to provide pedagogical support for teachers, such as: grading of objective and discursive assessments; individualized intelligent tutoring; analysis of students' individual pedagogical development; preparation of individual student diagnoses; suggestions of specific pedagogical actions based on curricula and materials used; and all other pedagogical actions that support teachers in their educational journey. This work was funded by CAPES, CNPq, and FAPEMIG.

Keywords: artificial intelligence; education; sustainable development goal 4; teacher shortages; world

1. Introduction

The issue of teacher shortages is nothing new in academic discussions, at least in the last decade. Every year, UNESCO presents data showing that there is a global shortage of teachers, with a particular overload in poor countries located in sub-Saharan Africa and South Asia.

According to data from UNESCO [1], there is a shortage of more than forty-four million teachers worldwide if the need to universalise basic education by 2030 is to be met.

Lack of interest in the teaching profession and other factors have contributed to the shortage of these professionals. Since 2002, UNESCO has pointed to the need for long-term policies and improvements in teachers' working conditions and pay to tackle this challenge.

The explanations for the lack of teachers must be addressed and analysed in depth, considering not only salary aspects, but also effective working conditions, the available infrastructure, and the particularities inherent in teaching young people.

Data from Brazil shows that a teacher earns half the lowest salary offered to other professional categories with the same qualifications. According to UNESCO [1], only one in two countries pays primary school teachers as much or more than other professions requiring a similar level of qualifications. Europe and North America account for only three of the ten countries where the phenomenon is most prevalent. Many high-income nations pay upper secondary teachers seventy-five percent or less than they would in other occupations that are similar.

Although the problem is complex, there is a search for different solutions that have not yet found fully successful paths. It is worth emphasising that the lack of teachers has a direct impact on the United Nations' (UN) Sustainable Development Goal 4. It also has an impact on Goal 10, which is about reducing inequalities, because the failure to universalise basic education is directly related to countries' difficulties in generating wealth from the production of knowledge, as well as reducing the gap between those who earn more and those who earn less, thus increasing a country's socio-economic inequalities.

In general, it can be said that the improvement of SDG 4 enhances the achievement of all other sustainable development goals, since the quality of education involves increased productivity, social justice, equality, clean energy, and/or economic growth. Therefore, the focus on SDG 4 allows us to weave a global and interconnected reach for the remaining sustainable development goals [2].

The SDG 4 is a significant component of contemporary society capable of influencing all other social aspects [3]. For example, to eliminate unemployment, a skilled workforce is necessary, which is achievable through education. Moreover, to attain gender equality in all areas, the education of women is crucial so that they can acquire the same skills as men and have the same rights. SDG 4 aims to address all global issues that are directly or indirectly related to education and can be addressed through effective education for global citizens.

As a way of tackling the challenge related to teacher shortages and the quality of education, in the US context, Podolski [4] proposes measures such as increasing teacher salaries, greater social support from the federal government, and restructuring teachers' careers.

In his examination of the Brazilian context, André [5] identifies parallel challenges faced by educators. He asserts that, beyond the augmentation of salaries and the reformation of career structures, it is imperative to establish supportive policies focused on the induction and professional development of novice teachers. Such policies should not only bolster formal relationships but also fortify the teaching profession, ensuring that educators are well-prepared, connected, and empowered within their roles.

Cudowska [6] reached the same results in a wide-ranging study comparing several European countries. Low salaries, young people dropping out of training courses or the first few years of teaching, poor infrastructure conditions, and unattractive careers are among the findings of this comparative study. These results are remarkably close to those obtained by Ladd [7] when he analysed the situation in developed countries 16 years earlier.

According to UNESCO [8], among the strategies proposed to improve teaching conditions are the development of gender-sensitive policies to attract qualified

teaching candidates, the review and improvement of the quality of teacher training (both initial and continuing), and the development of a qualifications framework for teachers.

It is crucial to acknowledge that the successful implementation of Goal 4, which focuses on education and sustainable development, hinges directly or indirectly on the presence of a sufficient number of qualified teachers. This is because key objectives, such as the universalization of education, ensuring foundational knowledge in mathematics, achieving gender equality, and acquiring the essential knowledge to fulfil all other sustainable development goals, are linked to having a populace that has attained at least basic levels of educational development. Therefore, to turn these ambitions into reality, a robust and well-supported teaching workforce is fundamental.

And because this is a problem that has become chronic worldwide, there is no prospect of it being resolved in the short term. This is not only because of the difficulties observed but also because social challenges tend to increase as school education fails in society. When considering the sustainability goals proposed for 2030, it can be inferred that educational difficulties may make all the other goals unlikely to be achieved, since the level of education is an element strongly related to the population's adherence to sustainability policies.

Based on these gaps, we propose to analyse the possibilities for transformations in teachers' work, in the sense of incorporating artificial intelligence in a way that creates pedagogical support situations in their activities.

Hence, the focus should not be on the concept of creating "robot teachers," but rather on exploring how generative artificial intelligence (AI) can bolster the efficacy of educators. The aim is to provide support that allows teachers to enhance their professional performance, enabling them to streamline their workload and alleviate the pressures of their roles.

This is particularly vital in contexts where educators are overwhelmed by high student-to-teacher ratios due to teacher shortages. Generative AI offers a pathway to optimizing educational delivery, ensuring teachers can focus more on quality teaching and less on the burdens of overextended responsibilities.

We believe that the use of artificial intelligence as pedagogical support can reconfigure teaching work and create the conditions to reduce the impact of teacher shortages.

2. Method

The method used in this article is content analysis and the construction of a theoretical essay on the possibilities of artificial intelligence being incorporated into countries' educational policies to allow teaching activities to receive pedagogical and administrative support in the management of data and students.

From a methodological point of view, we conducted extensive research into the conditions of teacher shortages as well as references that propose to present the possibilities of artificial intelligence as an element of didactic-administrative support for teachers.

From a conceptual point of view, we consider artificial intelligence to be generative content creation models that help teachers provide didactic and

administrative support to their students. By didactic support, we mean help in preparing teaching materials, monitoring student learning, detecting learning difficulties, or creating strategies to reduce student difficulties. From an administrative point of view, we consider creating databases on students that allow for performance analyses, organising learning difficulties, organising school documents, personal and social information, and broad data analyses on classes.

3. Discussion and theoretical framework

In one of the classic books that deals conceptually with Artificial Intelligence (AI), Ertel [9] presents us with the dimensions and dilemmas of this technology, especially with regard to what is potentially being built around artificial intelligence, from the perspective of it being able to fulfil human actions that we are even better at, and from the perspective of programming adaptability, from which intelligent systems self-develop from the perspective of better developing the activities for which they were built.

Artificial intelligence involves dimensions based on algorithms and programming and ethical issues of the utmost importance to humanity, especially regarding machine decisions that directly impact life, health, social coexistence, and state structures.

Recent technological transformations, including the possibility of using generative artificial intelligence (GAI), have sparked discussions about the prospect of AI in teaching practices and problematise changes that may occur in the educational environment [10]. These changes concern the ways in which students begin to produce their educational content, as well as the ways in which teachers can conduct pedagogical activities with the support of AI.

According to Yu and Lu [11], the field of scientific management has witnessed the advantages of artificial intelligence and big data technologies. These advantages can also be applied to educational management. Monitoring the educational and academic process as well as quality dynamically can leverage the organisation, integration, recording, and development of intelligent systems for data mining and deep learning. It is also a technically reliable approach to managing academic and administrative matters in education.

Farrokhnia [12], in turn, states that AI can enable more efficient interactions between students and teachers, changing the way we research and create content. However, it must be considered that the concept of efficiency and interaction needs to be problematised, since we do not yet have concrete elements that allow us to make analyses about the strengthening of relationships between teachers and students mediated by artificial intelligence.

These competences not only lead to changes in the way teachers relate to technology but also open the door to broader changes in the educational context, relating to the assessment of learning, the development of intelligent tutoring, and adaptive teaching [13,14].

4. Research limitations

This research is theoretical, limiting the results of its analyses. In addition, it is noted that the theme of artificial intelligence is extremely recent, which makes the number of academic productions to support the arguments presented scarcer.

In addition, it is necessary, in a continuity of discussions, to promote greater dialogue between SDG 4 and the other SDGs and to analyze data that allows us to better understand the relationships between them, especially based on demonstrated empirical results.

5. Results

As highlighted by Edwards and Cheok [15], integrating AI into educational practices does not equate to creating "robot teachers." Instead, these authors envision a scenario where educators can orchestrate and manage teaching activities characteristic of human instructors without necessarily being physically present.

They delve into the current utilization of robots within educational settings, serving as classroom aides, components of educational technology, and supports for teaching. The discussion extends to how, with the advancement of AI, robotics, and machine learning, robots could potentially outperform human teachers in specific areas such as expertise in subject matter and cost-effectiveness in maintenance. This perspective suggests a future where AI could complement or enhance the educational process, providing innovative solutions to the challenges faced by traditional teaching methods.

However, Edwards and Cheok [15] recognise that there are significant challenges to implementing robot teachers. These include the need for skills such as emotional intelligence, creativity, and communication, which are inherent characteristics of human teachers. In addition, the authors emphasise the need to consider social and demographic factors, such as culture and religion, when developing AI systems for education.

One of the strongest elements to consider is respect for the authority that the teacher exercises in the classroom. It is extremely easy to switch off an automated environment; you just press a button. This is different from the interaction between human students and teachers, as social, cultural, and authority relations discourage simple absence from the educational environment.

Celik et al. [16] state that AI offers teachers many opportunities to improve the planning, implementation, and evaluation of their teaching. In addition, teachers play various roles in the development of AI technology, acting as models for training AI algorithms and participating in AI development by checking the accuracy of automated AI assessment systems.

The role of the teacher as AI "trainer" is perhaps the one that generates the most discomfort because, as stated above, the lack of transparency about the codes and programmes, as well as the intentions of the large companies supplying AI, makes it unclear that the work of teachers is not being appropriated by the machines for a future situation of assimilation and teacher replacement, despite all the problems that such an action would incur.

However, political choices are not always based on scientific production, which is why these concerns are solid enough to be considered a risk to work, practices, and teaching itself in formal school contexts.

Although it is not a mathematical formula that contains a directly proportional relationship, numerous studies have shown that an increase in a country's educational levels makes it possible to reduce economic inequality, above all because better educational indices make it possible to obtain higher-paying jobs, as well as expanding the possibilities for a country's scientific and economic development [17–19].

When we look at the sustainability targets and indicators proposed for 2030, we realise that we are already just under six years away from meeting indicators that are still a long way from reality. It should be borne in mind that targets and commitments do not mean full fulfilment, but they are built collectively from a perspective that is the best possible reality for human improvement.

In the context of a shortage of millions of teachers, as we noted earlier, there will hardly be enough time to train so many teachers to guarantee universal access to primary and secondary education. This is because it takes a minimum of between three and six years, depending on the legislation of each country, for a teacher to be fully trained for primary and secondary education.

The data shows, however, that fewer and fewer young people want to become teachers, and those who enroll in courses drop out within the first few years, as noted above. Brazilian data from Inep [20] shows that even in areas where there are far more trained teachers than jobs, many choose not to work as teachers.

Gašević et al. [21] explore the ways in which we can enhance learning with the support of artificial intelligence. For the authors, the explainability of AI, educational assessment, and design help teachers better fulfil their teaching activities.

However, beyond these issues, which are presented as the most immediate answers to the educational gaps, we need to build paths that allow us to include artificial intelligence as an element that will minimise or allow an improvement in educational performance while countries fail to solve the shortage of teachers.

It is therefore not the best situation in which we should think of education as an element for reducing inequalities, but what is most readily available to us to reduce the development time of the poorest countries when compared to rich countries. The longer it takes to provide educational access, the greater social and economic inequalities become in local and international contexts.

6. Conclusions

Generative artificial intelligence software is still in the first wave of innovation, in the process of being perfected and learned. However, the results of using AI to produce texts, videos, and images are already impressive and are likely to become even better in terms of accurate responses in a short space of time.

This gives us important clues about the future that is opening for education and the construction of machine learning models that work to alleviate the shortage of teachers in countries—without, however, replacing them. This is a perspective in which A.I. becomes a source of teaching support for repetitive activities, for contexts

with too many students, and for individualised analyses that allow teachers to make pedagogical decisions that improve student performance.

What is more, we need to consider that this is not just a technical use of artificial intelligence in teaching. It is a cycle of transformation in teaching work, yet unmeasured, that will bring different actions and activities to teachers in their daily school lives.

In addition to the teaching activities previously learned in training courses, new activities emerge, such as learning how to use educational data generated by A.I. to improve school performance, how to develop individualised student monitoring based on the learning feedback provided by A.I., or even incorporating new teacher-student interaction strategies in contexts in which A.I. develops certain pedagogical interventions and frees up the teacher for other work, such as more in-depth analysis of a specific student's learning difficulties or collective difficulties with certain content.

The integration of artificial intelligence (AI) in education presents transformative potential to meet the United Nations' Sustainable Development Goals (SDGs) for 2030. AI has the potential to enhance educational accessibility for disadvantaged populations or those in remote areas. This can help reduce educational inequalities and promote gender equality in education, aligning with other sustainable development goals such as reduced inequalities (SDG 10) and gender equality (SDG 5).

Furthermore, AI systems can provide valuable insights from large educational datasets, enabling policymakers to make informed decisions to improve the quality and efficacy of educational systems. This can contribute to the construction of resilient and sustainable educational infrastructure, aligning with the goal of sustainable cities and communities (SDG 11).

By equipping students with skills in emerging technologies, AI-supported education can prepare the workforce for future challenges, promoting sustainable economic growth (SDG 8) and innovation and industrial infrastructure (SDG 9).

Therefore, we see an open future in which the use of artificial intelligence to help achieve SDG 4 could lead to improvements across all other goals through a positive dialogue in which the education provided to all becomes the best path to sustainable development.

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Article

A study of the impact of regional O2O teaching quality on the digital transformation of listed companies

Xuanming Zhang, Lingjie Tian, Zijun Liu, Yuhan Huang, Zifan Gong, Bangjun Wang*

School of Economics and Management, China University of Mining and Technology, Xuzhou 221116, Jiangsu, China
*** Corresponding author:** Bangjun Wang, wxczxm20020706@163.com

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Abstract: With the acceleration of global digital transformation, listed companies urgently need to adapt to this trend in order to enhance competitiveness and achieve sustainable development. Focusing on the data of listed companies in China over the period from 2010 to 2022, this study examines the role of regional O2O teaching quality in the process of corporate digital transformation and its influence mechanisms. It is found that regional O2O teaching quality has a significant facilitating effect on the digital transformation of listed companies, and this effect is more pronounced in companies with larger financing constraints, larger firm sizes, and less institutional attention. In addition, regional O2O teaching quality further accelerates the digitalization process of enterprises by enhancing the management's foresight and innovation awareness. High-quality O2O teaching not only enhances employee skills and innovation but also facilitates management's ability to make longer-term planning and decisions in the face of a rapidly changing market environment, laying a solid foundation of talent and technology for an enterprise's digital transformation. These findings provide new perspectives on how listed companies can utilize regional educational resources to promote digital transformation and provide practical guidance for the development of related digital strategies.

Keywords: O2O teaching quality; digital transformation; management myopia; financing constraints

1. Introduction

In a globalized and technology-driven economic environment, the digital transformation of listed companies has become the key to achieving competitive advantage and sustained growth [1–3]. Digital transformation involves not only adopting new technologies to improve decision-making and operational efficiency but also enhancing the customer experience through personalized services and market segmentation to gain a leading position in the market [4]. Successful implementation of this transformation not only optimizes resource allocation and improves operational efficiency but also enables firms to demonstrate greater agility and efficiency in the face of market volatility and changing consumer demands [5,6].

The quality of regional O2O (online-to-offline) teaching plays a crucial role in this transformation process. High-quality O2O teaching can effectively enhance employees' digital skills and innovation capabilities, providing the necessary talent support for the digital transformation of organizations. By integrating online and offline teaching modes, O2O teaching not only improves the efficiency and quality of teaching but also provides employees with a flexible and diverse learning experience, which is conducive to the rapid enhancement of employees' skills and the timely updating of their knowledge.

Although regional O2O teaching plays an important role in promoting the digital transformation of listed companies, the mechanism of its influence has not been sufficiently explored in academia. To fill this research gap, this study empirically examines the effect of regional O2O teaching quality on corporate digital transformation using data from listed companies in China from 2010 to 2022. It is found that regional O2O teaching quality has a significant positive effect on the digital transformation of listed companies, especially among companies with greater resource constraints and less external attention.

The contribution of this study is to provide a new perspective and empirical support for the necessity and urgency of the digital transformation of listed companies. Through an in-depth analysis of the mechanism of the role of regional O2O teaching quality, this study emphasizes the importance of high-quality teaching for the implementation of corporate digital strategies. In addition, this study reveals the differences in the impact of regional O2O teaching quality in different enterprise environments, which provides a reference for enterprises to develop effective digital transformation strategies according to their own characteristics [7–9].

In summary, this study not only expands the understanding of the impact of regional O2O teaching quality on enterprise digital transformation but also provides theoretical and empirical support for listed companies to formulate effective digital strategies and provides valuable references for enterprises to maintain their competitive advantages in the rapidly changing market environment.

2. Mechanisms and hypotheses

2.1. Regional O2O teaching quality and digital transformation

The facilitating effect of regional O2O teaching quality on enterprise digital transformation can be understood from two perspectives, namely, enhancing talent cultivation efficiency and strengthening organizational innovation atmosphere.

First of all, from the perspective of talent cultivation efficiency, regional O2O teaching quality provides more flexible and diverse learning methods for enterprise employees through the combination of online and offline teaching modes. This teaching mode can effectively adapt to the learning habits and needs of different employees and enhance the relevance and effectiveness of learning. As described by Kim [10], high-quality O2O teaching can promote the rapid dissemination and absorption of knowledge and skills, help employees quickly master the key skills needed for digital transformation, and thus improve the efficiency of the entire enterprise in resource allocation and utilization.

Second, from the perspective of organizational innovation climate, the spirit of collaboration and interaction emphasized in the quality of regional O2O teaching builds a positive and open learning culture for enterprises [11]. Under the influence of this culture, the enterprise encourages knowledge sharing and teamwork among employees, creating a work environment conducive to innovation. This not only enhances the innovation ability and motivation of employees but also provides a constant impetus for technological innovation and solution development in the process of digital transformation. At the same time, high-quality O2O teaching also focuses on cultivating employees' critical thinking and problem-solving skills, which are

particularly important when enterprises deal with the various challenges encountered in the process of digital transformation.

In summary, the quality of regional O2O teaching provides strong support for the digital transformation of enterprises by enhancing the efficiency of talent training and strengthening the innovation atmosphere within the organization. This not only helps enterprises to utilize and allocate resources more effectively but also provides a solid foundation for them to maintain their competitiveness and innovation in the rapidly changing market environment.

In summary, this paper proposes hypothesis 1: Regional O2O teaching quality promotes the digital transformation of enterprises.

2.2. Mediating effect of management myopia on regional O2O teaching quality affecting digital transformation

Regional O2O teaching quality effectively inhibits the shortsightedness of enterprise management through the values of continuous learning, innovative thinking, and long-term planning it advocates, thus facilitating the digital transformation of enterprises. First, the flexibility and interactivity of regional O2O teaching provide a platform for continuous learning for enterprise employees, making knowledge updating and skill enhancement possible, which directly enhances the ability of enterprises to cope with digital challenges. Second, the O2O teaching model encourages innovative thinking and cross-border cooperation, which brings new solutions and business models to enterprises, which is crucial for their innovative development in the process of digital transformation. Finally, the long-term planning and ethics emphasized by the regional O2O teaching quality prompt the management of enterprises to consider a wider range of stakeholders and long-term impacts when making key decisions, thus avoiding decisions that merely pursue short-term benefits and laying a solid foundation for sustainable development and digital transformation. In summary, regional O2O teaching quality effectively inhibits management's short-termism through these mechanisms and provides support and facilitation for the digital transformation of enterprises.

Therefore, this paper proposes the hypothesis that regional O2O teaching quality inhibits management shortsightedness through inhibiting management shortsightedness and then facilitates the digital transformation of enterprises.

3. Model construction and data description

3.1. Model construction

According to the research setting of this paper, Equation (1) is constructed to examine the impact of regional O2O teaching quality on digital transformation:

$$\mathrm{DIG}_{i,t} = \alpha_0 + \alpha_1 \mathrm{O2O\ Teaching\ Quality}_{i,t} + \sum \mathrm{Controls}_{i,t} + \mathrm{Year} + id + \varepsilon_{i,t} \quad (1)$$

In Equation (1), *i* denotes the firm, *t* denotes the year, $\mathrm{DIG}_{i,t}$ represents the firm's level of digital transformation in year *t*, and $\mathrm{O2O\ Teaching\ Quality}_{i,t}$ denotes the firm's level of regional O2O teaching quality within the same year, as measured by the two variables and jointly. In addition, $\sum \mathrm{Controls}_{i,t}$ is a control variable, year and

id are year and individual fixed effects, and $\varepsilon_{i,t}$ is a random error term.

To further test the mediating effect of managerial myopia, this paper constructs Equations (2) and (3):

$$\text{Myopia}_{i,t} = \alpha_0 + \alpha_1 \text{O2O Teaching Quality}_{i,t} + \sum \text{Controls}_{i,t} + \text{Year} + id + \varepsilon_{i,t} \quad (2)$$

$$\text{DIG}_{i,t} = \alpha_0 + \alpha_1 \text{Myopia}_{i,t} + \sum \text{Controls}_{i,t} + \text{Year} + id + \varepsilon_{i,t} \quad (3)$$

where $\text{Myopia}_{i,t}$ represents the level of management myopia, Equation (2) aims to analyze how regional O2O teaching quality slows down the myopic behavior of corporate management and thus has an impact on corporate long-term strategic decisions, while Equation (3) is used to assess the strength of the impact of management myopia on corporate digital transformation. These two models allow for a more in-depth exploration of the indirect impact mechanism of regional O2O teaching quality on firms' digital transformation, i.e., facilitating firms' long-term technological innovation and digitization processes by changing management's myopic behavior.

3.2. Description of variables and data sources

3.2.1. Explained variables

Digital transformation (DIG): the metric of enterprise digital transformation (DIG) draws on and integrates the approaches of Wu et al. [12] and Zhao et al. [13] in order to achieve a comprehensive and precise quantification of the extent of enterprise digital transformation. Specifically, Wu et al.'s [12] approach involves five key dimensions, including artificial intelligence, big data, cloud computing, blockchain, and digital technology applications, and contains 76 relevant keywords. The core of the method is to comprehensively capture the activities and developments of enterprises in these key technology areas through extensive word frequency analysis so as to comprehensively assess the depth and breadth of enterprises' digital transformation. In contrast, Zhao et al.'s [13] approach focuses on four dimensions, namely digital technology application, Internet business models, smart manufacturing, and modern information systems, covering 99 digitization-related terms, and aims to assess enterprises' efforts in adopting emerging digital technologies, developing new business models, and transforming traditional manufacturing and information systems.

This study defines the degree of digital transformation (DIG) of firms in the data analysis phase mainly based on Wu et al.'s [12] methodology, based on the comprehensive and broad nature of their approach. In order to increase the robustness of the study, this paper employs Zhao et al.'s [13] method (DIG2) as a proxy variable in the robustness checking stage to further validate the stability and reliability of the results of this study. Through the application of this dual methodology, this study not only ensures a comprehensive and accurate assessment of the extent of digital transformation in enterprises but also enhances the robustness and reliability of the findings.

3.2.2. Explanatory variables

Regional O2O teaching quality (Confucian): the article designs the questionnaire with four dimensions: teaching behavior, teaching cognition, knowledge construction, and external environment, and uses the entropy method to construct personal O2O teaching quality. Referring to Du's study [14], the strength of regional O2O teaching quality is measured using the mean values of individual O2O teaching quality within a 200 km (r_200) and 300 km (r_300) radius of the company's registered location. The advantage of this measure is that it not only takes into account the distribution density of regional O2O teaching quality in a certain area but can also more accurately reflect the popularity and influence of regional O2O teaching in the location of the company.

3.2.3. remaining variables

Mechanism variables

Management myopia (Myopia): this study draws on Hu et al.'s [15] methodology to measure management myopia through quantitative analysis. Specifically, we constructed a word frequency analysis framework based on 43 words related to short-term horizons. These words are considered to be effective in reflecting management's short-term focus when writing management discussion and analysis (MD&A) reports. The index is calculated by taking the percentage of these short-term horizon words in the total word frequency of MD&A and multiplying it by 100 to obtain a quantitative index of management short-termism.

Control variables

To ensure that this study can reduce the interference of other variables and decrease the bias of the estimation results when exploring the relationship between regional O2O teaching quality and firms' digital transformation, we meticulously selected a series of key control variables. First, firm size (size) serves as an important control variable that reflects a firm's market influence and resource allocation capacity, which may have a significant impact on a firm's ability and willingness to undergo digital transformation. Second, capital structure (Lev), as an indicator of a firm's financial stability and risk tolerance, has an indirect impact on a firm's decision to make digital investments. In addition, the net rate of return on total assets (ROA), as a key indicator of a firm's profitability, can reflect the operational efficiency and profitability level of a firm, thus having an impact on a firm's ability to invest in digital transformation. Meanwhile, corporate growth (growth) is also included as a control variable, which reveals the growth potential and market expansion capability of a company and is an important guide to the urgency and likelihood of a company to undergo digital transformation. Finally, board structure, including the number of directors (Board) and the proportion of independent directors (Indep), as a reflection of the diversity and independence of corporate decision-making, has an important impact on the strategic direction and execution of corporate digital transformation. With these comprehensively considered control variables, this study aims to provide a more accurate and comprehensive analysis to explore in depth the actual impact of regional O2O teaching quality on enterprise digital transformation and to ensure the reliability and validity of the findings.

3.3. Data sources and descriptive statistics of variables

In this paper, the conceptual stocks in China's Shanghai and Shenzhen markets from 2010 to 2022 are selected as research objects. Among them, the financial and regional O2O teaching quality data come from the WIND and CSMAR databases. In terms of data processing, we took the following measures: (1) ensure that companies meet the statistical standards of national industries; (2) ensure the completeness of the concepts and their representativeness; (3) exclude ST-marked companies; (4) disregard companies in the year of the IPO and those observations with incomplete data; and (5) trim the continuous data before and after 1% to reduce the bias of the extreme values on the results. After screening, we obtain unbalanced panel data covering 63 firms with a total of 723 data points.

Table 1 shows the descriptive statistics for the key variables. For the dependent variable, firms' digital transformation (DIG), the data show a mean of 2.490 and a standard deviation of 1.155, ranging from 0 to 5.366, reflecting the variability and imbalance of the industry in terms of digital transformation. This result suggests that despite the obvious digitalization efforts within the industry, there are still significant differences in the degree of transformation and maturity. Regarding the intensity of regional O2O teaching quality, the mean values of the two indicators are 2.647 and 3.272, with standard deviations of 0.471 and 0.455, respectively, demonstrating the prevalence and stability of regional O2O teaching quality in the selected sample. This finding implies the intensity and prevalence of regional O2O teaching quality on different geographical scales, providing an empirical basis for further exploring its potential impact on digital transformation. In terms of control variables, the statistics on the variables of firm size (Size), capital structure (Lev), net rate of return on total assets (ROA), firm growth (Growth), and board structure (Board and Indep) reveal the plurality and complexity of the firms in the sample. In particular, the large standard deviations of firm size and capital structure point to differences in resource allocation and financial strategies across firms. These differences may have a significant impact on firms' digital transformation strategies and capabilities.

Table 1. Results of descriptive statistics.

Variable	*N*	Mean	SD	Min	Max
DIG	28,123	2.490	1.155	0	5.366
r_200	28,123	2.647	0.471	0.693	3.912
r_300	28,123	3.272	0.455	0.693	4.369
Size	28,123	22.80	1.530	19.12	26.46
Lev	28,123	0.539	0.197	0.0702	0.975
ROA	28,123	0.0314	0.0540	−0.208	0.196
Growth	28,123	0.264	0.897	−0.692	6.459
Board	28,123	2.194	0.212	1.609	2.773
Indep	28,123	0.375	0.0586	0.333	0.571

3.4. Correlation analysis

According to **Figure 1**, the correlation coefficients of r_200 and r_300 with DIG

are 0.1 and 0.091, respectively. This indicates a slight positive correlation, implying that as regional O2O teaching quality increases, the degree of digital transformation in enterprises also increases. Although the correlation is not very strong, this positive association provides preliminary evidence for the role of regional O2O teaching quality in firms' digital transformation.

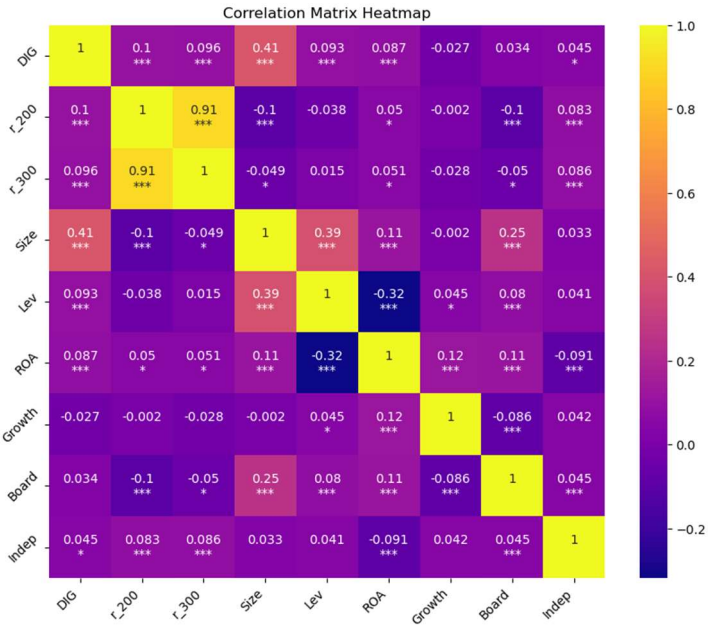

Figure 1. Heat map of Pearson correlation.

Note: *, ** and *** indicate significant at the 10%, 5% and 1% levels, respectively. Same below.

Among the control variables, the correlation coefficient between firm size (Size) and DIG is 0.41, showing a moderately positive correlation, indicating that larger firms are more likely to undergo digital transformation. This may be due to the fact that larger firms typically have more resources and capabilities to invest in new technologies and innovations. The low correlation coefficient between capital structure (Lev) and DIG suggests that there is no significant relationship between debt level and firms' digital transformation. The correlation coefficient of the net rate of return on total assets (ROA) is 0.087, indicating a relatively limited direct link between profitability and digital transformation.

The correlation between firm growth and DIG is also insignificant, implying that a firm's growth potential does not directly determine the extent of its digital transformation. The weak correlation between board structure (board and index) and DIG may reflect the fact that the size and independence of the board are not decisive factors in the strategic decision-making process of digital transformation.

In summary, the analysis of this correlation matrix heat map reveals a slight positive correlation between the strength of regional O2O teaching quality and firms' digital transformation, as well as providing evidence that firm size may be an important predictor of digital transformation. These findings are revealing for understanding how regional O2O teaching quality affects firms' progress on the digitalization path and also suggest the need to consider firm size and resource allocation when developing a digitalization strategy.

4. Empirical analysis

4.1. Benchmark regression results and discussion

As shown in **Table 2**, firstly, r_200 and r_300 are both significantly and positively correlated with the digital transformation of enterprises at the 1% level, with specific coefficients of 0.2077 and 0.2026, respectively, which strongly suggests that the impact of regional O2O teaching quality is significant and positive in the digital transformation of enterprises, and with the increase of the intensity of regional O2O teaching quality, the degree of digital transformation of enterprises increases accordingly. The coefficient of size is significant in both models, with coefficients of 0.3337 and 0.3356, which are also significant at the 1% level. The coefficient of Lev is insignificant in both models, with coefficients of 0.0885 and 0.0612, and standard errors of 0.1656 and 0.1667, respectively, suggesting that there may not be a significant relationship between capital structure and the digital transformation of enterprises. significant relationship. The coefficient of ROA is significant at the 1% level, indicating that firms' profitability significantly and positively affects their degree of digital transformation. The coefficients of Board and Indep are insignificant in both models, which may imply that the composition and independence of the board of directors do not have a significant impact on digital transformation. Overall, these benchmark regression results suggest that regional O2O teaching quality intensity and firm size have a significant positive impact on firms' digital transformation, while profitability is likewise an important contributor to digital transformation. These findings provide empirical evidence on the role of regional O2O instructional quality in economic decision-making and provide an important reference for firms when formulating their digitalization strategies.

Table 2. Results of the benchmark regression.

Variables	DIG	DIG
r_200	0.2077***	-
	(0.0577)	-
r_300	-	0.2026***
	-	(0.0645)
Size	0.3337***	0.3356***
	(0.0204)	(0.0204)
Lev	0.0885	0.0612
	(0.1656)	(0.1667)
ROA	1.5823***	1.5529***
	(0.4808)	(0.4836)
Growth	−0.0300	−0.0282
	(0.0285)	(0.0287)
Board	−0.1897	−0.1974
	(0.1326)	(0.1326)
Indep	−0.1722	−0.1935
	(0.4900)	(0.4906)

Table 2. (*Continued*).

Variables	DIG	DIG
Constant	−5.2785***	−5.3943***
	(0.5370)	(0.5518)
R-squared	0.5587	0.5581

Note: Robust standard errors clustered to the firm level are in parentheses; all regressions control for control variables, year, and firm fixed effects; all sample sizes are 28,123 below.

4.2. robustness and endogeneity tests

As shown in **Table 3**, columns (1) and (2) show the results of the robustness test for replacing the digital transformation measurement variables. In the regressions in columns (1) and (2), the coefficients of r_200 and r_300 are 0.3373 and 0.2889, respectively, which are both significant at the 1% level. Not only is this result highly statistically significant, but the magnitude of the coefficients also suggests that the intensity of regional O2O instructional quality has a strong positive effect on DIG2. This finding reinforces the conclusion of the preliminary regression results that the influence of regional O2O teaching quality has a significant role in facilitating the digital transformation of firms.

Table 3. Results of robustness and endogeneity tests.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	DIG2	DIG2	r_200	DIG	r_300	DIG
r_200	0.3373***			0.3070***		
	(5.2760)			(3.1743)		
r_300		0.2889***				0.2835***
		(3.9705)				(3.1641)
ZJPF			0.3338***		0.3458***	
			(18.7366)		(19.7175)	
Constant	−5.9580***	−6.0137***	1.8617***		2.4705***	
	(−9.8112)	(−9.6714)	(9.8381)		(16.1404)	
R-squared	0.4955	0.4919	0.6089	0.1591	0.6541	0.1537

Columns (3) through (6) employ Chastity Junction Place (ZJPF) as an instrumental variable designed to address possible endogeneity issues. The estimated coefficient of ZJPF as a proxy variable for regional O2O teaching quality is 0.3338 for r_200 in Column (3) and 0.3070 for r_300 in Column (4), indicating that this instrumental variable strongly confirms the relationship between regional O2O teaching quality and digital transformation. After controlling for the endogeneity issue of regional O2O teaching quality, the regression results in columns (4) and (6) continue to show that r_200 and r_300 are significantly positive at the 1% level with DIG, further reinforcing the results of the benchmark regression.

4.3. Heterogeneity analysis

The results in **Table 4** demonstrate the heterogeneity of the impact of regional O2O teaching quality on firms' digital transformation for firms with low and high

financing constraints, small- and large-scale firms, and firms with low and high institutional focus.

Table 4. Results of heterogeneity analysis.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Low Financing Constraints (SA)		High Financing Constraint SA		Small-scale Enterprises		Large-scale Enterprises		Low Institutional Attention		High Institutional Attention	
Variables	DIG	DIG	DIG	DIG	DIG	DIG	DIG	DIG	DIG	DIG	DIG	DIG
r_200	0.1452		0.1302**		−0.0226		0.1603**		0.2519***		0.0879	
	(0.1915)		(0.0559)		(0.0977)		(0.0745)		(0.0799)		(0.0962)	
r_300		0.2519		0.1118*		−0.0390		0.1612*		0.2136**		0.1233
		(0.2118)		(0.0607)		(0.1050)		(0.0885)		(0.0939)		(0.0991)
Constant	−5.4133***	−6.0392***	−5.0014***	−4.9954***	−2.1780*	−2.1278*	−5.3957***	−5.4963***	−5.6327***	−5.7090***	−4.1583***	−4.3176***
	(1.2933)	(1.3661)	(0.6847)	(0.6927)	(1.2490)	(1.2549)	(0.8993)	(0.9083)	(0.6385)	(0.6665)	(1.0736)	(1.0843)
R-squared	0.6385	0.6413	0.5989	0.5982	0.5898	0.5899	0.5570	0.5568	0.6033	0.6012	0.5785	0.5792

Among firms with low financing constraints, the effects of r_200 and r_300 are not significant, which may indicate that the impact of regional O2O teaching quality is masked by other factors in a relatively well-funded environment. In contrast, among firms with high financing constraints, the coefficient on r_200 is 0.1302, significant at the 5% level, while the coefficient on r_300 is 0.1118, significant at the 10% level. This finding implies that the positive impact of regional O2O instructional quality is more significant among firms with greater financing constraints, possibly because firms rely more on the values in regional O2O instructional quality to guide their long-term growth strategies in the context of resource constraints.

In the size analysis, r_200 and r_300 are not significant for small-scale firms, while the coefficients of r_200 and r_300 for large-scale firms are 0.1603 and 0.1612, which are significant at the 5% and 10% levels. This suggests that regional O2O teaching quality has a more significant positive impact on digital transformation in large-scale enterprises, probably because large-scale enterprises have more resources and greater organizational capacity to absorb and practice the values of regional O2O teaching quality.

When institutional focus is taken into account, r_200 and r_300 are significant at the 1% and 5% levels in low institutional focus firms, while the coefficients are not significant in high institutional focus firms. This may imply that intrinsic cultural factors, such as the quality of regional O2O teaching, have a more significant impact on firms' decision-making and transformation strategies when they are subject to less external scrutiny.

To summarize the above analysis, there is significant heterogeneity in the role of regional O2O teaching quality in the digital transformation of different types of firms. In particular, the positive impact of regional O2O teaching quality is more prominent in high-financial constraints and large-scale enterprises, as well as in enterprises with low institutional focus. These results not only deepen our understanding of the role of regional O2O instructional quality in firms' strategic decisions, but also provide a basis for customizing recommendations based on firms' characteristics for business management practices and policy formulation.

4.4. Mechanism effect analysis

As shown in **Table 5**, in columns (1) and (2), r_200 and r_300 show significant negative correlations with myopia, with coefficients of −0.0198 and −0.0182, respectively, and both of them are significant at the 1% level. This result suggests that as the intensity of regional O2O instructional quality increases, the tendency toward management myopia significantly decreases. This is consistent with the values of long-term planning and prioritization of global interests emphasized by regional O2O instructional quality and reveals that regional O2O instructional quality may influence firm behavior by shaping management's long-term decision-making orientation.

Table 5. Results of the analysis of mechanism effects.

	(1)	(2)	(3)
Variables	**Myopia**	**Myopia**	**DIG**
r_200	−0.0198***		
	(0.0048)		
r_300		−0.0182***	
		(0.0048)	
Myopia			0.9583***
			(0.2921)
Constant	0.4187***	0.4261***	−5.0787***
	(0.0622)	(0.0634)	(0.5457)
R-squared	0.2089	0.2072	0.5580

In column (3), a significant positive correlation is shown between management myopia (Myopia) and firms' digital transformation (DIG) with a coefficient of 0.9583, which is significant at the 1% level. This suggests that a reduction in management myopia is strongly associated with an increase in the degree of digital transformation at the firm. This may reflect the fact that firms are more likely to make long-term strategic investments, including digital transformation projects, under management that is less affected by shortsightedness.

Overall, these results support the mediating role of management myopia in the impact of regional O2O teaching quality on firms' digital transformation. Not only does regional O2O teaching quality directly affect digital transformation, but it may also indirectly contribute to digital transformation by reducing management myopia. These findings strengthen the economic basis for understanding how cultural factors in supply chain management influence firms' strategic decisions and innovation behavior and provide insights for firm management and policymaking.

5. Conclusions, recommendations and shortcomings

5.1. Conclusion of the study

In today's wave of the digital economy, the industry, as a dynamic field, is experiencing a profound digital transformation. Using data from listed companies in China from 2010 to 2022, this study conducted a systematic empirical analysis of the role of regional O2O teaching quality in promoting the digital transformation of

enterprises. It is found that regional O2O teaching quality not only positively promotes the digital transformation of enterprises, but also that this impact shows significant heterogeneity across different types of enterprises. In particular, the impact of regional O2O teaching quality is particularly significant among relatively capital-constrained firms, larger firms, and those firms that do not often receive attention from institutional investors. The findings further reveal how regional O2O teaching quality facilitates digital transformation by influencing the behavior of firms' decision-makers, i.e., reducing management myopia. Under regional O2O teaching, management is more inclined to move beyond short-term financial performance to focus on long-term technological innovation and the sustainability of the firm. This finding emphasizes the important role of educational factors in shaping corporate strategy and driving technological innovation. In summary, this study not only provides new research perspectives on the digital transformation of the industry but also offers lessons that can be learned from the digital transformation of other traditional industries, especially in developing countries that are rich in educational resources. Through a deeper understanding of the connotation of regional O2O teaching quality and its application in modern enterprise management, enterprises can be better guided to seize the development opportunities brought by digitalization and achieve long-term competitive advantages.

5.2. Policy recommendations

First, enterprises should pay attention to and invest in the construction and optimization of O2O educational resources, especially in the design of training content and the innovation of teaching methods. By providing customized training programs related to digital transformation, it can accelerate the improvement of employees' skills and lay a solid foundation for the digital transformation of enterprises. Second, it is recommended that enterprise management establish a long-term vision of development, go beyond reliance on immediate financial performance, and pay more attention to technological innovation and the construction of corporate culture. This requires enterprises to incorporate the long-term planning and ethics advocated by O2O teaching quality into their decision-making to ensure the sustainability and effectiveness of their digital transformation strategies. Finally, given the heterogeneity of the impact of regional O2O teaching quality on different types of enterprises, it is recommended that enterprises consider their own specific circumstances, such as capital status, enterprise scale, and market focus, when implementing digital transformation. For enterprises with tight capital or large scale, it is more important to strengthen the utilization of O2O teaching resources and, at the same time, actively attract external investment to enhance the visibility and attractiveness of enterprises in the market. With these three recommendations, enterprises will not only be able to effectively respond to the challenges of the digital economy era but will also be able to maintain sustained growth and innovation in a competitive market.

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Article

Striking a balance: Resolving conflicts of interest in Hong Kong's insurance market

Zion Lee

Programme Manager (Applied Learning), Division of Hospitality and Applied Learning, Hong Kong College of Technology, Hong Kong, China; zionlee@hkct.edu.hk, zionleejh@yahoo.com.hk

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Abstract: Hong Kong's insurance sector plays a vital role in the city's robust financial landscape, contributing significantly to the economy and serving essential individual protection needs. However, ongoing governance is required to address issues that could undermine consumer confidence and market integrity. The article examines key conflicts of interest in Hong Kong's insurance industry, including misaligned sales incentives, misleading information from agents, and a lack of commission transparency. It proposes regulatory reforms such as standardized commission disclosure and the development of a "Policy Comparator" tool to empower customers and promote ethical practices. By implementing these evidence-based solutions, the insurance industry can enhance transparency, reduce information asymmetries, and incentivize suitable recommendations. Cooperation among regulators, insurers, and consumer advocates remains critical to maintaining responsiveness to emerging risks and upholding customer-centric standards. Leveraging technology-enabled reforms, Hong Kong's insurance sector is well-positioned to thrive while safeguarding vulnerable policyholders and public confidence in this crucial financial pillar.

Keywords: Hong Kong insurance; insurance conflicts; commission transparency; regulatory reforms

1. Introduction

Hong Kong, known worldwide as a highly regarded and significant financial center, holds a remarkable position with its financial services sector making a substantial contribution to the city's gross domestic product (GDP) and job market growth, as identified by HKTDC Research in their analysis for the year 2023 [1]. It is predicted that Hong Kong will steadfastly retain its impressive fourth-place ranking on the Global Financial Centres Index, thereby reinforcing its status as one of Asia's foremost and most influential international financial hubs.

Integral to this thriving financial landscape is Hong Kong's insurance industry, which plays a vital role within the city's financial landscape. According to the Insurance Authority [2], the insurance industry contributed 4.1% to Hong Kong's GDP in 2021, amounting to HK$113.7 billion. The insurance sector, particularly in the areas of long-term life insurance and general business insurance, is a crucial component of Hong Kong's financial ecosystem, as indicated by sources such as HKTDC Research [1] and the Insurance Authority [2]. Facilitating the distribution of insurance products, intermediaries such as professionally licensed agencies and competent individual agents are extensively involved in the insurance ecosystem, according to comprehensive findings from HKTDC Research [1].

The insurance industry makes significant contributions to the economy and employment in Hong Kong. In 2021, 4.1% of the city's GDP, which amounted to HK$113.7 billion, was attributed to the insurance sector, as reported by HKTDC Research [1]. The largest segment within the industry, accounting for over 80% of premiums in 2022, is life insurance, according to the Insurance Authority [2]. Cultural factors also influence the prevalence of individual life and health insurance policies, as concluded by a study conducted by Leijen and van Herk [3].

Preliminary data from the Insurance Authority [2] reveals that the total value of premiums in 2022 was $556 billion, with long-term in-force policies amounting to $491.4 billion. Certain standalone non-linked and linked products experienced declines, which were attributed to changes in payment patterns and reduced new sales, as reported by the Insurance Authority [2]. Notably, visitor premiums from mainland China increased substantially by 200.3% to $2.1 billion, representing 1.5% of individual sales. The majority of policies purchased by mainland Chinese visitors offer medical, critical illness, and whole-life coverage, according to the Insurance Authority [2].

In 2022, aggregate premiums for general insurance increased by 4.5% to $64.6 billion. The reclassification of marine business led to a decline in this category, while accident, health, and liability insurance experienced growth [2]. Improved results from underwriting activities greatly contributed to the increase in profits.

As the leading financial center that it is, Hong Kong's expansive insurance sector significantly contributes to the local economy and job market and serves as a crucial risk mitigation tool. Specifically, life and health insurance products cater to essential individual protection needs. However, various challenges may pose risks to the effectiveness of policyholder protections if left unaddressed. Research shows that information gaps hinder comparisons and comprehensive cost assessments [4,5]. The utilization of complex language and the absence of standardized disclosure formats impede comprehension among non-experts [6,7].

Sales incentives prioritizing commercial objectives over appropriate guidance could potentially create obstacles and lead to detrimental outcomes for individuals and the larger financial landscape [8,9]. The extensive research [10] provides compelling evidence regarding the susceptibility of individuals to complex financial instruments, highlighting the need for increased vigilance and consumer protection. It becomes apparent that difficulties in obtaining assured benefits, along with the misrepresentation of coverage provisions and ambiguous selling practices, have the potential to yield far-reaching and enduring consequences for consumers [7]. These consequences can extend beyond immediate financial loss, impacting individuals' long-term financial security and overall well-being. Therefore, it is crucial to ensure that sales incentives are aligned with providing accurate and transparent information, promoting consumer empowerment, and safeguarding the interests of individuals and the wider market.

Recent official data indicates that these issues warrant consideration. The Insurance Complaints Bureau of Hong Kong reported an 18.6% annual increase in the number of cases, reaching 695 in 2022 [11]. Critical illness, life, and medical protection policies accounted for over 75% of these cases, mainly involving residents.

In 359 claims-related disputes, 75% were resolved amicably, resulting in 89 complainants receiving $8.16 million in compensation [11].

The upward trend highlights the need for increased transparency through standardized disclosures and enhanced suitability safeguards. Adequate consumer education and adherence to protection principles are particularly important when addressing hospitalization and long-term care needs, as highlighted by Fan et al. [12]. Miscommunication in complex and long-term commitments such as medical policies can jeopardize both health and financial security.

Achieving a harmonious balance between regulatory bodies, insurers, and consumer advocates while promoting sustainable markets through evidence-based reforms may require cooperative solutions [10]. However, the primary concern should always be safeguarding vulnerable individuals from potential risks that could undermine public confidence and the sector's reputation in the long run [10]. Vigilant monitoring of emerging issues will further facilitate the implementation of adaptable policy enhancements.

Thus far, Hong Kong's robust regulatory framework and expansive insurance sector have effectively protected policyholders and maintained overall economic stability. However, ongoing risk-based scrutiny and collaboration among stakeholders are necessary to strengthen consumer-centric oversight in the future.

Following this introduction, the subsequent sections will delve into the key conflicts of interest that exist within Hong Kong's insurance industry. This will include an examination of the misaligned incentives between policy approval and claims handling, the use of misinformation by agents to entice sales, and the lack of transparency surrounding fee structures and commission guidelines. The article will then propose regulatory reforms to address these issues, such as standardized commission disclosure requirements and the development of a "Policy Comparator" tool to empower consumers and promote ethical practices. Finally, the conclusion will emphasize the critical importance of cooperation among regulators, insurers, and consumer advocates to maintain responsiveness to emerging risks and uphold customer-centric standards in this crucial financial sector.

2. Conflicts of interest

Like any other financial sector, the insurance industry has inherent structural complexities that can lead to conflicts of interest among different stakeholders if not effectively controlled. Inadequate oversight is necessary to mitigate the risks to policyholder protections that arise from mismatched incentives at many levels, spanning from the underwriting process to claims administration. Hence, it is crucial to promptly identify and resolve possible conflicts in order to maintain the integrity of the market and instill long-term trust in consumers. The subsequent sections delve into significant sources of conflict and propose recommended strategies for their mitigation.

2.1. Policy approval vs. claims handling conflict

Insufficient regulation of sales commissions has the potential to lead to a lack of alignment with suitability, resulting in adverse consequences and potential harm to

consumers [9]. Placing an imbalanced emphasis on upfront payment during sales transactions rather than prioritizing post-sales service and customer satisfaction may inadvertently prioritize quantity over quality outcomes. Comprehensive research and expert insights emphasize the urgent need for more effective systems to prevent conflicts that commonly arise between the approval process and claim administration. Recent investigations conducted by the Independent Commission Against Corruption (ICAC) have brought to light the intricate network of conflicts that surface due to misaligned incentives within the industry [13]. These investigations have exposed the harsh realities of fraudulent activities within the market.

As a proactive measure to manage conflicts of interest, separating compensation for sales transactions from claims administration emerges as a pivotal solution [9]. By deliberately decoupling these processes, inherent conflicts between sales-driven goals and service-oriented objectives can be significantly reduced. Additionally, advocating for transparent and ethical underwriting practices becomes crucial in ensuring the evaluation of the adequacy and appropriateness of recommendations or denials. Regular and thorough reviews of interactions between agents and policyholders can act as an early detection mechanism, revealing noncompliant activities that may require immediate corrective action. Reinforcing this argument, Tennyson [6] unwaveringly emphasizes the importance of conducting random checks as an effective monitoring strategy, strengthened by prompt action in response to customer complaints.

2.2. Misinformation used by agents to entice sales

Agents often employ various tactics, such as utilizing persuasive high-pressure sales techniques, intentionally misleading customers about the true conditions, offering policies that are clearly unsuitable for the customer's specific needs, and deliberately concealing hidden charges or fees in an attempt to cunningly manipulate the information provided to the unsuspecting individuals. They resort to these unscrupulous methods in order to exert control and influence over the customers, ultimately aiming to ensure their own personal gains at the expense of the customer's trust and well-being. [14]. These tactics involve manipulating individuals into making hasty decisions, providing misleading reassurances, keeping important information hidden, and including hidden fees to exaggerate the benefits of a particular policy [15]. Unethical behavior of this nature can have negative consequences for policyholders, potentially resulting in inadequate coverage or unexpected expenses [16]. As a result, consumers must be diligent in thoroughly researching policies, asking questions, and carefully examining all terms and conditions before making a decision.

By being aware and attentive, individuals can protect themselves from the deceptive strategies employed by unscrupulous agents. Transparency and honesty are essential in ensuring that policyholders obtain the appropriate coverage for their needs. Failure to uncover hidden information in a timely manner can lead to disputes that could have been avoided, damaging consumer relationships and the reputation of the insurance industry as a whole. Conducting standard mystery shopping can help identify inappropriate sales tactics, preventing their recurrence in other locations. Facilitating direct communication between regulators and insurers can facilitate the

prompt identification of noncompliant agents and prevent repeat violations by the same companies. Collaboration between oversight agencies is key to ensuring consistent adherence to principles and standards.

3. Unclear fee structures

3.1. Lack of commission guidelines

The absence of commission guidelines has resulted in non-standardized and undisclosed payment mechanisms and ratios in the insurance industry [17]. This lack of transparency not only creates conflicts of interest between clients and agents but also disadvantages independent clients in terms of knowledge and protection [18]. According to a recent report by Hui [19], the total sales commission of the insurance industry in Hong Kong reached HK$61 billion in 2021, with the average annual commission for each agent reaching nearly HK$550,000, indicating the significant financial incentives that may influence agent behavior. Customers are deprived of crucial information about the compensation received by their insurance agents, as agents are typically paid through various types of commissions that may extend over several years [20]. As a result, it is a widely accepted and adopted practice within the insurance industry for insurance agents to prioritize and give special emphasis to selling products exclusively from companies that not only provide exceptional coverage and benefits but also offer the highest commissions and lucrative incentives to agents [21]. This approach ensures that agents are motivated to extensively promote these particular companies and their insurance products, as it directly correlates with their financial gain and overall remuneration. By focusing on selling policies from these highly profitable companies, insurance agents are able to maximize their potential earnings and build rewarding long-term relationships with such companies while also providing customers with comprehensive coverage options that meet their specific needs and preferences. Consequently, this strategy not only benefits agents by increasing their earning potential but also serves as a catalyst for fostering strong partnerships and alliances between agents and the insurance companies they represent [22].

3.2. Information asymmetry impacts

Information asymmetry means that not everyone has equal access to all information. In the insurance sector, the salesperson from whom the customers buy their insurance knows much more about the product than the customers do [23]. Agents are given financial documents such as sample policies and clauses that help explain the terms of the insurance contract. A customer looking to buy insurance could ask for explanation documents from the provider to help understand the terms, but many customers do not feel confident enough to ask for these materials or might be misled about the nature of the materials and the information that they can provide. Clients of these insurance companies may never receive full and transparent information on the insurance product [24]. As a matter of fact, they might end up with a product that is not suitable, not the best option for fulfilling their needs, but the best option for the vendor’s. In respect of the vendors, the structural advantages over

individual clients, given the information asymmetry, are explored as well. Usually in the literature about information asymmetry in the insurance sector, people mainly focus on the point about the salesperson having access to medical history, occupation, and other private details on the clients, whereas clients may not have such medical or any professional training to assess the terms of the insurance contract. This is the so-called 'personal bias', arguing that the lack of medical training made customers rely too much on the advice of the salesperson, but this point can go against this information asymmetry between clients and vendors at the same time [25]. Vendors know that they have a different focus in the market, and they specialize in certain types of insurance. For example, the company FWD Insurance mentioned in an article has announced an acquisition of Metlife Hong Kong and therefore become the top provider in Hong Kong for life and health [26]. It is reasonable to suggest that those vendors know which is the best insurance product that best suits the clients' needs, and they would use their specialized knowledge to promote certain types of insurance on the marketing side so as to consolidate the majority position in that type of insurance. By doing this repeatedly, clients cannot really have a free choice in choosing the insurance product. Clients are manipulated to the extent that they will have to pick one of the most recommended insurances from the vendors, and the informational advantage shall still remain on the vendors' side. The lack of customers' free will and the potential loss of huge social welfare are emphasized when identifying the structural advantages enjoyed by the vendors.

4. Suggested reforms

4.1. Commission transparency

In the new era of global financial reforms, there is a growing emphasis on the implementation of standardized disclosures for payment mechanisms and percentages. Governments around the world are proposing comprehensive measures to ensure transparency in the insurance industry. A significant development in this regard is the introduction of the Insurance Companies Ordinance in Hong Kong [27].

Under this groundbreaking legislation, life insurance intermediaries and agents operating in Hong Kong are now required to provide clear and transparent declarations regarding the monetary and non-monetary benefits they receive from insurers and other affiliated parties. These benefits encompass a wide range of factors, including commissions, costs, expenses, and any indirect interests that may have an impact on their regulated activities.

To foster greater transparency, such detailed information must be disclosed in written or electronically generated documents [28]. Moreover, when offering advice or arranging an insurance policy for a client, insurance intermediaries are obligated to explain the disclosed information either verbally or in writing. This ensures that clients have a complete understanding of the financial arrangements involved in their insurance coverage.

By implementing standardized disclosure requirements, the insurance industry aims to further enhance transparency and responsiveness to the needs of customers. Not only does this serve to empower clients, but it also elevates the overall quality of service provided by insurance companies and intermediaries. Customers can make

more informed decisions about their insurance purchases, fully aware of the potential benefits and costs involved.

However, it is important to note that the introduction of these disclosure requirements may necessitate a public release of information regarding commissions and benefits, potentially impacting the income of insurance agents. Nevertheless, the main objective of this new transparency regime is to prioritize the understanding and protection of customers, ensuring they receive fair and equitable treatment.

4.2. Empowering policy comparison

In the contemporary era of abundant data, there is a proposal to utilize advanced tools and technology to facilitate policy comparison and empower consumers in their decision-making process. One such tool, known as the "Policy Comparator," could be developed and made available to customers at no cost when they purchase insurance. By incorporating machine learning algorithms and data analytics into the "Policy Comparator," customers will be able to visually evaluate the strengths and weaknesses of different insurance policies, thereby aiding them in making well-informed choices. For instance, customers will simply need to input their preferences and basic personal details, such as age, gender, and existing medical conditions. Following this, the tool will analyze and present various inpatient and outpatient insurance options in a clear and easily understandable manner on the computer screen. The successful implementation of this proposed reform will gradually reduce the current dominance of individual insurance intermediaries, who manipulate information to control policy sales. Initially, insurance seekers will have access to distinct tools and information on the "Policy Comparator" and online comparison websites, eliminating the need for intermediary advice. Once this reform is successfully implemented, the digital landscape for insurance consultation and purchase will undergo a complete transformation. The "Policy Comparator" will become a new platform through which insurance policies are recommended and solicited. This will not only change how advice and comparison are provided by existing players but also establish an open and integrated channel for every insurance company to promote and showcase their range of insurance products.

With the advent and implementation of the groundbreaking and revolutionary "Policy Comparator," it will undoubtedly assume the pivotal role of the ultimate conduit through which insurance products are introduced, presented, and exhaustively recommended to consumers. Consequently, the previously prevalent and necessary in-person intermediaries, who traditionally held sway over the messaging and dissemination of information pertaining to insurance policies, will rapidly diminish. This, in turn, will foster intense competition within the insurance industry, liberating it from outdated practices.

By ushering in a new era characterized by increased reliance on cutting-edge technology, the realm of insurance stands poised for a monumental shift. One of the most conspicuous manifestations of this transformation will be the decrease in insurance policy prices, fueled by the competition brought about by the "Policy Comparator." In this manner, innovative technological advancements will create a

mutually advantageous environment that empowers policyholders and optimizes efficiency within the digital insurance marketplace.

As a consequence of this seismic shift, customers and policyholders will inevitably alter their behavior. They will no longer solely depend on traditional avenues for insurance advice. Instead, they will gravitate towards the "Policy Comparator," acknowledging its value and ability to comprehensively assess and recommend tailored insurance solutions that cater to their evolving needs and preferences.

Thus, as the veil of confusion surrounding insurance policies is lifted, insurance companies will equip themselves with indispensable tools and resources to meet and surpass the expectations of their discerning customer base. No longer reliant on guesswork, insurers will have an unprecedented ability to gauge the pulse of their clientele, optimizing their product offerings. This heralds a new chapter, driven by technological prowess and customer-centricity, ensuring the insurance industry thrives in a digitally-driven world.

5. Conclusion

In conclusion, Hong Kong's insurance industry plays an integral role in the city's robust economy and thriving financial sector. Life and health insurance, in particular, fulfill important protection needs for residents. However, ongoing governance is required to address issues that could undermine consumer confidence and market integrity.

Standardized commission disclosure, as implemented through new regulations, aims to promote transparency. This will empower customers and help curb misaligned sales incentives. Comparative tools like the proposed "Policy Comparator" also have the potential to reduce information asymmetries and support more informed decision-making.

While reforms target specific issues, cooperation across stakeholders remains vital. Regulators must continue rigorous oversight through investigations and assessments. Insurers should prioritize suitable recommendations and transparent documentation. Consumer advocates, in turn, can play a crucial role in enhancing financial literacy and advocating for policy suitability. This multi-stakeholder collaboration will be essential in ensuring that the proposed reforms are effectively implemented and that the industry remains responsive to emerging challenges.

Through this collaborative, evidence-based approach, Hong Kong's insurance sector can adapt to changing market dynamics and maintain its position as a pillar of the city's financial system. By empowering customers and incentivizing ethical conduct, the proposed reforms can help safeguard vulnerable policyholders and ensure the long-term sustainability and integrity of the insurance industry. As the regulatory framework evolves, staying responsive to new risks through regular forums for stakeholders to discuss and share best practices will be essential for upholding customer-centric standards and fostering public confidence in this crucial sector.

Looking ahead, if technology-enabled reforms fulfill their objectives of empowering customers and incentivizing ethical conduct, Hong Kong's insurance sector is well-positioned to thrive. By maintaining responsiveness to emerging risks

through risk-based scrutiny and multi-party cooperation, customer-centric standards will strengthen public welfare and confidence in this crucial pillar of Hong Kong's financial system.

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Article

Tuna: Investigations of value addition and potential EU investments in tuna fisheries in Africa

Pierre Failler[1,2], Grégoire Touron-Gardic[1], Juliana Arias Hansen[3], Alexandre Rodriguez[4], Sonia Doblado[4], Øystein Hermansen[5], Jónas R. Viðarsson[6], Andy Forse[1,*], Benjamin Drakeford[1]

[1] Centre for Blue Governance, University of Portsmouth, Portsmouth PO1 3DE, UK
[2] UNESCO Chair in Ocean Governance, 75007 Paris, France
[3] Blue Resource/Sjókovin, 520 Leirvík, Faroe Islands
[4] Long Distance Advisory Council – LDAC, 28001 Madrid, Spain
[5] Nofima, NO-9291 Tromsø, Norway
[6] Matís, 113 Reykjavik, Iceland
*** Corresponding author:** Andy Forse, andy.forse@port.ac.uk

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Abstract: This research studies investment opportunities within the tuna fish pole and line fishery along the coast of the African Atlantic Façade (mainly SW-Senegal) and the associated value chains. Also, a section is dedicated to investigating the specific case of the investment of French capital in tuna fisheries in the Seychelles in the Indian Ocean. The investigation was conducted under the FarFish project, whose overarching objective is to provide knowledge, tools, and methods to support responsible, sustainable, and profitable EU fisheries outside European waters, both within the jurisdiction (EEZ) of non-EU coastal states as well as in international waters and high seas. In order to achieve this, the aim of this research is to identify, study, and potentially recommend investment opportunities for EU operators within some of the project's case study countries. The investigations into tuna fisheries were based on interviews with relevant stakeholders, including shipowners and key personnel from public bodies and institutions both in West Africa and Europe (see Appendix A for the list of stakeholders consulted). In addition, most of the data presented in this section was acquired from DG-Mare in a non-public dataset compiling every fishing lot from EU vessels operating within SFPAs in Senegal. A second case study in tuna fisheries, in this case in the Indian Ocean, investigates the investment from the French company SAPMER to improve the land infrastructure in the Port of Victoria (Seychelles), as this would be the only notable investment by European interests in recent years for tuna fishing in Africa. These sections conclude that the fishing area where EU pole-and-line vessels are active is becoming less productive, decreasing the profitability of European-flagged vessels as well as of Senegalese-flagged vessels that maintain close partnerships with Europe. As a response, they have attempted to extend their fishing grounds. Additional fishing opportunities are opening in The Gambia (whose EEZ is restricted), and other countries are expected to follow. Contrastingly, the EU sustainable partnership fisheries agreement with Senegal or Mauritania could include fewer fishing opportunities in terms of tonnage as well as increasingly restrictive conditions for access and landings. European operators have reacted so far by considering the switch to a private regime instead of operating under SFPA as a preferred strategy.

Keywords: climate change; adaptation measures; vulnerability; co-creation; sustainability

1. Introduction

European tuna fisheries within SFPAs are widespread along the African coasts; 11 African coastal states currently have such an agreement with the EU. However,

difficulties are growing for the three major European purse seine, longline, pole, and line fleets targeting tropical tuna and tuna-like species operating in West African waters. Challenges for their operation arise mainly due to the overall decrease in fishing opportunities contained in SFPAs signed with West African countries. This decrease has been exacerbated by the non-renewal of the largest European tuna agreement in Africa (in reference to tonnage and reported catch) with the Coastal State of Gabon in 2017 and by the access restrictions (derived from technical measures and zoning) to the small pelagic fisheries in Mauritania, which is the largest EU fisheries agreement in terms of tonnage.

According to tuna shipowners, there would be a stagnation in European fisheries activities within SFPAs. Despite the above-mentioned trend, tuna-related activity carried out by pole and line vessels seems to be increasing in Dakar, mostly due to economic-related activities. On the one hand, the operation of the European pole-and-line vessels in the Atlantic Ocean is stable, while the national Senegalese fleet is growing to a large degree through foreign investments, including from Spanish operators. On the other hand, EU activities in the Indian Ocean have a different outlook than those in West Africa, with higher catches and even an investment in land that is planned by a French company in the Seychelles.

The purpose of this section is to carry out an analysis of the possibilities for tuna activity investments in African waters for some of the most relevant case studies in FarFish. First, an analysis of the recent increase in economic activity from the pole-and-line vessels based in Dakar. This is in order to investigate how the European and Senegalese-associated vessels are operating, through evaluating the economic profitability and distribution of income from the activity and finally drawing a summary of advantages and disadvantages for vessels operating under the SFPA and Senegalese flag. A second study is investigating the investment from the French company SAPMER to improve the land infrastructure in the Port of Victoria (Seychelles), as this would be the only notable investment by European interests in recent years for tuna fishing in Africa.

The analyses are based on literature describing the performance of the fisheries agreements in Senegal, Cabo Verde, ad Guinea Bissau over the last 2 decades (mainly the EU ex-post evaluation of fishing agreements) and interviews with relevant stakeholders, including shipowners, institutions, and experts both in West Africa and Europe (see Appendix A for the list of stakeholders consulted). In addition, it relies on the DG-Mare dataset, which compiles every fishing lot from EU vessels operating within SFPAs performed in Senegal [1].

2. Economic activity of the EU Pole-and-line Vessels in West Africa

2.1. Context of the EU tuna fleet operating in West Africa

In the Atlantic Ocean, three European tuna fleets are active. The first and largest fleet segment is the industrial purse seiners targeting tropical tuna species (i.e., bigeye, skipjack, and yellowfin), whose great mobility makes it possible to extend their fishing grounds from Mauritania to the north to Angola in the south of the Atlantic façade in Africa. The main landing ports for this fleet are Abidjan on the Ivory Coast, Tema in Ghana, and Dakar in Senegal. The annual catches of the European industrial fleet of

purse seiners are around 40,000 tonnes [1]. The second fleet segment is the pole-and-line vessels operating in the far west of Africa, whose port base is Dakar. Their annual catch volume is around 10,000 tonnes [1]. Finally, the third fleet segment is composed of longliners with the main port base in Mindelo (Cabo Verde), focusing on tuna-associated species such as blue shark, shortfin mako, and swordfish. Catch volumes are more modest than the purse seiners, summing up to around 2000 tonnes annually. These three fleets are essentially composed of Spanish and French vessels. Spanish shipowners are represented within the groups OPAGAC, ANABAC, and Dakar Tuna. French ships are represented by the group ORTHONGEL.

2.2. European pole-and-line vessels based in Dakar and operating in West Africa

The pole-and-line vessels from the EU are all based in Dakar, which is also their landing port (see Appendix B). The fleet consists of seven Spanish pole-and-line vessels represented by the shipowners' group ANABAC and one French vessel represented by ORTHONGEL. In addition to the EU vessels, 16 tuna vessels flying the Senegalese flag are also based in Dakar [2]. Six out of the 16 tuna vessels are owned or controlled by the Spanish capital, including five bait boats and one purse seiner. Thus, overall, there are 13 pole-and-line vessels and one purse seiner of European flag or capital (see Appendix C for the list of Tuna vessels based in Dakar). The other ten Senegalese-flagged vessels have beneficial ownership from South Korea. The whole pole-and-line fleet is active in Senegal, while less than half of seiners are regularly present in Senegalese waters (10 out of 25 vessels active in West Africa between 2014 and 2019—DG MARE, 2020), as seen in **Table 1** below.

Table 1. Number of EU tuna vessels by gear type fishing in Senegal 2015–2017 [3].

Year	Country	Number of Tuna seiners	Number of Pole and line Tuna vessels
2015	France	5	1
	Spain	4	7
	Total	9	8
2016	France	0	1
	Spain	8	7
	Total	8	8
2017	France	1	1
	Spain	9	7
	Total	10	8

Total catches from the EU-owned and associated pole-and-line vessels flagged in Senegal have varied from 13,000 to 18,000 tons annually between 2014 and 2018 [4]. The average catches of Spanish and French-flagged pole-and-line vessels are 10,000 tons per year in the region [1]. These catches are mainly composed of skipjack tuna (see **Figure 1**) linked to FADs. The catch composition of the EU purse seiners and pole-and-line vessels is quite similar, after showing considerable differences until 2015; since then, the latter also focuses on Skipjack tuna. This fleet has left yellowfin tunas found in free schools because of the decrease in the number of large yellowfin

[5,6]. The two fleets (seiners and pole-and-line vessels) collaborate by sharing information about the location of tunas (information collected from interviews).

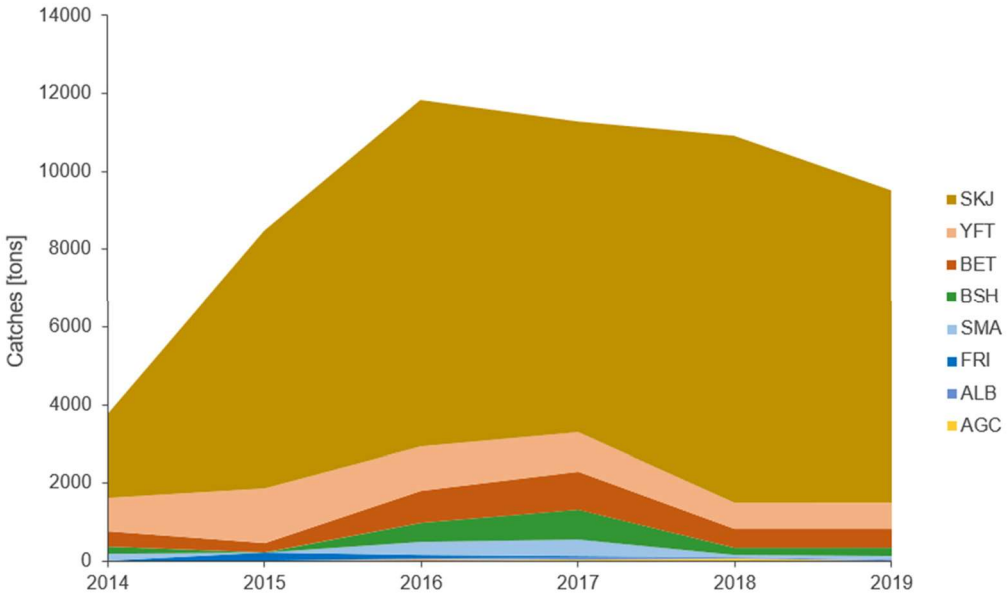

Figure 1. Total catches by EU bait boats based in Dakar according to species.
Source: DG-Mare.

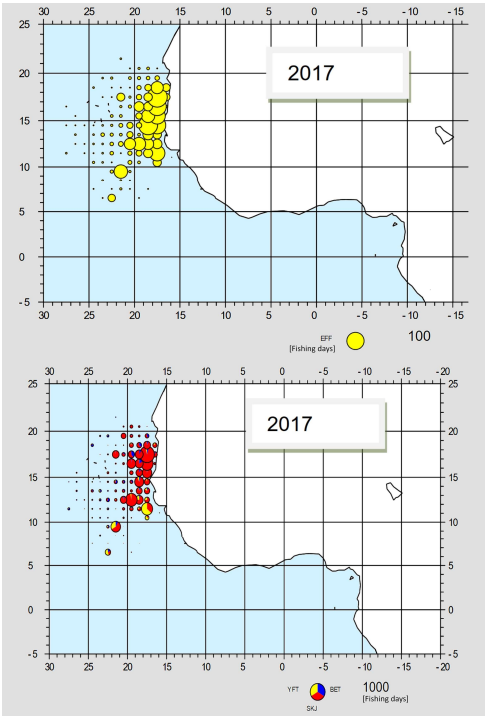

Figure 2. Fishing zone for Spanish bait boats according to fishing effort and amount of catches [8].
Note: There are seven Spanish bait boat, and only one French. Considering Senegalese bait boats linked to European Investments, they share more or less the same fishing areas (collected from interviews).

The EU pole and line vessels are of medium size, generally between 30 and 40 m LOA [7]. As they are not very mobile and have limited autonomy, their activity is concentrated in a geographical area of neighbouring countries located within reach of the port of Dakar. In this way, the EEZs of Senegal, Mauritania, Cabo Verde, and

Guinea-Bissau, as well as the adjacent international waters, are the main fishing areas where most catches take place (see **Figure 2**). In terms of volume of catches, Senegal is the main fishing area (47% of total catches between 2016 and 2019, according to the DG-Mare database), followed by Mauritania (32%), Cape Verde (17%), and Guinea-Bissau (3%).

The share of yellowfin tuna in catches increases as vessels move south. The development of the Senegalese national fleet, partially linked to Spanish interests/capital, has led to the emergence of competition disputes between foreign vessels and investors in Senegal. The rapid incursion of the Korean fleet in the region, among other drivers, led to the creation of GAIPES (shipowners and fisheries manufacturer groups in Senegal), where the main tuna shipowners in Senegal have a platform to voice their concerns and defend their interests in the face of foreign fleets. Another factor of tension in these fisheries is the stock status of the three species of tropical tuna targeted (yellowfin, skipjack, and bigeye), which are under considerable pressure, according to STECF [9]. In response, some shipowners are considering extending their fishing area towards Guinea-Conakry, Sierra Leone, and even Liberia (collected from interviews).

2.3. Economic considerations: Gross value addition in West African coastal states under SFPA

In terms of further operations and economic activities, the pole-and-line vessels generally store their catches frozen in brine on board for subsequent processing in canneries [1]. A notable difference is found for products exported from the port of Dakar, where tuna products are mainly processed into loins or whole frozen tunas [10], which is only a small part of the whole product transformation. These products would then be shipped to Thailand and Europe mainly, according to interests from Princes Group (UK) and Thai Union Group PCL (Thailand) in launching a “Pole and Line Tuna Fishery Improvement Project” (FIP) in Senegal in order to reach Marine Stewardship Council Standards. Also, a small portion of the catch irregularly supplies the two canneries present in Dakar (SCASA and CONDAK). In addition, the Senegalese bait boats linked to European investments only supply these canneries sporadically (collected from interviews). They mostly supply Spanish operators based in Spain (Pereira Armadora and FRINSA in particular).

Since the fishing area for these vessels has been distributed over four countries through SFPAs (Mauritania, Senegal, Cape Verde, and Guinea-Bissau) since 2014, the main features within each country are presented next.

Senegal:

The prospective and retrospective analysis of the last SFPA agreement between the EU and Senegal [11] provides information about the economic performance of the EU vessels. The turnover of European bait boats was €7.838 million per year on average between 2015 and 2018 in Senegalese waters. On the cost side, intermediate consumption is estimated at €4.7 million, the details of which would be estimated as follows in **Table 2**:

Table 2. Comparative costs between Senegalese SFPA and Regional costs for European flagged pole-and-line vessels.

Cost item	2015-2019 average costs (million Euro) in Senegalese EEZ according to European Commission [11]	Fleet costs (according to interview with Dakar Tuna 2020)
Fuel and lubricant	1.023 (13.05% of the turnover)	15%–20%
Repair and maintenance	0.599 (7.64%)	
Other variable costs: Total Including crew member salaries Licenses	 2.699 (34.43%) 1.526 (19.47%)	 35% 10%–15%
Other fixed cost	0.379 (4.84%)	
All fixed & unfixed charges		Previous years: 70%–80% At the time of the interview: >90%

The added value would therefore be €3.138 million, i.e., 40% of the turnover. Deducting salaries and various taxes, mainly access rights, the gross operating profit would be €1.264 million, or 16% of turnover. At the same time, the average gross operating profit for European fleets fishing outside the EU is 22%, according to STECF [11]. In addition to **Table 2** summarizing the costs for intermediate consumption, a summary of the main economic features developed in this sub-section is presented in **Table 3** of subsection "Countries Synthesis", along with features from the other countries where European bait boats based in Dakar operate.

Among the main costs deducted from the added value, access costs for EU bait boats in the current agreement are around €400,000 per year. For all technical categories combined (purse seiners, pole-and-line, and trawlers targeting hake), the SFPA, including approximately 35 vessels, generates around €1.7 million per year for Senegal (EU counterpart plus shipowners' fees). This excludes sectoral support at about €750,000 annually. At the same time, the hundreds of Senegalese industrial vessels directly bring about €1.2 million per year to Senegal in royalties [11].

From the shipowners' point of view, the 4003 tons fished in Senegalese waters in 2017 [3] would represent €268,000 in access costs according to the increasing fees, or €64 per tonne (according to DG Mare Dataset, all bait boats exceeded the initial catches agreed upon within the advance payment). If the costs paid by the EU are included and distributed in proportion to the total tonnage following the data contained in the JSC report [3], 46% of the financial contribution and sectoral support (i.e., €800,000) are added. The access price for bait boats in Senegalese waters would then correspond to €264 per ton.

The indirect added value upstream of the activity generated by pole-and-line vessels would be €559,000 per year, while the indirect added value downstream from the fishery would be €1.96 million euros [7,11]. On average, over the four years, 50% of the total added value (direct and indirect) is for the benefit of the EU, 32% for the benefit of Senegal, and 18% for the benefit of other African ACP countries. The comparatively modest share of Senegal in the distribution of added value is explained by the fact that catches from EU vessels under agreement do not enter far into the marketing/processing chain of Senegal, limiting the process to freezing, storing, and transformation into tuna loins. Therefore, relatively little of the value added by this sector goes to the Senegalese processing/canning/marketing industries.

Table 3. Summary of some key figures of EU bait boats activities according to fishing areas.

Turnover		**Added value**	**Gross operating**	**Shipowners'**	**EU access costs**	**Indirect added value**	**Added value redistribution**	**Jobs created (estimate**
(millions of euros)		(millions of euros)	surplus (EU average outside European waters: 22%)	access costs (per ton)	(per ton)	upstream/downstream	(direct + indirect)	equivalent to full-time annual employment)
Senegal 7.838		3.138 (40%)	1.264 (16%)	91 euros	200 euros	559 000/1.96 million	• 50% EU (5.01 million euros) • 16% other west African countries (1.863 million)	101 (10 EU)
• 32% Senegal (3.244 million)								
Mauritania	4.611	1.791 (39%)	638 (14%)	70 euros	integrated with other categories	Total: 1.975 million	Undetermined (but mostly EU and Senegal)	90 (9 EU)
Cabo Verde	1.851	0.88 (47.54%)	0.273 (14.75%)	48 euros	integrated with other categories	130 000/506 000	Undetermined (but mostly EU and Senegal)	27 (5)
Guinea Bissau	1.002	0.372 (37.16%)	0.105 (10.49%)	25.06 euros	integrated with other categories	10 000 euros/178 000 euros	• 57% EU (107 000 euros) • 43% west African countries (81 000 euros)	8 (1 EU)

Finally, the estimated number of equivalent annual jobs on board for EU pole-and-line vessels during their fishing campaigns in Senegalese waters would be 101 jobs, including 10 nationals from the EU [7,11]. The remuneration costs for the employees on board the pole-and-line vessels during their activity in Senegalese waters would be €1.526 million annually during the period 2015–2018. In addition, there are 34 equivalent full-time indirect jobs upstream (including 7 from the EU) and 126 equivalent full-time indirect jobs downstream, including 38 from the EU (and only 16 from Senegal).

Mauritania:

The prospective and retrospective analysis of the last SFPA agreement between the EU and Mauritania [12] provides information about the economic performance of the EU vessels. The turnover of European bait boats was €4.611 million per year on average between 2016 and 2018 in Mauritanian EEZ waters (there were no active European bait boats in 2015). On the cost side, intermediate consumption is estimated at €2.82 million, the details of which would be estimated as follows in **Table 4**:

Table 4. Comparative costs between Mauritanian SFPA and Regional costs for European flagged pole-and-line vessels.

Cost item	2016–2018 average costs (million Euro) in Mauritanian EEZ according to European Commission [12]	Fleet costs (according to interview with Dakar Tuna 2020)
Fuel and lubricant	0.56 (12.14% of the turnover)	15%–20%
Repair and maintenance	0.37 (8.02%)	
Other variable costs: Total Including crew member salaries Licenses	 1.669 (36.2%) 0.916 (19.87%) 0.237 (5.14%)	 35% 10%–15%
Other fixed cost	0.222 (4.81%)	
All fixed & unfixed charges		Previous years: 70%–80% At the time of the interview: >90%

The added value would be €1.791 million, or 38.84% of turnover. Deducting salaries and various taxes, mainly access rights, the gross operating profit would be €0.638 million and 13.84% of turnover. According to STECF, the average gross operating profit for European fleets fishing outside the EU is 22% [12]. Alongside **Table 4** summarizing the costs for intermediate consumption for EU bait boats operating in Mauritania, a summary of the main economic features for Mauritania as well as Senegal, Cabo Verde, and Guinea-Bissau is recapitulated in **Table 3** of subsection "Countries Synthesis".

From the shipowners' point of view, the 4347 tons fished in Mauritanian waters in 2019 [1] by EU pole-and-line vessels would represent €304,290 in access costs, according to the increasing fees. Since one vessel out of eight has caught less than the annual flat-advance (calculated to be equivalent to 35 tons), the price per ton in 2019 would be slightly superior to €70 per tonne.

The indirect added value upstream of the activity generated by pole-and-line vessels would be €341,000 per year, while the indirect added value downstream from the fishery would be €1.634 million [12]. On average, over the four years, 44% of the

total added value (direct and indirect) is for the benefit of the EU, 43% for the benefit of Senegal, and 13% for the benefit of other countries (mainly in West Africa). The comparatively modest share of Mauritania in the distribution of added value is explained by the fact that catches from EU vessels under agreement do not enter far into the marketing/processing chain of Mauritania, limiting the process to transhipping, landing, freezing, and storing. Therefore, most of the total added value for Mauritania comes from access compensations.

Finally, the estimate of the number of equivalent annual jobs on board for EU pole-and-line vessels during their fishing campaigns in Mauritanian waters would be 90 jobs, including 9 from the EU [7,12]. The remuneration costs for the employees on board the pole-and-line vessels during their activity in Mauritanian waters would be €0.916 million annually during the period 2015–2018. In addition, 100 equivalent full-time indirect jobs would be generated by EU pole-and-line tuna vessels, but none of them would happen in Mauritania, and only 17 would be in the EU.

Cabo Verde:

The average annual turnover for the period 2015–2017 would be €1.851 million [13], while the average catch volume was 1570 tons during the same period [1]. The estimated added value would be €0.880 million, or 47.54% of turnover. About the gross operating surplus, it would be €0.273 million, or 14.75% of turnover.

In terms of the main charges for European flagged pole-and-line vessels, license costs would represent 4% of turnover and 9% of added value (which would be around €75,000 and around €48 per ton), despite the fact that the fact that details about these charges aren't available in the current Ex-post and Ex-Ante Analysis [13]. In addition, the indirect added value generated downstream would be 506,000 euros, while the one generated upstream was estimated at €130,000. Main economic features are summarized in **Table 3** of subsection "Countries synthesis", along with features from other countries where European bait boats based in Dakar are active.

The European flagged pole-and-line generated 27 direct jobs, of which 5 were for European workers and 4 for workers from Cape Verde; the remaining 18 are for West African workers. In addition, according to the latest ex-ante and ex-post SFPA analysis in Cape Verde, these vessels generated 39 indirect jobs (9 upstream and 30 downstream), but none of these indirect jobs occurred in the EU or Cape Verde [13]. However, a part of the processing of tuna catches in Cape Verde by European vessels is still carried out in Europe.

Guinea Bissau:

European-flagged pole-and-line vessels would not generate direct employment in Guinea-Bissau. Out of 120 people on board in 2015, 24 crew members were from the EU and 96 from the West African region (excluding Guinea-Bissau and mainly from Senegal). In addition, 18 people were employed in the EU as management staff [14]. Related to the proportion of the catches in Guinea-Bissau, the number of jobs generated would be 8 direct jobs and 21 indirect jobs, with most of these jobs generated in West African countries other than Guinea-Bissau (Senegal, Ivory Coast, and Ghana mainly) and in the EU.

The turnover of European pole-and-line vessels would be €1.002 million in 2015 (for 838 tons of catches [14]). Afterwards, these vessels seemed to be less present [1]. The intermediate costs were estimated to be €0.630 million, detailed in **Table 5** (while

the main economic features are recapitulated in **Table 5** of subsection "Countries Synthesis", alongside features from Senegal, Mauritania, and Cabo Verde):

Table 5. Comparative costs between Bissau-Guinean SFPA and Regional costs for European flagged pole-and-line vessels.

Cost item	2016–2018 average costs (million Euros) in Guinea Bissau EEZ according to European Commission [14]	Fleet costs (according to interview with Dakar Tuna 2020)
Fuel and lubricant	0.182 (18.18% of the turnover)	15%–20%
Repair and maintenance	0.065 (6.49%)	
Other incompressible intermediate consumptions	0.014 (1.4%)	
Other variable costs:		
Total	0.359 (35.86%)	
Including crew member salaries	0.246 (24.58%)	35%
Licenses	0.021 (2.1%)	10%–15%
Other fixed cost	0.222 (4.81%)	
All fixed & unfixed charges		Previous years: 70%–80% At the time of the interview: >90%

Among the main charges, fuel would have cost €182,000 in 2015 (18.18% of turnover), and various taxes would have cost €10,000 (1%). Other variable costs would have been €359,000 (35.86%) in total. In this way, the cumulative variable intermediate consumption would be €551,000, or 55.04% of turnover. At the same time, the incompressible intermediate consumptions would be distributed as such: maintenance and repair would have cost €65,000 (6.49%) within the year 2015, while the other incompressible intermediate consumptions were estimated at €14,000 (1.4%).

When all these charges are subtracted from turnover, the added value would be €372,000, or 37.16% of turnover.

From this added value, the access costs for fishing are deducted (€21,000 for 838 tons in 2015, which means 2.1% of turnover and a cost of €25.06 per ton) and the costs inherent in salaries for the crew members (€246,000 representing 24.58% of turnover) to calculate the gross operating surplus. In this way, this surplus would have been €105,000 in 2015, or 10.49% of turnover.

Finally, the indirect added value linked to the supply of fuel in 2015 would have been €5000, mostly profitable for the port of Dakar. Considering the indirect added value linked to ship maintenance and repair activities in 2015, this was also estimated at €5000 in favour of Senegal. Regarding the indirect added value linked to the processing of the catch within the Guinea-Bissau fishing zone in 2015, this would have been equivalent to €107,000 for the EU and €71,000 for West African countries. Since no vessel had economic interaction with Guinea-Bissau (except for fishing), no indirect added value was generated upstream or downstream (this economic activity linked to landings and processing in West Africa is mainly concentrated in Senegal and Côte d'Ivoire).

Countries Synthesis:

Key figures from national waters constituting the EU pole-and-line vessel fishing zone are recapitulated in **Table 3**. Added value and gross operating surplus seem globally homogenous, despite big differences in license costs. The access price varies greatly, with the most frequented areas being the most expensive. According to the DG-Mare dataset, Senegalese and Mauritanian EEZs were the most frequented by

pole-and-line vessels under French and Spanish flags between 2014 and 2019 (25,000 and 15,000 cumulative tons). Guinea-Bissau is not a common fishing area for the moment, despite the low cost of access; the abundance of tuna takes priority over the access costs. On the other hand, Cape Verde is a regular fishing area (10,000 tons accumulated between 2014 and 2019), with a very low access cost for pole-and-line vessels. However, this country faces a lack of bait species, which is decisive for the establishment of the home port.

2.4. Perspectives from EU investors in West African tuna fisheries

The fishing area where EU pole-and-line vessels are active is becoming less and less productive, which decreases the profitability of European-flagged vessels as well as of Senegalese-flagged vessels that maintain close partnerships with Europe. The fleet informants reported that the pole-and-line fleet has responded by extending their fishing grounds. Which also concurred with the increasing price of fuel, which further reduced the profitability and attractiveness of fishing in areas far from the landing ports.

Regarding additional fishing opportunities, The Gambia (whose EEZ is restricted) has had a tuna agreement with the EU since 2019. Other countries are expected to follow. Contrastingly, the EU sustainable partnership fisheries agreement with Senegal or Mauritania could include fewer fishing opportunities in terms of tonnage as well as increasingly restrictive conditions for access and landings. European operators have reacted so far by considering switching to a private regime instead of operating under SFPA as a preferred strategy.

The development of the port of Mindelo is interesting for tuna vessels, since more of them are landing there. The infrastructure is adequate, and the port is located near the fishing area. However, in the case of pole-and-line vessels, the factor limiting their installation is the need to provide bait along the coasts of Senegal. In Las Palmas, the port is a hub for maintenance and repair. However, it is situated relatively far from the main fishing areas.

Another point is the constitution of a Fisheries Improvement Project (FIP) for pole-and-line tuna Fishery in Senegal [15]. Jointly led by Dakar Tuna shipowner group (in charge of pole-and-line vessels under European flags), Senegalese shipowner TUNASEN (under Spanish capital), WWF-UK, and some manufacturers (Thai Group from Thailand, Princes Group from the UK, and SENEMER from Senegal), the project aims to improve stock management, environmental impacts, and efficiency in the sector in order to achieve Marine Stewardship Council (MSC) standards. Therefore, the products would be valued in order to reach demanding markets in terms of quality.

Some other challenges are the lack of specialized crew members, which adds to the problem of crew rotation. This could be mitigated by the establishment of a regional agency. There are also growing issues linked to the emergence of Korean tuna vessels fishing under the Senegalese flag. The latter have opaque practices, and the government has only little control over them. There are now 10 Senegalese tuna vessels under Korean capital (6 purse seiners and 4 long liners; see Appendix C).

2.4.1. Joint ventures and Senegalese societies linked to European investments

Some key facts and figures:

Bait boats (pole and line vessels):

Out of the six Senegalese tuna vessels linked to European ownership interests, five are bait boats. Out of these 5, 4 are owned by the same group (Société d'exploitation des ressources thonières, SERT/Dakar Thon/Sénégalaise de la pêche thonière), whose direction is the same for all of them. The last pole-and-line vessel belongs to the company TUNASEN, which relies on Spanish investment. The Senegalese company Sénégalaise de Thon, which owns the last Senegalese vessel linked to European investments, is owned by SOPERKA, a Spanish fishing operator also present in Dakar and who shares the same office.

The SERT group is large and generates an annual turnover of around 5 to 6 million euros, with annual catches of around 3500 to 4000 tons. According to its head director and expressed to the author of this report important charges to the operation, although not in detail. However, some of the charges mentioned have been described as follows:

- The handling and transport costs at the port are €600 per shipment and per container. A shipment consists of 2 to 15 containers, which are serviced on an irregular basis timewise (approx. once every week).
- The monthly costs of storing fish in the only cold warehouse in the port of Dakar (Socofroid, owned by the French group Bolloré) are around €914 for 300 tons (€3.04 per ton) per month, or around €11,000 per year.
- License prices represent only a small share of the total charges, since there are official agreements between governments in Senegal, Cabo Verde, and Guinea-Bissau. In this way, the shipowner would only pay €500 per year for the license fee in Cabo Verde. The sum of all licenses would not exceed a few thousand euros annually.

Industrial tuna purse seine vessels:

Regarding the Senegalese tuna purse seiner, it generates a turnover of 7 to 8 million euros annually. The license fees in foreign countries are up to 1 million euros per year, since the fishing area extends from Mauritania in the north to Angola in the south. On the other hand, the salary expense is only 600,000 euros, or less than 10% of turnover. In addition, material costs are estimated at 300 to 400,000 euros, which corresponds to 5% of turnover.

2.4.2. Perspectives from Joint ventures and Senegalese societies linked to European investments

For Senegalese shipowners who are in close partnerships with Europe, there is a challenge linked to unfair competition with other fleets. Among others, the group of shipowners and fishermen in Senegal (GAIPES) is trying to highlight to the government the unfair competition with European vessels, including the purse seiners. But above all, the local shipowners are concerned about the rapid emergence of a South Korean fleet. This fleet has several purse seiners and longliners, partially linked to the SCASA cannery based in Dakar. In addition, these Korean vessels under the Senegalese flag have opaque activity since they show a lack of will in collaboration with the institution responsible for the monitoring of landings in Senegal. According to local actors, it is said that Korean vessels supply the local fake tuna market (damaged or undersized tuna as well as by-catches that are not used by canneries) and

that they also supply fishmeal factories. In this way, the action undertaken by Senegalese companies maintaining close partnerships with European companies is mainly aimed at protecting their activities against competition from foreign investors who can mobilize greater financial resources. However, TUNASEN (a Senegalese shipowner under Spanish capitals) joined a Fisheries Improvement Program for Pole-and-Line Tuna Fishery in Senegal jointly with European and Asian stakeholders in order to reach MSC's standards.

Because of the perceived decrease in productivity in the area, the SERT group is considering extending its fishing zone to Liberian waters (they are already active in Sierra Leone), implying more fuel consumption and less time available for fishing.

Finally, Senegalese shipowners worry about gas and oil prospects in the region because they do not know how this could impact fishing. Purse seiners' shipowners keep in mind that Angola and Gabon have compromised their own fishing prospects in this way.

2.4.3. Advantages and disadvantages: SFPA vs. private status

As a European shipowner, there should be no alternatives to SFPA for European fisheries within a country where an agreement is pending. The financial arrangements that use the Senegalese flag will therefore leave direct room for maneuver within the European Union, with the risks that this implies. **Table 6** shows that our advantages as shipowners are very interesting: low fees and a clear and transparent framework. However, the additional obligations and contractual restrictions are perceived as disadvantages from an investor's perspective.

Table 6. Advantages and disadvantages: SFPA vs private status. Investor's perspective.

	SFPA	Private
Advantages	• Stability during several years • Low license fees (EU contribution) • Clear legal framework, protection under the SFPA protocol • Solidarity in terms of allocation of fishing possibilities and information exchange between the different EU fleets (communications between bait boats and purse seiners)	• Selected legal framework • Independence from limited perspectives under the SFPA • Autonomy, freedom to pursue access to all countries • Possibility of elaborating a financial "package set up" following the principle of "communicating jars" by involving foreign companies (i.e. SOPERKA/Sénégalaise de Thon) • The supply chain structure is clear and well-established (long-time Spanish partnerships) • For pole-and-line vessels where the fishing area is limited to a few countries, the costs of accessing foreign EEZs are relatively low. In addition, some agreements are in force with other countries in the region, which further lower the costs allocated to license fees.
Disadvantages	• Compromised access in countries where agreements are suspended • Subject to SFPA negotiations hazards, whose prospects for fishing possibilities are "downing" • Contractual restrictions (reduced fishing zones, landing obligations, obligations to employ local staff although some EEZs are only sparsely frequented and situated far from home ports...) • Obligations to work closely with unplanned partners (i.e. intermediate agencies in Mauritania) • Potential risk of carding system linked to implementation of IUU Regulation (e.g. red card for Guinea Conakry in the past forbidding fishing and trading products into the EU market)	• No protection in case of dispute with administration (boarding, seizures, fines …) • Unsuitable or uncertain legal framework (can be patchy, outdated, unclear or incomplete due to lack of transparency) • High license fees for purse seiners, whose fishing area is extended to many countries (but possibility of "circumvention" of these commitments, and preferential agreements are in force in certain neighbouring countries) • "Unfair" competition from European fleets which communicate with each other • Dependence on one or few customers for the sale of the products, vulnerability of the supply chain.

2.5. Conclusions on bait boats fishing in West Africa

It might be interesting to analyse in the same way, the national tuna fleets in other West African countries. For example, Ghana and Liberia also have national tuna vessels (Ghana even has a bigger fleet), although these countries go beyond the scope of this project and some do not have a SFPA (i.e., Ghana). However, we recommend that further investigations be made in countries that have national tuna fleets and which have SFPA in order to make a more complete comparison, which could also extend to seiners and long liners.

The pole-and-line vessels under the European flag, as well as the pole-and-line vessels under the Senegalese flag, who are in close partnerships with European interests, are all subject to transparency requirements. Thus, they all meet ICCAT's conditions, including the use of VMS. By the way, European-flagged tuna vessels are also monitored by an AIS system. In addition, European and associated shipowners actively participate in the initiative for the transparency of the tuna fishery (TTI), led by the Ministerial Conference on Fisheries Cooperation between African States Bordering the Atlantic Ocean (COMHAFAT). Among others, the initiative stipulates that the coverage with on-board observers has to be fully complete [16,17]. Although this coverage has declined since then (collected from interviews), it remains relatively high.

3. Conclusions on investigations in tuna fisheries in Africa

As tuna fisheries continue to be highly profitable, limitations arise for European investors in West Africa with the reduction of fishing opportunities contained in SFPAs signed with these coastal states. The largest European tuna agreement in West Africa with Gabon has now ended with non-renewal renewal, and new agreements have been contracted in order to compensate. In addition, other foreign fleets are rapidly growing, some of them not adhering to the same rules and requirements that the European fleet abides by through the SFPAs. This growing competition affects the business environment and profitability, as well as an even playing field in West African fisheries. National companies, particularly in Senegal, with European relations are forced to focus on protecting their activities against competition from foreign investors who can mobilize greater financial resources.

Moreover, fishing areas where EU baitboats are active are becoming less productive, further affecting the profitability of European flagged vessels, as well as of national flagged vessels, in the analysed case from Senegal, that maintain close partnerships with Europe. The response of these actors is then to extend their fishing grounds. Yet if the price of fuel increases, this can further reduce the profitability and attractiveness of fishing in areas far from the landing ports.

Nevertheless, when analysing the costs that the European fleets incur to operate in this area, the added value and gross operating surplus seem globally homogenous, despite big differences in license costs. The access price varies greatly, with the most frequented areas being the most expensive. According to the DG-Mare dataset, Senegalese and Mauritanian EEZs were the most frequented by pole-and-line vessels under French and Spanish flags between 2014 and 2019 (25,000 and 15,000 cumulative tons). Guinea-Bissau is not a common fishing area for the moment, despite

the low cost of access. This analysis concurs that the abundance of tuna takes priority over access costs. Yet, with fewer fishing opportunities as well as increasingly restrictive conditions for access and landings under SFPA, European operators are considering whether to shift to the private regime, further threatening the sustainability and transparency of the tuna fisheries.

On the other side of the continent, in the tuna fisheries taking place in the Seychelles, European investors are facing similar factors, but mostly the need to extend their turnover. Private investors, in particular from the French group SAPMER, have adopted the clear strategy of developing their presence with large modern seiner as close as possible to the fishing areas. To this end, investments are made in the relevant landing ports to build the necessary infrastructure, such as landing docks, storage halls, etc. In this way, developing a strong tuna fishing fleet entails a mobile fleet with landing ports close enough to the fishing areas, even investing in them to be adequate for the operation. The particular case of the Seychelles, a country with an active SFPA, might be an interesting one to evaluate how to overcome the challenges currently growing for tuna fishing on the west coast of Africa and potentialize a closer collaboration with West African coastal states with the potential to extend the available fishing grounds for foreign investors and benefit from it. The question remains on how to promote the utilization of a clear and transparent framework, such as the SFPA, when competition arises under different conditions.

4. Final remarks

The research reports important challenges on all of the fishing grounds, analyzes them, and highlights different strategies that investors are preferring under the growing competition and productivity of the fishing areas. In the centre of the investigations stand the Sustainable Fisheries Partnership Agreements (SFPA), which aim to create a transparent and clear framework to operate in these areas. However, the growing presence of large fleets entering the fishing areas under different, sometimes not transparent, conditions may deteriorate the business environment, potentially threaten profitability, and even affect the sustainability of these fisheries.

In tuna fisheries, investigations were based on FAO and the EU for the ex-post evaluation of fishing agreements, as well as on interviews with relevant stakeholders, including shipowners and key personnel from public bodies and institutions both in West Africa and Europe. The data analysed was accessed from unpublished raw data provided to the FarFish project by DG-Mare. The investigations show that the fishing areas where European vessels are active on the west coast of Africa are becoming less productive. Both European-flagged vessels and national-flagged vessels with close ties to European interests are showing less profitability. As a response, these investors are seeking to expand their fishing grounds, which can potentially lead them to incur additional costs when the landing ports are farther away and some of the closer ones do not have the capacity to handle the landings. Additional fishing grounds are opening up; however, the restrictive conditions for accessing fishing rights and landings are pushing European investors to consider whether to continue abiding by the SFPAs or to shift to the private regime, especially in light of emerging competition

from third-party nations, including host countries, that are not abiding by the same regulations.

Yet, on the other side of the continent in the Indian Ocean, facing similar circumstances, a clear strategy has been adopted by private European investor SAPMER Group. They seek to develop their presence as close as possible to the fishing areas, investing in the necessary facilities in the relevant landing ports. This strategy indicates a closer collaboration with the coastal states as well as a long-term investment approach to establishing and consolidating a large, mobile fleet with supportive landing ports close to the fishing grounds. They prioritize access to the tuna over the current additional burden of investing in adequate landing ports. The contrasting prospective in these two areas, West Africa and the Indian Ocean, invites us to further reflect on the different factors that might be contributing to adopting a more long-term investment strategy under the SFPA framework. Instead of retreating from it and seeking to operate under the private regime, an initial analysis was presented here; however, as concluded in the relevant section, extending this analysis to other coastal states will provide a broader and clearer picture of the potential to continue to expand and establish long-term investment in profitable and sustainable tuna fisheries on the African coast.

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Appendix A

Table A1. Stakeholders consulted.

Contact	Institution
Moustapha Deme	Fisheries Economist, CRODT (Senegal), in charge of the economic Component of the World Bank Project for the Free Economic Zone of Nouadhibou
Sidy Mouhamed Kandji	Director/Shipowner, Sénégalaise de thon (Senegal)
Adama Mbaye	Fisheries Economist, CRODT (Senegal)
Khallahi Brahim	IMROP
Abu Elimane Kane	IMROP
Marie Traore	General Secretary, RAMPAO (Regional Network for Marine Protected Areas in West Africa)
Ndiaga Thiam	CRODT
Fambaye Ngom Sow	Tuna Specialist, CRODT (Senegal)
Renaud Bailleux	IUCN (Marine & Coastal Program, IUCN West & Central Africa)
Ibrane Ndao	Director, SERT Group (Senegal)
José Maria Aurtenetxe	Dakar Tuna (EU – Senegal) Representative
Patrick Furic	Fleet Director, Saupiquet (France)
Vincent Defaux	DG-Mare (EU) consultant, Poseidon Aquatic Resource Management Ltd.
Didier Moisan	Ex-ORTHONGEL (France)
Michel Goujon	Director, ORTHONGEL (France)
Miguel Herrerra	Director, OPAGAC (Spain) – E-mails exchanged only
Anthony Claude	Saupiquet (France)
Alain Fonteneau	Tuna Specialist, Institut de recherche pour le développement - IRD (France)
Pierre-Alain Carre	Fleet Director, CFTO (France)
Philippe Lallemand	Poseidon Aquatic Resource Management Ltd.
Abdou Daïm Abdoul Aziz Dia	Socio-Anthropologist, IMROP (Mauritania)
Mohamed Ould Lemine Tarbia	Economiste, Adviser to the ministry of Fishery, Mauritania
Mohamed Vall	Director, IUCN Mauritania
Ad Corten	Biologist, Scientist in charge of small pelagic CECAF working group
Hachim El Ayoubi	Former COMHAFAT Excecutive Secretary
Mikia Diop	CSRP Adviser for small pelagic fishery management
Peter Wekesa	OACP Secretariat Fishery expert

Appendix B

Table B1. List of EU flagged Tuna vessels operating in Senegal.

NAME	MMSI	FLAG	BASE PORT	FS GEAR
STERENN	226180000	FRANCE	CONCARNEAU	PS
GUEOTEC	227549000	FRANCE	CONCARNEAU	PS
GUERIDEN	227550000	FRANCE	CONCARNEAU	PS
GEVRED	228066900	FRANCE	CONCARNEAU	PS
PENDRUC	228071900	FRANCE	CONCARNEAU	PS
CAP BOJADOR	228280000	FRANCE	CONCARNEAU	PS
CORONA DEL MAR	228967000	FRANCE	BAYONNE	HL
PEGASO	247083500	ITALY	MESSINA	LL
SALVATORE PRIMO	247110330	ITALY	MARTINSICURO	LL
AITA FRAXKU	224070000	SPAIN	Ex-HONDARRIBIA	PL
GAZTELUGAITZ	224073650	SPAIN	BERMEO	PL
KERMANTXO	224089000	SPAIN	HONDARRIBIA	PL
SAN FRANCISCO	224098930	SPAIN	HONDARRIBIA	HL
RIO LANDRO	224295000	SPAIN	A GUARDA	PL
PLAYA DE BAKIO	224405000	SPAIN	BERMEO	PS
SIEMPRE NUEVO ANGEL	224452000	SPAIN	FOZ	PL
PLAYA DE NOJA	224531000	SPAIN	BERMEO	PS
EGALUZE	224580000	SPAIN	BERMEO	PS
ZUBEROA	224587000	SPAIN	BERMEO	PS
ALBACORA QUINCE	224727000	SPAIN	VIGO	PS
MAR DE SERGIO	224733000	SPAIN	CÁDIZ	PS
ALBONIGA	224745000	SPAIN	BERMEO	PS
PILAR TORRE	224896000	SPAIN	BERMEO	PL
PLAYA DE RIS	225459000	SPAIN	BERMEO	PL

Data source: LDAC/GFW 2012-2016/ICCAT Vessel Finder (up to 2019)/WhoFishesFar Database
Other flags but linked to European Interests between 2015–2020 (data source: Joint Scientific Committee 2019/ISSF database): No bait boats. Seiners from Belize (2), Cabo Verde (3), Curaçao (5), Salvador (4), Guatemala (2) and Panama (2).

Appendix C: List of Tuna vessels based in Dakar

Table C1. Senegalese flag.

No.	Vessel name	Vessel type	Shipowner	Equity	Remark
1	PRESIDENT MAGATTE AYA DIACK II	PL	SERT (Société d'Exploitation des Ressources Thonières)	According to shipowner: Senegal (but exclusive partnership with Spain: FRINSA)	
2	PRESIDENT MATAR NDIAYE II	PL	SERT (Société d'Exploitation des Ressources Thonières)	According to shipowner: Senegal (but exclusive partnership with Spain: FRINSA)	Same group. Contacted
3	COMMANDANT BIRAME THIAW	PL	DAKAR THON	? (exclusive partnership with Spain: FRINSA)	
4	RAMATOULAYE	PL	SENEGALAISE DE PECHE THONIERE	? (exclusive partnership with Spain: FRINSA)	
5	LIO I	PL	TUNASEN	Supposed: Spain, as TUNASEN is member of the organisation Dakar Tuna along with EU pole-and-line vessels	No answers
6	PONT SAINT LOUIS (UVI Number 8222422)	SEI	SENEGALAISE DE THON	Spain (SOPERKA/Perreira Almadora)	Contacted
7	GRANADA (UVI Number 8102907)	SEI	CAPSEN SA	South Korea (Dongwon)	
8	WESTERN KIM (UVI Number 8003242)	SEI	CAPSEN SA	South Korea (Dongwon)	
9	XIXILI (UVI Number XIXILI)	SEI	CAPSEN SA	South Korea (Dongwon)	No answers
10	ORIENTAL KIM (UVI Number 7827495)	SEI	CAPSEN SA	South Korea (Dongwon)	
11	SOLEVANT (UVI Number 8104204)	SEI	GRANDE BLEUE (formerly CAPSEN SA)	South Korea (supposed: Dongwon)	
12	SEA DEFENDER (UVI Number 8996190)	SEI	GRANDE BLEUE (formerly CAPSEN SA)	South Korea (supposed: Dongwon)	No answers
13	LISBOA	LL (supposed)	HSIN-FEI TRADING & INVESTMENT Co. LTD (NATIC) (formerly JUH JAN ENTERPRISE CO.LTD)	South Korea	
14	MAXIMUS	LL (supposed)	HSIN-FEI TRADING & INVESTMENT Co. LTD (NATIC) (formerly JUH JAN ENTERPRISE CO.LTD)	South Korea	
15	MARIO 7	LL (supposed)	HSIN-FEI TRADING & INVESTMENT Co. LTD (NATIC) (formerly JUH JAN ENTERPRISE CO.LTD)	South Korea	No answers
16	MARIO 11	LL (supposed)	HSIN-FEI TRADING & INVESTMENT Co. LTD (NATIC) (formerly JUH JAN ENTERPRISE CO.LTD)	South Korea	

Table C1. (*Continued*).

No.	Vessel name	Vessel type	Shipowner	Equity	Remark
17?	CAP ATLANTIQUE?	PL		Japan?	Source: ISSF ProActive Vessel Register (PVR)
18?	LIO II?	PL		TUNASEN (supposed Spain)?	Source: ISSF ProActive Vessel Register (PVR

Table C2. European flags.

No.	Name	Type	Flag	Shipowner	Equity
1	CORONA DEL MAR? (UVI Number 9093206)	PL	France		Source: ISSF ProActive Vessel Register (PVR)
2	AITA FRAXKU (UVI Number 9212943)	PL	Spain		Source: ISSF ProActive Vessel Register (PVR)
3	BERRIZ SAN FRANCISCO (UVI Number 9297450)	PL	Spain		Source: ISSF ProActive Vessel Register (PVR)
4	GAZTELUGAITZ (UVI Number 9200249)	PL	Spain		Source: ISSF ProActive Vessel Register (PVR)
5	IRIBAR ZULAIKA (UVI Number 9154373)	PL	Spain		Source: ISSF ProActive Vessel Register (PVR)
6	KERMANTXO (UVI Number 9212955)	PL	Spain		Source: ISSF ProActive Vessel Register (PVR)
7	NUEVO SAN LUIS (UVI Number 6403979)	PL	Spain		Source: ISSF ProActive Vessel Register (PVR)
8	PILAR TORRE (UVI Number 6403979)	PL	Spain		Source: ISSF ProActive Vessel Register (PVR)

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Article

Climate change challenges: Case of the Thai agriculture business sector

Nattavud Pimpa

Faculty of Business, American University of Business and Social Sciences, Dover, DE 19901, USA; nattpimpa@yahoo.com

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Abstract: Climate change and its effects are accelerating, with climate-related disasters piling up season after season. This study explores the impact of climate change on Thailand's agricultural business by examining the views and experiences of stakeholders in the sector. Through in-depth interviews and thematic analysis, the study reveals the multifaceted challenges faced by the agricultural community. Participants highlight the disruptive effects of irregular rainfall patterns and rising temperatures on crop productivity and economic stability, exacerbating food shortages and livelihood insecurity. Additionally, the study underscores the critical issue of food security and the need for resilient agricultural practices. Furthermore, the inadequate integration of climate change education in the Thai education system and its implications for farmer adaptation are discussed. The study emphasizes the urgent need for comprehensive support measures and a holistic approach to address climate change impacts on Thailand's agricultural sector, ensuring its sustainability and the well-being of farmers.

Keywords: climate change; sustainable development; agriculture; Thailand

1. Introduction

Climate change poses a wide range of challenges and impacts across different sectors. The adverse effects of climate change are diverse, affecting agriculture, biodiversity, and human health [1,2]. Climate change can result in changes in land surface phenology, impacting ecosystems and biodiversity [3].

The consequences of climate change extend beyond environmental aspects to socio-economic factors, with developing economies projected to shoulder a significant burden [3,4]. Challenges related to climate change are further complicated by factors such as poverty, high population density, and existing inequalities [5,6].

Adapting to climate change is essential, as evidenced by farmers in regions like the Nile Basin of Ethiopia making decisions on adaptation strategies to alleviate the effects of climate change on agriculture [7]. Smallholder farmers in Sri Lanka have been observed implementing perception-driven coping mechanisms to address climate change impacts, such as adjusting their agricultural practices to combat crop failure [8]. Nevertheless, despite these initiatives, the challenges posed by climate change persist, necessitating a deeper comprehension of how societies confront and respond to these challenges [9].

Furthermore, the impacts of climate change go beyond environmental and economic domains to impact public health, with vulnerable populations like teenagers being particularly at risk of the health consequences of climate change [10]. The imperative for policy interventions and mitigation strategies to tackle the impacts of climate change is evident, underscoring the importance of enhanced planning and readiness for health-related consequences, akin to the lessons learned from the COVID-19 pandemic.

Indeed, climate change presents a complex and multifaceted challenge with widespread implications for agriculture, biodiversity, human health, and socio-economic systems. Addressing these challenges demands a comprehensive understanding of the various factors at play and the formulation of adaptive strategies to mitigate the adverse effects of climate change.

2. Situation in Thailand

Thailand is indeed facing significant challenges due to climate change. The situation of climate change in Thailand is a pressing issue that requires immediate attention and concerted efforts from various stakeholders. By understanding the specific vulnerabilities and impacts of climate change on different sectors, Thailand can develop effective adaptation strategies to build resilience and mitigate the adverse effects of a changing climate.

Studies have shown that the country is highly vulnerable to climate change impacts such as floods, droughts, sea-level rise, and changes in precipitation patterns [11–13]. The observed trends indicate that Thailand has experienced significant warming over the past four decades, leading to changes in extreme temperature events [14]. Additionally, the country is projected to experience increased risks of flooding and drought, which will impact various sectors, including agriculture and water resources [15,16].

The impacts of climate change in Thailand are diverse and affect different aspects of the country. For instance, the agriculture sector, which is crucial for the country's socio-economic development, is particularly vulnerable to climate fluctuations, including changes in rainfall patterns and temperatures [16,17]. Furthermore, coastal regions, such as the Andaman Coast, and islands, such as Koh Phi Phi, are at risk of sea-level rise, which could have detrimental effects on tourism and local communities [18].

Efforts are being made to address climate change adaptation in Thailand. Studies have highlighted the importance of developing adaptation strategies for various sectors, such as energy, agriculture, and urban planning, to mitigate the impacts of climate change [15,19–21]. Additionally, there is a growing recognition of the need for policy and legal interventions to manage the atmosphere effectively and transition towards a low-carbon society [22].

The situation of climate change in Thailand is a pressing issue that requires immediate attention and concerted efforts from various stakeholders. By understanding the specific vulnerabilities and impacts of climate change on different sectors, Thailand can develop effective adaptation strategies to build resilience and mitigate the adverse effects of a changing climate.

One of the key vulnerabilities in Thailand is the impact of climate change on agriculture. The changing weather patterns, including irregular rainfall and an increased frequency of extreme weather events such as droughts and floods, pose a significant risk to the country's agriculture sector. This has direct implications for food security, rural livelihoods, and the overall economy.

In light of these vulnerabilities, it is imperative for Thailand to prioritize adaptation measures that encompass a range of strategies, including sustainable land

and water management, coastal protection and restoration, urban planning and design, and the promotion of climate-resilient agricultural practices. Collaboration among government agencies, local communities, civil society organizations, and the private sector is essential to ensuring the successful implementation of these adaptation strategies. The research question for this paper is set as follows:

What is the impact of climate change on Thailand's agricultural business?

3. Research design

The research design is informed by a phenomenological approach, aiming to uncover the lived experiences and perceptions of key stakeholders within Thailand's agricultural sector regarding climate change impacts.

3.1. Data collection

Semi-structured interviews serve as the primary data collection method. This approach allows for flexibility and depth in exploring participants' perspectives, while also ensuring consistency across interviews. Participants were selected based on their expertise, involvement in agricultural activities, and geographical representation across different regions of Thailand.

Interviews were conducted with a diverse range of stakeholders involved in Thailand's agricultural business, including five farmers, three agricultural policymakers, three industry experts, and two representatives from relevant government agencies and non-governmental organizations (NGOs). Purposeful sampling was employed to ensure representation of various perspectives and experiences related to climate change impacts on agriculture in Thailand.

Probing questions were designed by the researcher and used to explore participants' perceptions of climate change impacts on different aspects of agricultural business, including crop yields, water availability, pest and disease prevalence, market dynamics, and adaptation strategies.

3.2. Data analysis

Thematic analyses were employed to identify recurring patterns, themes, and insights within the interview data. Transcribed interviews were initially coded and analyzed iteratively, allowing for the emergence of key themes related to climate change impacts on Thailand's agricultural business.

To enhance the trustworthiness and rigor of the study, strategies such as member checking, peer debriefing, and reflexivity were also employed. Member checking involves sharing key findings with participants to verify accuracy and enhance credibility.

3.3. Ethical considerations

This study adheres to ethical guidelines and obtains ethical approval from the American University of Business and Social Sciences review board. Informed consents are obtained from all participants, ensuring confidentiality, anonymity, and voluntary participation.

4. Findings

4.1. Climate change and overall production

Climate change has had significant impacts on agriculture in Thailand, affecting crop yields and overall production. It was addressed by the participants that rising temperatures and changes in precipitation patterns due to climate change can lead to severe damage to crop yields. The vulnerability of the agricultural sector to climate change can result in a decrease in agricultural production, impacting the livelihoods of farmers and their families. Unstable weather conditions, including extreme temperatures, droughts, and changes in rainfall patterns, have started to impact their work, contributing to crop failures and planting difficulties.

Some participants addressed irregular rainfall patterns as a major problem. Climate change can lead to unpredictable rainfall patterns, with periods of drought followed by heavy rainfall events. and flooding. These variations in precipitation can significantly affect crop yields, leading to food shortages and economic instability in rural areas.

Rising temperatures can negatively impact crop productivity, as certain crops may struggle to adapt to the changing climate conditions. This can lead to reduced agricultural output and income for farmers, further exacerbating food insecurity and poverty in the agricultural sector.

4.2. Food security

Views from delegates who work in the agricultural sector also emphasize how climate change poses a threat to food security and local economic stability. The condition of the weather, level of rain, and changes in the pattern of nature in the hometown where subsistence agriculture is practiced make rural communities highly vulnerable to the negative impacts of climate change on agricultural and food production.

Developing drought-resistant crop varieties, implementing efficient water management techniques, and promoting agroforestry and sustainable land use practices are essential steps in building resilience in the agricultural sector. Furthermore, providing farmers with access to climate information, financial resources, and knowledge exchange on climate-smart agricultural techniques will be crucial for enhancing the sector's resilience. This issue can be related to the global food issue. For instance, the projected declines in sugarcane production, a vital crop for Thailand's economy, could adversely affect the well-being of sugarcane growers and global sugar prices.

Climate-smart agriculture is seen as a promising approach to enhance food productivity, build resilience in agricultural systems, and reduce greenhouse gas emissions in response to climate change impacts. Additionally, technological advancements play a role in helping farmers adapt to changing climatic conditions, although the rate of technological changes may outpace the rate of climate change impacts on agriculture in Thailand.

The effects of climate change on food security in Thailand are multifaceted, encompassing changes in temperature, precipitation, extreme weather events, and crop

yields. Implementing effective adaptation strategies and policies is essential to safeguarding the agricultural sector and ensuring food security in the face of a changing climate.

4.3. Education issues

Climate change topics are poorly integrated into the Thai education system, particularly in rural areas. In agricultural education for Thai farmers, climate change is lacking, with teachers ill-prepared to teach the subject matter effectively. Theoretical teaching of climate change and agriculture does not translate into practical knowledge for students.

Research funding and collaboration on climate change and farmers' readiness for this issue are insufficient. Many individuals perceive climate change and environmental issues as unrelated or unimportant, leading to apathy towards measures in the education sector.

Limited understanding and attention to preventative strategies in agriculture results in reactive rather than proactive behaviors among Thai farmers when it comes to climate change adaptation.

Participants in this study suggested that we should integrate climate change education into all educational sectors. Thai policymakers should prioritize the integration of climate change topics into the national education curriculum, particularly in rural areas where awareness and understanding of climate change may be limited. Providing teachers with training and resources on climate change education can enhance their capacity to teach the subject effectively and equip students with the knowledge and skills needed to address climate-related challenges.

Some participants agreed that improving public health education is essential for raising awareness about the health impacts of climate change and promoting preventive measures among the general population. Thai policymakers should invest in teacher training programs, curriculum development, and educational campaigns to ensure that public health education is comprehensive, accessible, and culturally relevant.

To bridge the gap between theoretical knowledge and practical application, Thai policymakers should promote experiential learning and hands-on activities that allow students to apply their knowledge of climate change and public health in real-world contexts. Field trips, community engagement projects, and interactive learning experiences can help students develop practical skills and foster a deeper understanding of the connections between climate change, public health, and environmental sustainability.

4.4. Climate change and farmers

Climate change has a profound impact on the lives of farmers in Thailand, posing significant challenges to their livelihoods and overall well-being. Climate change has disrupted traditional farming practices in Thailand, leading to increased uncertainty and risk for farmers. The irregular rainfall patterns and increased temperatures have made crop cultivation more challenging, affecting agricultural output and farmers'

incomes. Additionally, the prevalence of pests and diseases has caused substantial losses for farmers, further exacerbating the already precarious situation.

In response to these challenges, it is crucial for the Thai government to implement comprehensive support measures for farmers. This includes providing access to climate-resilient seeds and agricultural technology, as well as offering training and education on sustainable farming practices. Financial assistance and insurance programs can also help mitigate the economic impact of climate-related losses on farmers, ensuring their livelihoods and well-being are safeguarded.

Furthermore, fostering knowledge exchange and collaboration among farmers, research institutions, and agricultural experts can facilitate the sharing of best practices and innovative strategies for climate-resilient agriculture. By creating a supportive environment for farmers and empowering them with the necessary tools and resources, Thailand can strengthen its agricultural sector against the challenges of climate change [23].

The holistic approach to enhancing agricultural resilience outlined above not only addresses the immediate threats posed by climate change but also contributes to the long-term sustainability and prosperity of the agricultural community in Thailand. By prioritizing the well-being of farmers and the resilience of the agricultural sector, Thailand can navigate the challenges of climate change and secure a stable and prosperous future for its agricultural industry.

5. Conclusion

In conclusion, this study has shed light on the multifaceted challenges that climate change poses to Thailand's agricultural business, as articulated by the participants. Four overarching themes emerged from the discussions, each highlighting the intricate interplay between climate variability and its impacts on agricultural livelihoods, food security, education, and the well-being of farmers.

The first theme underscored the disruptive effects of irregular rainfall patterns and rising temperatures on crop productivity and economic stability in rural areas. Participants voiced concerns over the unpredictability of precipitation, leading to periods of droughts and floods that significantly affect crop yields and exacerbate food shortages.

Linked closely to this, the second theme emphasized the critical issue of food security, particularly in vulnerable rural communities reliant on subsistence agriculture. Climate change threatens local economic stability and food production, necessitating the adoption of resilient agricultural practices and the provision of support mechanisms to mitigate its adverse effects.

Furthermore, the lack of integration of climate change education in the Thai education system emerged as a significant challenge. Participants highlighted the inadequate preparation of educators and the limited attention given to climate-related topics in agricultural education. Addressing this issue requires concerted efforts to enhance climate literacy among students and educators, bridging the gap between theoretical knowledge and practical application.

Lastly, the profound impact of climate change on farmers' livelihoods and overall well-being was evident. Disrupted traditional farming practices, increased uncertainty,

and heightened risk underscored the urgent need for comprehensive support measures. These include access to climate-resilient seeds and technologies, financial assistance, and knowledge exchange platforms to empower farmers to adapt to climate change.

Moving forward, addressing these challenges demands a holistic approach that integrates scientific research, policy interventions, and community engagement. By prioritizing the resilience of the agricultural sector and the well-being of farmers, Thailand can navigate the complexities of climate change and pave the way for a sustainable and prosperous future. Through collaborative efforts and innovative solutions, Thailand can emerge stronger and more resilient in the face of evolving climate threats, ensuring the continued vitality of its agricultural industry and the welfare of its farming communities.

6. Recommendations

Addressing the complex intersection of climate change and public health in Thailand requires a multifaceted approach that tackles systematic and administrative issues, improves education and awareness, and empowers individuals to take proactive measures to protect their health and the environment. By addressing these key challenges, Thai policymakers can enhance the resilience of communities and reduce the health risks associated with climate change. Here are some suggestions for mitigating the impact of climate change on the health of Thai citizens:

According to the themes from this study, when it comes to supporting the process of policy development and implementation, they should prepare to bring a variety of issues to stakeholders in agriculture. The Thai government should formulate and implement comprehensive climate change adaptation policies specifically tailored to the agricultural sector.

They can also invest in research and development by allocating funding for research on climate-resilient crop varieties and sustainable agricultural technologies. More importantly, facilitate collaboration between research institutions, agricultural experts, and farmers to co-develop and disseminate innovative solutions.

Support for community leaders and capacity building will be useful for the rural areas of Thailand. Thai policymakers should provide support and resources to empower community leaders to understand and expand the concept and actions to mitigate climate change impacts on the environment within their communities. This support could include training programs, capacity-building workshops, and educational materials focused on climate change awareness, adaptation strategies, and sustainable environmental practices. By equipping community leaders with the knowledge and skills to mobilize their communities, policy makers can foster grassroots engagement and empower communities to take meaningful action to address climate change.

Promoting awareness about climate change through education seems to be an important and powerful method to mitigate risks relating to climate change. Education can enhance public awareness and risk perception of climate change, which are essential for taking informed actions to mitigate its impacts. Furthermore, school-based education has the potential to incorporate the prevention and health co-benefits of climate mitigation and adaptation within the curriculum, thereby contributing to

addressing climate change and its impacts [21,24]. emphasized that sustainable education equips young people with the necessary knowledge and skills to understand and implement the changes required for mitigating climate change and global warming.

Finally, working with the local farmers on promoting how to collaborate with fellow farmers, local communities, and relevant stakeholders to share knowledge, resources, and experiences in adapting to climate change will be helpful for them. If they participate in collective action initiatives, such as farmer cooperatives and community-based adaptation projects, to strengthen resilience at the community level, they will be prepared to mitigate climate change risks.

By implementing these suggestions collaboratively, the Thai government and farmers can work together to build resilience, adapt to climate change, and ensure the long-term sustainability and prosperity of the agricultural sector in Thailand.

Ultimately, by heeding the insights and recommendations presented herein, Thailand can chart a more resilient and sustainable path forward in the face of climate change. It is our collective responsibility to act decisively and inclusively, ensuring a brighter and more sustainable future for generations to come.

Conflict of interest: The author declares no conflict of interest.

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Article

Political connections and corporate ESG performance

Ying Hu*, Hui Cheng, Heng Li

School of Electrical and Optoelectronic Engineering, West Anhui University, Luan 237012, China
*** Corresponding author:** Ying Hu, wxczxm20020706@163.com

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Abstract: With the popularization of the concept of sustainable development, corporate ESG performance has attracted more and more attention from all walks of life. However, there is still a lack of in-depth discussion on what factors affect corporate ESG performance, especially in a political and economic system like China. This article takes A-share listed companies as a sample to empirically analyze the impact of political connections on corporate ESG performance. The study found that political connections can promote corporate ESG performance by increasing media attention and reducing financing constraints. Further research found that this promotion performance is more significant in non-state-owned enterprises. This article combines the national conditions with Chinese characteristics, enriches the research on the factors that promote corporate ESG performance from the government perspective, and deepens the research on the role and consequences of political connections.

Keywords: political connections; corporate ESG performance; media attention; nature of property rights

1. Introduction

As environmental problems become increasingly severe, it is urgent to achieve dual carbon goals and sustainable development goals. Against this policy background, the ESG system has become the focus of attention from all sectors of society [1]. Corporate ESG performance not only affects corporate value [2], but also reflects the level of corporate sustainable development [3]. Therefore, domestic and foreign academics and practitioners have conducted a large number of studies on corporate ESG performance and its influencing factors and consequences. Although my country's ESG market is developing rapidly, there is still a big gap compared with developed countries [4], and it needs continuous improvement.

There are two main flaws in the existing research on corporate ESG performance: first, the analysis of factors affecting corporate ESG performance is not comprehensive and in-depth; second, it ignores the important role that the government level may play in corporate ESG performance under the characteristics of China's market economy. In response to these two major shortcomings, this article will explore whether and how political connections affect corporate ESG performance.

Choosing political connection as the analytical perspective is mainly based on the following considerations:

First of all, the revised version of the "Guidelines for the Governance of Listed Companies" states that listed companies should strengthen ESG information disclosure and strengthen their leading role in assuming social responsibilities. It also emphasizes the importance of party and government leadership in corporate governance. The relevant legal system construction of my country's market economy is not yet fully mature. The government is the key leader in social and economic

development. Political connections, as an important resource for enterprises [5], play the role of a "supporting hand" and can help enterprises. Obtaining more loans [6], reducing financing constraints [7,8], and obtaining financial subsidies and tax incentives have a non-negligible impact on corporate financial and non-financial indicators. Studying the impact of political connections on corporate ESG performance will help reveal the mechanism of the political environment on corporate sustainable development and provide a theoretical basis and empirical support for the government to formulate relevant policies and norms.

Secondly, existing research mostly focuses on the impact of political connections on sub-indexes of corporate ESG performance and rarely analyzes the relationship between the two as a whole. Moreover, there are different views on how political connections affect sub-indicators of ESG performance. Regarding the impact of political connections on corporate environmental responsibilities, one side believes that political connections make companies more likely to receive media attention, and companies will take the initiative to fulfill more environmental responsibilities in order to maintain their reputation [9]. In addition, political connections will promote corporate green innovation and play a role in the "Resource effect" [10]. The other side believes that political connections may lead to companies abusing power or enjoying privileges, helping companies circumvent environmental systems [11], and punishing companies for environmental violations. Producing a "shelter effect" [12], that is, reducing the intensity of penalties for violations, thereby relaxing the emphasis on and improving environmental issues. Regarding the impact of political connections on companies' performance of social responsibilities, one party believes that political connections can promote corporate charitable behaviors [13] and the fulfillment of social responsibilities [14]. The other side believes that political connections may weaken companies' consideration and response to social interests and reduce corporate social responsibility information disclosure [15]. Regarding the impact of political connections on the quality of corporate internal governance, one party believes that political connections can enhance executives' enthusiasm for implementing corporate internal governance, and their execution will also be enhanced [16], so that companies will have better internal governance. Control governance performance. The other side believes that political connections increase the ability and motivation of major shareholders to misappropriate funds [17], thereby increasing agency costs. To a certain extent, this will increase the risk of adverse selection by management and weaken corporate governance elements such as internal control.

Generally speaking, political connections have a non-negligible impact on the overall ESG performance of companies, and this impact may be positive or negative. In this context of the dual drivers of social markets and macropolitics, this article attempts to answer the following questions: Does the impact of political connections on the overall performance of corporate ESG indicators promote or inhibit? And through what channels does this influence occur? In response to this problem, this article uses empirical analysis methods to explore the impact and mechanism of political connections on corporate ESG performance.

Compared with existing research, the main contributions of this article may be reflected in the following aspects: (1) filling the gap in the literature, exploring the impact of political connections on the overall performance of corporate ESG for the

first time, and deepening the understanding of the market economy with Chinese characteristics and the background of sustainable development Related research on political connections: (2) based on reputation pressure theory, it is found that media attention plays a mediating role between political connections and corporate ESG performance, enriching the impact of media information disclosure on corporate non-financial indicators; (3) in companies with different property rights, the impact of political connections is different. This paper divides companies into categories of property rights. The study found that political connections have a more positive effect on the ESG performance of non-state-owned enterprises, enriching the impact of political connections on companies with different property rights research.

2. Theoretical analysis and research hypotheses

First, based on rent-seeking theory, in the context of an incomplete market economy, the government will allocate market resources through intervention or regulation, thereby creating or protecting certain privileges. Establishing political connections is a typical rent-seeking behavior that strengthens the mutually beneficial relationship between the government and enterprises [18]. This relationship is mainly reflected in the following two aspects. First, enterprises are highly dependent on some resources controllable by the government. By using the intervention of government administrative power, they can increase their chances of obtaining excess income, such as: obtaining more financial subsidies [19], reducing financing constraints [7,8], etc., thereby increasing the company's own profits; secondly, in order to improve performance indicators, government officials are forced to be promoted and differentiated. The competitive pressure of local governments [20–22] requires enterprises to assume some social responsibilities and enhance the quality of relevant information disclosure. To sum up, through the rent-seeking behavior of establishing political connections, enterprises obtain more additional resources, relieve financing pressure, and increase the pressure on environmental and social responsibilities. In order to maintain this mutually beneficial relationship, companies may use part of their funds for corporate ESG performance investment to promote corporate ESG performance.

Second, based on the moral compensation theory, an individual's moral decision-making will be affected by prior behavior. If an unethical behavior was performed previously, a more moral behavior will be performed later, and vice versa. Companies that establish political connections may breed corruption among government officials [23], increase the moral hazard of executives, and harm the interests of small and medium shareholders. These unethical behaviors for self-interest will prompt executives to feel shame [24] and subsequently make moral compensation [25]. In addition, enterprises can obtain more social resources by establishing political connections, which may cause unfair competition between enterprises and harm the interests of enterprises that have not established political connections. In order to alleviate the guilt caused by previous unethical behavior and make up for the harm of these unethical behaviors to the corporate image, corporate executives may show higher ethical behavior in other aspects, such as: assuming more social and

environmental protection responsibilities, increasing charitable donations, etc., these behaviors will improve the ESG performance of enterprises to a certain extent.

Third, based on institutional theory, when companies face external pressures brought about by establishing political connections, they may adopt a decoupling strategy to complete tasks symbolically [26] rather than truly changing their behavior. and attitude. This may lead to companies not investing too much resources in fulfilling social or environmental responsibilities when facing public pressure, as long as they meet legal requirements to avoid punishment. In addition, political connections will weaken the impact of institutional constraints on corporate operations or investment activities [27], which means that companies can evade or reduce institutional responsibilities or penalties through political channels, thereby reducing their recognition of ESG performance. level of knowledge and compliance. On the other hand, political connections may make companies more dependent on political resources, reduce their motivation to participate in market competition, and reduce their motivation to enhance their competitiveness and reputation by improving ESG performance. To sum up, political connections may have a negative impact on corporate ESG performance, because it not only reduces corporate investment in and emphasis on ESG performance, but also weakens corporate motivation and willingness to improve ESG performance.

In summary, this article puts forward the following hypotheses:

- Hypothesis 1a: Political connections will improve corporate ESG performance.
- Hypothesis 1b: Political connections will reduce corporate ESG performance.

The mediating effect of media attention on political connections and corporate ESG performance.

From the perspective of agenda setting theory, the media will pursue important issues in society and process and report on them. This behavior will affect the public's perception of this issue. Political connections are controversial and socially sensitive topics, which are in line with the media's tendency to pursue hot topics. In real life, once executives establish political connections, their relevant information will be reported eagerly [10], thereby being exposed to the attention of stakeholders and facing higher reputational risks. Combined with the analysis of reputational pressure theory, media attention brings reputational and exemplary pressure to management, which will prompt management to actively or passively adjust their behaviors and strategies to adapt to the expectations and standards of social groups. In order to respond to public expectations for companies to protect the environment and fulfill social responsibilities, companies will enhance their performance of social responsibilities [28], thereby improving corporate ESG performance.

- Hypothesis 2: Political connections will improve corporate ESG performance by increasing media attention.

3. Research design

3.1. Sample source

This article takes all A-share-listed companies from 2010 to 2020 as the research sample and screens them through the following criteria: First, exclude financial and insurance companies; second, exclude ST and *ST listed companies; and third,

exclude the required data from the missing company. A total of 20,093 sample values were obtained after screening. This article winsorizes all continuous variables at the upper and lower 1% to eliminate the impact of extreme values on the study. The data required in this article comes from the Wind database.

3.2. Model construction

In order to test the impact of political connections on corporate ESG performance, this article constructs the following model. The specific variable definitions are shown in **Table 1**.

$$ESG_{i,t} = \alpha_0 + \alpha_1 PC_{i,t} + \alpha_2 Controls_{i,t} + Industry + Year + \xi_{i,t} \quad (1)$$

where the explanatory variable *ESG* denotes the *ESG* performance of the firm in year *t*, reflecting the firm's performance in environmental protection, social responsibility, and corporate governance. The explanatory variable PC indicates whether the firm has political connections, which is a binary variable where 1 indicates the presence of political connections and 0 indicates the absence of political connections. The presence of political connections may affect a firm's *ESG* performance through various channels, such as through higher policy attention or better access to resources. The control variable Controls include other factors that may affect *ESG* performance, such as firm size, profitability, and capital structure, which are selected for inclusion in the model based on existing literature and theoretical foundations. The model also includes industry-fixed effects and year-fixed effects to control for the time effects of industry characteristics and macroeconomic or policy environments that do not vary with firm operations in order to more accurately estimate the impact of political linkages on *ESG* performance. In addition, we control for heteroskedasticity and robust standard errors.

Table 1. Variable names and definitions.

Variable name	Variable symbol	Variable definition
Corporate ESG performance	ESG	Based on the ESG rating of Huazheng, according to the rating "C~AAA" from low to high, "1~9" is used as the proxy variable of the company's ESG performance
political connection	PC	If any one of the chairman and general manager of the enterprise is currently or has been a government official, the value of PC is 1, otherwise it is 0
Enterprise size	Size	Take the natural logarithm of the total assets of the enterprise
Assets and liabilities	Lev	Total Liabilities/Total Assets
Return on total assets	ROA	Net profit/total assets
Operating income growth rate	Growth	(Operating income of the current period - operating income of the previous period)/Operating income of the previous period
Number of directors	Board	Number of people on the company's board of directors
Ratio of independent directors	Indep	Number of independent directors/total number of board members
Shareholding ratio of the largest shareholder	Top1	Number of shares held by the largest shareholder/total number of shares
Equity checks and balances	Balance	Total shareholding ratio of the second to fifth largest shareholders/shareholding ratio of the first largest shareholder
Property rights structure	SOE	If the enterprise is a state-owned enterprise, take 1, otherwise take 0

3.3. Variable definition

3.3.1. Corporate ESG performance

Nowadays, the ratings of corporate ESG performance at home and abroad are complicated, and there are no certain standards. This article takes into account the national conditions with Chinese characteristics and the adequacy of the sample size, and selects the Huazheng ESG with the longest annual interval, drawing on foreign rating standards and combining Chinese characteristics. Ratings measure corporate ESG performance. Specifically, it is based on the Huazheng ESG annual rating, that is, the ratings C to AAA are assigned values from low to high from 1 to 9, and the explained variable (ESG) is constructed based on this assignment method.

3.3.2. Political connections

Drawing on the practices of Fan et al. [29] and Zhang et al. [30], the political connection studied in this article is set as a dummy variable. If the company's chairman or general manager is currently or has served as a government official, the PC value is 1, otherwise it is 0.

3.3.3. Control variables

The control variables in this paper include enterprise size (Size), asset-liability ratio (Lev), return on total assets (ROA), business income growth rate (Growth), number of directors (Board), proportion of independent directors (Indep), Shareholding ratio of the largest shareholder (Top1), equity balance (Balance) and ownership structure (SOE). Finally, the paper also controls the annual effect and fixed effect. Specifically, as shown in **Table 1**.

3.4. Descriptive statistics of variables

Table 2 reports the results of descriptive statistics of the variables. As can be seen from **Table 2**, the mean value and standard deviation of corporate ESG performance (ESG) are 6.525 and 1.196 respectively, indicating that there are large differences in ESG between different companies; the mean and standard deviation of political connection (PC) are 0.316 and 0.465 respectively, indicating that political. The degree of dispersion of the association is relatively large. The above shows that the sample data in this article are diverse and meet statistical requirements.

Table 2. Variable descriptive statistics.

Variable	*N*	Average	Standard deviation	Min	Max
ESG	20,093	6.525	1.196	1	9
PC	20,093	0.316	0.465	0	1
Size	20,093	22.38	1.302	19.52	26.21
Lev	20,093	0.467	0.209	0.0668	0.961
ROA	20,093	0.0323	0.0683	−0.289	0.217
Growth	20,093	0.179	0.564	−0.632	4.124
Board	20,093	8.687	1.720	5	15
Indep	20,093	0.3749	0.0538	0.3333	0.5714
Top1	20,093	0.3400	0.1464	0.0923	0.7365
Balance	20,093	0.0066	0.0057	0.0002	0.0255
SOE	20,093	0.465	0.499	0	1

4. Empirical results and analysis

4.1. Political connections and corporate ESG performance

Table 3 lists the regression results for political connections and corporate ESG performance. Column (1) is the regression result of corporate political connections and corporate ESG performance under the premise of controlling industry fixed effects and year fixed effects. Among them, the regression coefficient of PC on ESG is 0.108 and is significant at the 1% level, indicating that the positive impact of political connections on corporate ESG performance has been preliminary proven. Column (2) is the regression result after controlling for industry and year-fixed effects and adding control variables. Among them, the regression coefficient of PC on ESG is 0.058, both of which are significantly positive at the 1% level. The above results indicate that political connections will promote corporate ESG performance. This conclusion supports hypothesis 1a.

Table 3. Political connections and corporate ESG performance.

Variable	(1)	(2)
	ESG	ESG
PC	0.108***	0.0580***
	(0.0177)	(0.0160)
Size	-	0.354***
	-	(0.00744)
Lev	-	−0.718***
	-	(0.0454)
ROA	-	1.887***
	-	(0.122)
Growth	-	−0.0982***
	-	(0.0133)
Board	-	0.0222***
	-	(0.00524)
Indep	-	0.00372**
	-	(0.00155)
Top1	-	−0.000306
	-	(0.000733)
Balance	-	−0.0773***
	-	(0.0180)
SOE	-	0.390***
	-	(0.0173)
Constant	5.719***	−2.104***
	(0.102)	(0.179)
Year	Yes	Yes
Industry	Yes	Yes
Observations	20,093	20,093
R-squared	0.103	0.280

Note: *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively, with heteroscedasticity robust standard errors in parentheses. Same as below.

4.2. Mediating effect test

Examine the mediating effect of media attention. Therefore, this article refers to the approach of Tao and Jin [31] and selects the logarithm (MT) of the total number of times that A-share listed companies are reported by newspapers and media each year plus 1 as the measurement variable of media attention. To test the mediating effect of media attention, a three-stage regression was conducted. Among them, the relationship between political connections and corporate ESG performance has been listed above and will not be described at this stage. As shown in **Table 4**, according to column (1), PC and MT are significantly positive at the 1% level, indicating that corporate political connections can increase corporate media attention. According to column (2), MT and corporate ESG performance are significantly positive at the 1% level, indicating that newspaper and media attention will improve corporate ESG performance. The path of "political connections → (increased) media attention → (improved) corporate ESG performance" has been verified. Corporate political connections can improve corporate ESG performance by increasing corporate media attention.

Table 4. Mediating effect test of media attention.

Variable	(1)	(2)
	MT	ESG
MT	-	0.0498***
	-	(0.00724)
PC	0.102***	0.0587***
	(0.0182)	(0.0173)
Size	0.505***	0.290***
	(0.00764)	(0.00813)
Lev	0.126***	−0.236***
	(0.0248)	(0.0236)
ROA	0.220***	0.266***
	(0.0457)	(0.0435)
Growth	7.05×10^{-6}	-1.16×10^{-5}
	(8.04×10^{-6})	(7.63×10^{-6})
Board	0.0327***	0.0238***
	(0.00590)	(0.00561)
Indep	0.0108***	0.00344**
	(0.00168)	(0.00159)
Top1	−0.00417***	0.00128*
	(0.000805)	(0.000766)
Balance	−0.0458**	−0.0462**
	(0.0197)	(0.0187)
SOE	−0.0275	0.346***
	(0.0197)	(0.0187)

Table 4. (*Continued*).

Variable	(1)	(2)
	MT	**ESG**
Constant	−7.872***	−1.357***
	(0.204)	(0.202)
Year	Yes	Yes
Industry	Yes	Yes
Observations	17,292	17,292
R-squared	0.363	0.258

5. Robustness test

5.1. Surrogate variables for political connections

Since the impact of political connections on corporate *ESG* performance may vary depending on the level of political connections, this article draws on the research of Fan et al. [29] and sets an ordinal variable for the level of political connections (PCLEVEL). Among them, if the chairman or CEO of the company has an administrative level in the past or present or serves as a party representative, a deputy to the National People's Congress, or a member of the Chinese People's Political Consultative Conference, the assignment will be divided into four levels based on China's political level or regional level. The higher the level, the greater the intensity of the political connection. Specifically, 1 is taken at the departmental, district, or county level; below, 2 is taken at the divisional or city level; 3 is taken at the departmental or provincial level; and 4 is taken at the ministerial or national level. Otherwise, 0 is taken. If both exist, the maximum is taken. value to measure. This paper brings the measured PCLEVEL into the benchmark model for regression analysis. The results are shown in column (2) of **Table 5**, which shows that the above results are robust.

Table 5. Robustness test regression results.

Variable	(1)	(2)
	CNRESG	**ESG**
PCLEVEL	-	0.0158***
	-	(0.00486)
PC	0.292**	-
	(0.140)	-
Size	1.747***	0.353***
	(0.0684)	(0.00747)
Lev	−1.574***	−0.719***
	(0.494)	(0.0454)
ROA	3.718***	1.887***
	(1.299)	(0.122)
Growth	−0.286*	−0.0981***
	(0.155)	(0.0133)

Table 5. (*Continued*).

Variable	(1)	(2)
	CNRESG	**ESG**
Board	0.173***	0.0223***
	(0.0410)	(0.00524)
Indep	−0.0101	0.00375**
	(0.0129)	(0.00155)
Top1	0.0298***	−0.000342
	(0.00653)	(0.000733)
Balance	0.965***	−0.0777***
	(0.168)	(0.0180)
SOE	−0.0877	0.391***
	(0.164)	(0.0174)
Constant	−28.24***	−2.088***
	(1.653)	(0.180)
Year	Yes	Yes
Industry	Yes	Yes
Observations	6129	20,093
R-squared	0.401	0.280

5.2. Proxy variables for corporate ESG performance

Referring to the practice of He et al. [32], the dummy variables of the six contents of product advantages, charity volunteer activities and social controversy advantages, diversification advantages, corporate governance advantages, employee relations advantages, and environmental advantages in the CNRDS database are summed to This serves as a proxy variable for corporate ESG performance (CNRESG). As shown in column 1 of **Table 5**, after replacing the ESG performance of the explained variable, the conclusion of this article is still significant.

6. Further analysis

Based on resource dependence theory, enterprises need to establish connections with external organizations to obtain the resources required for production and operations. In the context of the system with Chinese characteristics, the government is the main allocator of resources, and enterprises with different property rights have varying degrees of dependence on the government [33]. There is an irreplaceable connection between state-owned enterprises and the government. This is reflected in the fact that most of the executives of state-owned enterprises are government officials and have state-owned equity. In contrast, non-state-owned enterprises do not have a state-owned holding background, and their development is more uncertain and risky [34]. Therefore, enterprises can only actively seek political connections through their own efforts, hoping to obtain government resources and protection. The establishment of political connections by non-state-owned enterprises has proactive characteristics and is more difficult than that of passive state-owned enterprises. Therefore, non-state-owned enterprises will be more careful to maintain the mutually beneficial relationship

between government and enterprises brought about by rent-seeking, aggravating the impact of rent-seeking theory on enterprises and thereby enhancing the role of political connections in promoting corporate ESG performance.

This article interacts the nature of property rights (SOE) with political connection (PC) to obtain the interaction term SOE × PC and puts it into the benchmark model for regression, as shown in **Table 6**. It can be seen that SOE × PC and ESG are significantly negative at the 1% level, indicating that compared with state-owned enterprises, political connections have a more obvious impact on the ESG performance of non-state-owned enterprises. This conclusion confirms hypothesis 2.

Table 6. Test of moderating effect of property rights nature.

Variable	**(1)**
	ESG
PC	0.118***
	(0.0213)
SOE × PC	−0.136***
	(0.0318)
SOE	0.431***
	(0.0198)
Size	0.353***
	(0.00744)
Lev	−0.720***
	(0.0454)
ROA	1.888***
	(0.122)
Growth	−0.0974***
	(0.0133)
Board	0.0233***
	(0.00524)
Indep	0.00391**
	(0.00155)
Top1	−0.000360
	(0.000732)
Balance	−0.0771***
	(0.0180)
Constant	−2.126***
	(0.179)
Year	Yes
Industry	Yes
Observations	20,093
R-squared	0.281

7. Conclusion and enlightenment

This paper takes the relevant data of A-share listed companies from 2010 to 2020 as the research object and uses theoretical analysis, empirical analysis, and robustness analysis to systematically study the impact of political connections on corporate ESG performance and its mechanisms. Research has found that political connections have a significant role in promoting corporate ESG performance. Political connections can increase the media's attention to the company, making corporate executives under the pressure of reputation protection and exemplary effect, increasing the degree of corporate social responsibility fulfillment, which in turn has an incentive for companies to enhance ESG performance. Further research found that political connections have a greater impact on the ESG performance of non-state-owned companies than state-owned companies.

Based on the above research conclusions, this paper draws the following enlightenment: First, political connections have a significant impact on corporate ESG performance, and companies should use political connections reasonably to help companies improve ESG performance, but they should also pay attention to avoid over-reliance on or abuse of political connections so as not to damage the long-term development and social reputation of the enterprise. At the same time, enterprises should also focus on improving their internal competitiveness and innovation capabilities, as well as fulfilling their environmental, social, and governance responsibilities, so as to achieve sustainable development. Second, media attention is an important intermediary variable between politics and corporate ESG performance, indicating that media supervision has an important impact on corporate behavior and can prompt companies to pay more attention to environmental, social, and governance responsibilities and performance. The government should establish relevant laws and regulations to enable the media to play a better role in information transmission and disclosure, and then help the government supervise and regulate corporate behavior. Third, non-state-owned enterprises face greater market competition pressure than state-owned enterprises. When non-state-owned enterprises cannot further improve their ESG performance with their own resources, they can obtain more resources and protection by seeking political connections, thereby helping themselves improve corporate ESG performance. At the same time, non-state-owned enterprises should also pay attention to the legal and reasonable use of political connections to avoid damaging the rights and interests of other stakeholders or violating laws and regulations because of political connections, so as not to cause negative public opinion or regulatory penalties.

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Article

Long-term effects of food safety incident: Example of Sanlu milk powder incident

Qing Yang[1], Li Zhou[2], Lei Lei[3,*]

[1] Department of Economics and Management, Nanjing Agricultural University, Nanjing 210000, China
[2] Department of Economics and Management, Tongji University, Shanghai 200000, China
[3] Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO) Wakaba 3-2-2, Mihamaku, Chiba 261-8545, Japan
*** Corresponding author:** Lei Lei, lei_lei@ide.go.jp

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Abstract: The purpose of this study is to examine the long-term consumer response to food safety incidents. The Sanlu incident that broke out in 2008 offers us an example to discuss the long-term impact of the impact of the incident on consumption behavior. In 2018, a survey was distributed to consumers in selected regions. Probit and Tobit techniques are used to analyze the long-term effect of food safety incidents on consumers' trust in various subjects through memory and cognition and how trust further influences their consumption behaviors. Results indicate that consumers showed the highest level of trust in the central government and the lowest in domestic salespeople and producers. The effects caused by trust in foreign producers were more significant than those caused by trust in authorities and the central government. Additionally, the middle-income group preferred to buy domestic milk powder the most. Little research has explored the long-term consumer response to food safety incidents. This study enriches the previous literature by exploring whether consumer choices can be influenced by trust and how.

Keywords: food safety; consumer trust; food consumers; food supply chain; long-term effects

1. Introduction

Global food markets have faced many food safety incidents in the past. Examples include lead found in crab in South Korea in 2000, beef discovered to contain horsemeat in Europe in 2013, and so on [1]. Food safety incidents not only directly affect public health but also result in significant economic losses. For example, it was the carcinogenic dioxin contamination that affected poultry and cattle in Belgium in 1999. The losses amounted to more than 10 billion euros [2]. Meanwhile, food safety incidents also result in indirect economic losses such as lost markets, loss of consumer demand, litigation, and company closures [3]. It has been found that consumer purchases will decline significantly in the short term after food safety incidents [4]. However, little research has explored the long-term consumer response to food safety incidents. In the long run, whether consumer choices can be influenced by trust and what is the mechanism of the influence.

In this paper, we used the example of the Sanlu incident, an infamous food safety incident in China, to study the long-term impact. This example was chosen because of the huge influence and attention it has received internationally in recent years. In 2008, Sanlu, a leading milk supplier, was discovered to have adulterated their milk products with melamine to artificially enhance their protein content [5]. In the aftermath of China's dairy industry inspection by pertinent agencies, it was revealed that the infant formula produced by 22 prominent domestic dairy companies contained melamine.

Subsequently, approximately 300,000 children were found to have suffered deeply from kidney stones, and at least six infants died from consuming melamine-contaminated milk powder [6]. The incident destroyed consumers' trust in domestically produced milk powder in China [7].

The distrust of domestic milk powder changed the consumption behavior of domestic consumers by switching to imported milk products [6]. Although considerable efforts, such as implementing the Chinese Food Safety Law, have been made to search for solutions to the problems plaguing China's dairy sector [6], Chinese consumers have continued to show distrust of domestic milk powder. The results of a national dairy consumption survey conducted by the China Dairy Association in June 2010 showed that 70% of respondents trusted imported dairy products, whereas only 16% continued to trust domestic ones. The impact has lasted until 2021 or even longer. The volume of milk powder imported in China has experienced a noteworthy escalation, surging from 98,000 tons in 2007 to 1.54 million tons in 2021 [8].

As time goes by, when will consumers forget? Is the increasing importing volume of milk powder due to the remaining impact of the Sanlu milk powder incident? Has consumers' trust in domestically produced milk powder recovered? What is the impact of trust on consumers' purchasing behaviors? What are the factors affecting trust? Answering these questions could not only give insights on the reconstruction of the Chinese dairy industry but also provide the entire agriculture and food sectors worldwide with long-term coping strategies. This discussion focused on two aspects. The first are the different levels of trust consumers place on "trust objects"[1] after the Sanlu incident. The second are the effects of different "trust objects" on consumer behavior and the mechanisms behind such behavior.

This paper provides insights into consumers' long-term responses to food safety incidents and makes a marginal contribution in two important ways. First, it addresses the long-term effects of such incidents on consumer behavior, filling a research gap that often focuses on immediate or short-term effects after the incident took place. However, the effects usually last for a long time. It is important to understand them to make better food safety policies and business strategies for both the public and private sectors. Second, it adds new empirical evidence to the agricultural marketing literature by examining consumer trust from the perspective of key supply chain actors. Through an in-depth analysis of consumer trust in entities such as the central government, local governments, domestic and foreign sellers, and domestic and foreign producers, this study reveals the psychological and cognitive mechanisms that affect consumer choices.

The paper is organized as follows: literature review, background, data, variables, methodology, results, discussion, and conclusion.

2. Literature review

Trust is complicated to measure. Some have posited that trust is composed of two parties, among whom one party, i.e., the trustor, can choose whether or not to voluntarily place trust in the other party, i.e., the trustee [9]. Umer and Li viewed trust in two dimensions: optimism and pessimism [10]. Trust can also be defined in both specific and general senses [11]. General trust means to trust all members of a

particular social system [12]. Specific trust can be measured by different stakeholders, for example, trust in the government, retailers, manufacturers, and farmers, and trust in consumer organizations [13,14].

Numerous factors affect trust, and in turn, it has diverse implications for consumer behavior across various channels. External incidents have been found to erode trust levels [15], resulting in lower consumer trust in food safety [16] and decreasing sales of affected products [17]. Meanwhile, internal demographic characteristics, such as gender, income level, and education level, were highly related to consumer trust in the food chain. Furthermore, trust has been identified as a core factor affecting consumer behavior among various factors [18], including confidence, attitude [19,20], consumer loyalty [21], and buying intention [22].

While the existing research base has extensively explored consumer trust, it has primarily focused on defining consumer trust, analyzing influencing factors, and studying their impact on short-term consumer behavior. However, the evolution of consumer trust following food safety incidents over time remains inadequately addressed in the literature. In particular, there is a gap in understanding the long-term, lagged effects of such incidents on consumer trust and how this trust, in turn, affects consumption behavior over time. Furthermore, the existing literature lacks a comprehensive delineation of trust modalities in terms of their impact on purchase behavior in the long run. Building on these gaps, this study investigates the impact of consumer trust on long-term consumption behavior in the context of the Sanlu incident. In addition, it categorizes and classifies trust based on the perspectives of key industry chain actors to explore how different categories of trust influence purchasing behavior.

3. Background

In 2008, China experienced a significant melamine[2] contamination incident in the dairy industry. This crisis was caused by dairy farmers increasing the melamine content of milk, resulting in widespread contamination of milk products. Over 300,000 infants were sickened, 50,000 were hospitalized, and six died after consuming powdered milk contaminated with melamine. This food safety incident shattered the confidence of people in the entire Chinese food supply. This incident highlighted the failure of the government, media, dairy farmers, milk collection stations, and companies to uphold regulatory standards and ensure product safety. This section aimed to provide an introduction to the Sanlu incident, including its background and related information.

Figure 1 illustrates the Chinese dairy industry chain in 2008, comprising key stakeholders: dairy farmers, milking stations, dairy processing companies, governments, and social media [13]. From left to right, dairy farmers raised cows and produced milk in family units, with an average breeding size of five cows in 2008 [23]. Such scattered productions as small household family units have resulted in low traceability of milk sources. Sanlu provided dairy cows and technical advice free of charge to small dairy farmers who paid off their loans with milk [24]. In addition to raising cattle, dairy farmers also took up farming for a living.

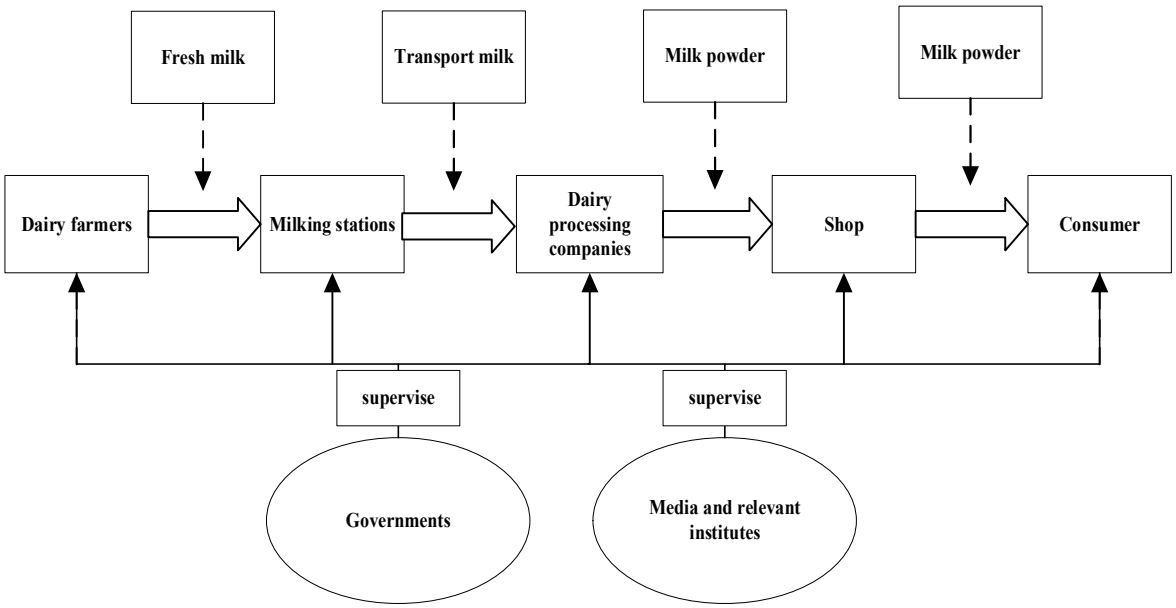

Figure 1. Supply chain and supervision of milk products in China.

Then cows or milk were sent to a milking station. Dairy processing companies set up milk stations in villages where cows were concentrated. The milk collection station's regular daily activities included sterilization of cows' udders, milking, milk storage, and shipment. After that, the milk was shipped to dairy processing companies for milk powder production. At dairy processing companies, quality tests were conducted by both the processor and inspection authorities, such as research institutes and other relevant institutes [25]. However, the top processors were exempt from inspections as the government allowed them to set their own standards and carry out their own inspections [26]. Finally, milk powders were sold to consumers through various retailers, such as large supermarkets and milk powder stores.

Another two key stakeholders, the government and the media, were not directly involved in the supply chain but were supervising throughout the entire process. The dairy industry chain was generally supervised by the central government's ministry and also by local governments, such as township and village governments. In addition, the media supervised the dairy industry chain indirectly by monitoring and reporting.

How did the Sanlu incident happen, and which stakeholders were involved in it? Who should take responsibility? The fundamental cause of the Sanlu incident was the extremely rapid growth of the dairy industry in China [27]. This has resulted in the failure of each stakeholder in the Chinese dairy supply chain. According to the official report of the Sanlu incident [28], details are summarized in **Table 1**.

Table 1. Fault and improvement.

Stakeholders	Dairy farmer	Milking station	Dairy processing company	Government	Media and relevant institutes
How did they fail in the incident	Added melamine to their milk to reduce production costs	Lacked of rigorous and clear means of quality monitoring	Overused melamine to increase the protein content in the milk	Failed to prioritize the supervision of food safety	Failed to report promptly and objectively.
Improvement after the incident	Improved the production mode and adopted technology	Strengthened the collection and management of milk sources	Bettered production management and quality control methods	Introduced laws and strengthened the management of practitioners	Strengthened supervision on food safety issues

Dispersed feeding patterns made it difficult to trace and control milk sources. Then cows or milk were sent to a milking station. Because quality inspections have not been a part of these stations' regular daily activities, inspecting the milk's quality was also difficult before it was taken to dairy processing companies. Milk was then taken to dairy processing companies. Dairy processing companies overused melamine to increase the protein content in the milk to "improve" product quality as a way to compete for market share [29]. However, melamine was not expressly listed as an illegal additive at that time. The top four dairy processing companies, including Sanlu, were exempt from official controls because the government was focused on improving productivity, which enabled these companies to take risks.

The failures of dairy farmers, milking stations, and dairy processing companies also reflected the dereliction of duty in food safety supervision by the Chinese government. The government has focused on increasing production without keeping pace with inspections [30]. Furthermore, certain media reports on the incident were inadequate, lacking a sense of public responsibility to promote food safety. In light of the above situation, the Sanlu incident happened due to a collective failure.

To regain consumers' trust and rebuild the dairy industry, stakeholders have been actively searching for solutions. According to the government's report on the effectiveness of the reforms [31], we summarized their actions in the second row of **Table 1**. Dairy farmers began to strengthen the quality control and management of milk. For example, they chose to join organizations such as feeding communities or cooperatives to purchase feed and veterinary services. Dairy processing companies established quality control systems and conducted comprehensive testing and monitoring of all aspects of the production process. The government took a series of reform measures to improve food safety levels after the Sanlu incident. For example, they revised the food safety law and set up food safety institutions [32], leaving dairy processing companies with no exemptions from monitoring. The Ministry of Health announced that the standard for protein in raw milk should be lowered to 2.8% [33]. Meanwhile, the media strengthened their coverage and supervision of food safety issues, as well as public propaganda and education measures [34].

Although stakeholders in the dairy industry have taken steps to rebuild trust, the effects have been limited in the short and medium terms. **Table 2** provides consumer preferences for various trust objects after the incident in the short and medium terms. Regarding domestic milk powder, trust in the government has recovered significantly. The highest willingness to pay was for government-certified traceable milk, followed by industrial association-certified and third-party-certified milk. However, consumers still had low trust in domestic milk powder. Chinese parents switched from domestic milk powder to imported milk powder and relied on food supplies from friends and relatives in the interim. In the long term, consumers showed more pessimism than optimism toward domestic milk powder, largely because of their distrust in its safety and the fear caused by previous safety incidents. Exploring the exact long-term influence of incidents through different trust objects could help the reconstruction of the reconstruction of the Chinese dairy industry and provide relevant industries (e.g., food) worldwide with long-term strategies to cope with incidents. Therefore, this study examined the long-term impact of melamine on consumers and analyzed how trust affects the results later.

Table 2. Preference of trust objects.

Most trusted				**Least trusted**
Authorities[1] Governments	>	Organizations; Media	>	Merchants; Farmers; Producers

[1] Expert, research institutions and universities.

4. Data, variables, and methodology

4.1. Hypothesis

During the Sanlu incident, it was discovered that almost all domestic dairy brands had failed to meet the required quality standards. While the government and dairy processing companies have taken measures to address the issue, the media coverage has not kept up with the progress, especially compared to the initial disclosure of the incident. As a result, consumer memory and cognition of the Sanlu incident may still be fleshed out and remain negative. Therefore, this paper tested two hypotheses.

Hypothesis 1: The Sanlu incident affected long-term purchasing behavior via consumers' trust. We expected that the more consumers trusted foreign producers, the more likely they were to buy imported milk powder; the more they trusted the Chinese government and domestic producers, the less likely they were to buy imported milk powder.

Hypothesis 2: memory and cognitive level would change consumers' trust in relevant objects. We expected that the better the consumer memory, the lower the trust level in domestic products; the higher the cognition consumers had about melamine, the more they bought imported milk powder.

4.2. Survey introduction

Figure 2. Map of China.

To test the long-term impact mechanism of the Sanlu incident on consumer decision-making, this study conducted a survey in Beijing, Nanjing, Yangzhou, and Tangshan (**Figure 2**) in November and December 2018. The sampling cities were representative for geographic, economic, and political characteristics referring to different relationships with the central government (**Table 3**). The sample included a national capital, a provincial capital, and two local cities. The survey was designed to cover most key factors that might affect long-term consumption after the incident, such as trust factors, diet, consumption habits, and others. The specifications are as follows.

Table 3. Characteristics of sample cities.

Sample Cities	Geographic	Economic	Politic
Beijing	North	First-tier	Country capital
Tangshan	North	Third-tier	Adjacent to the country's capital
Nanjing	South	Second-tier	Province capital

(1) Geographical representativeness. Geographical differences, such as climate and water resources, affected agricultural production and living habits, including cultural and political customs that may alter consumers' social networks and consumption behaviors. China has a vast territory with great differences in climate and geographical conditions between the north and south. Therefore, two southern cities and two northern cities were selected for the sample. Among them are Beijing and Tangshan, located in the north of China, and Nanjing and Yangzhou, located in the south.

(2) Political representativeness. Beijing is the capital of China as well as the political and cultural center of China, so it was strongly influenced by the central government. Nanjing is the capital city of Jiangsu province, where the provincial government is located. It was easier to accept information from both levels of government. In this regard, it is equivalent to Beijing in terms of its political impacts. Tangshan and Yangzhou are two cities in Hebei province and Jiangsu province, respectively. Tangshan is close to the capital, while Yangzhou is adjacent to Nanjing.

(3) Economic representativeness. In China, Beijing is a first-tier city[3], and Nanjing is a second-tier cities[4], representing the more economically developed regions of north and south cities. Tangshan and Yangzhou are two third-tier cities[5] that are geographically adjacent to Beijing and Nanjing. Although first-tier, second-tier, and third-tier cities do not have geographical differences, economic differences exist, such as in GDP and population factors. Families with a higher monthly income have more knowledge about safe food and a higher likelihood of purchasing it [35]. A total of 500 questionnaires (**Figure 3**) were distributed (Nanjing 150; Beijing 150; Yangzhou 100; and Tangshan 100). Among them, 303 were valid questionnaires, and the effective rate was 60.6% (**Figure 4**). Among the survey samples (**Figure 5**), 115 were from Nanjing, 70 were from Beijing, 69 were from Yangzhou, and 49 were from Tangshan.

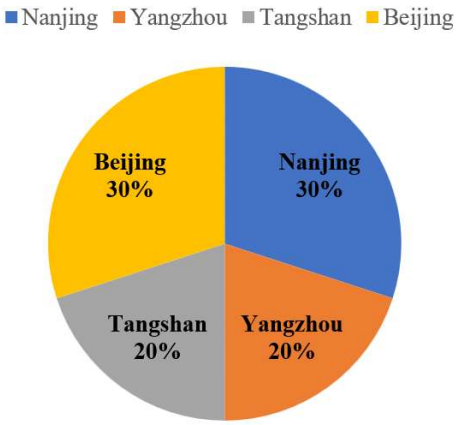

Figure 3. Distribution of 500 questionnaires.

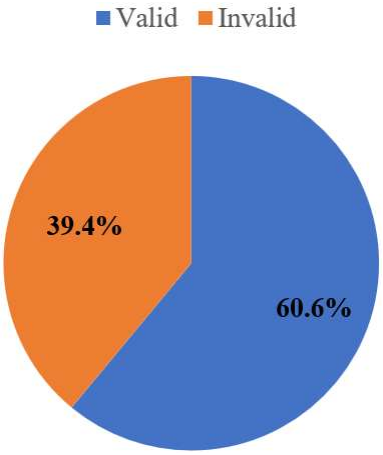

Figure 4. The proportion of valid questionnaires.

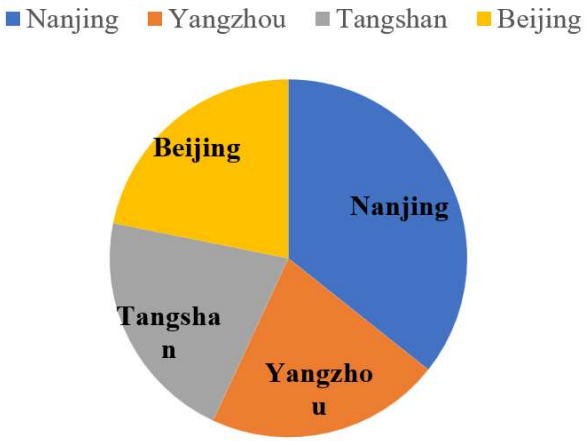

Figure 5. Distribution of 303 valid questionnaires.

4.3. Data and variable descriptions

At first, in order to test whether hypothesis 1 holds, this paper measured whether or not consumers bought, and we defined the variable decision. For each consumer, the variable Decision was a dummy variable that took the value of 1 if consumers bought imported milk and 0 otherwise. Then, the variable quantity was defined, which measured the amount of imported milk powder purchased. This amount can reflect consumers' level of trust in different trust objects in the long term after the Sanlu

incident and takes a value larger than or equal to 0. If a consumer chose to buy domestic milk powder, the value of the variable quantity was 0.

For explanatory variables, trust was adopted as a core variable. Many studies integrated trust into economic models [36]. Regarding trust, individuals make decisions by strongly considering trust factors [37]. To measure the variable trust, eight trust objects were selected. They were key players in the China dairy chain and the Sanlu incident. If consumers placed trust/distrust in trust objects, their behavior would be positively/negatively influenced by them [38]. There were eight questions with trust or distrust (trust = 1, distrust = 0) to define the variable Trust[6]. The value of the variable trust was either 0 or 1.

To test hypothesis 2, this paper tested variables memory and cognition that influenced consumption behavior in the long term. Consumer choices depend on their memory capacity [39]. The decision to repeat a behavior was based on the memory of a similar prior experience [40]. The long-term effects of the Sanlu incident were related to consumers' memories. If a consumer had a better memory, he or she would remember the incident longer, thereby negatively influencing his or her domestic milk powder consumption behavior. Moreover, consumers' cognition was a direct influencing factor for consumer behavior [41]. According to the theory of planned behavior, cognition of events is one of the important reasons that affect consumers' purchasing decisions [42]. For example, green consumption cognition significantly promoted consumers' consumption. Cognition indicated the consumer value of melamine harm and implied how people perceived the risk of food unsafety [43]. If a consumer showed a high level of cognition about melamine and the Sanlu incident, he or she would consider the negative effects of them when making relevant purchase decisions. As a result, variable memory and variable cognition were included in the models.

The number of details recalled by survey participants was used to define the variable memory. The more details a participant recalled, the better memory he or she had. A test[7] was taken to measure how many details a consumer can remember. A total of 5 points were used, with a higher score representing that the consumer had better memory [44]. The value of the variable memory was between 0 and 5.

The variable cognition was defined by the survey responses to the melamine and Sanlu milk powder incidents. According to the research on the cognition evaluation of Zhou, six questions were included in the survey[8]. Each question gave five options of four similar statements of the incident facts and "unknown". Subjects were asked to choose the only true statement. If the answer was correct, the subject's cognitive value was increased by one. The value of the variable cognition was between 0 and 6.

Other variables affecting consumption behavior were included. Duralia et al. reported that consumers' behavior related to food consumption was a function of four main factors: personal, economic, socio-cultural, and marketing [45]. Thus, geographic, consumer, family, and child characteristics were selected as control variables to measure personal and economic characteristics. Variable Beijing, Nanjing, and Tangshan were selected as control variables to limit the various economic effects caused by geography, and variable Yangzhou was selected as a base group to prevent collinearity. Consumer characteristics, such as gender, age, and education, were selected because they significantly affected purchasing decisions.

Table 4 showed that domestic consumers preferred imported milk powder over domestic milk powder. In the sample, the proportion of decisions to purchase imported milk powder was close to 77.7%. The mean of the variable (3.086) was more than half the full mark (5 points), implying that consumers may clearly remember the Sanlu incident. The mean value of the variable cognition was equal to 1.132, representing that consumers in the sample had limited knowledge about melamine facts and Sanlu milk powder incidents. The mean value of the variable quantity was 8.440, implying that each family consumes 8.440 cans of imported milk powder in three months[9]. The mean of the variable Child (0.293) indicated that the proportion of infants and adults in the sample family was about 1/5.

Table 4. Variables and definitions.

Variables	Definition	Mean	Std. Dev.
Decision	Purchase decision in three months (1 = imported 0 = domestic)	0.777	0.417
Quantity	Total purchase quantity in three months (900g/can)	8.440	9.536
Trust objects			
Trust central government	I trust the central government. (trust = 1 distrust = 0)	0.640	0.481
Trust local government	I trust the local government. (trust = 1 distrust = 0)	0.317	0.466
Trust authorities	I trust experts and research institutes. (trust = 1 distrust = 0)	0.356	0.479
Trust media	I trust magazines and newspapers. (trust = 1 distrust = 0)	0.221	0.415
Trust foreign producers	I trust milk powder producers. (trust = 1 distrust = 0)	0.118	0.324
Trust sales people	I trust milk powder sales staff. (trust = 1 distrust = 0)	0.102	0.303
Trust relatives	I trust relatives. (trust = 1 distrust = 0)	0.244	0.430
Trust friends	I trust friends. (trust = 1 distrust = 0)	0.234	0.424
Memory	The higher the better (0–5)	3.086	1.061
Cognition	Cognitive level of melamine and Sanlu incident (the higher the better; 0–6)	1.132	1.272
Gender	1 = male 0 = female	0.228	0.420
Age	Age of purchaser (years)	31.323	5.439
Education	Education years (years)	17.346	3.558
Family member	Total household population (heads)	4.231	1.141
Family income	Ten thousand yuan/per year	24.736	22.093
Senior members	Proportion of elder	0.159	0.211
Child	Proportion of children	0.293	0.099
Child age	Age of child who drinks baby formula (years)	1.811	1.375
Child gender	1 = male 0 = female	0.577	0.495
BMI	Health condition of the child (18.5–23.9 means healthy)	19.599	7.096

Initially, an overall view of consumer trust was provided, and the incidental effects on trust were attempted to be identified. Survey results showed (**Figure 6**) that most consumers trusted the central government (0.640), but trust in the local government was weaker (0.317), followed by trust in authorities (give positive information about domestic milk powder). Consumers trusted them (0.356) more than they trusted the media (0.221), which covered the Sanlu incident. Similarly, consumers' trust in relatives (0.244) and friends (0.234) who provided information from their

experiences was low. Closer directly related to the milk powder sector, the lower the trust (e.g., milk power producers and milk powder sales staff). According to **Figure 6**, consumers had the lowest trust in stakeholders closely relevant to milk powder, including milk powder producers (0.118) and milk powder sales staff (0.102).

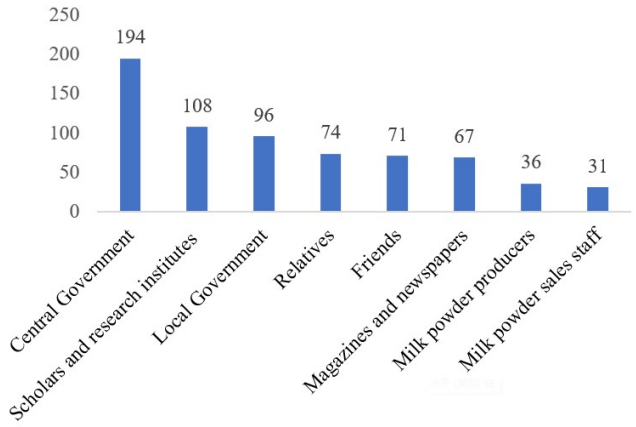

Figure 6. Numbers of trust in 303 subjects.

4.4. Econometric specification

The empirical investigation had two critical measures for consumption behaviors. To test the two hypotheses mentioned above, this paper built Probit and Tobit models, respectively, to analyze consumers' purchasing behaviors and the influencing mechanisms.

First, we established a Probit model to analyze consumers' decisions to purchase imported milk powder. Because the dependent variable Decision was in the form of "binary discrete", the nonlinear Probit model was selected for estimation. Then we used the Probit model to explore how consumers' purchasing decisions were affected by trust factors. The model can be written as follows:

$$Decision = \beta_1 + \beta_2 * Trust + \beta_3 * Z + \mu$$
$$\text{Decision} = \begin{cases} 1, & \text{imported} \\ 0, & \text{domestic} \end{cases} \quad (1)$$

where variable the decision denoted whether the consumers bought imported milk powder or not. The trust variable represented consumers' trust in trust objects. The matrix Z contained the following set of control variables: (1) memory of the Sanlu incident; (2) consumers' cognition of melamine facts and the Sanlu incident; (3) city dummies; (4) personal characteristics of milk powder consumers; (5) family characteristics of milk powder consumers; (6) characteristics of children who consumed milk powder. The variable μ was the error term that covers all unobserved variables and random noise.

Next, we established a Tobit model to analyze consumers' actual purchase quantity. The actual consumption of imported milk powder was measured. Because 23% of consumers (68 people) purchased domestic milk powder, the value of the variable quantity (consumption of imported milk powder) took the value of 0 for 68 times. Given the property of the Tobit model, which included observations with a positive probability of 0, adopting the Tobit model in this analysis was appropriate.

The independent variables in model (2) were the same as those in model (1), and model (2) can be written as:

$$Quantity=\beta_1+\beta_2*Trust+\beta_3*Z+\mu \quad (2)$$

Consumers' heterogeneity may also affect their preferences for trust objects and consumption behavior [46]. The cities where consumers live and their family income may directly influence their consumption behaviors. These effects were captured by running a sub-sample regression by dividing family income. The Tobit model was adopted to analyze the impact of the purchase quantity of imported milk powder under different classifications.

An interaction analysis was run to explore the mechanism of trust effects on consumers' purchasing decisions long-term after the Sanlu incident. Trust may affect consumers' behaviors through factors such as memory and cognition in the long term. The variable memory reflected consumers' ability to remember something, which implied whether consumers still remembered the Sanlu incident. People with better memory were more impressed by the Sanlu incident, and their consumption decisions were more affected by the incident. The variable cognition could be written as (3) and (4). means consumers' knowledge of melamine and the Sanlu incident. A higher value indicated consumers were likely to know the damage of melamine and the negative effects of the Sanlu incident, hesitating to purchase domestic milk powder. For example, if consumers knew that melamine may cause infant death, consumers would be more afraid to buy domestic milk powder. The model could be written as (3) and (4).

$$Quantity=\beta_1+\beta_2*Trust+\beta_3*Trust*Memory+\beta_4*Z+\mu \quad (3)$$

$$Quantity=\beta_1+\beta_2*Trust+\beta_3*Trust*Cognition+\beta_4*Z+\mu \quad (4)$$

5. Results and discussion

5.1. Preliminary regression

First, Equation (1) was used to determine whether a consumer bought imported milk powder. Then, Equation (2) was used to explore the quantity purchased and the factors that affect the behavior. **Table 5** provided the results.

Table 5. Probit and Tobit regression.

Variables	Decision	Quantity
Trust objects		
Trust central government	0.270	−2.405*
Trust local government	−0.248	1.089
Trust authorities	−0.394**	−3.491***
Trust media	−0.158	−1.653
Trust foreign producers	0.602*	5.473***
Trust salespeople	0.0533	−1.600
Trust relatives	−0.406	−1.749
Trust friends	0.176	−2.241
Memory	−0.0511	1.102*

Table 5. (*Continued*).

Variables	Decision	Quantity
Cognition	0.0508	−0.167
Gender	−0.330	0.381
Age	0.00168	−0.0351
Education	0.0333	−0.210
Family member	0.0363	−0.129
Family income	−0.00102	0.00449
Senior members	−1.174**	−5.817
Child	−1.775	−21.03***
Child age	0.0708	−0.280
Child gender	0.155	3.134**
BMI	−0.0186	−0.0818
Geographic		
Beijing	−0.794*	−2.319
Nanjing	0.0989	1.659
Tangshan	−1.920***	−11.30***
Constant	1.776	20.89***
Observations	303	303

SoNoNotes: Asterisk (*), a double asterisk (**), and a triple asterisk (***) denote the 10%, 5%, and 1% significance levels, respectively.

The results showed that trust had long-term effects on consumer behavior. However, the effects differed for different trust objects. The variable trust of the central government showed that such trust had a significant negative impact (–2.405) on the volume of imported milk powder consumed. One reason may be that, of all the trust factors, Chinese consumers had the highest willingness to pay for government-certified products [47]. Alternatively, not long after the Sanlu incident, the central government implemented the Chinese Food Safety Law, which improved the supervision and management of food products. This action helped to regain consumers' confidence in the food production industry [48]. Until now, because these actions were still being executed, some Chinese consumers had switched back to purchasing domestic milk powder gradually.

The variable trust authorities showed that such trust can significantly decrease the possibility (−0.394) of purchasing imported milk powder and the quantity (−3.491) purchased. One reason may be that most Chinese consumers consider specialized institutions to be the second-most trustworthy source of information. Chinese consumers had positive attitudes toward food that can be demonstrated to be authentic and expressed strong intentions to purchase such food [49]. In recent years, domestic milk powder safety information released by research and testing institutions has significantly reduced consumers' distrust of domestic milk powder.

The variable Trust among foreign milk powder producers showed that such trust increased consumer demand for imported milk powder. Specifically, through such trust, the possibility of purchasing imported milk powder rose by 60.2%, and the demand for the number of imported cans increased by 5.473 cans.

Why do consumers trust foreign dairy companies more? On one hand, the risk of domestic milk powder made Chinese consumers look for imported products as alternatives. Even the domestic milk powder brands "helped" emphasizing the good quality image of foreign milk powder. In many domestic milk powder commercials, they mentioned that the milk source of their milk powder was from overseas, such as New Zealand or the Netherlands. On the other hand, the rising price of domestic milk powder in recent years may also be a reason. After the Sanlu milk powder incident, the domestic diary industry chain raised production standards. The high cost of feed, labor, and food safety testing has pushed up the price of domestic milk [50]. According to the China Business Information Network, the China Dairy Industry Quality Report showed that the price of domestic brand infant formula milk powder had increased by 17.4% over the past five years, and the price of domestic infant milk powder still maintained the rising trend in 2021 [51]. Therefore, consumers chose to buy more imported milk powder.

We also found that the results of the control variables were consistent with our expectations. The coefficient of the variable senior members (−1.174) showed that senior people were less likely to buy imported milk powder due to stronger ethnocentric factors among the general wise [52]. The variable child gender showed that families with male babies bought more imported milk powder than families with female babies. It was consistent with the traditional Chinese thought of son preference[10] [53]. At the same time, the closer the region was to the capital, the less likely it was for consumers living in the area to buy foreign milk powder. This also confirmed the view that the Chinese people trust the central government more than the local government.

The coefficient of variable Child (−21.03) showed that the more children the families have, the less imported milk powder they bought. This may be because families with more children may have tighter budgets to rely on milk powder (whether foreign or domestic) in the first place. Moreover, low-income families tend to have more children because they believe that having more children will be more rewarding [54].

5.2. Sub-samples regressions

The effects of heterogeneity on consumer behavior through trust were studied (see **Table 6**) by dividing the samples. In each sub-sample, samples were divided into low-income, middle-income, and high-income families according to the data on family income. Among them, the average income of the low-income group was 100,000 yuan, the middle-income group was 210,000 yuan, and the high-income group was 570,000 yuan, respectively.

Income had significant effects on consumer behavior via trust. Both low-income and high-income families trusted foreign milk powder producers increased their imported milk powder consumption. Low-income families trusted by foreign milk powder producers have increased (8.126) their purchases of imported milk powder. The possible reason was that consumers in the low-income group were more sensitive to safety risks than those in the high-income group [55]. The Sanlu incident has caused them to lose trust in domestic milk powder producers. For high-income families, the

possible reasons were twofold. One reason might be their better cognition of the incident because income level is often positively associated with education level. Another reason might be that high-income families access to foreign products produces mild power when they travel abroad.

Table 6. Family income tests of parameters in Tobit regression.

Variables	Low	Middle	High
Trust objects			
Trust central government	0.981	−4.050**	−3.375
Trust local government	−0.171	1.028	−2.971
Trust authorities	−4.396	−2.251	−3.922*
Trust media	−2.552	−1.216	−0.397
Trust foreign producers	8.126**	1.173	7.888**
Trust salespeople	2.301	−1.762	−3.808
Trust relatives	−3.842	0.196	−1.259
Trust friends	−1.717	−5.729*	0.163
Memory	1.931	−0.636	2.176**
Cognition	−0.162	−0.715	0.340
Gender	9.898***	−3.932*	−0.671
Age	−0.118	0.172	−0.453*
Education	−0.0857	−1.454	2.059
Family member	1.708	−0.862	−3.358**
Family income	−0.669**	0.489	0.00133
Senior members	−1.881	−7.683*	−1.480
Child	−25.38*	−17.15*	−26.61
Child age	0.0464	0.0868	−1.010
Child gender	3.149	2.682	1.506
BMI	−0.266	0.0160	0.0427
geographic			
Beijing	−12.70	0.592	−10.27**
Nanjing	6.232*	1.189	−6.123**
Tangshan	−14.01***	−7.782**	−52.48
Constant	17.11	14.67	38.54***
Observations	116	93	94

Notes: Asterisk (*), a double asterisk (**), and a triple asterisk (***) denote the 10%, 5%, and 1% significance levels, respectively.

Middle-income families' trust in the central government caused them to reduce (−4.050) their purchased quantities of imported milk powder. Trust in friends made them consume less (−5.729) imported milk powder. Most Chinese families fell into the middle-income group. The friends and relatives of middle-income families also tended to be middle-income. Similar backgrounds led to similar ways of thinking and consumption patterns. Friends who may have tried domestic milk powder that provided authenticity and safety assurances had higher confidence in the reliability of

authenticity cues. And because of their trust in the government, they would choose domestic milk powder.

5.3. Interactive analysis

In addition, an interactive analysis of trust was done to test the mechanism of the long-term impact of trust on consumption decisions. We introduced the variables memory and cognition as interaction terms with different trust actors. **Table 7** provides the results of the interactive analysis. If no additional interaction items were considered in the regression, trust in the central government and authorities would lead consumers to purchase less foreign milk powder. Believing in imported producers made consumers buy more imported milk powder.

Table 7. Interactive analysis.

Variables	Quantity	Quantity	Quantity
Trust objects			
Trust central government	−2.405*	−0.00821	−3.747**
Trust local government	1.089	1.389	0.963
Trust authorities	−3.491***	1.893	−0.642
Trust media	−1.653	−1.515	−2.016
Trust foreign producers	5.473***	−3.294	3.689
Trust salespeople	−1.600	−1.981	−1.362
Trust relatives	−1.749	−1.566	−1.748
Trust friends	−2.241	−2.663	−2.400
Memory	1.102*	1.845	1.033*
Cognition	−0.167	−0.211	−0.366
Control variables	YES	YES	YES
Trust central government*Memory		−0.884	
Trust authorities *Memory		−1.769	
Trust foreign producers*Memory		2.893*	
Trust central government*Cognition			1.175
Trust authorities* Cognition			−2.364**
Trust foreign producers* Cognition.			1.548
Constant	20.89***	18.65**	20.15***
Observations	303	303	303

Notes: Asterisk (*), a double asterisk (**), and a triple asterisk (***) denote the 10%, 5%, and 1% significance levels, respectively.

Trust influences consumer behavior in the long term through memory and cognition. A consumer with better memory tended to purchase imported milk powder (the coefficient of variable memory is positive). When consumers trust foreign milk powder producers, the impact of their long-term memory increases (2.893) purchases of imported milk powder. Because their better long-term memory allowed them to retain a clear memory of the negative influence of the event, Better memory can

strengthen consumers' trust in foreign producers, leading to more purchases of foreign milk powder for about three cans.

Trust can change consumer behavior by mitigating the negative effects of cognition. The coefficient of variable Trust authorities * Cognition (−2.364) implied that when consumers trust in authorities (who support domestic milk powder), the negative impact on domestic milk powder consumption from the melamine and the Sanlu incident can be offset by 2.364 cans.

6. Conclusion

In this paper, survey data from 303 valid questionnaires from Beijing, Nanjing, Tangshan, and Yangzhou were used to analyze the long-term impact of food safety affairs on trust and consumption behavior. The Probit and Tobit regression models were applied, and the following key findings were revealed from the econometric analysis:

1) With years of endeavor after the Sanlu incident, the central government has regained the trust of most Chinese consumers, followed by authorities and local governments. Trusts in the above objects had significantly influenced Chinese consumers' milk powder purchasing choices in the long term. 2) Among the descriptive characteristics of consumers, income level played an important role in influencing purchasing behaviors. Families with different income levels varied in purchasing behavior changes in the long run compared to the short-term immediate reaction. 3) Memory and cognition are important factors that can interact with trust to influence consumer behavior in the long term.

Based on the above findings, discussion and policy suggestions were made to cope with the long-term impact of food safety incidents, not only specific to the Sanlu incident but also to general cases.

Thanks to the high trust consumers place in government objects and authorities, the central government should continue to reform dairy product management and improve associated laws, regulations, and technical standards. The local government should continue to increase support to rebuild the industry by combining their better knowledge of the local economy and market. Governments in rich areas should highlight information from the central government. In contrast, those in poor areas were allowed to supervise certifications more strictly because they were more sensitive to risk. They can also promote domestic milk powder through the media, as consumers in small cities trust the media more, according to the survey.

Authorities should also play a guiding role in food safety incidents. It has been confirmed that trust in them had a positive influence on domestic milk powder purchases. Research institutions and experts should conduct and publish food safety inspection reports and relevant information on domestic milk powder regularly. Authorities should make more efforts in outreach and dissemination to improve awareness of domestic-produced milk powder after the incident.

Different strategies should be adopted to target consumers with different income levels. Both accurate information dissemination and products with reasonable prices are key factors. Improving the domestic milk supply chain to reduce unnecessary costs and lower milk powder prices is critical. Domestic milk powder producers had

completely lost the market after the Sanlu incident. Although quality has improved after years of efforts (up to international standards), regaining market share has been more difficult. Therefore, in the past years, Chinese domestic milk powder producers have spent most of their money on commercials, hiring celebrities as image ambassadors, competing to monopolize local supplies, and so on. These costly expenses have been transferred to consumers by increasing the price of the price of milk powder. Meanwhile, to cater to consumers' impression that "higher price equals better quality", Chinese domestic milk producers had classified their products into too many grades. There are premium, super-premium, gold, and diamond categories of milk powder products. However, the quality of those products does not differ much. Most costs were spent on marketing and commercials to promote and establish the premium status of products. Consumption of domestic-produced milk powder has started to relate directly to income and social status.

However, milk powder sectors in other countries spent the most money on research, development, and quality improvement. The price of milk powder has been regulated by the government as a necessity to be accessible to all families and all kids. Regaining market share and regaining consumers' trust are important; however, a structural change in the Chinese domestic milk powder sector is urgently needed.

Through trust and cognition, strategies should be developed targeting different income groups. Universities, research institutes, and other relevant authorities have been another reliable source for milk powder information for most Chinese families. Solid scientific evidence could affect consumers' cognition and lead to a potential switch from imported milk powders to domestic ones. Trusting in those objects that support domestic milk powder offsets the negative influence of high cognition of melamine harm, reducing foreign milk powder purchases.

However, the above impacts were still limited. For consumers, not much trust was placed in domestic milk powder producers directly. When consumers trust foreign producers, they remember the incident more clearly. This negative impression from the incident memory would increase their foreign milk powder purchase. Therefore, it would take more efforts to influence the purchase decisions of people who have a good memory.

At last, learning from the cause of the Sanlu incident, controls over product safety and quality should also be strengthened, including establishing quality management systems, promoting the use of organic pasture [56], and constructing traceability systems [57]. These control systems should comprise the entire food supply chain, from production to marketing, and focus on building trust and communicating credibility.

Food safety incidents are happening and may still continue. It is crucial to first prevent them from the very beginning. In addition to taking immediate actions to compensate for the loss and minimize the costs, collective efforts are essential to cope with the long-term impacts. The impact of the Sanlu incident has been lasting for more than ten years, while witnessing the extreme hardship to regain trust and the market. Findings in this paper could shed light not only on the Chinese milk powder sector but also ring a bell for the entire agriculture-food industry.

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Notes

1. Central government, local government, authorities, media, foreign producers, sales people, relatives, and friends.
2. Melamine is an industrial chemical used for producing plastic.
3. Metropolises that are in important position in the country's political, economic and other social activities and have leading roles and the abilities to drive radiation.
4. A provincial capital city with active development, an economically strong city in the eastern region or a regional central city in an economically developed region.
5. Small and medium-sized cities that have strategic significance or are relatively developed or have a relatively large economic aggregate.
6. (1) I trust the central government. (2) I trust the local government. (3) I trust experts and research institutes (who promote domestic milk powder). (4) I trust magazines and newspapers (that previously reported the Sanlu incident). (5) I trust foreign milk powder producers. (6) I trust milk powder sales staff. (7) I trust relatives (who have used domestic milk powder after the Sanlu incident). (8) I trust friends (who have used domestic milk powder after the Sanlu incident).
7. The test is a mobile phone game. Participates were firstly given in-order numbers and they should not forget the order of numbers. Then they should reorder the disrupted numbers depending on the former order. The more a participate matched the same order, the higher the score he got.
8. What substances can be improved when adding melamine? What is the damage melamine caused to infants? Whether there is evidence that melamine can lead to cancer? Where does the Sanlu milk powder scandal happen? Which kind of victims have been compensated for the Sanlu milk powder scandal? Which kind of punishment does the mastermind of the Sanlu milk powder scandal receive?
9. Each can of milk powder is about 900 g, which can be used for a newborn for about 20 days.
10. Son preference is a social prejudice that values men and despises women.

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Article

The coupling and coordination of digital economy and manufacturing transformation and upgrading for industry 5.0 in Hebei Province

Jianfang Li[1], Jiachen Wang[2,*], Tongtong Sun[3], Shi Yin[3,4,*]

[1] Science and Technology Research Institute, Hebei Agricultural University, Baoding 071001, China
[2] Business School, Beijing Normal University, Beijing 100875, China
[3] College of Economics and Management, Hebei Agricultural University, Baoding 071001, China
[4] School of Economics and Management, Harbin Engineering University, Harbin 150000, China
*** Correspondence authors:** Jiachen Wang, 907603531@qq.com; Shi Yin, shyshi0314@163.com

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Abstract: In the context of the widespread application of digital technologies such as the Internet, big data, artificial intelligence, and cloud computing, digital transformation in the manufacturing sector has become an important engine to promote high-quality economic development in Hebei Province. This paper aims to objectively analyze the current situation of industrial integration between the Beijing-Tianjin-Hebei digital economy and the manufacturing industry and conduct level measurement so as to promote the in-depth integration and development of the digital economy and manufacturing industry in Hebei Province, so that the manufacturing enterprises in Hebei Province can rebuild their competitive advantages in future development, finally realize digital transformation, and promote the high-quality development of the manufacturing industry in Hebei Province. Therefore, it is very important to carry out empirical research on the integrated development of the digital economy and manufacturing industry in Hebei Province. First of all, this paper constructs the index evaluation system of the digital economy and manufacturing industry, respectively, takes the relevant data of the Beijing-Tianjin-Hebei region in the past five years as data samples, uses the entropy weight-TOPSIS method to measure the level of digital economy development and manufacturing industry transformation, and uses the coupling coordination degree model to measure the level of industrial integration of the two. The final results show that: (1) The development level of the digital economy in Hebei Province fluctuates greatly, and there is still a certain gap with Beijing and Tianjin, but the future development potential of the digital economy is huge. (2) The transformation level of manufacturing industry in Hebei Province shows a trend of fluctuation and rise on the whole, and the development trend is good, and the gap between Hebei Province and developed regions is gradually narrowing. (3) The integration of the digital economy and manufacturing industry in Hebei Province has a good development trend, but there is still a certain gap with Beijing and Tianjin, and there are problems of inadequate, unstable, and unbalanced industrial integration. Finally, based on the research conclusions, suggestions are put forward to promote the coordinated development of the Beijing-Tianjin-Hebei region, improve the level of digital economy and manufacturing integration of industrial convergence development, raise the level of digital infrastructure construction, and raise the level of science and technology innovation. This paper reveals the mechanism of the digital economy affecting the high-quality development of the manufacturing industry, studies the whole process of digitalization, information technology, and intelligence integration into the development of the manufacturing industry, and fully releases the positive effect of the digital economy driving the high-quality development of the manufacturing industry, which has important theoretical and practical significance for promoting the high-quality development of the manufacturing industry and formulating relevant industrial policies.

Keywords: manufacturing industry; digital economy; Hebei Province; entropy-topsis method; coupling coordination degree model

1. Introduction

In the Overall Planning and Layout for the Construction of Digital China issued by the Central Committee of the Communist Party of China and the State Council in 2023, it is emphasized that the construction of digital China is an important engine for promoting Chinese style modernization in the digital era, and it is necessary to make the digital economy bigger and stronger, cultivate and expand the core industries of the digital economy, and promote the integrated development of digital technology and the real economy [1]. At present, with the wide application of digital technologies such as the Internet, big data, artificial intelligence, and cloud computing, many domestic enterprises have begun to use big data analysis and artificial intelligence technology to carry out strategic formulation and decision-making [2]. Economic models characterized by digital technology have emerged and continue to develop. The development of digital technology and the digital economy has promoted the rapid flow of various resource elements in the market [3]. It will help all types of market entities update their organizational structure, change traditional production methods, and promote the country to build a modern and digital economic system [4]. The digital economy has become one of the important engines driving China's economic growth. The China Digital Economy Development Report (2022), released by the China Academy of Information and Communications Technology, pointed out that in eight years, China's digital economy development index increased by 4.61 times, and the compound annual growth rate reached 24.06%, significantly higher than the GDP index growth rate in the same period [5]. In the future, China's digital economy will be further developed.

At present, China is in a critical period of economic restructuring, upgrading, and transformation of traditional production modes. The integration of the digital economy and the real economy has become the backbone of promoting the construction of a modern economic system and strengthening China's international competitiveness [6]. China should make full use of the advantages of the digital economy and digital technology to update and transform traditional modes of production and build a modern economic system [7]. As a pillar industry of China's economic development, the manufacturing industry plays an important role in improving China's scientific and technological innovation ability and promoting the high-quality development of China's economy. However, at present, China's manufacturing industry is still in the low-end position of the global manufacturing value chain and plays a processing role in the global manufacturing value chain, so the transformation and upgrading of China's manufacturing industry are imminent [8]. In the era of the digital economy, the use of emerging digital technologies represented by the Internet, big data, artificial intelligence, cloud computing, etc., and the integrated development of the manufacturing industry have become the main driving force to promote the high-quality development of the manufacturing industry [9]. In recent years, China has introduced a series of policies to promote the digital development of the manufacturing industry, such as the "Made in China 2025" issued by the State Council, which pointed

out that it is necessary to improve the innovation capacity of the manufacturing industry, promote the deep integration of information technology and industrialization, and take intelligent manufacturing as the main direction of the integration of the two [10]. The Implementation Opinions on Promoting the Quality Improvement of Manufacturing Products and Services issued by the Ministry of Industry and Information Technology emphasize the need to strengthen the supporting role of digitalization, networking, intelligence, and other technologies in the manufacturing industry [11]. Under the guidance of these policies, the digital economy will enable the high-quality development of China's manufacturing industry, and the digital transformation of China's manufacturing industry will be further deepened, promote the digitalization [12], productization and service of manufacturing activities, accelerate the formation of new formats of China's manufacturing industry, and continuously emerge new models of intelligent, digital, and network coordination of manufacturing industry, promoting the high-quality development of China's economy [13].

Hebei Province has seized the opportunity of the development of the digital economy, vigorously implemented the "two-wheel drive" strategy of digital industrialization and industrial digitalization, and promoted the transformation and upgrading of Hebei's industrial structure. In 2022, the scale of Hebei's digital economy will reach 1.51 trillion yuan, accounting for 35.6% of Hebei's GDP [14]. However, at present, the digital application in Hebei Province is mainly concentrated in the service sector, while the digital transformation in the manufacturing sector is relatively small [15]. Moreover, there is still a large gap between the integration level of digital economy and manufacturing industry in Hebei Province compared with Beijing, Shandong and the developed areas along the eastern coast, and the competitive advantage of manufacturing enterprises in Hebei Province will continue to be weakened [16], if manufacturing enterprises in Hebei Province want to reshape their competitive advantages in the future development, they must be combined with digital technology to promote the integrated development of digital economy and manufacturing industry, and promote the digital transformation and upgrading of manufacturing enterprises to promote the high-quality development of manufacturing industry [17].

For Hebei Province, the digital transformation of the manufacturing industry has greater potential and space for economic growth. In order to give full play to the leading and supporting role of the digital economy in the high-quality economic development of Hebei Province, the most basic and primary problem is to estimate the current situation and development level of the integration of the digital economy and manufacturing industry in Hebei Province in order to better find the convergence point of the digital economy and manufacturing industry in Hebei Province through research on the integration and development of the digital economy and manufacturing industry. It is also easier to find the difficulties and pain points in the digital transformation of manufacturing enterprises and improve the integration efficiency of the digital economy and manufacturing industry in Hebei Province, which is particularly important for promoting the integration of the digital economy and real economy in Hebei Province, realizing the structural reform of the manufacturing industry, and promoting the high-quality development of China's economy. Therefore,

it is of great practical significance to study the current situation of the integrated development of digital economy and manufacturing industry in Hebei Province, reveal the dynamic mechanism of digital economy affecting the high-quality development of manufacturing industry, measure the level of integration of the two, and then integrate digitalization, information technology, and intelligence into the whole process of manufacturing industry development so as to promote the high-quality development of manufacturing industry in Hebei Province and formulate relevant policies by the government.

This paper will discuss the current situation and level of measurement of the integration of the digital economy and manufacturing industry and further study the current situation and mechanism of the integration of the digital economy and manufacturing industry in Beijing, Tianjin, and Hebei. The specific research objectives include the following: (1) enrich the theoretical research content of the digital economy and expand the research perspective on the industrial integration of the digital economy. (2) Provide diversified paths for the integrated development of the digital economy and manufacturing industry in Hebei Province and provide references for the statistical classification work of national government departments. (3) Based on the research theory and empirical research results, summarize and analyze the integration mechanisms of the digital economy and manufacturing industry, and provide policy suggestions for the integrated development of China's digital economy and manufacturing industry.

This paper summarizes the important references to the digital economy, the manufacturing industry, and the integrated development of the two industries. For the digital economy, the research content mainly focuses on the connotation, current situation, and related influencing factors [18]. Currently, the connotation of the digital economy is still continuously enriched, but the exact connotation has not been reached [19]. The relevant influencing factors of the digital economy mainly include digital infrastructure, digital technology development, digital industrialization, and industrial digitalization [20]. For the manufacturing industry, China's manufacturing industry is currently moving towards high-quality development and digital transformation. Therefore, the literature on these two aspects is reviewed and summarized. The key to high-quality development and digital transformation in the manufacturing industry lies in technological innovation, policy support, and market demand [21]. For the integrated development of the digital economy and manufacturing industry, a large number of scholars have analyzed the industrial integration of the two based on qualitative or quantitative analysis methods. A large number of research results show that the current trend of the integration of the digital economy and manufacturing industry is deepening, but there are still regional differences in industrial integration, and the internal problems of industrial integration between the two are insufficient and unbalanced [22].

Based on the annual data of the Beijing-Tianjin-Hebei region from 2017 to 2021, this paper uses the entropy weight topsis method to estimate the development level of the digital economy and the high-quality development level of the manufacturing industry, and then uses the coupling coordination degree model to measure the integration level. The main contents of this paper are as follows: First, this paper reviews and summarizes the relevant literature on the development of the digital

economy, the manufacturing industry, and their integration. Second, analyze the dynamic mechanisms of industrial integration. Thirdly, on the basis of dynamic mechanism analysis, the index evaluation system of the integration development of the digital economy and manufacturing industry is established, and on the basis of this system, the entropy weight topsis method and coupling coordination degree model are used to measure the industrial integration level of the two industries. Fourth, analyze the measurement results. Fifth, on the basis of the analysis, the present situation and level of integration of the digital economy and manufacturing industry in Hebei Province are studied. Sixth, summarize the conclusions and enlightenment to promote the better integrated development of the digital economy and manufacturing industry in Hebei Province.

The rest of this paper is as follows: Section 2 describes the relevant literature. Section 3 describes the dynamic mechanism and measurement method of industrial convergence. Section 4 is empirical research. Section 5 elaborates on the conclusion and enlightenment.

2. Literature review

2.1. Research on digital economy

With the rapid development of digital technology, the digital economy has come into being, and the related research on the digital economy has attracted the wide attention of many scholars. At present, scholars at home and abroad mainly carry out in-depth research on digital economy-related content from the following three aspects.

First, related research on the definition of the connotation of the the connotation of the digital economy. Li [23] analyzed the similarities and differences between the digital economy and other similar concepts by sorting out the origin and dissemination process of the concept of the digital economy, research results, and existing problems, and believed that the digital economy was essentially a new economic form of production in the form of digital technology. Bukht and Heeks seek a narrower definition for the digital economy by combing through the concept of intensive and widespread use of ICTs as the part of economic output derived entirely or mainly from digital technologies, whose business model is based on digital goods or services [24]. Chen et al. [25] sorted out the research process of "digital economy" and gave a relatively broad definition of the term "digital economy", holding that digital economy is a special new form of economic activity, its key resource is digital information, including data elements, the main information carrier is the Internet platform, and the new driving force is digital technology innovation. The digital economy includes three main features: data support, integration and innovation, and open sharing.

The second is research on the development status and level of the digital economy. Volkova et al. pointed out that the current trend of the digital economy is dominated by a few countries and relatively few companies. Although digitalization has potential benefits for the economic development of developing countries, it is very difficult to ensure their sustainable development under the current digital technology and policy model. Developing countries need to think outside the box and learn from the experience of developed countries. Produce more digital technology [26]. Batrancea et al., taking healthcare enterprises as the research object, adopted the two-

stage least squares method (2SLS) and the generalized moment (GMM) model to verify that the liquidity and solvency of corporate funds have a significant impact on corporate performance [27]. Wang et al. conducted a study on 285 prefecture-level cities in China and found that the development level of China's digital economy is rising steadily from the perspective of time and space, with the overall distribution pattern being higher in the east and lower in the west, and the distribution pattern being greater in the coastal areas than in the inland areas. They proposed the need to rationally coordinate the allocation of regional digital factors and narrow the differences in the level of the digital economy among regions [28]. Batrancea et al. [29] conducted data analysis on the determinants of economic growth in seven non-BCBS countries and found that national economic growth was mainly driven by bank capital and asset ratios.

The third is research on the relevant influencing factors of the digital economy. Zhang and Chen [30] pointed out that information technology progress and digital infrastructure construction are the main driving forces for the development of China's digital economy. Li and Liu [31] pointed out that factor input, technological progress, and institutional change are three important factors affecting the development of the digital economy. Batrancea and Tulai [32] study the energy sector, exploring the phenomenon of energy production and its main determinants in 37 European economies over the period 2011–2021, showing that energy production is largely dependent on energy productivity, primary energy consumption, and energy imports. Batrancea [33] takes panel data from SMES as the analysis object to study the determinants of economic growth in the EU and verifies that online import and export and import and export outside the EU have a significant impact on economic growth. Lv and Fan [34] studied the differences in the development level of the digital economy in different regions of China and pointed out that different driving factors at different times and regions have different influence levels on the development of the digital economy. Batrancea et al. [35] took 50 countries as research objects to discuss the sustainability of economic growth and proposed that more investment and green policies are needed to achieve the sustainability of national economic growth.

2.2. Research on manufacturing development

At present, scholars have carried out in-depth research mainly on two aspects: the high-quality development of the manufacturing industry and the digital transformation of the manufacturing industry.

On the one hand, in view of the high-quality development of the manufacturing industry, Li defined the connotation of high-quality development of the manufacturing industry as essentially a development paradigm that takes into account environmental benefits, social benefits, and economic benefits by meeting various needs and using various technical means [36]. Tian et al. explored new paths and methods to improve the high-quality development of China's manufacturing industry by studying the internal and external factors that affect China's business model innovation [37]. Wang and Shi analyzed the factors affecting the high-quality development of the manufacturing industry from both internal and external perspectives and pointed out that industry technology level, internal factor supply quality, opening to the outside

world, technological innovation, human capital, and producer services are important factors affecting the high-quality development of the manufacturing industry [38]. Wang and Liu [39] conducted a study on the factors affecting the high-quality development of the manufacturing industry based on the input-output method, and the results showed that the government, improving the investment environment, intellectual property protection, and other factors had a significant impact on the high-quality development of the manufacturing industry. Khin and Kee [40], based on a number of case studies on the manufacturing industry in Malaysia, pointed out the factors affecting the high-quality development of the manufacturing industry from three aspects: promotion, hindrance, and driving, among which the main driving factors are expected returns and market opportunities, the hindrance factors are lack of capital and knowledge, and the promotion factors are resources, skills, and support.

On the other hand, for the digital transformation of the manufacturing industry, Liere-Netheler et al. [41] identified 12 driving factors for the digital transformation of the manufacturing industry, including work environment improvement, vertical integration, and horizontal integration, through qualitative research methods. Liu uses a text mining algorithm to propose that digital investment, digital technology application, and business model transformation are the triple influencing mechanisms affecting manufacturing productivity, which has a significant impact on improving manufacturing productivity [42]. Wang and Wu point out that digital technology gives new connotation to traditional manufacturing industry through reshaping innovation, profit, production mode, service, and other modes of manufacturing industry and provides an important reference for the digital transformation and upgrading of China's manufacturing industry [43]. Liu and Yu analyzed the trend, current situation, and future development policies of China's digital transformation and proposed suggestions for manufacturing enterprises to improve their own digital transformation capabilities and give full play to the role of the market and government [44].

2.3. Research on the integration and development of the digital economy and manufacturing industry

At present, most domestic and foreign scholars have conducted in-depth research on the status quo, level, and existing problems of the integration of the digital economy and manufacturing industry based on qualitative and quantitative analysis methods.

In terms of quantitative analysis methods, Lv et al. [45] thought that there was a significant positive relationship between the basic industries of the digital economy and the manufacturing industry. Wang and Chen [46] used the Super-SBM-O-C method to estimate the high-quality development level of the manufacturing industry and the entropy method to estimate the development level of the digital economy and empirically verified that the digital economy has a significant positive impact on the high quality of the manufacturing industry. Batrancea et al. used the first-order differential generalized moment method (GMM) method and cross-section fixed effect to carry out data analysis, proving that export, import, FDI inflow, FDI outflow, social contribution, and wages have significant effects on economic growth [47]. Batrancea et al. analyzed the financing from 2005 to 2020 by combining the first difference generalized method of moment estimator and multiple time series analysis,

and the results showed that smes were mainly driven by interest rates, angel investment, bank support, and public support [48]. Zhou [49] uses the entropy weight method and the coupling coordination degree model to study the path of the digital economy, enabling high-quality development in the manufacturing industry. The results show that the digital economy can not only directly enable the high-quality development of the manufacturing industry but also indirectly promote the development of the manufacturing industry through the intermediary effect of industrial integration.

In terms of qualitative analysis methods, Li and Han conducted in-depth research on the connotation and characteristics of high-quality development in the manufacturing industry and the digital economy and put forward targeted suggestions for high-quality development in the manufacturing industry, such as scientific innovation, promoting industrial integration, and improving infrastructure [50]. Xue and Zhu analyzed the effect of manufacturing integration under the background of the digital economy from four aspects: cost constraint, organization optimization, market monopoly, and data fusion value-added, and the results showed that the integration of the digital economy and manufacturing industry is the general trend under the background of the digital economy [51]. Yin studied the blocking points, paths, and strategies of green innovation development in the manufacturing industry under the digital economy and put forward effective suggestions for the high-quality development of the manufacturing industry [52]. Some scholars combined qualitative and quantitative analysis methods to carry out research. Yin et al. [53] used the semantic integration method and comparative analysis method to define and classify the concept of digital economy, then used a complex network model to study the integration of manufacturing industry and digital economy and put forward targeted suggestions for promoting the integration of digital economy and manufacturing industry from the perspectives of enterprises themselves, the economy, and policies.

To sum up, a large number of scholars have conducted in-depth research on the development of the digital economy and the manufacturing industry. The relevant connotations, influencing factors, and research methods proposed by scholars have provided great references for this paper to study the integrated development of the digital economy and manufacturing industry. However, there are still three deficiencies in the existing research: First, there is a wide range of research objects. Scholars mostly conduct research on the digital economy and manufacturing based on national and other macroeconomic backgrounds and lack concentrated and targeted research on a certain province or region. Second, current research mainly focuses on the analysis of the integration degree of the digital economy and the real economy, with a lack of research on the status quo and level of manufacturing industry integration. There are relatively few achievements in in-depth analysis of the driving mechanism and measurement level of the digital economy to promote the high-quality development of the manufacturing industry. Third, the measurement of the integrated development of the digital economy and manufacturing industry mainly adopts a single index, which lacks pertinence and effectiveness. Therefore, this paper aims to determine a specific research object, take Hebei as the research object, and measure the development status of the digital economy and manufacturing industry and the integration level of the two by constructing an evaluation index system for the

development of the digital economy and the transformation of the manufacturing industry, and then put forward targeted suggestions to provide reference for the high-quality development of manufacturing enterprises in Hebei and the formulation of government policies.

3. Dynamic mechanism and measurement method of industrial integration

With the continuous development of the digital economy based on digital technology, the digital economy has begun to show a trend of integration with the real economy [54]. The integration of the digital economy with other industries has not only promoted the digital transformation of various industries but also helped various industries achieve industrial digitalization, and industrial integration has become an important engine to promote the development of the digital economy [55]. For China, the manufacturing industry is a pillar industry of the Chinese economy, so it should focus on promoting the integration of the digital economy and the manufacturing industry [56]. The degree of integration between the digital economy and the manufacturing industry mainly depends on the effect of the dynamic mechanism of the two, which is generally the result of the joint action of the external and internal dynamics of industrial integration [57].

3.1. Analysis of the dynamic mechanisms of industrial integration

3.1.1. Analysis of the integration of the digital economy and the manufacturing industry

Referring to the existing research on industrial integration, most scholars analyze the process of industrial integration, which roughly includes various forms of integration such as product integration, market integration, and factor integration. In the field of manufacturing, manufacturing enterprises have made use of emerging digital technologies such as the Internet, big data, and artificial intelligence to effectively promote the high-quality development of digitization, information technology, and service in the manufacturing industry. Combined with a large amount of literature and the actual situation, the integration of the digital economy and manufacturing industry mainly includes three aspects, namely technology integration, business integration, and product integration. The integration of the digital economy and manufacturing industry technology is mainly reflected in the application of relevant digital technologies to the production of different products and services by manufacturing enterprises. Technology integration mainly improves the technological innovation ability of manufacturing enterprises so as to enhance their productivity and finally reverse the competitive disadvantage of the manufacturing industry. Business integration is based on digital technology, the application of Internet technology, information technology, and other digital technologies to manufacturing enterprise product research and development, production design, operation management, and other processes. In addition to providing traditional manufacturing businesses, it is also important to provide new businesses formed by relying on relevant digital technologies so as to improve the business capabilities of manufacturing enterprises, extend the manufacturing industry chain, and update the manufacturing business

model. Product integration is mainly reflected in the new products produced by the integration of digital technology and traditional products in the manufacturing industry. Product integration promotes the transformation and upgrading of the product structure of the manufacturing industry, so that China's manufacturing industry can break through the bottleneck of low-end development and shift to the direction of service manufacturing and digital manufacturing.

3.1.2. Analysis of internal motivation mechanisms

The integrated development of the digital economy and manufacturing industry is the result of many factors. This paper analyzes the internal driving force from the perspective of supply and demand.

From the demand side, diversified user product demand and consumption upgrading requirements have driven the integrated development of the digital economy and the manufacturing industry. At present, China is in a critical period of consumption transformation and upgrading. Consumers are moving from the initial pursuit of low product prices to the pursuit of product quality. In this process, the traditional manufacturing industry has also put forward such things as rich product types, a shorter delivery period, accelerated speed of product replacement, and other requirements, so manufacturing enterprises must transform and upgrade their own products, technology, business, and other content. Inject the vitality of new production factors, integrate with the digital economy, and meet the needs of the consumer market.

From the supply side, the internal development requirements of manufacturing enterprises to improve production efficiency, save costs, and improve the level of innovation have driven the integrated development of the digital economy and the manufacturing industry. Digital technology innovation is the main driving force for the high-quality development of the manufacturing industry, and digital technology innovation is conducive to the integration and upgrading of traditional production factors in the manufacturing industry and improves the innovation ability and production capacity of manufacturing enterprises. Human capital provides a talent guarantee for the high-quality development of the manufacturing industry. High-level digital technical talents can effectively improve the production efficiency of enterprises and accelerate the level of digital development of enterprises. High-quality management talents can be sensitive to the problems existing in the development of enterprises, carry out effective management, and innovate the business development mode of manufacturing enterprises. Market capital is also one of the main driving forces behind promoting industrial integration. In the market competition, in order to ensure that they are in a favorable position and obtain advanced technology and data information, manufacturing enterprises often integrate with the digital economy through mergers and acquisitions, investment, and other forms, thereby reducing their financing costs and extending the manufacturing industry chain.

3.1.3. Analysis of extrinsic dynamic mechanisms

The economic environment and policy system are the two main factors that promote the integration of the digital economy and manufacturing industry. In terms of the economic environment, at present, China is in a critical period to promote high-quality economic development, and in the face of the current adverse environmental

situation, manufacturing enterprises, as a pillar industry of national economic development, need to assume the responsibility and obligation to promote high-quality economic development and protect environmental health. Based on the above background, manufacturing enterprises must actively transform and upgrade industrial structures. Integration with the digital economy industry involves the use of digital technology to promote the high-quality development of manufacturing. In terms of policies and systems, various departments in China have introduced many policies to encourage the high-quality development of manufacturing and digital transformation and upgrading. These policies can strengthen the guiding role of manufacturing enterprises and guide manufacturing enterprises to carry out digital technology innovation, so as to improve the competitiveness of manufacturing enterprises and break through the low-end position of Chinese manufacturing enterprises in the global value chain.

Based on the above analysis, this paper constructs the dynamic mechanism framework for the integration of the digital economy and manufacturing industry. It can be shown in **Figure 1**.

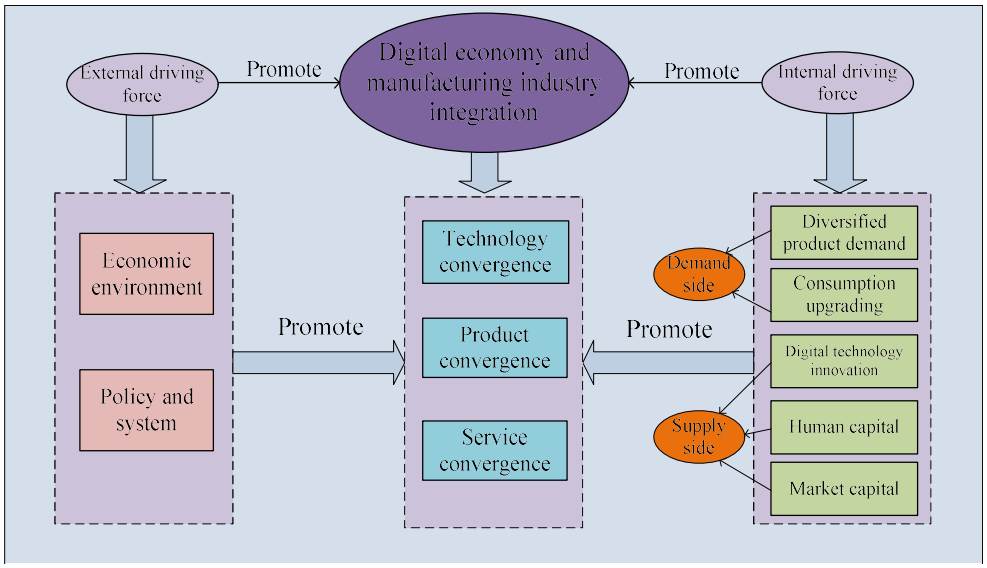

Figure 1. Dynamic mechanism framework of the integration of digital economy and manufacturing industry.

3.2. Analysis of industrial integration measurement methods

Through consulting relevant literature, the current domestic and foreign methods for measuring the development level of the digital economy and the transformation level of the manufacturing industry mainly include the input-output method, the value-added rate method, the establishment of an evaluation index system, and other methods. However, due to limited data acquisition and unstable data sources, it is difficult to use the input-output method and the value-added rate method to calculate the transformation level of the digital economy and manufacturing industry in Hebei Province. The establishment of a relevant evaluation index system has strong operability, more flexible index selection, and better data continuity. Therefore, this paper hopes to comprehensively evaluate the transformation level of the digital

economy and manufacturing industry in Hebei Province by constructing an evaluation index system for the digital economy and manufacturing industry. On this basis, based on the comprehensive scores of the two, the coupling coordination degree model is used to analyze the integrated development level of the digital economy and manufacturing industry, and specific suggestions are put forward for the integrated development of the digital economy and manufacturing industry in Hebei Province.

3.2.1. Digital economy and manufacturing index evaluation system construction

Most scholars have built a digital economy evaluation index system from the perspectives of digital infrastructure, digital technology applications, digital finance, and other aspects. Based on the reference to authoritative literature, this paper combines the connotational characteristics of digital economy with the development characteristics of digital economy in Hebei Province. The digital economy evaluation index system of Hebei Province was constructed from three aspects: digital infrastructure, digital technology innovation, and digital industrial foundation (**Table 1**).

Table 1. Digital economy index evaluation system of Hebei Province.

Primary index	Secondary index	Unit
Digital infrastructure(M1)	Internet penetration (X1)	%
	Mobile phone penetration (X2)	Department/Hundred People
	Number of Internet pages built (X3)	Ten thousand
Digital technology innovation(M2)	Number of patent applications (X4)	Piece
	Internal R & D expenditure for high-tech related industries (X5)	Ten thousand yuan
	Expenditures for new product development in high-tech related industries (X6)	Ten thousand yuan
	Technology market transaction volume (X7)	Billion
Digital industry foundation(M3)	E-commerce sales revenue (X8)	Billion
	Total postal and telecommunications services (X9)	Billion
	Software business revenue (X10)	Billion
	Employment in the digital industry (X11)	People

In addition, the measurement of the transformation level of the manufacturing industry in Hebei Province. Some scholars construct the evaluation index system from the perspective of input-output, while others mainly reflect the transformation level of the manufacturing industry by calculating the total output value and total proportion of the manufacturing industry from an overall perspective. With reference to the above research and comprehensive consideration of the actual development of the manufacturing industry in Hebei Province, this paper constructs the evaluation index system of the manufacturing industry in Hebei Province from the perspective of input-output (**Table 2**).

Table 2. Index evaluation system of Hebei manufacturing industry transformation level.

Primary index	Secondary index	Unit
Input index (N1)	Investment in technological transformation (Y1)	Billion
	Human capital input (Y2)	Ten thousand people
	Investment in fixed assets increased over the previous year (Y3)	%
Output index (N2)	Gross output value of manufacturing industry (Y4)	Billion
	Profit margin of manufacturing operating income (Y5)	%
	Gross manufacturing profits (Y6)	Billion
	Total energy production (Y7)	Tons of standard coal

3.2.2. Measurement methods and models

Entropy weight-topsis method:

Before calculating the level of digital economy development and manufacturing transformation, it is necessary to determine the weight of each index in the evaluation index system. There are two main methods to determine the weight of indicators, one is subjective weighting, such as the analytic hierarchy process, the Delphi method, and so on. The other is the objective weighting method, such as principal component analysis, entropy weight method, factor analysis, and so on. In order to enhance the objectivity of evaluation, this paper adopts the entropy weight method of objective weighting method to determine the weights of each index and adopts TOPSIS method to evaluate the comprehensive index of digital economy development and manufacturing transformation level of Hebei Province.

(1) Entropy weight method. Entropy weight method is a method that uses information entropy to determine the weight, effectively avoiding the interference of subjective factors, and its calculation steps are as follows:

1) Construct the initial data matrix of the evaluation system *X*:

$$X = \{x_{ij}\}_{m\times n} \tag{1}$$

In the formula, x_{ij} represents the value of the *j* evaluation index of the *i* sample.

2) Data standardization processing:

$$x'_{ij} = \begin{cases} \dfrac{x_{ij} - min\, x_{ij}}{max\, x_{ij} - min\, x_{ij}}, j\text{is a positive indicator} \\ \dfrac{max\, x_{ij} - x_{ij}}{max\, x_{ij} - min\, x_{ij}}, j\text{is a negative indicator} \end{cases} \tag{2}$$

In the formula, x'_{ij} is the standardized value, $min\ x_{ij}$ and $max\ x_{ij}$ are the minimum and maximum value of each index respectively, where $0 < i \le n, 0 < j \le m$.

3) Data standardization matrix:

$$y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} (0 \le y_{ij} \le 1) \tag{3}$$

The data standardization matrix is obtained: $Y = \{y_{ij}\}_{m\times n}$.

4) Calculate the information entropy of item *j*:

$$e_j = -K \sum_{i=1}^{m} y_{ij}\, ln\, y_{ij} \tag{4}$$

where K is a constant, $K = \frac{1}{ln\, m}, 0 \leq e \leq 1$.

5) Calculate the information utility value of each indicator:

$$d_j = 1 - e_j \tag{5}$$

6) Calculate the weight of each indicator w_j:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{6}$$

7) Calculate the overall score T_i:

$$T_i = \sum_{i=1}^{n} y_{ij} w_j \tag{7}$$

(2) TOPSIS method. The core of TOPSIS method is to determine the positive ideal solution and negative ideal solution of each index. By calculating the Euclidean distance between each evaluation subject and the positive ideal solution and the negative ideal solution, then calculating the relative proximity between each scheme and the ideal solution, ranking the pros and cons, and finally obtaining the comprehensive score.

1) Build a weighting matrix:

$$R = (r_{ij})_{m \times n}, \quad \mathrm{r_{ij}} = \mathrm{w_j} \times \mathrm{x_{ij}^{'}} \tag{8}$$

2) The positive and negative ideal solutions are determined according to the weighting matrix:

$$S_j^+ = max(r_{ij}); S_j^- = min(r_{ij}) \tag{9}$$

3) Calculate Euclidean distance:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (S_j^+ - r_{ij})^2}\,; d_i^- = \sqrt{\sum_{j=1}^{m} (S_j^- - r_{ij})^2} \tag{10}$$

4) Calculate the relative proximity to the positive ideal solution:

$$C_i = \frac{d_i^-}{(d_i^+ + d_i^-)} \tag{11}$$

Coupling coordination degree model:

This paper adopts the coupling coordination degree model to measure the integration level of digital economy and manufacturing industry in Hebei Province, and accurately measure the integration development degree of the two. The calculation formula is as follows:

$$U = \sqrt{C \times \ (\alpha T_1 + \beta T_2} \tag{12}$$

$$C = \frac{(T_1 + T_2)}{(\frac{T_1 + T_2}{2})^2} \tag{13}$$

where: U is the integration level of digital economy and manufacturing industry in Hebei Province; T_1 is the comprehensive score of Hebei Province's digital economy development level; T_2 is the comprehensive score of Hebei Province's manufacturing industry transformation development; α, β is the undetermined parameter, indicating the importance of digital economy and manufacturing industry, where $\alpha + \beta = 1$, and $0 \leq \alpha$、$\beta \leq 1$, based on the actual situation of Hebei Province, $\alpha = \beta = 0.5$.

3.2.3. Data source

Considering the continuity of data acquisition, this paper selects the data of Beijing, Tianjin, and Hebei Province from 2017 to 2021 as the research unit. The data involved are mainly from the Statistical Report on the Development of China's Internet, the Statistical Yearbook of China's High-Tech Industry, the Statistical Yearbook of China's Electronic Information Industry, the Statistical Yearbook of China's Energy, the Statistical Yearbook of China, and the statistical yearbook of the three regions and provinces.

4. Empirical analysis

4.1. Digital economy development level measurement results

The entropy weight-TOPSIS method is used to calculate the weights of the digital economy development indicators of the three provinces and cities in Beijing, Tianjin, and Hebei, and the comprehensive scores and rankings of the digital economy development level of the three provinces and cities are given. The specific results are shown in **Table 3** and **Figure 2**.

Table 3. Weight of each evaluation index of the development level of digital economy in Beijing, Tianjin and Hebei.

	Hebei	Beijing	Tianjin
X1	0.2255	0.0695	0.0697
X2	0.0510	0.0940	0.0583
X3	0.0490	0.0883	0.0972
X4	0.0967	0.1266	0.1237
X5	0.0836	0.1064	0.1141
X6	0.1175	0.0530	0.0663
X7	0.0656	0.0786	0.0728
X8	0.1016	0.0989	0.1345
X9	0.0685	0.1125	0.1254
X10	0.0754	0.0752	0.0810
X11	0.0654	0.0970	0.0571

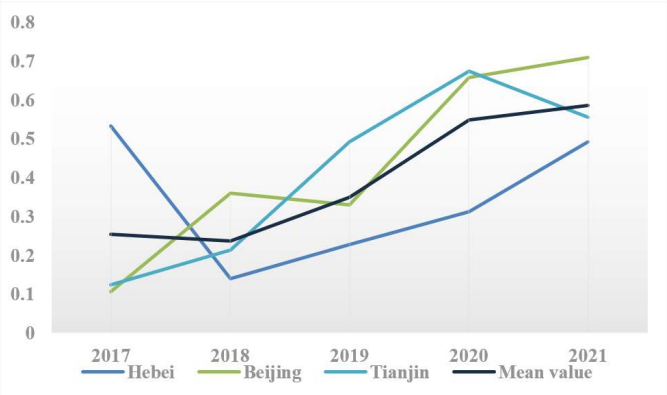

Figure 2. Comprehensive score of digital economy development level of Beijing, Tianjin, Hebei region from 2017 to 2021 based on entropy weight-TOPSIS method.

It can be seen from **Table 3** that there are obvious differences in the weights of 11 secondary indicators related to the digital economy in the three provinces and cities of Beijing, Tianjin, and Hebei. For Hebei Province, the top three indicators with greater weight are Internet penetration rate (0.2255), high-tech related industry new product development expenditure (0.1175), and the number of digital technology patent applications (0.0967), while the lowest weight is the number of Internet page construction (0.0490). In Beijing, the top three indicators with greater weight are the number of digital technology patent applications (0.1266), the total amount of postal and telecommunication services (0.1125), and the internal expenditure of high-tech related industry R & D funds (0.1064), and the least weight is the high-tech related industry new product development expenditure (0.0530). In Tianjin, the top three indicators with greater weight are e-commerce sales (0.1345), total postal and telecommunications business (0.1254), and the number of digital technology patent applications (0.1237), while the lowest weight is digital industry employment number (0.0571). It can be seen from comprehensive analysis that digital technology innovation has a significant impact on the development of the digital economy. Digital technology patent applications, new product development expenditure of high-tech related industries, and internal expenditure of R & D expenditure of high-tech related industries also play a large role in the development of the digital economy in various provinces and cities. The penetration rate of mobile phones, the number of web pages built, and the number of people employed in digital industries have less impact on the development of the digital economy than other indicators.

It can be seen from **Figure 2** the development of the digital economy in Beijing, Tianjin, and Hebei in the past five years. By 2021, the comprehensive scores of the three provinces and cities in terms of digital economy development level are Beijing, Tianjin, and Hebei respectively in order of magnitude. The highest score for Beijing is 0.7096, while the lowest score for Hebei is 0.4913. On the whole, the development level of the digital economy in Beijing and Tianjin showed a trend of fluctuation and rise from 2017 to 2021, while in Hebei Province, although the comprehensive score of the digital economy development level was high in 2017, it declined rapidly in 2018, although the level continued to rise after that. However, we can still find that the development level of the digital economy in Hebei Province has the problems of large fluctuations, unbalanced and unstable development, and there is still a certain gap between the development level of the digital economy in Beijing and Tianjin.

4.2. Manufacturing transformation level measurement results

By constructing the evaluation index system of the transformation level of the manufacturing industry, the comprehensive score and ranking of the transformation level of the manufacturing industry in the three provinces and cities of Beijing, Tianjin, and Hebei were measured by the entropy weight-TOPSIS method, and the specific results were shown in **Table 4** and **Figure 2**.

Table 4. Weights of each evaluation index of manufacturing transformation level in Beijing, Tianjin and Hebei Provinces.

	Hebei	Beijing	Tianjin
Y1	0.1048	0.0773	0.1351
Y2	0.1264	0.1556	0.0957
Y3	0.0778	0.1178	0.0809
Y4	0.1375	0.1201	0.2652
Y5	0.2261	0.0777	0.1214
Y6	0.2664	0.3717	0.1772
Y7	0.0610	0.0798	0.1244

As can be seen from **Table 4**, the largest weight index affecting the transformation level of Hebei's manufacturing industry is the total profit of the manufacturing industry, and the smallest weight index is the total energy production. The largest weight index affecting the transformation level of Beijing's manufacturing industry is the total profit of the manufacturing industry, and the smallest weight index is the investment in technological transformation and the total energy production. The largest weight index affecting the transformation level of Tianjin's manufacturing industry is the total output value of the manufacturing industry, and the smallest weight index is the proportion of fixed asset investment growth over the previous year. This shows that the total profit of the manufacturing industry and the total output value of the manufacturing industry have a significant impact on the transformation level of the manufacturing industry in a region, while the total amount of general energy production, the proportion of fixed assets investment growth over the previous year, and the investment in technological transformation have a small impact on the transformation level of the manufacturing industry in a region.

As can be seen from **Figure 3**, the average level of manufacturing transformation in the three provinces and cities of Beijing-Tianjin-Hebei from 2017 to 2021 is ranked as Tianjin, Beijing, and Hebei Province respectively. From the average of the transformation level of the manufacturing industry, it can be seen that the transformation level of the manufacturing industry in Hebei Province is still relatively backward. However, on the whole, the transformation level of the manufacturing industry in the Beijing-Tianjin-Hebei region shows a fluctuating upward trend, especially from 2020 to 2021, the transformation level of the manufacturing industry in the three provinces and cities will rise rapidly. From the growth rate, the average annual growth rate of the transformation level of the manufacturing industry in Hebei Province will reach 8.97%, indicating that the transformation speed of the manufacturing industry in Hebei Province will continue to accelerate. It is gradually narrowing the gap between Beijing and Tianjin in the level of manufacturing transformation.

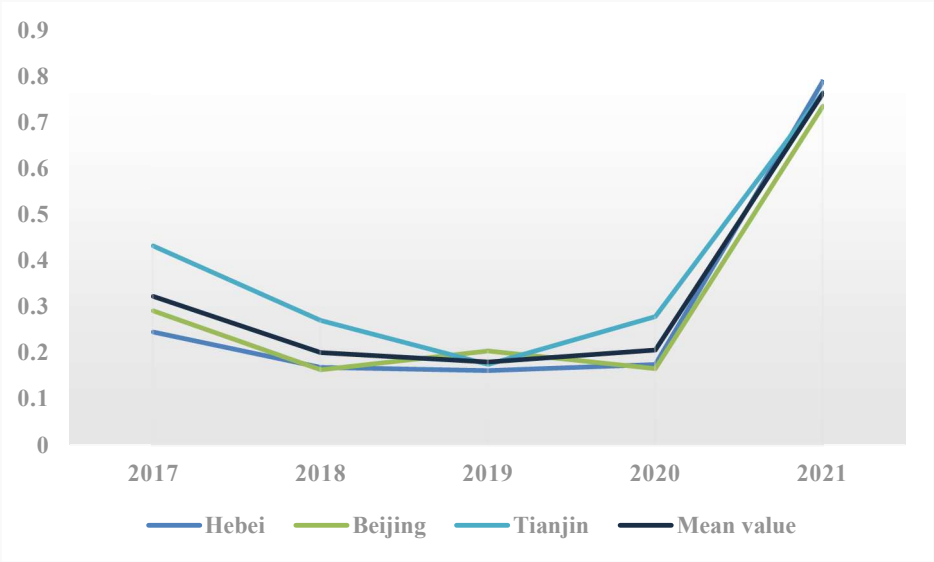

Figure 3. The comprehensive score of Beijing-Tianjin-Hebei manufacturing transformation level based on entropy weight-TOPSIS method from 2017 to 2021.

4.3. Digital economy and manufacturing integration development measurement results

According to the comprehensive scores of the development level of the digital economy and the transformation level of the manufacturing industry, the coupling coordination degree and coupling coordination degree of the integrated development of the digital economy and manufacturing industry in the three provinces of Beijing, Tianjin, and Hebei are calculated by using the coupling coordination degree model. The coupling level and coupling coordination degree classification standard of this paper is referred to by Yang [58]. The results are shown in **Tables 5** and **6**.

Table 5. 2017–2021 Coupling degree of integration and development of digital economy and manufacturing industry in Beijing, Tianjin, Hebei.

	Hebei	Coupling level	Beijing	Coupling level	Tianjin	Coupling level
2021	0.9727	Benign coupling	0.9998	Benign coupling	0.9874	Benign coupling
2020	0.9603	Benign coupling	0.8038	High level coupling	0.9106	Benign coupling
2019	0.9861	Benign coupling	0.9726	Benign coupling	0.8815	Benign coupling
2018	0.9951	Benign coupling	0.9286	Benign coupling	0.9928	Benign coupling
2017	0.9301	Benign coupling	0.8851	Benign coupling	0.8313	Benign coupling

As can be seen from **Table 5**, the coupling degree between the digital economy and manufacturing industry in the three provinces of Beijing, Tianjin, and Hebei in the past five years is greater than 0.8, basically in the benign coupling level, which indicates that there is a strong interaction between the dimensions of the digital economy and manufacturing industry in the three provinces of Beijing, Tianjin, and Hebei.

Table 6. 2017–2021 Beijing-Tianjin-Hebei digital economy and manufacturing integration development coupling degree coupling coordination degree.

	Hebei	Degree of coordination	Beijing	Degree of coordination	Tianjin	Degree of coordination
2021	0.7889	Moderate coordination	0.8497	Highly coordinated	0.8069	Highly coordinatedg
2020	0.4843	Primary coordination	0.5757	Moderate coordination	0.6587	Moderate coordination
2019	0.4388	Primary coordination	0.5101	Moderate coordination	0.5425	Moderate coordination
2018	0.3918	Primary coordination	0.4929	Primary coordination	0.4905	Primary coordination
2017	0.6015	Moderate coordination	0.4201	Primary coordination	0.4808	Primary coordination

As can be seen from **Table 6**, the coupling coordination degree between the digital economy and manufacturing industry is the highest in Beijing, with a value of 0.8497, followed by Tianjin, with a value of 0.8069, both of which are in the highly coordinated stage. The coupling coordination degree is the lowest in Hebei Province, with a value of 0.7889, in the moderate coordination stage. The low coupling coordination degree of integration and development of the digital economy and manufacturing industry in Hebei Province indicates that at present, the digital economy and manufacturing industry in Hebei Province have not formed a good driving mechanism. Although there is a strong interaction between the digital economy and the manufacturing industry in Hebei Province, the coordination level is moderate coordination, and the level of industrial integration and development of the two industries needs to be improved. From the perspective of the overall development trend, the integrated development level of the digital economy and manufacturing industry in Beijing and Tianjin has maintained a steady rise, gradually transitioning from primary coordination to advanced coordination, while the industrial integration development level of Hebei Province has experienced great fluctuations, falling from intermediate coordination to primary coordination, and then reaching intermediate coordination again. Although the growth level of the coupling coordination degree of the integration and development of the two industries in Hebei Province from 2020 to 2021 is 0.38, and the integration development level is growing rapidly, there are still problems of unstable development that need to be solved.

4.4. Discussion

4.4.1. Discussion on the development status of the digital economy in Hebei Province

According to the Hebei Provincial Department of Industry and Information Technology, by 2022, the scale of Hebei's digital economy will reach 1.51 trillion yuan, accounting for 35.6% of the province's GDP, which shows that the development level of Hebei's digital economy is constantly strengthening and gradually becoming an important driving force to promote the high-quality development of Hebei's economy.

However, comparing the above analysis results with developed regions, it can be found that there is still a certain gap between the development level of the digital economy in Hebei Province and developed regions, and the average annual growth rate is negative, and the development trend is not optimistic. By analyzing the measurement results of the development level of the digital economy and combining

them with the actual situation of Hebei Province, we find that there are many problems in the process of developing the digital economy in Hebei Province, mainly concentrated in the following three aspects. First of all, the speed of industrial digitalization and digital industrialization transformation in Hebei Province is slow, and the degree and scale of digital transformation in various industries are quite different. Generally speaking, the service industry has the highest degree of digital transformation, followed by industry and agriculture. Secondly, the digital technology innovation in Hebei Province is insufficient. According to the relevant data and empirical results, we find that the investment of capital, technology, and personnel in the digital economy in Hebei Province is small, and the investment degree is much lower than that of Beijing, Tianjin, and other developed regions. Finally, the overall development level of Hebei's digital economy lags behind that of developed regions. The proportion of Hebei's digital economy in GDP is 35.6%, lower than the national level of 41.5%. In 2021, Beijing's software business revenue and e-commerce sales are more than 10 times higher than Hebei's in the same period, indicating that Hebei's overall development level is relatively backward. There is still a big gap with developed areas.

4.4.2. Discussion on the current situation of transformation of the manufacturing industry in Hebei Province

The transformation level of Hebei Province's manufacturing industry reflects the scale and transformation degree reached in different years from 2017 to 2021. In the past five years, the transformation level of Hebei Province's manufacturing industry has shown a trend of fluctuation and rise on the whole. By 2021, the transformation level of Hebei Province's manufacturing industry has been greatly improved. The transformation level of Hebei's manufacturing industry increased from 0.2461 to 0.7884, with an average annual growth rate of 8.97%, indicating that Hebei's manufacturing industry is in a good situation of transformation and development, and is gradually narrowing the gap with developed regions. From the perspective of spatial dimension, Hebei Province is close to the two developed regions of Beijing and Tianjin. Hebei Province can make full use of its geographical advantages and the advantages of the Beijing, Tianjin, and Hebei coordinated development policy to effectively improve its own manufacturing development advantages.

However, at the same time, the transformation and development of the manufacturing industry in Hebei Province still have problems such as large fluctuations in development level and slow transformation and upgrading. Based on the empirical analysis, the main reasons are as follows. First, the industrial structure of the manufacturing industry in Hebei Province is too simple. The manufacturing industry in Hebei Province is mainly dominated by heavy industries such as steel, and the industrial structure is single, which cannot effectively promote the high-quality development of the manufacturing industry in Hebei Province. Second, Hebei's manufacturing technology innovation ability is insufficient. Compared with the innovation ability of developed areas such as Beijing and Tianjin, Hebei Province lacks professional technical personnel and sufficient financial support to promote the digital transformation and high-quality development of the manufacturing industry. Third, the manufacturing industry in Hebei Province is facing the problem of great

pressure on resources and the environment. When looking for indicator data, we found that the industrial waste emissions of the manufacturing industry in Hebei Province are the largest. Under the guidance of environmental protection policies such as "dual carbon" and low carbon policies, if the manufacturing industry in Hebei Province fails to carry out the transformation and upgrading of the manufacturing industry structure in time to promote the green development of the manufacturing industry, will face the increasing pressure of resources and environment.

4.4.3. Discussion on the development status of digital economy and manufacturing industry integration in Hebei Province

From 2017 to 2021, the integration development level of the digital economy and manufacturing industry in Hebei Province fluctuated from 0.6015 to 0.7889, indicating that both the digital economy and manufacturing industry in Hebei Province have achieved rapid development, and the two industries have carried out industrial integration in more and more fields. However, compared with developed areas such as Beijing and Tianjin, the integration level of the digital economy and manufacturing industry in Hebei Province is relatively backward, the driving mechanism of industrial integration of the two has not fully played a role, and the level of industrial integration still needs to be improved. The integration of the digital economy and manufacturing industry in Hebei Province is mainly reflected in the following three aspects.

First of all, the digital economy and manufacturing industry have obvious differences in the integration level of technology integration, product integration, and business integration. The automobile manufacturing industry and computer equipment manufacturing industry currently apply digital technology to a more mature and extensive degree, while some traditional manual manufacturing industries, limited by their own product characteristics and changes in market demand, still cannot carry out in-depth digital transformation. Secondly, the management level of related manufacturing enterprises is low. The integrated development of the manufacturing industry and digital economy requires excellent managers to carry out profound changes in the product production process, organizational structure, and business process within their companies, and carry out the digital transformation of the manufacturing industry in all aspects. However, at present, the various processes in the operation and management of manufacturing enterprises in Hebei Province have not been optimized, and the management level has not reached the stage of in-depth digital transformation. Finally, the digital foundation of manufacturing enterprises in Hebei Province is weak. According to the survey, most manufacturing enterprises in Hebei Province did not set up a special digital department, but usually dispersed to various departments to carry out relevant digital technology processing work, and did not form a professional business process, resulting in a low level of digital professionalism of manufacturing enterprises.

5. Conclusions and implications

5.1. Conclusions

This article takes the five-year data from 2017 to 2021 in the three provinces and cities of Beijing, Tianjin, and Hebei as samples. By constructing an evaluation system

for the development of the digital economy and manufacturing industry, the entropy weight-TOPSIS method is used to study the level of digital economy development and manufacturing industry transformation in Hebei Province. The coupling coordination degree is used to analyze the level of industrial integration development between the two. The specific conclusions are as follows:

First, in terms of the development level of the digital economy, the results show that from 2017 to 2021, the development level of the digital economy in Hebei Province fluctuated greatly, experiencing a process of first declining and then rising, and generally showing a trend of fluctuating and rising. In addition, the development level of the digital economy shows obvious regional differences, and there is still a certain gap between the development level of the digital economy in Beijing and Tianjin, but with the help of geographical advantages, Hebei Province has great potential for future digital economy development.

Second, in terms of the transformation level of the manufacturing industry, the results show that the transformation level of the manufacturing industry in Hebei Province shows a trend of fluctuation and rise during 2017–2021, and the transformation level of the manufacturing industry in Hebei Province also shows obvious regional differences. The average transformation level of the manufacturing industry in Beijing and Tianjin is higher than that of Hebei Province. However, in the past five years, the transformation and development level of Hebei's manufacturing industry has increased from 0.2461 to 0.7884, with an average annual growth rate of 8.97%, which also shows that Hebei's manufacturing industry is in a good situation of transformation and development, and is gradually narrowing the gap with developed regions.

Third, aiming at the integration development level of the digital economy and manufacturing industry, this paper studies and analyzes the integration level of the digital economy and manufacturing industry in Hebei Province by establishing the index evaluation system of the digital economy and manufacturing industry and using the coupling coordination degree model. The results show that there is a strong interaction between the three dimensions of the digital economy and the two dimensions of the manufacturing industry. The digital economy has been playing an increasingly important role in the development of manufacturing enterprises, but at the same time, the coupling coordination degree of digital economy and manufacturing industry integration and development in Hebei Province fluctuates greatly, and there are problems of inadequate, uncoordinated and unstable industrial integration and development.

5.2. Implications

5.2.1. Promote coordinated development of the Beijing-Tianjin-Hebei region

From the above analysis results, it can be clearly found that the development level of the digital economy, the transformation level of the manufacturing industry, and the development level of industrial integration of Hebei Province lag behind Beijing and Tianjin. Therefore, we should accelerate the coordinated development of the Beijing-Tianjin-Hebei region, make use of the geographical advantages of Xiongan New Area, gradually promote the in-depth cooperation between Beijing and Tianjin, promote the

coordinated development of digital economy elements such as digital infrastructure, digital technology innovation, and digital industrial foundation in Hebei Province, make up for the shortcomings of the integrated development of digital economy and manufacturing industry, and explore a new development model. At the same time, it has established a continuous and efficient communication mechanism with Beijing and Tianjin, advocated cross-regional and multi-department participation in the integrated development of the digital economy and manufacturing industry, promoted the integration of relevant resource elements, and improved the integrated development level of the digital economy and manufacturing industry in Hebei Province.

5.2.2. Improve the level of digital economy and manufacturing integration of industrial convergence development

At present, the integration of the digital economy and various manufacturing industries in Hebei Province is very different. From an external point of view, to promote the integration and development of various manufacturing industries and the digital economy, it is not only necessary to continue to improve the digital technology application level of high-tech manufacturing industries such as automobile manufacturing and computer equipment manufacturing but also to carry out in-depth digital transformation and upgrading of some traditional manufacturing industries. Get rid of traditional constraints and increase productivity. From the internal point of view, in order to improve the digitization degree of each operation and management process of manufacturing enterprises, managers should improve their professional ability, carry out profound digital changes in the company's internal product production process, business process, supply chain process, organizational structure, and other modules, establish professional digital technology departments, and form professional digital technology operation process. In order to improve the overall digital professional level within the manufacturing enterprise.

5.2.3. Raise the level of digital infrastructure construction

The level of digital infrastructure construction is related to the level of integrated development of the digital economy and manufacturing industry in Hebei Province, so it is very important to improve the level of digital infrastructure construction. On the one hand, digital infrastructure construction should be provided more effectively on the basis of scientific analysis and understanding of the specific needs of manufacturing enterprises in Hebei Province; on the other hand, digital infrastructure construction should be carried out according to local conditions, taking the overall pattern of various regions, the number of relevant enterprises and other relevant indicators into consideration, and digital infrastructure construction should be carried out according to the actual situation. Improve the use of digital infrastructure.

5.2.4. Raise the level of science and technology innovation

Scientific and technological innovation is the main driving force to promote the rapid development of the integration of the digital economy and manufacturing industry in Hebei Province, and it is necessary to increase scientific and technological innovation efforts to make up for the shortcomings of the two in the process of industrial integration so that the digital economy can deeply empower the

manufacturing industry, promote the digital transformation of the manufacturing industry and high-quality development. On the one hand, to improve the ability of scientific and technological innovation, the government should provide policy support for relevant enterprises, implement incentive mechanisms, and give relevant tax incentives and financial subsidies to benchmarking enterprises. On the other hand, it is necessary to strengthen the training of digital talents, encourage manufacturing enterprises to cooperate with relevant educational institutions to carry out vocational skills training on manufacturing digital technology and encourage colleges and universities to adjust and optimize the curriculum of relevant professional disciplines, and increase efforts to cultivate composite talents who understand both manufacturing knowledge and digital technology knowledge.

5.3. Deficiency and prospect

Subject to the influence of various factors, there are still many deficiencies in this paper to be further improved. On the one hand, the sample data selected in this paper is limited, which fails to carry out extensive and adequate research. In the future, more empirical studies are needed to put forward more targeted suggestions. On the other hand, there are some shortcomings in the construction of the evaluation index system of the digital economy and manufacturing industry in this paper, and the proposed rating index system needs to be fully tested and improved on the basis of in-depth research in the future.

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Review

Evaluating the social welfare model of Vietnam: An introductory overview

Bhavna Mahadew

Law Lecturer, University of Technology, Port Louis 11108, Mauritius; bhavna.mahadew@utm.ac.mu

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Abstract: The focus of this article is on the social welfare model of Vietnam in an evaluative manner, with the aim of introducing this system to researchers and academics. It is argued that the right to social welfare is a fundamental human right as prescribed by the United Nations and Article 34 of the Constitution of Vietnam. Against this backdrop, this article first provides an overview of the current social welfare model in Vietnam, with a particular focus on domestic legislation. Fundamentally, it is noted that this system is based on four pillars: employment, income, and poverty reduction; social insurance; social assistance for individuals in exceptionally difficult situations; and guaranteeing a minimum level of access to certain basic social services. Secondly, the article evaluates the ways in which the government plans to improve this system based on their outlook for 2021–2030. This is fashioned on five pillars, namely: 1) the labor market, employment and income, supply and demand, infrastructure and projections for the labor market, labor market data, and employment services; 2) social insurance, encompassing mandatory, supplemental, and elective plans; 3) social assistance, encompassing emergency and ongoing help as well as social care; 4) a social welfare floor with a "basket" of necessities; and 5) expert social work for social welfare. Finally, the article underlines the way forward for Vietnam to materialise the aim of ameliorating their social welfare system through human rights and sustainable development.

Keywords: Vietnam; social welfare; human rights; development; legislations; human rights-based approach

1. Introduction

One of the fundamental human rights, included in the category of economic, social, and cultural rights, is the right to social welfare. The national rules that form the social welfare system are enforced by public authorities. Viet Nam has developed and improved its social welfare law system in accordance with a philosophy based on human rights and sustainable development because it is fully aware of the significance of these rights to national stability and growth.

According to the 1948 United Nations "Universal Declaration of Human Rights", "everyone, as a member of society, has the right to social welfare and is entitled to realization, through national effort and international cooperation and in accordance with the organization and resources of each state, of the economic, social, and cultural rights indispensable for his dignity and the free development of his personality" (Article 22). This is one of the most fundamental human rights. Applying standards as the foundation for evaluating anticipated outcomes and embracing principles as the prerequisites and structure for the path of action toward the outcomes characterizes the human rights-based approach to social welfare [1]. This approach is different from the conventional one in that it emphasizes the methods used to attain the desired goals in addition to the results themselves [2]. In addition, it is assessed using the framework of a social welfare system.

A number of human rights principles have been introduced and implemented by the UN to protect people's rights to social welfare [3]. These principles include: 1) the concept of comprehensiveness and universality; 2) the principle of no hierarchical partiality in the protection of human rights; 3) the concept of interdependence and correlation; 4) the principle of equality and nondiscrimination in the protection of human rights; 5) the principle of participation and integration in the protection of social rights; and 6) the principle of responsibility and the rule of law in the protection of social welfare.

In many nations, the human rights-based approach to sustainable development has gained popularity. creating a flexible, multifaceted social welfare system in tandem that can assist individuals in avoiding, minimising, and overcoming hazards in their lives [4]. The UN-designed system is comprised of four parts: 1) social assistance (such as social assistance for disadvantaged groups, public health services, retirement pensions, and health insurance); 2) social insurance (such as short-term social insurance, unemployment benefits, and health insurance); 3) general social assistance (such as family allowances, public health services, and old age pensions); 4) private social assistance. The minimal standard of living is the cornerstone of social welfare policy, ensuring that everyone living below it is entitled to social welfare policies and programs.

To emphasize the importance of social welfare in fostering human development as well as economic growth and sustainable development, it is suggested that investing in social welfare is one of the fundamental elements of a successful market economy [5]. Building a social welfare system with a long-term vision that aligns with national development plans and places equal emphasis on sharing prosperity, sustainable development, and human development is also crucial.

As stated in the original Vietnamese Constitution of 1946, social welfare is thought to be the best aspect of socialism in Vietnam. The Constitution recognised the entitlement of public employees and officials to social insurance as well as the care that should be given to deserving individuals, the elderly, the disabled, and orphans. Through many community initiatives, the custom of "the whole leaves protect the torn leaves", which emphasises compassion and giving, has been highlighted. Since the establishment of the centralised, planned economy, social welfare protection has gained prominence. It has developed into one of the key tenets of the nation's social policy framework, which the Party and the State have worked hard to put in place. The goal of the social welfare model is to assist in resource release and social asset redistribution within the populace [6].

The development and implementation of social welfare policies during the course of 30 years of reform have produced a number of noteworthy outcomes, including the creation of jobs, the maintenance of minimum income levels for the populace, the elimination of hunger and poverty at a rate of progress recognised globally, the efficient provision of regular assistance to the impoverished and those in particularly difficult circumstances, the provision of emergency aid to those facing particular risks, and the creation of the conditions necessary for them to have access to basic social services. As a result, the number of people participating in and receiving benefits from social insurance policies has expanded, and the rate of poverty has drastically decreased. At the same time, people's ability to avoid,

reduce, and manage risks, as well as to stabilise their lives and integrate into communities, has greatly improved.

The 11th National Party Congress Document in Vietnam declares that citizenship, human rights, and other prerequisites must be met in order to achieve full human development. The Party Platform on nation-building during the socialist transition period (updated and developed in 2011) emphasizes the following points: "People are the center of development strategies as well as the subject of development; the socialist society that our people have been building is "a prosperous people and a strong, democratic, equitable, and civilized country".

Human rights are valued, upheld, and linked to national security and popular sovereignty (1). The Socialist Republic of Vietnam's (2013) Constitution originally stated in Article 34 that "Citizens have the right to social welfare". This is a novel approach that recognizes the right to social welfare as an objective and indispensable human need, a national development objective, and a development that is consistent with global development.

2. Defining Vietnam's present social welfare model

The Fifth Conference of the XI Party Central Committee adopted Resolution No. 15-NQ/TW on 10 June 2012, "Regarding some issues of social policy in the period 2012–2020", which states that the system of social welfare must be comprehensive, diverse, and shared among the people, the State, and population groups both within and between generations. Guaranteeing sustainability, equity, and social welfare is a common and significant task for the Party, the State, the political system in its entirety, and society [7].

The resolution also lays out the basic framework of the social welfare system, which is made up of four pillars: employment, income, and poverty reduction; social insurance; social assistance for individuals in exceptionally difficult situations; and guaranteeing a minimum level of access to certain basic social services (housing, health, education, clean water, and information). The basis for institutionalising social welfare into state laws, policies, and mechanisms is awareness that is in line with Vietnam's current stage of socioeconomic development. It has crept into existence thanks to people's acceptance and encouragement [8].

The State plays a crucial role in ensuring social welfare in accordance with Party standards. This can be shown in the following ways:

First, establishing laws and policies that are in line with the principles and standards of each pillar of the social welfare system; gradually internalising international treaties and obligations; and creating social welfare programs in order to establish a workable and efficient legal framework. In order to ensure that social welfare programs effectively reach the targeted population, the second step is to enforce social welfare policies, laws, and programs inside the state administrative structure while also promoting the involvement of social partners in order to meet targets. solving pressing social welfare concerns in particular, like minimal education, job stability, emergency help for individuals in case of unforeseen catastrophes, healthcare, and lasting poverty reduction [9].

Thirdly, creating an independent, non-profit system that offers social welfare services to the general public and guarantees that everyone has access to them; broadening the scope of social welfare offerings by pooling resources; and elevating the status of social work as a profession. Fourth, keep a close eye on, assess, and re-examine how social welfare laws and programs are being implemented. putting in place an information system that reports and provides social welfare statistics according to the requirements of pertinent people. implementing information technology in the administration and execution of social welfare laws and programs, implementing administrative changes, and establishing beneficiary-friendly environments.

There are notable outcomes from the application of social welfare laws and programs. Over 1.6 million jobs were produced annually between 2011 and 2019 as a result of the change; the unemployment rate is consistently low, averaging only 2.2% to 2%. The percentage of low-income households fell to barely 4% in 2019, and 15,185 million workers—roughly 31% of the labor force—enrolled in social insurance. Ninety percent of people have health insurance. 3,041,731 participants benefited from standard social assistance programs [10].

Nevertheless, there are still issues and restrictions with the current social welfare model: First off, while understanding of the social welfare model in the context of international integration and the socialist-oriented market economy has grown, it is still far from universal. In actuality, the current social welfare system has been largely shaped, but it has not yet been formalised into thorough and timely rules and legislation, nor has it been properly comprehended or contextualised in strategic planning. The sustainable development trend related to human rights has not been completely stopped by its structure. Despite numerous promulgations, supplements, and revisions, the laws pertaining to social welfare remain inadequate, erratic, and unable to keep up with rapidly evolving realities [11].

Second, there is still room for improvement in the institutions that guarantee social fairness in terms of social welfare policies and programs as the socialist-oriented market economy develops. They mostly rely on the state budget and have not closely integrated the market's active participation with the State's leadership in allocating resources for social welfare investments. Additionally, a portion of the population may find it difficult to access certain social welfare programs due to their tendency to be commercialized. Alternatively, people become dependent on the State and suffer negative effects as a result of being subsidized through the ask-give cycle [12].

Thirdly, the human-rights approach to sustainable development has greater potential the more developed society gets. However, a number of other elements, such as the effects of ongoing institutional reforms, integration, the aging of the population quickly, and global climate change, also have an impact on and provide challenges to the strategy. The needs to protect social wellbeing are higher and more varied the more social dangers that occur. Meanwhile, current social welfare policies' coverage of standard support levels is constrained and hasn't grown to ensure that recipients have a minimal quality of living. As a result, people's ability to tolerate risk is low and falls short of sustainability; self-welfare has not received much attention.

Fourthly, notwithstanding its steady advancement, the social welfare career system is oriented toward the establishment of public career organizations. There is a lack of robust and varied community and societal participation. The system has not yet shifted to provide public services; instead, it has mostly focused on community-based social welfare objectives. In social welfare, there hasn't been much encouragement for professional social work, and no staff team with the necessary qualifications has been assembled yet.

Fifthly, the state's approach to managing social welfare is still ineffective when it comes to creating and implementing new laws, policies, and programs. Numerous ministries and departments still have it overlapping and dispersed; administrative reforms on social welfare, particularly with regard to administrative procedures and the use of advanced technology and digitalization, have not satisfied practical needs. People still have trouble receiving social welfare; the social welfare database system is not updated or enhanced.

Regarding the impact of the social welfare system on the Vietnamese population, first off, there have been a lot of successes in implementing policies aimed at reducing poverty, increasing income, and creating jobs. A significant portion of the high percentage of jobs created for individuals 15 years of age and older (over 77%) and long-term poverty reduction can be attributed to policies to support job creation through the National Job Creation Fund, the Fund "For the Poor," preferential credit policies, vocational training, career guidance, etc. Vietnam is one of the nations with the lowest unemployment rates in the world, having consistently maintained a low rate between 2% and 3% for the previous ten years. Between 2013 and 2018, employees' average yearly pay increased by 8.7%, indicating a positive trend [13].

Second, by giving individuals more possibilities to participate and benefit from insurance, the updated social and health insurance policies have strengthened the financial stability of insurance funds. According to three main policy groups—compulsory, voluntary, and unemployment insurance—social insurance has been expanded to all employees. From 21.8% in 2011 to 32% in 2019, the percentage of the labour force in the age bracket eligible for social insurance has increased. Specifically, optional social insurance only drew about 270 thousand participants over the entire 2008–2018 period, but by the end of 2019, that number had risen to 545 thousand. Between 2011 and 2019, the percentage of the labour force in the age group enrolled in unemployment insurance rose from 17.1% to over 27%. In 2019, the number of people in the country with health insurance was 85.39 million, which accounted for 90% of the total population [14].

As a vital safety net for social welfare, social and health insurance helps people deal with illness, disease-causing accidents at work, pregnancy, unemployment, and other challenges. Over 3.1 million people nationwide currently receive a monthly pension and social insurance allowance; the Social Insurance Fund provides benefits to 6–10 million people each year who are unwell, have accidents, or become pregnant; as a result of the COVID-19 pandemic, over 500,000 people only received unemployment insurance for the first half of 2020. Health insurance promotes fairness in health care, particularly for the most vulnerable members of society, by lowering the direct cost of healthcare services from household income. In 2019, 186

million people covered by health insurance had their medical examination and treatment costs covered by the Health Insurance Fund (92.1 million people in 2009). The Health Insurance Fund reimburses a number of instances for medical examinations and treatments up to billions of VND annually.

Thirdly, human rights-based and human-centered approaches have gradually replaced traditional methods in the practice of social assistance for those living in exceptionally challenging circumstances. The amount of social allowance and the number of beneficiaries of social insurance have grown, which has helped to stabilise the lives of those who are more vulnerable. From about 1.7 million in 2011 (or 1.9% of the population) to over 2.9 million in 2019 (or 3% of the population), more people were getting monthly social stipends in cash. Unscheduled social assistance programmes help those who are vulnerable because of natural catastrophes and other legitimate reasons in a timely manner. Between 2012 and 2019, the Vietnamese government provided more than 343 thousand tonnes of rice (famine relief during the intercrop period and on Lunar New Year's Eve) to approximately 18.4 million people who were facing food insecurity. Additionally, the government provided more than 3700 billion VND to help communities recover from natural disasters [15].

The Vietnamese government, in particular, issued Resolution No. 42/NQ-CP on April 9, 2020, titled "Measures to support people facing difficulties due to the COVID-19 pandemic", and the Prime Minister issued Decision No. 15/2020/QD-TTg on 24 April 2020, titled "Regulations on implementing policies to support people facing difficulties due to the COVID-19 pandemic", which included a 62 trillion VND support package for those facing difficulties as a result of the pandemic. The international community and the people of Vietnam fully support the government's prompt responses to the COVID-19 outbreak.

Despite the relative success of the current Vietnamese social welfare system, there is still room for improvement, similar to any political-economic system around the world. The next section focuses on ways to improve the social welfare system in Vietnam.

3. Improving social welfare model

The authorised course of action involves creating the social welfare system within the broader socioeconomic development strategies, in accordance with Vietnam's economic outlook for 2021–2030; this involves balancing economic expansion with the maintenance of social welfare, upholding social equity, and supporting sustainable national development.

This is also marked by an ongoing enhancement of the multi-layered, adaptable life-cycle social welfare system, with a 5-pillar framework that guarantees minimum living conditions for all and aims for universal coverage: 1) the labor market, employment and income, supply and demand, infrastructure and projections for the labor market, labor market data, and employment services; 2) social insurance, encompassing mandatory, supplemental, and elective plans; 3) social assistance, encompassing emergency and ongoing help as well as social care; 4) a social welfare floor with a "basket" of necessities; 5) expert social work for social welfare.

Furthermore, it is imperative to enhance the social welfare system in accordance with national standards, progressively implement regional and worldwide norms, and promote regional and global collaboration in the social welfare domain. It is also planned to develop a long-term social welfare system with well-planned routes that serves the entire community. Prioritizing vulnerable groups in the short term, particularly children in extremely tough situations, the elderly, the disabled, the destitute, and ethnic communities, Ultimately, it is confirmed that the proper course of action is to guarantee the right to social welfare based on the responsibilities of the democratic system and every citizen. The government is crucial, particularly when it comes to funding social welfare, promoting the involvement of businesses, communities, and social partners simultaneously, and utilizing assistance programs to enhance individuals' self-welfare in order to facilitate their integration into the community.

4. The way forward

It is essential to encourage broad diffusion in order to increase awareness among the populace and within the political system through targeted initiatives that are implemented using a variety of cutting-edge techniques. Using cutting-edge communication technologies to obtain a clear understanding of the nature, substance, and recommendations for enhancing the social welfare model would increase the sense of accountability in its execution. Second, in order to evaluate the execution of Resolution No. 15-NQ/TW, it is necessary to conduct research and develop strategic orientations for social welfare that adhere to the new model for the years 2021–2030. The Central Committee's conclusion about continuing to enforce Resolution No. 15-NQ/TW, which is supplemented in terms of content, views, and strategic directions to form specific social welfare policies and programs, or the creation of an alternative resolution for the 2021–2030 period, is based on this [16].

It has been suggested that establishing a number of new laws on social assistance and social work for the formation of laws on social welfare will be crucial to institutionalizing the new model of social welfare on the basis of amending and supplementing current laws related to the four pillars of the system (Employment Law, Social Insurance Law, Elder Law, and Disability Law).

In particular, it's critical to concentrate on the following when it comes to the labor market, jobs, and income: 1) keeping the labor force free to utilize people's potential and resources for economic progress, resulting in the creation of numerous long-term jobs; 2) creating a synchronized labor market across the country to connect the supply and demand for labor; establishing peaceful, stable, and progressive labor relations; implementing equity in the salary and income distribution process, which is linked to productivity; guaranteeing hygienic and safe working conditions; and encouraging a positive corporate culture; 3) a growing market for highly skilled workers; 4) constructing a coordinated labor market infrastructure, such as employment services, databases, and labor market forecasts.

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Regarding social assistance, it is necessary to continue implementing Decision No. 488/QD-TTg, dated 14 April 2017, by the Prime Minister in the project on innovation and development of social assistance for the period 2017–2025 with a vision to 2030. This project aims to legislate for social assistance, institutionalize a holistic social assistance system that is diverse, multifaceted, advanced, appropriate for the human life cycle in an interconnected manner (three stages: pregnant mother and children/adolescents and people of working age as well as elderly), and share among the government, society, and people; specify standard social subsidy policies for all target populations with the allowance standard that is in line with minimum standards of living; and add norms on unanticipated allowance [17].

Regarding the social welfare floor, the following measures should be taken: 1) guaranteeing an income ceiling that is close to the minimum and multifaceted standards of living; 2) minimum health care, particularly primary health care, community health, and adolescent reproductive health; 3) developing a regulatory framework for creating a social welfare floor in accordance with Viet Nam's socioeconomic conditions and Convention 102 of the International Labor Organization (ILO) on minimum social welfare standards. Three: a minimum level of education; four: safe housing; five: sanitary household water; and six: preschool, primary, and secondary education.

Concerning social work in the profession: constructing legislation pertaining to professional social work as the foundation for a legal framework. defining, in the context of socialization, the organizational structure of social work service providers (centers, offices, social work sites, etc.). In particular, defining the legitimacy of social work service providers with expertise in education, vocational education, health, orthopedics, and rehabilitation... Fourth, creating and implementing the national goal program on social welfare for the years 2021–2030 in order to implement a new social welfare model for a number of social groups that require extra help.

This entire program is made up of five complete, multifaceted (in terms of processes, policies, resources, organizational structure, and coordination of implementation) fundamental components: 1) providing work and reducing sustainable poverty for laborers and low-income households (outside of areas inhabited by ethnic minorities); 2) caring for children in unique situations; 3) caring for individuals with severe disabilities; 4) caring for the elderly in challenging circumstances; 5) promoting careers in social work.

Finding solutions to issues with finance, organizational management, and investment in a new social welfare paradigm. putting the Ministry of Labor, War Invalids, and Social Affairs in charge of the consistent restructuring of the duties and responsibilities of ministries concerned with social welfare. securing funding

allocations for the new model's social welfare policies and initiatives. giving towns the strong authority they need to manage their communities holistically and carry out social welfare policies and initiatives in a proactive and efficient manner.

It is also important for the Vietnamese authorities to partner with international organisations in order to make the social welfare system more effective and all-inclusive. With the goal of ensuring Vietnam is inclusive and successful in addressing its own development issues, USAID and Vietnam have growingly collaborative and comprehensive development cooperation. While stakeholders work to improve economic competitiveness, modernise higher education, combat infectious disease, address issues related to the legacy of the war, conserve forests and biodiversity, and promote renewable energy, USAID also strengthens local leadership by engaging all Vietnamese citizens, including vulnerable populations, and through strategic partnerships with the Government of Vietnam, the private sector, and civil society. Such kinds of international partnerships and collaboration are and will remain critical to the success of the Vietnamese social welfare system.

Conflict of interest: The author declares no conflict of interest.

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Review

A review of technoeconomic benefits of torrefaction pretreatment technology and application in torrefying sawdust

R. S. Bello[1,*], A. O. Olorunnisola[2], T. E. Omoniyi[2], M. A. Onilude[2]

[1] Department of Agricultural & Bioenvironmental Engineering Technology, Federal College of Agriculture Ishiagu, Abakaliki 480001, Nigeria
[2] Department of Wood Products Engineering, University of Ibadan, Ibadan 200213, Nigeria
*** Corresponding author:** R. S. Bello, segemi2002@fcaishiagu.edu.ng

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Abstract: Economic analysis of the torrefaction process centers on the assessment of the economic feasibility of the production and utilization of torrefied biomass using developed models such as costs of biomass, electricity, labour, investment, transportation, etc. to evaluate the cost of biomass torrefaction. The increase in energy usage over the past century has raised concern over the energy insecurity and environmental unsustainability of current fossil fuel utilization; therefore, there is a need for energy diversification. An attractive alternative is biomass. However, the poor performance of raw biomass in energy generation further necessitates the development of refined technologies to enhance its performance, particularly at low temperatures between 200–300 °C. This study therefore reviews the technoeconomic benefits of torrefaction technology and reactors and their application in the pretreatment of sawdust. An overview of torrefaction technology, torrefied product characteristics, economic analysis of torrefaction reactors, and torrefaction cost/ton were reviewed. From the review, torrefaction significantly improved the physical, combustion, and performance characteristics of torrefied products, with comparable durability and storability to raw biomass. Compared with other thermal pretreatment methods, torrefaction is an economical way of improving biomass properties.

Keywords: technoeconomic; torrefaction; reactors; sawdust; pretreatment

1. Introduction

Energy plays a pivotal role in the development of any nation, so much so that the extent of energy development is a direct indication of the extent of economic development of a nation. Conventionally, fossil fuels are the primary energy source for most applications. However, the degrading consequences of fossil fuel exploitation and consumption, increased emissions of greenhouse gases (GHGs), and accelerated climate change have made fossil fuels less popular in recent years [1]. The increase in energy usage over the past century has raised concern over the sustainability of current fossil fuel consumption rates. The current trends in energy insecurity and environmental unsustainability can be addressed through energy resource diversification. Thus, the recent drive in the production of viable energy alternatives from biomass sources and low-carbon fuels is being promoted by the Renewable Fuel Standard (RFS) passed in 2005 [2]. The RFS promotes increased renewable fuel development to reduce overdependence on imported refined petroleum and greenhouse gas emissions [3].

An estimated two-thirds of the annual global biomass supply from different sources goes into household cooking, mostly in developing nations [4]. Apart from fuelwood, the global biomass resources largely revolve around fossil fuels [5,6] and

wastes generated from agricultural residues or dedicated energy crops and forestry residues, particularly mill residues from woody biomass and sawdust [7]. Sawdust is a waste product of the secondary wood conversion process that is massively produced from wood processing industries and is available in large volumes globally, constituting environmental hazards due to its poor handling through indiscriminate open burning and dumping in mill sites and landfills.

Despite the advantages of biomass, there are restrictions on its use as the primary feedstock for energy production. Such restrictions are due to luminous yellow flames, excessive moisture contents, poor energy per unit volume, hydrophilic properties, high oxygen contents, and high levels of smoke generation above acceptable levels for household use [1]. These constraints limit their conversion and replacement as fossil fuels for energy production [2]. Consequently, these products are processed into valuable products for energy applications, as reported in the literature [8]. **Figure 1** provides an overview of the biomass (typically below 50% moisture content) processing system before pretreatment [9].

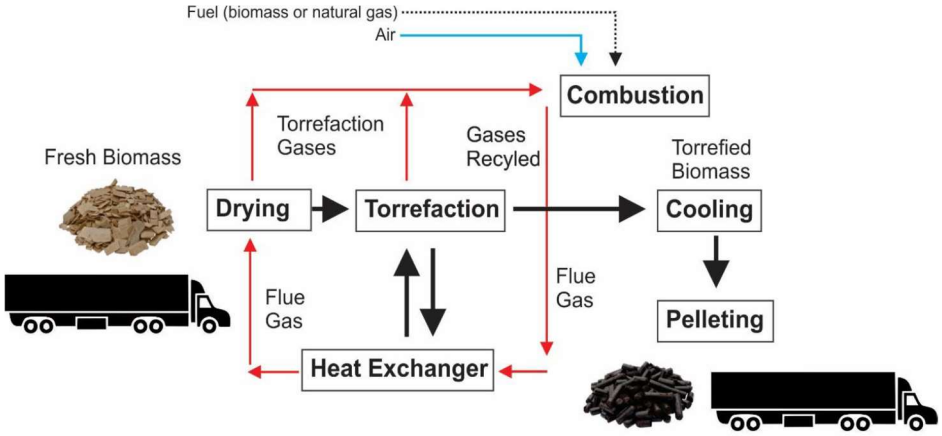


Figure 1. Torrefied pellets processing flowchart [10].

Sawdust preheating before densification is a suitable option for producing a higher-quality feedstock for a given energy input to reduce power consumption during the densification process [11,12]. This material process could equally increase the production rate, up to 340 to 360 kg/hr [13]. Kpalo et al. [14] revealed the concept of preheating feedstock material in a screw press to study its effect on energy savings. The result showed a total average energy saving of about 10.2% (23.5% at the heater and 10.8% at the motor).

Preheating or thermal pretreatment biomaterials to 200–250 °C before densification reduces compression and extrusion pressures by a factor of two, while a pressure reduction of 2.5–3.0 × 10^4 kN/m^2 with preheating is compared to an approximate pressure of 1.8 × 10^5 kN/m^2 without preheating. Pretreatment of sawdust before briquetting removes the volatile matter contents of the material, thereby improving its physical, mechanical, and combustion properties [15,16]. Pretreatment of lignocellulosic (biomass) materials before densification is an important age-long biomass-to-fuel conversion process for loosening or delignification of the compacted biomass structures to expose the cellulose fiber [17–19]. During this process, lignin, cellulose, and hemicellulose undergo chemo-structural changes to overcome the

resistance provided by the cell wall [20]. Due to its impact on technical, economic, and environmental systems, biomass pretreatment has drawn significant study attention worldwide [21,22].

To speed up substrate hydrolysis, various pretreatment techniques, including torrefaction, have been described in the literature [16,23,24]. Biomass pretreatment through torrefaction has been recognized as a more attractive and less expensive process for sawdust pretreatment [17,25,26], and an appropriate practical method for commercial and household heating applications [25,26]. **Figure 2** shows the various thermal conversion processes, routes, and their potential high-value by-products. The extent of heat conversion conditions determines the makeup of the final products. This study therefore seeks to review the technoeconomic benefits of torrefaction technology and reactors in the pretreatment of sawdust.

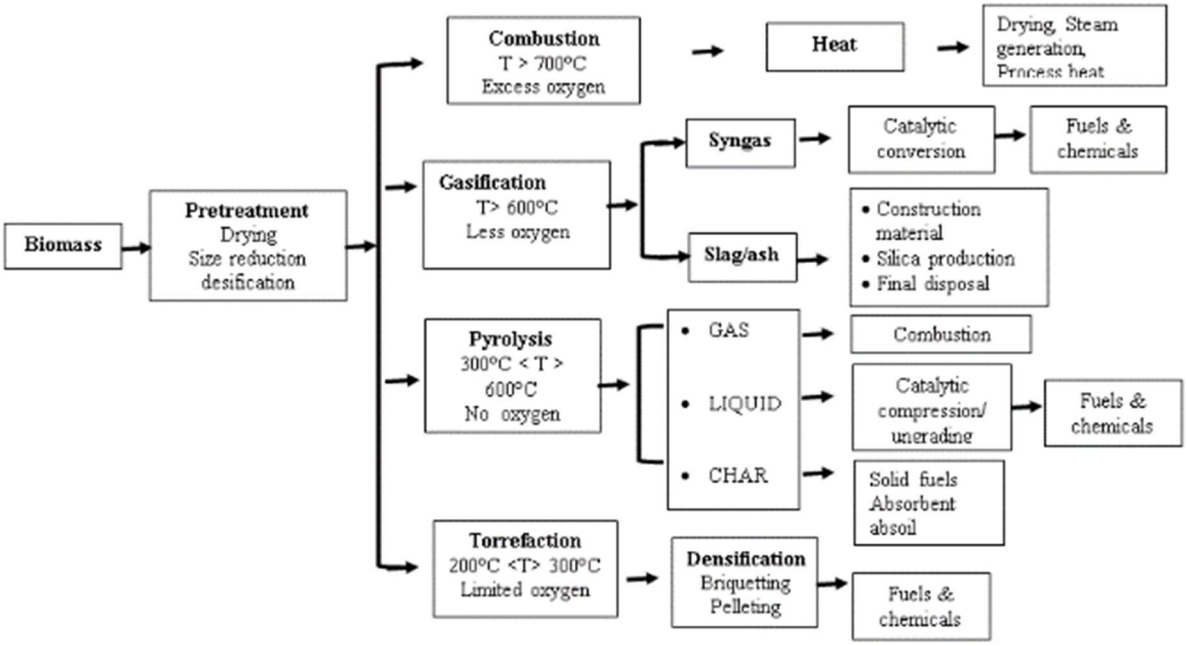


Figure 2. Biomass thermal conversion processes [27].

2. Methodology

Two methodologies employed in this work include a theoretical review of the works of reputable scholars and an analysis of torrefaction experiments, while the second methodology employs the empirical work of a developed laboratory batch reactor to torrefy the sawdust of Gmelina arborea *and* evaluate its products and economic viability.

2.1. Review of the torrefaction (semi-carbonation) process

Torrefaction technology was first investigated in the laboratory in the 1930s in France [28] and was derived from the French word for roasting [29]. In the last two decades, there have been renewed increases in interest in torrefaction as a potential feedstock pretreatment option [30,31]. Torrefaction is the roasting of feedstock in a near-inert (oxygen-free environment) atmosphere between 200–300 °C to increase the heating value, hydrophobicity, and combustion characteristics [25,26]. AMPC [32]

and Szufa et al. [33] described torrefaction as 'mild pyrolysis' characterized by slow heating rates (typically <50 ℃/min), relatively long residence times (30 to 90 min) and temperatures of 200 ℃ to 320 ℃ under atmospheric pressures [34,35]. There are several research works on torrefaction of other biomass: Ramos-Carmona et al. [36] reported on patula pine [37] at 200 ℃–300 ℃ and 30 min of residence time; Bridgeman et al. [38] torrefied wheat straw and willow; Bello et al. [15] torrefied Gmelina arborea, among others.

Torrefaction requires that feedstock be subjected to a slow heating process in an oxygen-deficit environment at a temperature range of 200–300 ℃ in a near oxygen-free environment [16,39]. Several research studies have further established biomass torrefaction at these temperatures [34,40–42]. Prior to torrefaction, the biomass was heated at less than 50 ℃ per minute up to 105 ℃, to evaporate the free water within the biomass to <10% moisture content. Drying processes take place at a non-reactive drying zone of 160 ℃ with material moisture released and most of the bond water removed at 160–200 ℃.

Degradation of hemicellulose occurred at 180 ℃, while thermal decomposition, devolatilization, and carbonization reactions occurred at between 200–270 ℃, during which the biomass thermally decomposed to release moisture, volatile gases, and low energy compounds with colour change from yellow to brown [43]. These colour changes were reportedly dependent on temperature, residence time, heating rate, biomass type, initial moisture, particle size, and shape of biomass. Around 280 ℃, torrefaction becomes entirely exothermic, with increased gas production, leading to the synthesis of extraneous gases and other weighty products [44,45].

During this process, near 100% of the moisture is eliminated, yet 90% of the energy content of the solid uniform product is preserved; about 70% of its dry weight mass remains [28], while hemicellulose materials are volatilized. The resulting torrefied solid component significantly differs in physical and chemical properties from the original biomass. These products possess hydrophobic characteristics, high energy density, and durable biodegradation [46]. Tumuluru et al. [44] gave a comprehensive review of the physical properties of torrefied products, such as density, grindability, pelletability, hydrophobicity, and storage behaviour in terms of off-gassing, spontaneous combustion, and self-heating.

At temperatures above 280 ℃, these reactions cause the degradation of hemicellulose to produce gaseous CO, CO_2, phenols, acetic acid, and other highly volatile hydrocarbons. In addition, during torrefaction, the lost hydrophilic bonds made the product more hydrophobic, thereby improving its storage stability. The solid biomass contains about 30% of dry mass, resulting in more energy per unit of mass (i.e., 30% higher MJ/kg) based on torrefaction severity [35]. The solid product has similar utilization performance to coal used in power boilers and acts as a quality enhancer for a multi-fuel feedstock [47]. **Table 1** shows the comparison of some characteristics of woodchips, torrefied biomass, charcoal, and coal [48,49]. **Figure 3** shows a graphic representation of the fuel properties of raw biomass, torrefied biomass, and coal [50].

Table 1. Fuel properties of woodchips, torrefied biomass, charcoal and bituminous coal [32,48,49].

Properties wood	Wood	Torrefied biomass	Charcoal	Coal
Moisture content (%wt.)	30–45	3	1–5	10–15
Calorific value (MJ/kg)	9–12	19.90	30–32	23–28
Volatiles (% db)	70–75	-	10–12	15–30
Fixed carbon (% bd)	20–25	-	85–87	50–55
Bulk density (kg/L)	0.20–0.25	0.23	0–0.20	0.80–0.85
Vol. energy density (GJ/m^3)	2.00–3.00	4.70	7.60–6.40	18.40–23.80
Dust	Average	High	High	Limited
Hygroscopic properties	Hydrophilic	Hydrophobic	Hydrophobic	Hydrophobic
Biological degradation	Yes	No	No	No
Milling requirement	Special	-	Classic	Classic
Handling requirements	Special	-	Easy	Easy
Product consistency	Limited	-	High	High
Transport cost	High	-	Average	Low

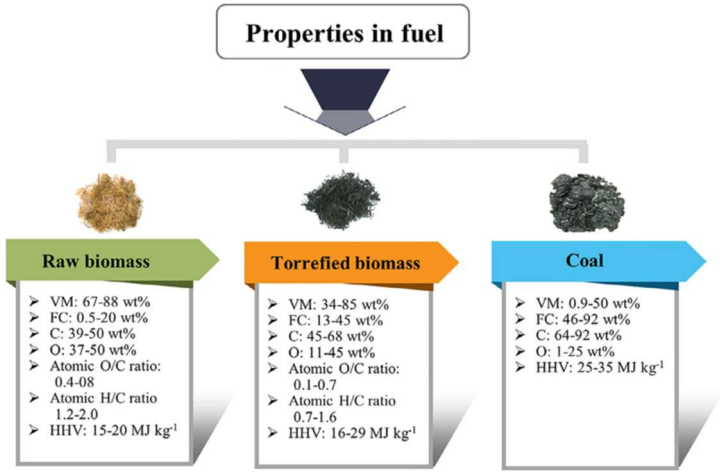


Figure 3. Fuel properties of raw biomass, torrefied biomass, and coal [50].

Torrefaction is suitable for the production of high-quality feedstock in pellets and briquettes, as well as a replacement for coal in thermal power plants and metalworking processes with significant energy and market potential [2,25,47,51]. Lange [52] viewed torrefaction as a more economical way of improving biomass properties. Despite the attractive potential of torrefaction and its extensive use in co-firing and energy applications, major limitations include difficulties in providing a passive environment, huge production costs of reactors, and design complexities [20]. Besides, Lal et al. [53] in Biomass and Research Development Board reported that the cost of collection, processing, storage, and transportation of torrefied products reportedly account for 25%–65% of total production costs. In addition, biomass feedstock costs highly varied based on collection techniques and local infrastructure; however, the biomass supply chain added an estimated 20%–40% to the cost of harvest and transportation, added an approximate 20%–65% to the total delivery cost, and added a 20%–25% increase to the pretreatment cost [54].

2.2. Classification and application of torrefaction

The main target of every torrefaction process is to enhance the quality of the torrefied product [54]. Torrefaction takes place under three conditions: dry, wet, and stream conditions (**Figure 4**). Dry torrefaction occurs in dry and non-oxidative (inert) or oxidative atmospheres at temperatures between 200 °C and 300 °C [55,56], while wet torrefaction occurs through water and dilute acid solution addition at temperatures of 180–260 °C [57,58]. Steam torrefaction improves biomass properties by utilizing high-temperature and high-pressure steam explosion reactors [59]. The torrefaction process aims at producing hydrophobic materials with improved grindability suitable for the production of durable and outdoor weather-resistant pellets or briquettes like coal. However, issues around the compatibility of torrefied biomass and torrefied dust material, achieving proven outdoor durable products, and leaching remained significant challenges.

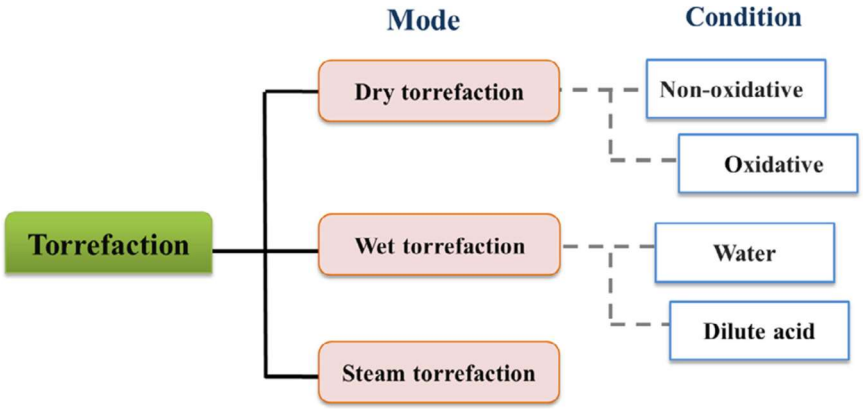


Figure 4. Classification of torrefaction [60].

The enhanced quality of torrefied biomass makes it an attractive process for combustion and gasification applications [60]. Torrefied product applications in co-firing processes with pulverized coal at electric power plants, as well as the production of value-added products replacing fossil fuels, have significantly promoted torrefaction applications in the energy supply chain. Other areas of product applications include utilization as a smokeless heat source for industrial, commercial, and domestic applications, for powering kilns and small-scale pellet burners, briquetting and as biochar for soil conditioning, and advanced bioenergy applications [61].

2.3. Torrefied product characteristics

Torrefaction enhanced biomass characteristics through the removal of oxygen and volatile contents from biomass, carbonization of hemicellulose, depolymerisation lignin and cellulose, and devolatilization of lignocellulosic biomasses [44]. Depending on the severity of the torrefaction process, the fibrous, tenacious, and hydrophilic properties of biomass tend to become brittle, grindable, and hydrophobic products. These behavioural changes have significant supply chain advantages, are cost-effective, and have properties compatible with coal [10]. Major quality characteristics of torrefied products include weight loss, high mass yield, energy yield, and density

yield. These characteristics are influenced by some critical factors such as type of feedstock, temperature, dwell/residence time, rate of biomass heating, reaction temperatures, reactor environment, atmospheric pressure, feedstock flexibility, particle size, and moisture content [15,39,62]. Classified proximate and ultimate analysis data for torrefied products was published as part of the ISO 17225 Standard [10].

Weight loss: Material weight loss explains the proportion of volatile matter contents removed from the torrefied sample.

Mass yield (MY): This is the ratio of the final to initial mass of torrefied product and raw feedstock (*daf*), which is usually less than unity. Mass yield accounted for the quantity of solid products retained and

$$MY = \frac{M_{f,daf}}{M_{i,daf}} x100\% \quad (1)$$

Energy yield (EY): Energy yield explains the quantitative performance of the torrefaction process; this is the energy recovery after torrefaction, which is dependent on the moisture and ash contents of the biomass. The energy yield increased with a reduction in these elements [63]. Energy yield is temperature- and torrefaction-time-dependent and determines the effectiveness of torrefaction [39]. Volatile organic matter loss during torrefaction results in energy loss [64]. However, it increases the energy yield, which is usually greater than unity. Energy yield is expressed mathematically in terms of mass yield and energy density enhancement factor as follows:

$$EY = MYxEDEF\ (\%) \quad (2)$$

Energy balance (EB): The best mass and energy balance in torrefaction resulted when an estimated 30% of its initial dry mass and 10% of its initial energy content were lost in the process [65]. In this case, the energy yield is 100 less 10%, and the mass yield is 100% less 30% of the initial dry mass, as reported by Kim et al. [66]. Thus, the net process thermal efficiency is usually less than one, but it is dependent on both the heat and the chemical energy recovery.

Energy density: This is the amount of stored-up energy in a unit mass of material. Torrefied energy density is determined by comparing the raw biomass energy with the torrefied product. Phanphanich and Mani [67] reported low energy densities, typically 8–14 MJ/kg for raw biomass, while Medic et al. [68] reported a 19% increase in energy density due to mass loss in raw material at elevated temperatures.

Energy density enhancement (EDE): expressed mathematically as a percentage increase in torrefied energy density and raw feedstock:

$$EDE = \frac{HHV_{tp,daf} - HHV_{raw,daf}}{HHV_{raw,daf}} x\ 100\% \quad (3)$$

where ($HHV_{tp,daf}$) is the torrefied product HHV, ($HHV_{raw,daf}$) is raw biomass HHV.

Energy density enhancement factor (EDEF): Expressed as ratio of torrefied product in dry and ash free (*daf*) basis using the expression below.

$$EDEF = \frac{HHV_{tp,daf}}{HHV_{raw,daf}} \quad (4)$$

In addition, feedstock particle size influences the torrefaction process kinetics, reaction mechanisms, and residence time for a given heating rate [69,70].

2.4. A review of torrefaction reactor studies

Tumuluru et al. [39] gave a comprehensive review of different concepts and designs of torrefiers. Several reactors are presently available on the market, with over 100 patents and more than 50 technology developers [71]; however, the choice of design for commercial applications is dependent on feedstock type. Generically, the choice of reactor is characterized by the design, distinct modes of heat transfer, and gas-solid or solid-solid mixing patterns in the reactor [9].

Global efforts relating to process gas handling and contamination, process upscaling, predictability and consistency of product quality, densification of torrefied biomass, heat integration, and flexibility in using different input materials. Are accompanied by surmountable challenges such as reactor design and data regarding torrefaction costs at the pilot and commercial scales. Critical technical challenges facing technologies have necessitated global efforts towards the development of torrefaction technologies prior to commercialization [72]. The torrefaction design models based on thermodynamic equations could provide a solution to designing torrefaction systems for uniform control of product quality [10]. Further research efforts to optimize the torrefaction process to meet the end-use requirements for commercialization purposes are a work in progress [42,61,73–75].

Reactors are either directly heated or indirectly heated. The directly heated reactors have the biomass in direct contact with the heat source in the absence of oxygen; a typical example is a fluidized bed and batch reactor. The indirectly heated reactors have the heat source and the biomass in separate compartments in an inert environment within the reactor [71]. Junsatien et al. [28] and Nhuchhen [2] gave a comprehensive review of torrefaction reactors at three different scales and capacities, i.e., laboratory-scale reactors less than 20 kg/hr, pilot-scale reactors between 20 and 600 kg/hr, and commercial-scale reactors at more than 600 kg/hr. In addition, Tumuluru et al. [76] reported a positive biomass torrefaction result with a sand bed reactor, and Ghiasi [77] reported other authors' works ranging from laboratory projects to pilot-scale projects. Ribeiro et al. [78] reported that some reactors operate at capacities of 8000–100,000 tons per year, mainly torrefying sawdust, while some facilities handle woody biomass [10]. Investigations revealed that the productivity of these reactors was constrained by the low heat intensity and mass transfer processes.

Several studies on a detailed review of selection criteria for biomass torrefaction reactors revealed factors influencing efficient torrefaction reactors in terms of heat transfer, cost, and complexity of operation [78]. Below are descriptions of different torrefaction reactors.

Fixed bed reactor: The fixed bed reactor (**Figure 5**) is a laboratory-scale torrefaction apparatus in which biomass is suspended in a metal mesh basket, dried, and torrefied in a furnace, then analyzed to understand the impact of process conditions on product properties [76,78,79]. The limitations of this reactor include poor heat transfer and temperature control [60].

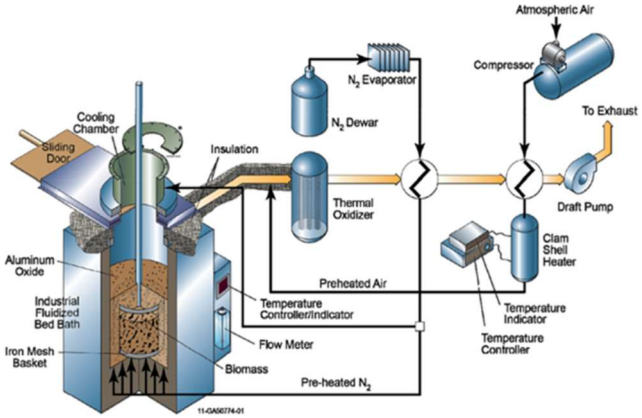


Figure 5. Fixed bed reactor for biomass torrefaction [76].

Rotary drum reactor: Rotary drum reactors (**Figure 6**) are electrically driven and require that the raw biomass be fed through the inlet as the drum rotates along a vertical axis while the torrefied product is discharged from the reactor outlet [79]. The biomass gyrates under gravity as the internal fixtures mixhe biomass heated indirectly via heaters installed from the outside of the drum, inside the drum, or by preheated inert or recycled torrefaction gas flowing through the drum, or via a combination of these modes of heating [44]. Manouchehrinejad and Mani [80] have developed other easy-to-scale-up simple technology models of rotary reactors. Disadvantages of this reactor include quick emissions and stoichiometry control along the sealed ends of the drum as it wears [39]. Other limitations include low thermal efficiency due to indirect heating, less plug flow, and scalability limitations compared to other reactors [60].

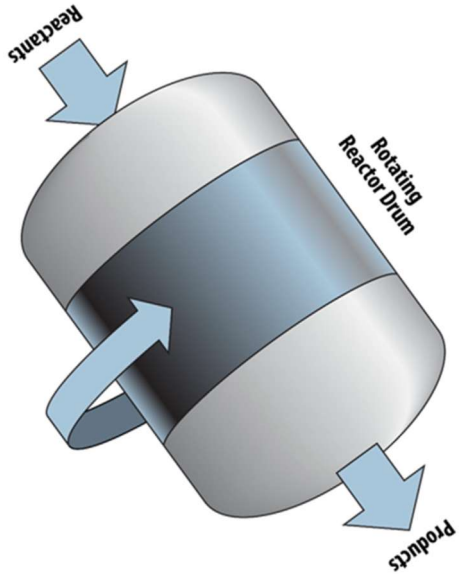


Figure 6. Rotary drum reactor for biomass torrefaction [60].

Microwave reactor: Microwave reactors (**Figure 7**) utilize electromagnetic radiation at frequency ranges of 300 MHz to 300 GHz [60] to rapidly, uniformly, and consistently heat biomass to agitate and set in motion the water molecules within the biomass, resulting in an increase in internal energy that helps to recycle the biomass [39]. The two main mechanisms involved in microwave torrefaction are dipolar polarization and ionic migration [60]. The residence time for biomass within a

microwave reactor depends on biomass type, size, radiation absorption capacity, and reactor power [39,81]. Several researchers have studied microwave reactors [82–84]. Tumuluru et al. [85] reported a sufficient torrefying residence time of six minutes with a maximum 21 MJ/kg calorific value and approximately 53% wt. carbon content, as opposed to 15 min to achieve the same calorific value using the thermal torrefaction technique.

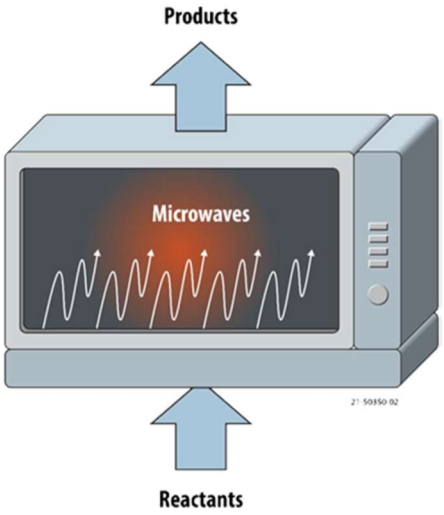


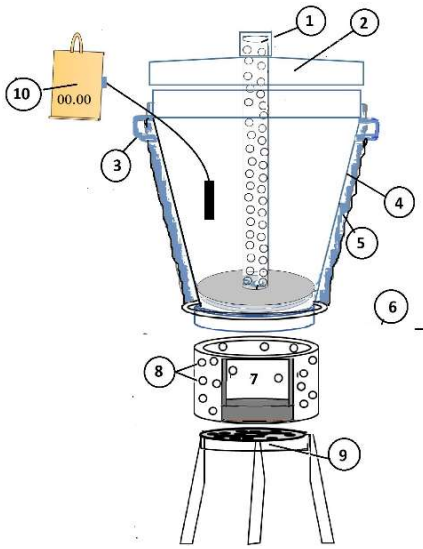
Figure 7. Microwave reactor for biomass torrefaction [60].

Fluidized bed reactor: In a fluidized bed reactor, biomass fluidization occurs using the inert hot gases blown from the bottom of the reactor. The raw biomass is size-reduced to smaller particles, requiring fluidization in the reactor to ensure a uniform temperature distribution throughout the bed [83]. The major challenge of this process is the size reduction of biomass to small sizes, which is very energy-intensive. The grinding energy is indirectly proportional to the grind size and inversely proportional to the moisture content. The smaller the grind size, the higher the grinding energy, and the higher the moisture content, the higher the grinding energy. The fluidization condition of a suitable inert gas velocity, which is usually higher than the minimum fluidization velocity, is essential. However, this system is not common for biomass torefaction applications.

Moving bed reactors: Two common designs of moving bed reactors are horizontal and vertical bed reactors. The horizontal moving bed reactor moves biomass with the aid of screw augers along a parallel axis into the torrefier. During this movement, the biomass is preheated by gas, or heating elements located within the reactor, in an opposing direction. This design is less efficient for heating biomass using preheated torrefier gas than the gas counter-flow design and has to rely more on indirect heating through the reactor walls. The potential benefit of this design is reduced tar and moisture buildup in the torrefier as compared to the counter-flow designs. Horizontal moving bed reactors are relatively cheaper and simpler to adapt to compared with large-scale industrial reactors. However, they are limited in production capacity due to uneven biomass heating, excessive product charring, and condensed tar and coke buildup, which tends to plug the system.

The vertical moving bed reactor operates in an opposing direction to the horizontal moving bed reactor with gravity downflow of biomass and buoyant heated gas upflow [44]. In other designs, there are internal stirrers to prevent particle bridging. An essential consideration in the cost of the torrefaction process is the blower cost [60]. The compact, simple design, optimized conditions, lower blower cost, and high heat transfer rate of the reactor give it an advantage over other reactors [60]. Sarkar et al. [86] provided more details about studies on switch grass biomass using vertical moving bed reactors and miscanthus and white oak sawdust using fixed bed torrefaction in collaborative work with Oklahoma State University [39].

Batch reactor: The laboratory batch reactor utilizes the concept of co-firing in the pulverized coal-fired stove [87] to develop a simple direct-heating torrefaction reactor for sawdust heating (**Figure 8**). During operation, the biomass poured into the reactor receives heat directly from the heating chamber through primary air vents at the base. The charcoal, when ignited at a full-gate opening, provided a maximum primary air supply to support ignition. However, the gate is adjustable to regulate the primary air supply as torrefaction progresses. The air inlet vents at the lid provided supplemental secondary air to support feedstock torefaction from the top. After torrefaction, the torrefied products were cool to atmospheric temperature and stored for briquetting.



S/NO	PART LIST	QTY
1.	FLUE VENT	1
2.	REACTOR COVER	1
3.	HANDLE	2
4.	REACTOR CHAMBER	1
5.	BIOMASS	1
6.	SCREEN	1
7.	HEATING CHAMBER	1
8.	AIR VENTS	1
9.	REACTOR BASE	1
10.	GATE	1

Figure 8. Direct heating batch reactor [12].

2.5. Review of torrefied products performance characteristics

Tumuluru et al. [49] carried out a broad-based review on the performance of torrefied products in energy generation with consideration to process reactions and carbonization, while Pahla et al. [88] investigated the changes in the properties of torrefied cow dung (animal waste), corncobs, and pinewood (Pinus radiata) against those of coal. They concluded that corncobs and pinewood responded better to torrefaction and co-fired with coal for energy production. In addition, cow dung utilization in biogas production through anaerobic digestion is common. Bridgeman et al. [31], in their study of reed canary grass and wheat straw torrefaction at 230, 250, 270, and 290 °C for 30-minute residence times, found that the moisture content decreased from an initial value of 4.7% to 0.8%. However, Adnan et al. [25] reported

the torrefaction of empty fruit bunch (EFB) and palm kernel shell (PKS) materials at temperatures of 150 ℃.

Mamvura et al. [89] reported product characteristics comparable to coal at temperatures between 275 and 300 ℃, and residence times between 20 and 40 min, maintaining a heating rate of 10 ℃/min within the reactor temperatures. In another study, Bridgeman et al. [31] discovered temperature as the most significant parameter affecting energy crop grindability (willow and Miscanthus), which implied that biomass pulverization becomes easier as the torrefied biomass properties approach those of coal. Torrefaction improves the combustion characteristics of biomass by removing moisture and volatile matter from the raw materials, making the torrefied product typically brittle and easily grindable, with significant energy and market potential in comparison to the combustion reactivity of coal and wood. It equally has the potential to increase its heating value by approximately 17%, and its equilibrium moisture decreased by approximately 73% compared with its raw material [90].

Bridgeman et al. [31] found that mass and energy yields for woody biomass ranged from 61–82% and 73–92%, while for agro-biomass it was 25–76% and 29–81%, respectively. In a related review, Chen et al. [91] reported that below 290 ℃, biomass degraded into different components at different temperatures and rates. The experiment also concluded that torrefied products at higher temperatures have low moisture content in storage. Pelaez-Samaniego et al. [92] reported that varying the temperature from 200 to 350 ℃ during the torrefaction of Ponderosa pine could cause pyrolysis and established that the lignin decreased with an increase in temperature. Nhuchhen and Basu [70] investigated the torrefaction of poplar wood under mild pressure of 200–600 kPa in a batch reactor and concluded that the effect of replacing air with nitrogen was significant at higher temperatures. Hill et al. [93], during the torrefaction of Pinus *radiata* wood chips, found that increasing the temperature resulted in the production of hydrophilic crystal products. These studies showed the significance of temperature, material moisture, residence time, and material type on the final solid products.

2.6. Empirical study on torrefaction using a batch reactor

Feedstock collection: Gmelina arborea sawdust was produced from a table saw machine with a specialty teeth blade and a 4-inch, 1-TPI blade on a CD 4 band saw machine, respectively, from a local sawmill along Amagu-Okue road in Ishiagu [12]. The feedstock was sorted to remove foreign matter such as stone pebbles, leaves, visible bark, etc.

Reactor design considerations: In the design of the reactor, the following are some considerations kept in focus:

- Size of reactor: The reactor chamber is the frustum of a conical cylinder with a closed lower end perforated as an air vent for heated primary air to penetrate the biomass in the reactor.
- Size of combustion chamber: The combustion chamber is cylindrical with air vents and a gate for charcoal feed. The volume of the cylindrical chamber determines the size of the chamber.

- The air required for combustion: The airflow per unit mass of charcoal was computed using the formula,

$$AFR = \frac{\varepsilon x FCR x SA}{\rho_a} \quad (5)$$

where: *AFR* = airflow rate (m^3/hr), ε = equivalence ratio, (0.3–0.4), *FCR* = fuel consumption rate (kg/hr), *SA* = Theoretical air required to burn 1kg of charcoal (7.1:1 kg), ρ_a= air density (1.25 kg/m^3).

1) Apparent air velocity: This is the rate of airflow within the fuel, computed using the expression below,

$$V_s = \frac{AFR}{Area\ of\ inner\ combustion\ chamber} \quad (6)$$

where: V_s = apparent air velocity, (m/s), *AFR* = airflow rate, (m^3/hr).

2) Energy input: This is the fuel energy input into the reactor, computed using the formula,

$$Q_n = HV_f.FCR.\eta \quad (7)$$

where: Q_n = heat energy needed, MJ/hr, HV_f = heating value of fuel (charcoal) (28 MJ/kg), *FCR* = fuel consumption rate, ~0.19 kg/hr, η = stove efficiency, (80%).

3) Torrefaction experiment: Torrefaction process accomplished between 250–300 °C with limited air supply at three residence times of 30, 45, and 60 min [62,94]. The batch reactor chamber was filled with a weighed sample of Gmelina arborea sawdust. Charcoal was fed into the heating chamber and ignited, with air supply to the chamber controlled by a metal gate and air vents around the chamber. A K-type digital thermocouple with a temperature range of 50 ℃ to 1300 ℃, manufactured by Digital Instrument, Italy, attached to the insulator monitors the temperature within the upper chamber as the sawdust roasts in limited air.

The reactor cover is taken off intermittently to release some of the volatile materials in the form of misty gases and trace quantities of coagulated organic compounds visible as condensed black crystals on the cover. At the expiration of the residence period, the remaining solid material with higher fixed carbon and fewer volatile matters was recovered from the reactor. After torrefaction, the char obtained was stored in bags for densification. The following reaction influenced the torrefaction process, according to Li [95].

$$Biomass \rightarrow \begin{Bmatrix} \nu_{co}CO + \nu_{co_2}co_2 + \nu_{CH_4}CH_4 + \nu_{H_2}H_2 \\ \text{Released gases} \end{Bmatrix} + \begin{Bmatrix} Torrefied\ biomass \\ \text{solid residues} \end{Bmatrix} \quad (8)$$

3. Results and discussion

3.1. Economic analysis of torrefaction

The bio-renewable market significantly thrives in biochemical and thermochemical conversion applications, including torrefaction, gasification, and pyrolysis. The economic analysis of the torrefaction process centers around an assessment of the economic feasibility of the production and utilization of torrefied biomass and, consequently, the market perspectives, keeping in mind the value additions compared with other studies. The key focus is the return on investment (RoI)

and the torrefaction value addition when compared to raw products. Commercially developed markets and pricing structures for torrefied biofuels are not readily available, with assumptions of premium payment for potentially superior storage products similar to coal [10].

Several economic assessment models are available to evaluate the cost of biomass torefaction [96]. The assessment model includes an analysis of the costs of biomass, electricity, labor, investment, and transportation in comparison with the cost of coal replacement [10]. These analyses reported torrefaction production cost savings of over 3% above pelletization, with considerable transport and end-user savings [10]. There are reported cases of earlier torrefaction along the supply chain to preserve fuel quality while reducing transportation and storage costs [54]. Shah et al. [22] reported an estimated total torrefaction cost of $17.5/ton for a material with an initial moisture content of 30% wb and a processing temperature of 240 °C. Further reduction of this cost under optimal process integration and operating conditions is possible.

3.2. Performance characteristics of batch reactors

3.2.1. Physical and proximate characteristics of raw and torrefied sawdust

The physical and chemical characteristics of products produced in a batch reactor were evaluated to determine their performance characteristics. The particle lengths of raw sawdust used were 8.57 mm, with a mean standard deviation of 4.594 at a 95% confidence interval [97], and a mean density of 159 ± 0.02 kg/m^3 at a moisture content of 9.41%. The sample proximate analysis reported high volatile matter content (72.93%), low ash (2.19%), and carbon contents (17.10%) at 7.78% moisture content. The heating value of sawdust was 17.38 MJ/kg. The samples of untreated and torrefied sample products at different torrefaction times are shown in **Figure 9**.

Figure 9. Samples of untreated and torrefied sawdust produced at 30, 45, and 60 min [12].

The most significant physical characteristics observed in the torrefied samples were their colour and weight changes. The colour changed from light brown to golden brown with specks of black at 30 min (mild torrefaction) to dark brown at 45 min and dark colour at 60 min (severe torrefaction). Bello et al. [12] reported that beyond 60 min, the colour turned charred. Qualities of torrefied sawdust were in. The fixed carbon and ash contents increased with an increase in torrefaction time. The fixed carbon increased from 17.10% for untreated sawdust to 21.30%, 38.57%, and 65.38% at 30 min, 45 min, and 60 min torrefaction times, respectively. These increases were similar for ash contents, which also increased from 2.19% to 5.76%, 5.76%, and 5.76%, respectively, for torrefied sawdust. Mohamed et al. [98] obtained comparable results.

Torrefaction time has consequential effects on the product as volatile matter and fixed carbon contents are significantly changed. For instance, an increase in torrefaction time from 30 to 45 min increases the fixed carbon from 17.63% to 21.02% and reduces the volatile matter from 65.19% to 47.92%, implying a substantial amount of volatile and oxygenated compounds expelled from the hemicellulosic fractions through thermochemical reactions. Consequently, as the torrefaction time increases, the volatile matter further decreases while the fixed carbon simultaneously increases. These findings agreed with those of other studies, like Li [95], Adegoke et al. [99], and Mohamed et al. [98], in torrefying sawdust within the same range of temperatures and a 20 min residence period. The untreated HHV increased from 17.23 kJ/kg to 26.28 kJ/kg at 60 min of torrefaction time. These observed results agreed well with the findings of the studies by Ghani et al. [100] and Mohamed et al. [98].

3.2.2. Batch reactor performance

The performance of the batch reactor evaluated by percentage energy yield (EY), percentage loss in mass, and torrefaction degree showed that percentage energy yields at 30, 45, and 60 min were 36.33%, 58.10%, and 69.80%, respectively. The percentage weight loss and energy densification ratio increased as torrefaction time increased. The reactor's total energy input was 4.26 MJ/hr. The torrefaction degree varied from 10.61% ± 0.2%, 34.29% ± 0.2%, and 71.18% ± 0.2% for 30, 45, and 60 min respectively. The performance characteristics of the batch reactor were satisfactorily compared with literature results.

The solid mass yield of the products at 30 min, 45 min and 60 min residence times were 76.7%, 33.6%, 45 min and 28.2%, respectively. Expectedly, the solid mass decreased appreciably with an increase in torrefaction time. Similar studies by Lasode et al. [101] and Nhuchhen [2] found that torrefied woody biomass yielded 80 weight percent after 30 min, whereas non-wood torrefied biomass yielded 50 weight percent at 240 and 300 °C, respectively. The energy yield, which describes the energy contents of material (determined by mathematical expression), retained after torrefaction increased from 36.33 wt.%, 58.10 wt.%, and 69.89 wt.% with an increase in torrefaction time of 30 min, 45 min and 60 min respectively. The energy yield at 30 min was below the limits of literature values of 55–93 wt% for energy woods [102,103]. This implies that the energy yield of sawdust is not significantly affected by the 30 min torrefaction time, as evident in the values of Energy Density Enhancement (EDE).

Furthermore, the Energy Densification Ratio (EDR) at 30, 45, and 60 min (0.91, 1.08, and 1.35) and Energy Density Enhancement Factor (EDEF) at 1.01, 1.21, and 1.51, respectively, increased due to an increase in torrefaction time and consequently increased the energy yield. Weight loss was associated with volatile matter decomposition as well as moisture. These observations were similar to those obtained by Nhuchhen [2] in the thermal pretreatment of cylindrical-shaped poplar wood and loblolly pine samples, respectively.

3.3. Torrefaction cost analysis

The cost analysis of reactor acquisition and the cost per ton of torrefying sawdust at different residence times, as presented in **Table 2,** show that the total unit cost of

acquiring the reactor was NGN 92, 800.00 ($12.00). Compared with the cost of commercial reactors ($50–100.00), the batch reactor is cheaper. Sawdust is available in dumpsites and regarded as waste meant for disposal, so the cost per ton is at giveaway prices. The cost of charcoal is relatively high at 8000.00/50 kg bag due to the competitive nature of charcoal in the face of the rising cost of fossil fuel. Labour costs are cheap at 2700.00 per ton. Feedstock transportation per ton is high at 12,000.00 due to the rising cost of fossil fuels (diesel).

Table 2. Operational cost torrefaction operation.

Operations	Amount (NGN)	Product quality
Cost of reactor	92,800.00	-
Cost of biomass/ton	5000.00	-
Cost of charcoal/50 kg bag	8000.00	-
Feedstock transportation cost	12,000.00	-
Torrefaction at 30 min/ton	15,000.00	Low
Torrefaction at 45 min/ton	20,300.00	High
Torrefaction at 60 min/ton	25,500.00	High
Torrefaction labour cost/ton	2700.00	-

Torrefaction cost per ton varied with time, increasing with an increase in residence time. The cost variation between 45 and 60 min is high compared with the characteristic properties of products obtained under each process. The cost of torrefaction significantly increased torrefying for 60 min without significant improvement in quality compared to 45 min torrefaction. This implies that there are more cost-benefits to recycling at 45 min than at 60 min.

4. Conclusion

Economic analysis of bio-renewable materials from the perspective of production and processing revolves around the economic feasibility of sustainable production and utilization of biomass and market prospects, keeping return on investment (RoI) and value additions in focus. The technoeconomic benefits of batch reactor technology, product characteristics, and economic analysis showed that batch torrefaction significantly improved the physical quality and combustion performance of torrefied products. The products have better grindability and storability compared to raw biomass. The costs of torrefied sawdust products exhibit comparable characteristics with agricultural biomass, with assurance that its positive characteristics translate to an economic advantage over the high cost of torrefier reactors. A critical technical challenge in the development of torrefaction processes relates to the possibility of product quality uniformity. Proving optimal reactor design considerations and simplicity of process conditions for the production of stable and high-quality products is a work in progress. Comparing with other thermal pretreatment methods, torrefaction was considered a more economical way of improving biomass properties.

Conflict of interest: The authors declare no conflict of interest.

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Review

Examination of the interplay between corporate governance theories and sustainable practices in companies: A review study

Muhammad Aiman Awalluddin[1,*], Anisa Safiah Maznorbalia[2]

[1] Faculty of Administrative Science and Policy Studies, Universiti Teknologi MARA, Seremban 70300, Negeri Sembilan, Malaysia
[2] Department of Business and Public Administration, Universiti Tunku Abdul Rahman, Kampar 31900, Perak, Malaysia
*** Corresponding author:** Muhammad Aiman Awalluddin, mdaiman@uitm.edu.my

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Abstract: The objective of this review study is to comprehensively investigate and integrate existing corporate governance theory and its influence on sustainability performance. In light of the growing importance placed on sustainable development goals and ethical business practices, scholars and practitioners must comprehend the impact of corporate governance systems on sustainability results. This study aims to analyze academic publications in order to find patterns and trends in the literature. By doing so, it aims to get insights into how corporate governance theory may promote sustainability actions. This review aims to provide a detailed understanding of the intricate relationship between corporate governance structures and sustainable business practices by analyzing different aspects of corporate governance theories, such as agency theory, stakeholder theory, institutional theory, and legitimacy theory. The results of this study can provide helpful advice to governments, business executives, and investors that aim to improve sustainable performance through the implementation of efficient governance structures. Moreover, this review offers valuable knowledge for scholars and researchers regarding the specific corporate governance theories that are strongly linked to sustainable practices.

Keywords: sustainable; corporate governance; stakeholder theory; legitimacy theory; institutional theory

1. Introduction

The discussion of corporate governance and sustainability has become increasingly prominent in academic research and company practices in recent years. As society becomes more conscious of environmental, social, and governance (ESG) issues, stakeholders are paying closer attention to how corporate governance frameworks contribute to sustainable business practices [1,2]. The increased scrutiny arises from the understanding that efficient corporate governance procedures not only protect the interests of shareholders but also have a crucial role in addressing broader societal issues and promoting the creation of long-term positive value [3,4]. The convergence of corporate governance and sustainability is a complex and ever-evolving field that includes various corporate governance structures, sustainability initiatives, and stakeholder demands [5,6].

Corporate governance systems, including the makeup of the board, CEO compensation, shareholder activism, and regulatory frameworks, have a substantial impact on a company's sustainability performance. Similarly, the need to prioritize sustainability, which includes taking care of the environment, being socially responsible, and following ethical business practices, has a growing influence on how firms are governed and how decisions are made [7]. Due to the lack of theoretical

exploration of the interaction between corporate governance and sustainability, it is crucial to have a thorough grasp of their relationship and the impact they have on business strategy, performance, and engagement with stakeholders. Corporate governance refers to the systems, procedures, and frameworks that regulate the direction and control of corporations. These governance principles not only guarantee responsibility and openness but also impact the incorporation of sustainability factors into business strategy and operations [8].

Multiple studies have emphasized the importance of corporate governance in promoting sustainability initiatives within companies. For instance, Gaio and Gonçalves [9], Issa and Bensalem [10] discovered that organizations with boards that include a varied representation of genders will generally surpass their counterparts in terms of environmental and social performance. They proposed that boards with a variety of members are more inclined to take into account environmental matters and implement ethical business practices. In a study conducted by Dodd et al. [11], it was found that there is a positive correlation between cultural diversity on corporate boards and corporate social performance. They contended that boards with diverse members contribute varied perspectives and values to the decision-making process, resulting in a more comprehensive assessment of social and environmental consequences.

Furthermore, Chong et al. [12] emphasized the significance of board composition in fostering sustainable governance. Research has revealed that boards consisting of a variety of members, encompassing different genders, ethnicities, and areas of competence, are more inclined to give importance to sustainability matters. It implies that boards with a variety of backgrounds and perspectives are more capable of comprehending and tackling intricate sustainability issues, resulting in enhanced sustainability outcomes.

These findings emphasize the importance of corporate governance processes in influencing sustainability practices within firms. Effective governance structures facilitate the integration of sustainability issues into firms' decision-making processes, resulting in enhanced environmental and social results. It is achieved through fostering diversity, transparency, and accountability. Thus, companies that give importance to robust corporate governance procedures are in a better position to handle sustainability concerns and contribute to the production of long-term value for stakeholders and society at large.

The motivation behind this study is based on the understanding that corporate governance plays a crucial role in promoting sustainable development and responsible business behaviour. As the world focuses on achieving sustainable development goals and tackling important social and environmental issues, it is crucial to understand the complex relationship between corporate governance frameworks and sustainability performance. The relationship between corporate governance and sustainability is intricate, resembling a mutually beneficial symbiosis. Effective corporate governance procedures can enable organisations to attain long-term sustainability by promoting a commitment to stakeholders beyond just shareholders. In addition, robust governance frameworks facilitate efficient risk management, enabling organisations to proactively recognise and address environmental, social, and governance (ESG) problems that may impede sustainability initiatives. Nevertheless, this complex interaction encounters substantial obstacles. The pursuit of immediate financial gains frequently

conflicts with the long-term objectives of maintaining sustainability. Investors and executives may give higher importance to fast financial gains, which can impede investments in sectors such as renewable energy or sustainable resource management. Moreover, the process of incorporating sustainability into fundamental corporate processes and established governance frameworks might present challenges. Sustainability initiatives might become compartmentalised, impeding their efficacy. Therefore, this study aims to examine the complex relationship between corporate governance processes and sustainability outcomes. The study's objective will be achieved by conducting a thorough analysis of existing literature and enhancing the influence of corporate governance theories in promoting sustainable practices.

2. Related literature review

Corporate governance and sustainable practice

The notion of corporate governance encompasses a broad range of aspects within the business realm, including managerial responsibility, board composition, and shareholder rights. Corporate governance (CG) refers to the set of rules, principles, and processes that oversee the management, control, and functioning of a company with the aim of promoting accountability, transparency, and effective decision-making. Historically, corporate governance has been conceived as a framework aimed at safeguarding shareholder investments against the manipulative actions of self-serving management [13]. It also entails adhering to particular codes, statutory requirements, and internal company regulations with the goal of reconciling the frequently divergent interests of stakeholders [14].

There is currently a rising trend toward utilizing corporate governance to supervise economic activities, including their impact on society and the environment [15]. Sustainability practices encompass the incorporation of environmental, social, and governance (ESG) considerations into firm strategies and activities, with the aim of fostering long-term profit generation while simultaneously tackling societal and environmental issues. In recent years, there has been a notable surge in interest in the connection between corporate governance and sustainability. There has been a significant increase in interest in the relationship between corporate governance and sustainability. This surge can be attributed to causes such as growing environmental consciousness, changing investor preferences towards ESG aspects, tougher legislation, and the potential for gaining a competitive edge. Companies are being compelled to acknowledge that good governance now encompasses more than simply financial measures. It involves promoting a sustainable future by implementing robust environmental, social, and governance (ESG) strategies that generate lasting value for all stakeholders. It has led to an increasing acknowledgment of the influence of governance systems in promoting sustainable business practices. The majority of stakeholders have redirected their attention towards sustainability rather than prioritizing short-term revenues that do not ensure the long-term survival of the company. Sustainability has emerged as a global priority for all governments. The additional aspect of business responsibility towards sustainability often arises as a result of requests from stakeholders.

Without a doubt, sustainability is increasingly becoming an essential and influential element of the strategies employed by firms [16], as well as the connections they establish with various partners in the value chain. In 2015, the United Nations (UN) implemented the Sustainable Development Goals (SDG) with the objective of safeguarding the environment and the planet. This initiative seeks to prevent global communities from experiencing poverty and to guarantee prosperity by the year 2030. Stakeholders in the field of sustainable development, such as investors, NGOs, local communities, and consumers, have called for firms to enhance their understanding and action in fulfilling their obligations, such as addressing issues related to global warming and human rights [17].

Besides, various considerations have prompted firms to reassess their approach and augment investments in sustainability initiatives. These factors include a focus on the company's sustainable goals, the necessity to adjust to changing regulations, the requirement to enhance product quality while reducing production costs, the desire to improve the company's image and reputation among environmentally conscious consumers, and the emergence of new market prospects [18]. Companies have recognized the increasing connection between green practices and success [19]. As a result, sustainability has expanded beyond its initial focus on environmental challenges and now includes the company's entire business model. Many theoretical frameworks, such as agency theory, stakeholder theory, institutional theory, and legitimacy theory, substantiate the correlation between corporate governance and sustainability practices. The aim is to foster the growth of sustainable value over a prolonged period while concurrently addressing societal and environmental concerns by encouraging companies to integrate sustainable practices.

3. Methodology

The study employed an unstructured literature review to elucidate the corporate governance theories that can be utilized to illustrate sustainable practices. The unstructured literature review method uses a versatile and investigative approach to examining pre-existing literature pertaining to a particular topic or research query. Unstructured reviews offer greater flexibility and adaptability in the search and synthesis process compared to structured reviews, which adhere to predetermined criteria and procedures.

During an unstructured literature review, researchers usually initiate the process by doing comprehensive searches across many academic databases, journals, and other sources to locate pertinent literature. To ensure complete coverage of the issue, they can utilize keywords, key phrases, and related terms. During the literature review, researchers might use several methodologies, such as snowballing, to identify and explore other pertinent studies by tracing the citations and references in the recognized papers.

In an unstructured review, the literature synthesis process includes the identification of crucial themes, patterns, and trends found in the gathered papers. Researchers can employ qualitative methodologies, such as topic analysis or content analysis, to classify and analyse the discoveries derived from the literature. Unstructured reviews highlight qualitative insights and interpretations, in contrast to

structured reviews, which typically contain quantitative analysis and statistical methodologies.

The unstructured literature review method provides researchers with the flexibility to examine various viewpoints and ideas on a particular topic, enabling a thorough comprehension of the existing literature and the development of new research questions or hypotheses for further exploration. Contrary to systematic reviews, which follow a rigorous procedure for extracting and synthesising data, unstructured reviews take a more narrative approach. The researcher engages in a thorough examination and evaluation of the literature, discerning significant patterns, arguments, and possible areas of knowledge that have not been explored. The data sources include databases such as Scopus, WOS, and Google Scholars, which contain information on corporate governance and sustainability initiatives.

4. Discussed corporate governance theories

4.1. Agency theory

Agency theory explains the connection between environmental performance and corporate governance characteristics [20]. The conflict of interest between the primary, or shareholders, and the agent, or managers, is explained by agency theory. Agency theory emphasises the possible discord between shareholders (principals) and management (agents) within a corporation. Shareholders, who are seeking financial gains, want managers to prioritise profitability. Nevertheless, managers may possess individual objectives such as ensuring job stability or pursuing organisational growth, which can result in initiatives with higher levels of risk, unwarranted expansion, or extravagant expenditures. In order to address this issue, organisations can align the incentives of their employees with the profits received by shareholders. They can also build robust governance practices and enforce transparency to guarantee that management makes decisions that are in the best long-term interest of the company, which ultimately helps the shareholders as well. Long-term investors, in particular, demand that companies make sufficient investments in the environment in order for the businesses to become more secure and self-sustaining. On the other hand, environmental investments are frequently costly with uncertain returns. However, in their capacity as owners' agents, managers must maximize returns for shareholders and ensure sufficient cash flow to cover principal payments to debt holders in addition to interest. Based on Jensen and Meckling [20] agency theory, the involvement of ESG introduces a conflict of interest between managers and shareholders, known as an agency dilemma. Agency theory posits that environmental, social, and governance (ESG) factors can give rise to a divergence of interests between managers and shareholders. Historically, managers have prioritised the objective of maximising shareholder returns. ESG programmes may prioritise environmental or social benefits over short-term profitability, leading to an agency problem. Managers may engage in greenwashing or neglect to invest adequately in significant environmental, social, and governance (ESG) initiatives as a result of immediate demands. Companies that have a strategic and forward-thinking approach, together with incentives that are in line with their goals, can overcome this challenge by acknowledging the connection between responsible practices and the production of long-term value for both

shareholders and society. In line with this idea, spending on ESG initiatives is not beneficial for shareholders as it directly depletes cash and decreases profitability. Previous research supporting agency theory includes [21–24]. Nevertheless, it is possible to attain a state of "harmony". Companies that acknowledge the enduring value generation of environmental, social, and governance (ESG) policies, the changing focus of investors towards them, and the potential edge they provide in competition can reconcile the disparity between immediate profitability and long-term sustainability objectives. This fosters a more enduring and environmentally responsible future for the organisation, its stakeholders, and the broader community.

Conflicts between principal and agent arise in diverse ways, such as the manipulation of financial information, the perpetration of accounting fraud, and the appropriation of shareholders' money. Sustainable activities can give rise to agency concerns in at least three distinct ways. One instance is when managers allocate company resources for their own gain. Managers may engage in sustainable initiatives for their own benefit. Individuals may pursue personal interests or excessively invest in order to gain private rewards, such as enhancing their status as good citizens, even if it comes at the expense of shareholders [21]. From this perspective, engaging in sustainable activities is considered to be an overall inefficient use of a corporation's resources, resulting in a decrease in firm performance. Furthermore, engaging in sustainable activities may necessitate enterprises forgoing projects that would yield higher profits for the firm [25]. Allouche and Laroche [26] argue that corporate social achievements incur financial expenses that are funded by the company's capital and other resources. It puts the company at a competitive disadvantage relative to less socially engaged firms. Additionally, the managerial opportunism argument posits that managers strategically utilize company resources to participate in sustainable initiatives as a means to evade negative scrutiny and to counterbalance or rationalize subpar financial results. It is commonly referred to as window dressing. Sustainable operations are conducted with the intention of garnering positive publicity as a means to mask underperforming results.

To address these conflicts effectively, it is imperative to establish a robust corporate governance framework. The board of directors utilizes accounting figures as instruments to oversee and regulate the system as part of the corporate governance mechanism [27]. For instance, a board that consists of a higher number of independent directors is considered to possess a more vital ability to reconcile the financial and non-financial objectives of the company while making intricate environmental decisions [28,29]. Lastly, research has demonstrated that having a board with a greater variety of members, including female directors, can significantly improve the company's focus on and understanding of social and environmental matters [30].

4.2. Stakeholder theory

Stakeholders prioritize the environment, leading to a heightened demand for corporations to adopt greater environmental responsibility in their operations [31]. In contemporary times, environmental issues are regarded as companies' obligations by society. Companies are delivering a high level of environmental performance due to the increasing concerns of stakeholders about the environment. Stakeholders are

defined as individuals or groups who experience either positive or negative consequences as a result of a firm's actions [32]. The concepts of stakeholder theory and sustainability are intimately interconnected and have garnered considerable attention in modern company management and academics. Stakeholder theory asserts that corporations should take into account the concerns and welfare of all parties involved, including shareholders, employees, customers, communities, and the environment, when making decisions. The stakeholder theory underscores the significance of actively applying and harmonizing the concerns of different stakeholders in order to accomplish enduring value generation and organizational triumph.

Within the realm of sustainability, stakeholders assume a pivotal role in exerting influence over business conduct and propelling the adoption of sustainable practices. In Freeman's view, the most accurate measure of a company's success is its ability to meet the needs and expectations of all its stakeholders, rather than solely focusing on shareholders [32]. Pursuant to the stakeholder theory, sustainable activities can be transferred or combined with a firm's market performance. For instance, employees who are satisfied with their company's sustainable policies will demonstrate increased excitement and dedication towards their work. Likewise, satisfied customers will develop a strong sense of loyalty, while content producers will provide discounted prices. Consumers who prioritize environmental concerns may opt to endorse companies that demonstrate a commitment to sustainable production methods and ethical business conduct. Investors are now giving more importance to environmental and social factors when assessing companies for investment.

As a result, there is a rising need for corporations to provide clear and comprehensive sustainability reports and disclosures. These factors, in turn, contribute to the enhancement of a company's reputation and ultimately result in improved financial performance and long-term viability. Jo and Harjoto [33] and Ghoul et al. [34] research shows that engaging in sustainable activities has a good impact on a firm's performance. Moreover, Tian and Tian's [35] empirical study on a sample of 306 Chinese data points reveals that stakeholder pressure has a beneficial influence on business sustainability performance. Ruf et al. [36] endorse a notion in stakeholder theory that states shareholders, as the primary stakeholder group, gain financial advantages when management fulfills the desires of many stakeholders. More precisely, there was a favourable correlation between changes in corporate social performance and increases in company sales. It is because sustainable activities help to settle conflicts between management and stakeholders. It suggests that the implementation of active, sustainable measures is crucial to safeguarding financial performance and enhancing shareholder worth.

4.3. Institutional theory

Scholars have demonstrated a specific focus on the convergence of sustainable practice and institutional theory [6,37,38]. The examination of institutions sheds light on how broader social and political contexts influence the responsible and irresponsible conduct of companies. In addition to expanding the conceptual understanding of sustainable practice, there has been growing interest in an

institutional view that goes beyond the immediate organizational boundaries of particular organizations. This interest has been sparked by developments in the global economy throughout the late 2000s. The so-called financial crisis has not only shown new types of corporate irresponsibility but also exposed the crucial involvement of private firms in other issues that were previously considered the responsibility of governments. The interdependence between businesses and society, as well as the systems of governance and institutional integration, have led to new perspectives on CSR and the role of modern corporations [39].

Institutional theory examines various organizational types. It further elucidates the reasons behind the presence of comparable traits or structures within a certain corporate domain. DiMaggio and Powell [40] define an organizational field as a collection of organizations that form a recognized area of institutional life. It includes regulatory agencies, suppliers, resource and product consumers, and other organizations that produce similar services or products. Bansal [41] highlighted the significance of social circumstances within the company in this approach. The statement asserts that organizational change is a reaction to the social environment [40,41]. A company's value is inherently linked to its ability to maintain a productive connection with its social environment. They assert that companies exist to fulfill specific requirements of individuals or groups in society through the creation and sale of products or services [42].

The theory identifies three factors that cause uniformity in organizational strategy, structures, and procedures. Organizations within institutional environments often conform to a standardized structure as they adopt specific patterns to gain institutional legitimacy [43]. Institutionalization can lead to the exclusion of other organizational forms, making them challenging to consider [44]. The first motivation for seeking a new corporate form may be efficiency. Still, subsequently, it spreads in order to gain legitimacy, according to a two-stage model of diffusion proposed by Tolbert and Zucker [45]. Uncertainty can result in the occurrence of isomorphism, which is influenced by coercive, normative, and mimetic forces [40]. Coercive pressures arise from influential forces that are essential for promoting environmental management and sustainability [46]. Normative drives guarantee that organizations conform to established standards in order to be viewed as engaging in lawful acts [47]. Ball and Craig [48] argue that organizations are motivated to become more environmentally conscious and responsive to environmental challenges due to normative pressures.

This motivation is based on a social obligation to meet public standards. Mimetic isomorphic drives refer to the phenomenon when companies emulate successful competitors in order to replicate their path to success and obtain legitimacy. Within the context of sustainability, these drivers are intimately associated with business sustainability since they serve as powerful incentives [49,50]. Lastly, this paradigm facilitates the process of incorporating sustainability practices into companies by emphasizing the need to establish them as standard procedures [40,41].

4.4. Legitimacy theory

This notion pertains to a mutual agreement between society and companies, wherein the companies embrace socially conscious behaviours in order to obtain societal validation [51]. The presence of a social compact between corporations and society is essential for the aim of legitimization. A contract is established between the companies and persons that comprise a local community, although it is described in general terms. The corporation relies on the local community for the provision of natural and human resources. In return, the company produces goods and services for the community while also generating trash. The contract is founded upon mutually advantageous transactions.

The provisions of this social agreement embody the societal norms for the administration of the company. Expectations can be categorized as either explicit or implicit. Explicit expectations refer to the firm's adherence to laws and regulations, while implicit expectations pertain to the community's interests in the firm's activities [51]. Legitimacy theory posits that organizations must adhere to the norms, boundaries, and regulations established by the community in which they operate [52]. By using this approach, a corporation will proactively disclose all its actions, provided that the management perceives that particular activities have gained the attention of the community. According to the legitimacy theory, sustainable practice involves addressing the demands and interests of stakeholders as well as adhering to a socially created system of norms, values, and beliefs [53,54].

Corporate governance is responsible for ensuring that timely and correct disclosures are made regarding all significant aspects of the firm, such as its financial position, performance, ownership, and corporate governance. The board of directors will establish stringent regulations specifically formulated to safeguard the company's interests in the domains of financial reporting, internal control, and risk management [55]. Legitimacy theory posits that the nature of an industry can impact its level of political exposure and compel it to provide information in order to mitigate societal pressure and criticism [56]. Previous research has frequently used industry type as a variable to analyse and clarify the nature and scope of disclosure [57–59]. More sensitive industries are generally more prone to criticism in terms of corporate social responsibility due to the impression of higher risk associated with their actions [60]. The concept of industries being 'sensitive' is a recurring subject in legitimacy theory. Roberts [61] employs a binary categorization system to classify businesses as either high-profile or low-profile. High-profile sectors are characterized by consumer visibility, a significant amount of political risk, or severe concentrated competition. Hackston and Milne [62] present evidence indicating that industries with a high level of public visibility reveal a much more significant amount of social and environmental information compared to industries with a low level of public visibility.

Companies that are more susceptible to risks owing to their size or industry tend to release additional information as a means of proactive risk management. The stakeholder theory and legitimacy theory share certain parallels that might elucidate why a corporation may want to provide specific details voluntarily [63]. Companies can meet stakeholder expectations by incorporating disclosure into their strategic

approach, either as a genuine demonstration of commitment or as a minimal effort to maintain a certain level of legitimacy, which may be purely symbolic or tactical [64].

5. Theoretical highlights of discussed corporate governance sustainable theories

Agency theory, stakeholder theory, institutional theory, and legitimacy theory are fundamental frameworks for comprehending organizational behaviour and decision-making related to sustainable practices and corporate governance considerations. These theories converge in their emphasis on organizational behaviour, consideration of stakeholder interests, and identification of institutional factors. All of them emphasize the significance of taking into account the viewpoints of different stakeholders, such as shareholders, employees, consumers, and the wider community, when making organizational decisions related to sustainability considerations. Furthermore, these theories acknowledge the influence of institutional restraints, such as regulatory limitations, normative expectations, and cultural norms, on how organizations address sustainability concerns and implement sustainable practices.

Nevertheless, although these theories have commonalities, they also display unique attributes and prioritize diverse elements of sustainable practice. Agency theory focuses on the connection between principals and agents in organizations, with a particular emphasis on aligning incentives to reduce conflicts of interest. Stakeholder theory, on the other hand, expands the range of consideration to include the concerns of different stakeholders and promotes their active involvement in decision-making procedures. Institutional theory examines how organizations react to external influences and embrace established practices concerning sustainability issues. On the other hand, legitimacy theory emphasizes the tactics employed by organizations to preserve their credibility by being transparent, engaging with stakeholders, and conforming to societal norms. By incorporating perspectives from many corporate governance theories, one can gain a thorough comprehension of the complex dynamics that contribute to the advancement of sustainability performance in companies.

6. Conclusion

Ultimately, the analysis of corporate governance theories, including agency theory, stakeholder theory, institutional theory, and legitimacy theory, demonstrates their substantial impact on the implementation of sustainable practices in firms. The concept of agency theory emphasizes the significance of matching incentives between individuals who have authority (principals) and individuals who act on their behalf (agents) in order to encourage long-lasting decision-making and reduce conflicts of interest. The stakeholder theory highlights the involvement of many stakeholders in organizational procedures to tackle sustainability issues and promote the production of lasting value. Institutional theory emphasizes the influence of external pressures and institutional norms on the behaviours and practices of organizations regarding sustainability. Legitimacy theory, on the other hand, focuses on the strategies organizations use to uphold public trust and legitimacy by being transparent in their reporting and conforming to societal norms.

Collectively, these ideas offer unique perspectives on the intricate dynamics of corporate governance and its influence on sustainable practices. Companies can enhance their governance structures and decision-making processes by incorporating the principles of agency theory, stakeholder theory, institutional theory, and legitimacy theory. This integration allows for a greater emphasis on environmental stewardship, social responsibility, and ethical conduct. In essence, a thorough comprehension of these ideas will enable firms to effectively negotiate the intricacies of sustainability difficulties and achieve favourable societal and environmental results. It, in turn, leads to long-term corporate success and increased value for stakeholders.

7. Limitation and future study

Although the analysis of corporate governance theories provides valuable insights into sustainable practices, it is crucial to recognize certain limitations. Firstly, these theories may not comprehensively encompass the dynamic and varied nature of sustainability concerns, especially in fast-evolving business settings and global marketplaces. Moreover, the implementation of these ideas can differ depending on the specific organizational contexts, sectors, and geographical locations, which presents difficulties in generalizing their findings.

Subsequent research endeavours in this field should strive to overcome these constraints by embracing a comprehensive and situation-specific methodology. Researchers could investigate the relationship between corporate governance theories and new sustainability movements, including climate change mitigation, social impact investing, and responsible supply chain management. Interdisciplinary research that combines knowledge from corporate governance, environmental science, sociology, and other disciplines can provide fresh viewpoints and creative solutions to sustainability issues in the corporate sector. By bridging these gaps and enhancing our comprehension of the correlation between corporate governance theories and sustainable practices, researchers and professionals can contribute to the formulation of more efficient governance frameworks and strategies to accomplish sustainable development objectives.

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