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Urban digital economy, business model innovation and corporate ESG performance: A industry chain upstream and downstream perspective

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Abstract: Vigorously developing the digital economy is a future national strategy of the Chinese government, and the sustainable development of the industrial chain is a future challenge for Chinese enterprises. The environmental, social and governance (ESG) performance of enterprises is an important micro-indicator of sustainable development, which links the development of the digital economy with the safety of the industrial chain. In order to explore the mechanism and path of digital economy to enhance corporate ESG performance under the industry chain perspective, this paper conducts an empirical analysis with a sample of 4,482 listed companies in Shanghai and Shenzhen, China, from 2013 to 2022. The results of the study show that, first, the development of urban digital economy not only improves the ESG performance of enterprises in the jurisdiction but also enhances the overall ESG performance of the industry chain in which the enterprises are located. Second, the effect is significant in both the eastern and central and western samples, but there is heterogeneity in the nature of property rights, and the effect is more significant in the sample of state-owned enterprises. Third, although both green technological progress and business model innovation play a role in the influence mechanism in the transmission of the industrial chain, the influence of business model innovation is more significant in terms of size. This study complements the research on the relationship between digital economy and corporate ESG from the industry chain perspective.

Keywords: *Corporate ESG performance, Data of listed companies in China, Digital economy, Supply chain.*

1. Introduction

Since China's economy has shifted from a phase of rapid growth to a phase of high-quality development, China and all sectors of society have paid attention to how to realize high-quality economic development. Enterprises are the basic cells of economic operation, and the concept of Environment, Social and Governance (ESG) advocates that enterprises should protect the ecological environment, assume social responsibility and improve the governance system in the process of development, which is exactly the meaning of high-quality development of the economy (Sun et al., 2022), and therefore among the many indicators reflecting high-quality development of the economy and the level of sustainable development of enterprises, ESG evaluation indexes have become the mainstream international indicators. Therefore, among the many indicators reflecting the high-quality development of the economy and the level of sustainable development of enterprises, ESG evaluation indexes have become one of the mainstream international investment indicators, and many international organizations have launched relevant indicators involving ESG (Cao, 2024).

For governments, in order to realize the goal of high-quality economic development, and for enterprises, in order to enhance their own sustainable development capabilities, they are constantly looking for positive influencing factors and paths to help them achieve their goals and enhance their capabilities. However, in the face of rising trade protectionism around the world, coupled with the impact of the three-year-long Covid-19 epidemic, the industrial chain of global markets is facing a huge risk of "breakage", and in order to maintain high-quality and sustainable development momentum, it is necessary to pay attention to the level of resilience and security of the supply chain (Wieland and

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Durach, 2021). In this context, the impact of the digital economy on the industry chain began to receive attention gradually. The digital economy was firstly proposed by American scholars in 1996 (Cavoukian and Tapscott, 1996), and in 2012, China's central government upgraded the development of the digital economy to a national strategy. At the same time, China's Ministry of Industry and Information Technology (MIIT), in the "Industrial Green Development Plan (2016-2020)", has also clearly stated that it wants to promote enterprises to build green supply chains as a way to enhance their sustainable development capabilities. This shows that the relationship between the digital economy and the ESG performance of enterprises, especially their relationship in the industrial chain, has been emphasized by the government and the community.

Logically, from the definition of ESG, it contains three aspects, namely, environment, society and governance, and it is inevitable to start from these three aspects if we want to improve the ESG performance of enterprises and the whole industrial chain. In contrast, the development of digital economy is undoubtedly based on green production technology (Mansouri and Momtaz, 2022) and business model (Mo et al. 2023), which has revolutionized the environmental impact and resource efficiency in all aspects of the industry chain upstream and downstream. If we compare the definition of ESG with the planning and strategy of digital economy development, we can find that the two are highly compatible in the two concepts of technological advancement and upgrading of development model (Bhattacharya and Bhattacharya, 2023). Then, it is worth pondering whether digital economic development can become a means to enhance the sustainable development ability of enterprises and guarantee the high-quality development of social economy, and what is the medium of transmission between the upstream and downstream of the whole industrial chain.

Based on this, in order to examine whether the development of urban digital economy will enhance the ESG performance of enterprises and radiate the impact to the upstream and downstream industries of the supply chain in which the enterprises are located. Through a literature and theory review, this paper first proposes that the development of urban digital economy not only enhances the ESG performance of enterprises, but also leads to the sustainable development of the upstream and downstream industries of the whole supply chain through two mechanisms, namely, green technological advancement and business model innovation. Subsequently, using a sample of 4,482 A-share companies listed on China's Shanghai and Shenzhen stock exchanges from 2013 to 2022, an empirical study was conducted with the fixed-effects model as the main methodology, and the results of the study show that:

First, when the city where the enterprise is located vigorously develops the digital economy, its own ESG performance will be significantly improved. In terms of effect size, when the city where the enterprise is located vigorously develops the digital economy, its ESG score will be increased by 1.8389. Secondly, when the city where the enterprise is located vigorously develops the digital economy, the overall ESG performance of the industries upstream and downstream of the industry chain in which it is located will also be improved, and the overall ESG performance of the downstream industry chain will rise more significantly. Thirdly, in terms of impact mechanisms, the continuous improvement of green technology and the continuous optimization of business models are the two impact mechanisms by which the development of digital economy positively affects the sustainable development of enterprises and the whole supply chain. Finally, the non-economic impact effect of digital economic development is heterogeneous in the nature of property rights.

This study makes several important contributions to the literature on digital economy platforms and corporate ESG performance:

Empirical Evidence for Improving the ESG Performance of Enterprises and the Overall ESG Performance of the Upstream and Downstream of the Industrial Chain in Which They Are Located: By demonstrating that the construction of urban digital economy platforms can improve the ESG performance of enterprises themselves as well as the overall ESG performance of the downstream of the industrial chain in which they are located, this study provides empirical evidence to support the key role of digital infrastructures in facilitating enterprises as well as in promoting the sustainable performance of the industrial chain. While there is a large body of empirical evidence on the facilitating role of urban digital economy development on firms' ESG performance. However, it is one of the contributions of this paper to analyze the different impacts of urban digital economy development on firms and the upstream

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and downstream of the industrial chain in which they are embedded from an industrial chain perspective. The conclusions of this paper find that urban digital economy development does not have a significant facilitating effect on both the upstream and downstream of the industry chain, but focuses more on the overall ESG enhancement of the downstream of the industry chain.

Influence mechanisms: Generally speaking, technology is the most critical factor driving sustainable development, although business model innovation is increasingly emphasized by academics. In the influence mechanism of corporate ESG performance, although the two key mechanisms, green technology progress and business model innovation, both play a mechanism role, but in terms of the size of the coefficient as well as the significance, business model innovation plays a greater role in the process of industry chain transmission. This paper is one of the contributions to the existing research by emphasizing the new innovation path of business model innovation while emphasizing technology and development model.

Contextual Insights: This study reveals the different impacts of digital economy platforms on different types of enterprises, especially under the sample of state-owned enterprises. This contextual analysis contributes to a deeper understanding of how regional and industry differences affect the relationship between digital economy initiatives and ESG performance.

Policy relevance: by linking the digital economy strategy of China's central government to the sustainable development of firms and the development of the industrial chain as a whole, this study emphasizes the need for policymakers to promote digital economy development as part of the overall sustainable development strategy of the industrial chain. This contribution highlights the importance of the industrial chain in the overall socio-economic sustainable development.

Framework for future research: This study lays the groundwork for future research to analyze the mechanisms by which the digital economy affects environmental, social and governance performance from a holistic industry chain perspective, encouraging further exploration of the interplay between digitization, business model innovations, and green technological advances.

Together, these contributions advance the understanding of the intersection between the digital economy and corporate sustainability, providing a valuable foundation for academic exploration and practical application.

In addition to the introduction, the following section is structured as follows: the second part is Theoretical Background, which introduces the theoretical foundation from the perspective of innovation theory and business model; the third part is Literature Review and Hypothesis Formulation, which the part the part from the impact factors of enterprise ESG performance and enterprise industry chain research two aspects, the review of the existing relevant research system, and through logical deduction, the influence process of green supply chain management on the overall performance of the whole supply chain industry chain; the fourth part is Methodology, which constructs an empirical model in order to verify the theoretical hypotheses and introduces the research design and data sources; the fifth part is Results, which analyzes the results obtained from the empirical model; the sixth part is Conclusion, which provides a summary of the conclusions of this paper. Part VI is Conclusion, which summarizes the findings of this paper.

2. Theoretical Background

2.1. Key Concepts

Tapscott (1996) pioneered the concept of digital economy, while Kim et al. (2002) defined it for the first time, arguing that the essence of digital economic activities is that products and services are traded in an informatized form. In 2016, the Group of Twenty (G20) Initiative on Development and Cooperation in the Digital Economy promoted the definition of digital economy as an economy in which digitized knowledge and information are the key factors of production, an economy that uses modern knowledge and information as key factors of production, modern information networks as an important carrier, and the effective use of ICT as an important driving force for efficiency improvement and economic structure optimization. This definition is widely recognized by the academic community.

In 2004, UNGC (2004) formally proposed the concept of ESG, which encompasses environmental, social and governance aspects, and its core meaning is to harmonize and balance the harmonious and

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sustainable development of the economy, society and the environment. Although the construction of China's ESG evaluation system started late, it has developed rapidly in recent years. the Overall Plan for the Reform of the Ecological Civilization System released in September 2015 requires China's domestic financial market to establish a mandatory environmental information disclosure mechanism for listed companies.2021 So far, China's capital market regulators have issued a series of policies related to the ESG system. For example, in June 2021, the China Securities Regulatory Commission (CSRC) issued new guidelines on the format and content of annual and semi-annual reports of listed companies, in which "environmental and social responsibility" is required to be set up as a separate section; in October of the same year, the China Association of Insurance Asset Management Industry (CAIMI) set up the ESG Committee on Responsible Investment with the aim of promoting the construction of ESG investments.

2.2. The Theory of Innovation

Schumpeter's theory of innovation is the most important theory of innovation in economics, and he argues that there are five driving sources of innovation: new products, new raw materials, new designs, new processes and new organizational methods. From this definition, we can see that the ESG development model is also a comprehensive form of innovation, which includes both new technologies and new ideas, as well as new organizational methods and production relations (Ren and Cheng, 2024).

2.3. The Theory of Green Technology and Business Model

Green technological innovation is a technological innovation activity that aims to protect the environment, conserve resources and achieve sustainable development. The contents of green technology innovation mainly include pollution control and prevention technology, source reduction technology, waste minimization technology, recycling technology, eco-processes, green products, purification technology and so on. These technologies are dedicated to saving energy and reducing or avoiding environmental pollution, and are considered to be an important driving force for improving environmental quality (Miao et al., 2021). Business model at first refers to the specific mode of business management of enterprises, which first appeared around 1957, On the basis of Osterwalder (2005), Chinese scholars have proposed a "six-factor" business model theory (Wei et al. 2020), which includes six elements: positioning, business system, profit model, key technology resources, cash flow and enterprise value, to characterize the business model of Chinese enterprises. This theory is more in line with Chinese reality, so this paper is based on this theory when constructing business model innovation indicators.

3. Literature Review and Hypotheses Development

3.1. Digital Economy Improves ESG Performance of Companies and Supply Chains

With regard to the environment, the digital economy helps enterprises to manage energy consumption and waste emissions more accurately by providing efficient information processing and analytical capabilities, thereby realizing energy conservation and emission reduction (Chen et al., 2022). Through digital means, enterprises can optimize production processes, improve resource efficiency and reduce negative impacts on the environment (Deng et al., 2023). On the social front, the digital economy enables companies to collect and analyze employee feedback more easily, thereby improving the work environment and employee well-being. Through digitalization, companies can enhance internal communication and increase employee satisfaction and loyalty (Chen et al., 2023). In terms of governance, the digital economy enables enterprises to collect and analyze market information more efficiently and thus make more informed decisions. Through digitization, enterprises can strengthen internal oversight and control and increase the transparency and effectiveness of corporate governance (Broadstock et al., 2021).

Based on this, we propose hypothesis 1 to be empirically tested:

Hypothesis 1: Companies' own ESG performance improves following the development of the digital economy in their cities.

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Digital economy development improves the ESG performance of companies and the chains in which they operate Rising global trade protectionism and the three-year delay of the Covid-19 epidemic have brought serious impacts to global capital markets and commodity markets. The industrial chain of each global market is facing the great risk of "breakage", and the smoothness and safety of the upstream and downstream industries in the industrial chain are more and more emphasized by enterprises (Wieland and Durach, 2021). In addition, extending, supplementing and strengthening the chain has also become the focus of China's central and local governments during the "14th Five-Year Plan" period. Therefore, the ESG improvement of the whole industrial chain is also a key point for enterprises to enhance their sustainable development capability. Therefore, the development of digital economy should not only improve the ESG performance of enterprises themselves, but also include the ESG performance of the industries upstream and downstream of the supply chain in the scope of work (Zeng et al., 2022).
Based on this, we propose hypothesis 2 to be empirically tested:

Hypothesis 2: The overall ESG performance of the upstream and downstream industries in the supply chain of an enterprise will increase when the city in which the enterprise is located vigorously develops the digital economy.

3.2. Digital Economy, Green Technological Innovation and Supply Chain ESG performance

In terms of the incentivizing role of downstream customers for upstream firms, the ESG advantages of downstream customers can motivate upstream firms to make green innovations and improvements. Through channels such as strengthening green awareness, providing commercial credit support and green technology spillover, downstream customers can motivate upstream firms to improve their ESG performance. In terms of the transmission effect of upstream firms to downstream firms, the ESG performance of upstream firms will also affect the ESG performance of downstream firms (Han et al., 2023). If upstream companies can adopt green production technologies and have good ESG performance, the products and services they provide will be more in line with the ESG requirements of downstream companies. There is synergy between the ESG performance of upstream and downstream enterprises in the industrial chain. By strengthening cooperation and communication between upstream and downstream enterprises in the industrial chain, and jointly promoting the improvement of ESG management and the development of green technologies, the ESG optimization and sustainable development of the industrial chain as a whole can be achieved (Miao et al., 2021). Therefore, we propose hypothesis 3 to be empirically tested:

Hypothesis 3: Technological innovation plays a mechanistic role in the development of the digital economy for supply chain's ESG performance.

3.3. Digital Economy, Business Model Innovation and Supply Chain ESG Performance

The development of the digital economy has forced the enterprise's organizational environment to become increasingly complex, and environmental uncertainty has increased significantly, making the enterprise's business model innovation diversified and randomized. The traditional business model is not compatible with the development model under the digital economy, and the production and operation boundaries of enterprises are broken (Mo et al., 2023). The digital economy has improved the social responsibility and transparency of enterprises upstream and downstream of the industrial chain through business model innovation. Enterprises can utilize digital technology to publicly disclose ESG information and enhance communication and cooperation with consumers, investors and stakeholders. The digital economy also promotes flexibility and inclusiveness in the labor market. Enterprises can use digital technology to optimize the allocation of human resources and improve employee satisfaction and well-being, while promoting social employment and entrepreneurship (Agarwal et al., 2024).
Therefore, we propose hypothesis 4 to be empirically tested:

Hypothesis 4: Business model innovation as an influential mechanism of digital economy development for supply chain's ESG performance.

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4. Methodology

4.1. Research Context

Based on the above analysis, the inherent relationship between digital economy development and sustainability requires further empirical test. In the recent decades, China emphasizes on improving the digital economic attributes in city (Guo et al., 2020), such as digital infrastructure (Pan et al., 2022), digital technology innovation (Cai and Zhu, 2020), and digital network development (Pan et al., 2021) resulting in fiber optic network available in all cities and more than 450 million people easily access to 5G net. Specifically, it is assumed that the construction of a city's digital platform will significantly reduce the cost of incident tracking and handling and corporate governance processes for companies in the region (Pan et al. 2022). Therefore, the paper considers whether firms headquartered in the city with a digital economy platform can enhance their ESG performance. More importantly, we explore what could be the underlying mechanisms.

4.2. Empirical Design

To formally investigate the relationship between city digital economy and corporate ESG performance, we empirically tested the following model specification.

$$esg_{it} = \beta_0 + \beta_1 digital_{it} + \sum \alpha_j control_{ijt} + firm_i + year_t + u_{it} \quad (1)$$

In model (1), the dependent variable esg denotes the environmental, social, and governance performance of A-share listed firms. The impact of the digital economy development status of a company's city on its ESG performance has been confirmed by many scholars. Before testing whether the ESG performance upstream and downstream of the industry chain where the enterprise is located will be affected by the development of the digital economy, it is intuitive to test the direct impact on the enterprise.

At present, the indicators for ESG performance of Chinese listed companies mainly come from third-party assessment institutions at home and abroad, and due to the differences in governance structure, social status and other external environments, as well as the development history of ESG evaluation systems with their own characteristics, the ESG indicators obtained by different institutions at home and abroad differ to some extent (Serafeim et al., 2022). For Chinese listed companies, there are four main types of domestic ESG rating agencies and their related indicators: (i) ESG indicators for Chinese listed companies from 2015-2022 provided by SynTao Green Finance database, which mainly targets large Chinese listed companies represented by CSI 300; (ii) ESG indicators for Chinese listed companies from 2018-2021 provided by R&L Global, which mainly targets large Chinese listed companies represented by CSI 800; and (iii) ESG indicators for Chinese listed companies from 2009-2022 provided by Sino-Securities ESG Index (SSESGI), which covers all Chinese A-share listed companies; (iv) ESG indicators for Chinese listed companies from 2007-2022 provided by Chinese Research Data Service (CNRDS), which also covers all Chinese A-share listed companies.

Compared with the indicators provided by other rating agencies, the CNRDS has obvious advantages, as it contains the indicator consists of three primary, 14 secondary and 39 tertiary indicators., with a time span of more than 15 years and a total of more than one million data, and therefore it is one of the most widely used in the field of ESG research in China (He et al., 2024; Zhao et al., 2024).

digital is the explanatory variable of this paper, reflecting the development of the city's digital economy. Based on the existing studies related to studying the development of digital economy in Chinese cities (Yao et al., 2021; Xin et al., 2024), the following five aspects are selected as the elements for constructing digital economy development indicators: digital financial inclusion index, the number of international Internet users per 100 people, the percentage of employees in the information transmission computer services and software industry, the total amount of telecommunication services per capita, and the number of cell phone users per 100 people. These elements reflect the current state of digital economy development in Chinese cities in terms of five aspects: digital finance, Internet maturity, digital human capital, digital infrastructure, and telecommunications infrastructure, respectively. In constructing the composite indicators, the entropy method is used, consistent with the operationalization of most of the literature. In the robustness test, in order to ensure the robustness of

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the results from the perspective of different construction methods, factor analysis was also used to construct another proxy indicator *digitalf*.

control is a vector of control variables, which mainly contains other control variables reflecting the financial characteristics of the company to control other factors affecting corporate ESG performance. Among the many variables affecting corporate behavior (Broadstock et al., 2021; Zahid et al., 2023), this paper first identifies the main 6 aspects of the variables based on existing studies: firm size, firm age, debt level, equity structure, corporate earnings and cash flow level. By inflating the factors to test the relevant variables, six financial indicators at the enterprise level are finally identified as control variables: *size* is the natural logarithm of total assets, which reflects the enterprise size; *debt* is the enterprise's gearing ratio, *hhi* is the equity concentration of the top five shareholders, which reflects the equity structure; cash is the money funds, which reflects the level of cash flow, and *lnage* is the enterprise's listed log of years, they reflect the age of the firm; *roa* is the return on assets, which reflects the firm's earnings profile. *cash* is the ratio of an enterprise's monetary funds to an enterprise's operating revenues.

In addition, *firm* is the firm-individual effect that does not vary over time, *year* stands for the year dummy variable, *u* stands for the random disturbance term, subscript *i* denotes each firm, and subscript *t* denotes each year, as below.

In order to test the idea proposed in hypothesis of the theoretical analysis, when the city's digital economy develops, not only its own ESG performance will be significantly improved, but also the overall ESG performance of the upstream and downstream of the industrial chain in which he is located will also be significantly improved. The model to be empirically tested is set in the following form:

$$esg\_up_{it} = \beta_0 + \beta_1 digital_{it} + \sum \alpha_j control_{ijt} + firm_i + year_t + u_{it} \quad (2)$$

$$esg\_down_{it} = \beta_0 + \beta_1 digital_{it} + \sum \alpha_j control_{ijt} + firm_i + year_t + u_{it} \quad (3)$$

In models (2) and (3), *esg_up* and *esg_down* are the explanatory variables, which represent the overall ESG performance of the industry upstream of the industry chain and the overall ESG performance of the industry downstream of the supply chain, respectively. In studies that need to judge the relationship between upstream and downstream industries, the input-output table between industries or sectors is the most important basis for judgment (Hu et al., 2020), so this paper calculates the direct consumption coefficients and direct distribution coefficients of each industry based on the input-output tables provided by the National Bureau of Statistics of China (NBSC) for the years 2012, 2017, 2018, and 2020 to find the upstream and downstream industries in which the enterprise is located in the supply chain. upstream and downstream industries of the supply chain in which it is located. In the empirical evidence, the average ESG performance of the top three industries in the supply chain in which the enterprises are located is taken as the explanatory variable reflecting the upstream industries. At the same time, the average ESG performance of the top three industries in the direct distribution coefficient of the supply chain in which the enterprise is located is taken as the explanatory variable reflecting the downstream industry. The definitions of other variables in the model are consistent with model (1).

In the mechanism analysis, it can be seen that the development of the digital economy on enterprises and their upstream and downstream ESG performance is mainly transmitted through two innovative paths: one is to emphasize green development, requiring enterprises to comprehensively use green products, green equipment and green technology in procurement and sales, and ultimately promote the green development of the whole industrial chain; the other is to emphasize the upgrading of perfecting the enterprise's enterprise as well as industrial chain development mode, and to create a model of supply chain management in terms of risk The second is to emphasize the upgrading of the enterprise's corporate and industrial chain development model, and to create a model of a new business model in terms of risk control, information communication, internal supervision, environmental governance and strategy development. It can be seen that green technology innovation and business model innovation are two mechanisms that run through enterprises and their upstream and downstream supply chains.

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Referring to the research of Miao et al. (2021), the number of green patent applications *gpatent* of enterprises is used as an indicator to reflect the level of green technology of enterprises[1]. Referring to the study of classic theory of "six elements" business model theory (Wei, et al. 2012), the score of firms on business model innovation is used as another mechanism variable.

The ratio of sales to top five customers and the ratio of purchases from top five suppliers are selected to reflect user orientation; the inventory turnover ratio and accounts receivable asset turnover ratio are selected to reflect business system; the return on assets and financial leverage are selected to reflect profitability; the ratio of R&D expenses to operating revenues is selected to reflect the ability of key resources; is selected to reflect cash flow structure; basic earnings per share reflect the earnings model; and the Tobin's Q value and ACF method are selected to reflect business model innovation. Using factor analysis to downscale all the indicators reflecting the six factors. Based on Gompers et al. (2022), mechanisms were tested using a group approach. Models (1) to (3) were tested in groups according to the mean values of the firm and the industry chain of green patent and business model innovation scores to examine the two influence mechanisms.

From the definition of ESG, it contains three main aspects of environment, society and governance, and green technology and business model are the important components, so such two influence mechanisms have also been paid attention by scholars in ESG-related fields (Deng et al., 2023; Chen et al., 2022). Table 1 reports the definitions and data sources of the main variables in Models (1) to (3).

Table 1.
Variable list.

	Variable	Variable construction	Data sources	Purports to measure...
Dependent variables	*esg*	score	CNRDS Green Finance Database	Integrated corporate environmental, social, and governance performance evaluated by scores
	esg_up			Average ESG performance of the upstream and downstream sectors in which the company operates
	esg_down			
Main explanatory variables	*digital*	Indicators obtained by entropy method	Peking University Digital Inclusive Finance Index China City Statistical Yearbook	Indicators of digital economy platform construction in cities where listed companies are located
	digitalf	Indicators obtained by factor analysis		
Mechanism variables	*gpatentup*	Average number of green patents in the upstream and downstream of the industry chain	CSMAR database	green technological innovation
	gpatentdown			
	modelup	Average number of business model innovation score in the upstream and downstream of the industry chain		business model innovation
	modeldown			
Control variables	*lngdp*	The natural logarithm of GDP of the city where the publicly listed company is in	CECN statistical database	Regional economic development
	poprate	Population growth rate the city where the publicly listed		

[1] The CSMAR database for green patents for publicly traded companies is updated through 2021. Therefore, when using this indicator, the study interval of the sample is shortened accordingly.

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		company is in		
	size	The natural logarithm of total assets	CSMAR database	Basic operation conditions and financial positions of publicly listed companies
	lnage	The year of the observation of a publicly listed company minus the year when it was established		
	roa	Return on assets		
	debt	Total liabilities divided by total assets		
	hhi	Herfindahl Index		
	cash	Currency funds of listed companies/business income		

4.3. Sample Selection and Data Sources

The sample type of this paper is the panel data of China's A-share listed companies from 2013-2022, which contains 4,482 A-share companies from more than 410 cities in China and listed in China's Shanghai and Shenzhen exchanges. The reason why 2013 to 2022 is chosen as the study interval. Since its entry into China, the ESG concept has continued to gain recognition from all sectors of society, and after 2012, the new central government has paid great attention to the development of ESG in enterprises. At the end of 2017, the CSRC improved the hierarchical system of environmental information disclosure for listed companies, and established the basic framework for disclosure of information on the environment, social responsibility and corporate governance in the 2018 revised Guidelines on the Governance of Listed Companies. Therefore, the period from 2013 to 2022 can be regarded as a complete period for Chinese companies from recognizing ESG to practicing ESG. In addition to being a way to be able to observe the impact effects of the digital economy over a long enough period of time, it is also because some of the firm- or city-level data is only updated until 2022.

The reason why we choose Chinese listed companies as the main research object of this paper is, on the one hand, because the listed companies themselves are the leading enterprises in each industry or region, which not only can better reflect the development characteristics of the industry or region, but also is the easiest way to get the policy support from all levels of government; on the other hand, from the point of view of data availability, the listed companies have a complete record of their financial, industry, geographic and other types of information. On the other hand, in terms of data availability, listed companies have more complete records in terms of financial, industry, geographic and other types of information, which is necessary for judging the location of the supply chain in which the enterprise is located, as well as for conducting standardized empirical research.

The data sources of this paper are as follows: First, the financial statement database, notes to financial statement database, and green patent application database of Chinese listed companies in the Cathay Pacific database (CSMAR), with some missing data supplemented by the Wind database; second, the ESG index of Chinese listed companies provided by the CNRDS platform; third, the input-output table provided by the National Bureau of Statistics (NBS) for the period 2012-2020; and fifth, the Dibble internal control index provided by Dibble Enterprise Risk Management Technology Co. 2020 input-output table provided by the National Bureau of Statistics (NBS); and fourth, regional development data provided by the CECN statistical database.

Based on the characteristics of the empirical samples and the general processing rules for research on Chinese listed companies (Liu et al., 2024), this paper matches and processes the data in the following steps: (i) Calculate the level of urban digital economy development and the degree of business model innovation of the enterprises in accordance with the methodology of the existing literature; (ii) All the listed companies' industry categories are summarized in the SFC Industry Classification (2012 edition); (iii) Match the industry classifications in the input-output table according to the SFC Industry Classification (2012 edition) to clarify the upstream and downstream industries of the industrial chain in which each listed company is located; (iv) Exclude the listed companies in the category of finance and

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insurance; (v) Perform linear interpolation for each major variable in the model, and exclude samples that still have missing samples after interpolation; (iii) Exclude listed companies that have been dealt with by ST, PT, or *ST. Eventually, the sample used in the empirical model of this paper contains 4,482 A-share companies listed in China's Shanghai and Shenzhen stock exchanges from 2013 to 2022, totaling 32,154 observations.

4.4. Endogeneity Concerns and Mitigation Solutions

Overall, there are three sources of endogeneity problems that tend to exist for firm-level micro-panel data types: first, mutual causality between the explanatory variables and the explanatory variables; second, the possible omission of other important influences in the empirical model; and third, the existence of certain measurement errors in the research design of the model or in the application of the econometric methodology. To address the above three possible endogeneity problems, the paper develops the following discussion and treats them accordingly.

4.4.1. Two-Way Causality

Although the strategy of developing the digital economy has risen to the national level in China, and data and digital information have become the fifth most important factor of development after land, labor, capital, and technology, the degree of input as well as the degree of output in the development of the digital economy varies from region to region in China. The level of digital economy construction is linked to the multifaceted characteristics of individual cities. Generally speaking, economically developed cities on the eastern coast have advantages over cities in central and western China in terms of infrastructure, personnel quality, and institutional safeguards, so their digital economy tends to develop faster. In turn, firms in these cities tend to pay more attention to the choice of their development model due to whether their concepts are in line with international standards or not. This link creates a bidirectional causality between the dependent variable, firms' ESG performance, and the independent variable, cities' digital economy development.

The selection of appropriate instrumental variables can help mitigate endogeneity problems. The selection needs to fulfill two conditions: first, the selected instrumental variable should be highly related to the development and construction of the city's digital economy; second, the selected instrumental variable should be largely independent of the environmental, social and governance performance of the firms. Tao Z et al. (2022) argued that the digital economy is related to the entrepreneurial vitality of the city. Therefore, this paper takes urban entrepreneurial vigor as an instrumental variable; in addition, considering that the development of digital economy is a long-term process that does not happen overnight, this paper chooses the lagged period of digital economy development variables as another instrumental variable. Theoretically, there is a close connection between the two selected instrumental variables and urban digital economic development, but there is no direct relationship between them and enterprise performance, and at the same time, through the test of instrumental variables, it is tested whether these two instrumental variables satisfy the required two conditions.

The results of the tests on the instrumental variables show that the selected instrumental variables passed the under-identification test and the weak instrumental variable test at the 1% significance level. This verifies the endogeneity of the model and the correlation between the instrumental variables and the independent variables. Also, the instrumental variables were unable to reject the original hypothesis of over-identification at the 10% significance level, which validates the exogeneity of the instrumental variables.

4.4.2. Omitted Variables

If the problem of omitted variables arises in the empirical model, then the omitted important influencing factors will enter into the random disturbance term, and there is often a certain degree of linkage between the variables, which will make the correlation between the explanatory variables and the random disturbance term, thus leading to the endogeneity problem. In order to reduce the possibility of omitted variables, referring to the study of Pan et al. (2020), on the one hand, city-level and macro-level influences are added into the control variables, i.e., the logarithmic value of the GDP of

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the city where the enterprise is located, the ratio of the tertiary industry where the enterprise is located, rate3, and the uncertainty index of the economic policy, so as to control the interference that may be caused to the ESG performance of the enterprise. ESG performance.

4.4.3. Measurement Error

The data sources in this paper are all from government departments or authoritative third-party data organizations, and the data quality is guaranteed, so the possible source of measurement error is the estimation bias caused by choosing different measurement methods. Considering that the type of data used in this paper is firm panel data, the two-way fixed effects model is the main measure when individuals and time are fixed. In order to ensure the robustness of the results from different methodological perspectives, regressions are performed not only using the random effects model (RE) and the cross-sectional least squares (PLS) method, but also using the Pseudo-Poisson Maximum Likelihood (PPML) method with reference to the study by Head and Mayer (2021).

4.4.4. Alternative Specification

The Hausman test shows that when comparing the Fixed Effect Model (FE) and the Random Effect Model (RE), the original hypothesis of no systematic difference between the two types of models is rejected at the 1% significance level (p=0.000), so the Two-Way Fixed Effect Model (TWFE), which is fixed in time and individuals, is chosen as the main measure. Therefore, the Two-way Fixed Effect Model (TWFE), which is fixed in time and individuals, was chosen as the main measure. Considering that the time span of the sample is 10 years and there are thousands of firms, the model is tested for heteroskedasticity and serial correlation, and the test results reject the hypothesis that there is no heteroskedasticity and serial correlation at the 1% significance level (p=0.000), therefore, the clustering standard error is chosen to mitigate heteroskedasticity and serial correlation in the regression, and the robustness test is performed using the Driscoll-Kraay standard error to test the heteroskedasticity and serial correlation. test. Finally, to avoid interference from outliers, all control variables were winsorized at the 0.5% level before and after.

5. Results

5.1. Descriptive Statistics

Table 2 reports the descriptive statistics of the explanatory variables, the explanatory variables, the mechanism variables, and the control variables. From the ESG performance of firms and the upstream and downstream of the industrial chain in which they are located, it can be found that the average ESG performance of Chinese listed firms in the study interval from 2013 to 2022 is 27.285 (with a total score of 100), whereas the overall ESG performance of the upstream of the industrial chain in which the firms are located is 4.079 and 4.082, respectively, and that of the downstream of the supply chain in which the firms are located is 27.396 and 26.721, respectively. are 27.396 and 26.721.

From the standard deviation of ESG performance, the dispersion of the variables are smaller than the average value, and the degree of dispersion is not high. From such results, we can know that, on the whole, the ESG performance of Chinese listed companies still scores low compared with companies in developed countries in Europe and the United States, and the construction of the ESG system is still in its infancy, and the overall ESG performance of the upstream industry chain in which the companies are located is slightly better than that of the downstream industry. So, in the background of China attaches great importance to the building of ESG system, what kind of factors affect the ESG performance of enterprises, and what kind of paths can improve the ESG performance of the whole supply chain, which is the research theme of this paper.

From the descriptive statistical information of the explanatory variable digital, it can be seen that the standard deviation of this variable is slightly higher than the mean, indicating that both the maximum and minimum values leave the mean by more than one standard deviation, and that the city with the best digital economy development scores close to 0.9, while the city with the lowest scores has a degree of digital economy development close to zero.

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Table 2.
Descriptive statistics.

Variable	No. of obs.	Mean	Std. dev.	Min.	25th	Median	75th	Max.
esg	32154	27.285	10.933	7.573	19.592	24.718	33.035	62.967
esg_up	31401	27.396	5.362	20.06	23.661	25.565	30.469	44.333
esg_down	31705	26.721	4.894	18.589	22.878	25.506	30.186	42.227
digital	29100	0.2	0.204	0.002	0.032	0.133	0.326	0.898
modelup	32082	-0.066	0.229	-0.549	-0.252	-0.07	0.073	0.694
modeldown	32082	0.119	0.318	-0.600	-0.099	0.114	0.350	0.910
gpatentup	27629	5.774	8.997	0.333	1.627	4.392	7.792	108.735
gpatentdown	27941	5.747	5.144	0.211	1.758	4.159	8.69	25.039
size	32154	22.256	1.319	19.542	21.317	22.061	22.99	26.739
lnage	32154	2.952	0.313	1.946	2.773	2.996	3.178	3.611
debt	32154	0.419	0.207	0.003	0.253	0.408	0.568	1.957
hhi	32154	0.336	0.148	0.071	0.222	0.312	0.433	0.774
roa	32154	0.034	0.074	-0.463	0.013	0.037	0.067	0.237
cash	32154	0.424	1.351	0.001	0.126	0.242	0.471	166.385

From the descriptive statistics of the mechanism variable upstream and downstream green patent index and business model score index, we can see that the average number of green patents applied for by Chinese listed companies upstream and downstream of the industry chain is about 5.7 per year, with a maximum value of more than 100, while the average value of the business model score is near the value of 0, with the lowest score equal to -0.6 and the highest score of 0.9. From such results, it can be found that, on one hand, the Chinese government has put forward the "carbon reach" concept. On the one hand, since the Chinese government put forward a series of green development concepts such as "Carbon Peak and Carbon Neutral", Chinese listed companies have invested more in green technology and the number of green patent applications has reached a record high; on the other hand, most listed companies have initially constructed a business model that is in line with the international standards, and the degree of innovation of the business model of a number of companies is already at the advanced level in the world. advanced level in the world. In this paper, green technology and business model are taken as the influencing mechanisms to analyze their roles in the development of digital economy.

From the descriptive statistical information of firm-level control variables, we can see that the average firm size of Chinese listed companies has exceeded 4.6 billion yuan, the average gearing ratio is close to 42%, the average shareholding ratio of the first=largest shareholder is 33.6%, the average return on assets is 3.4%, the ratio of money funds is 42.4%, and the average age of firms is 19 years. This information indicates that there are more significant differences among Chinese listed companies in terms of firm size, firm age, equity structure, debt level, cash flow constraints, and corporate earnings. The descriptive results of the mean, standard deviation and maximum value of each variable in Table 2 show that the observations of Chinese listed companies used in the sample have basically overcome the outlier interference after the corresponding shrinking and interpolation process.

5.2. Baseline Regression Results

The empirical results in Table 3 validate part of Hypotheses 1 and 2 put forward by the theoretical analysis department, i.e., after the level of digital economy development in the city where the enterprise is located is increased, it will not only enhance its own ESG performance, but also positively promote the overall ESG performance of the entire industrial chain downstream industries. As the theoretical analysis points out, the digital economy is an important part of China's future development strategy, as well as an aspect of scientific and technological innovation and application, and its development and implementation is an important initiative to realize the goal of "accelerating the green transformation of the development mode, and focusing on improving the resilience of the industrial chain and supply chain," which was put forward in the report of the 20th National Congress of the Chinese government.

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It is an important initiative to realize the goal of "accelerating the green transformation of the development mode and striving to enhance the resilience of the industrial chain supply chain" proposed by the Chinese government in the 20th National Congress Report.

In terms of the direction of ESG impact in the industry chain transmission, the ESG performance of the industry downstream of the industry chain in which the enterprise is located will improve along with the enterprise, while the upstream enterprises are not found to be significantly affected. The reason behind this is that for downstream industries, enterprises affected by the development of the digital economy are their first party, and downstream industries are their customers, so they will naturally cater to their first party's requirements more proactively and focus on enhancing the sustainability of their products, so ESG performance can be transmitted to downstream industries in the industry chain.

At the government level, a series of policies and regulations to promote the development of the digital economy have been continuously launched, and enterprises selected for the pilot list of many policies will not only receive support in terms of human, material and financial resources, but also preferential treatment in terms of taxation, land, facilities and training, etc. At the enterprise level, with the attention and impetus of all sectors of the society, Chinese enterprises represented by listed companies are accelerating the digital transformation work, focusing on upgrading green technology, improving internal governance structure, and ultimately, improving their internal governance structure, which will ultimately lead to the development of a green supply chain. technology, upgrading their own development model, and ultimately improving the sustainable development capability of the whole industrial chain.

Table 3.
Baseline results.

	(1)	(2)	(3)	(4)	(5)
Variable	***esg***	***esg***	***esg***	***esg_down***	***esg_up***
Digital	1.7586***	1.8389***	1.8389***	1.1822***	-0.6507
	(0.417)	(0.417)	(0.327)	(0.205)	(0.416)
Size		0.7785***	0.7785***	-0.0219	-0.0885*
		(0.111)	(0.042)	(0.026)	(0.053)
Lnage		2.5113***	2.5113**	-0.5941***	1.1395***
		(0.942)	(1.175)	(0.190)	(0.110)
Debt		1.9523***	1.9523***	-0.255	-0.9299***
		(0.442)	(0.450)	(0.193)	(0.079)
Hhi		2.7356***	2.7356***	0.5716***	-0.146
		(0.761)	(0.339)	(0.138)	(0.153)
Roa		0.6138	0.6138	0.6470***	-0.4025
		(0.718)	(1.046)	(0.179)	(0.616)
Cash		-0.0943***	-0.0943***	0.0008	-0.0047
		(0.032)	(0.016)	(0.003)	(0.011)
Cons	22.6656***	-2.714	-2.714	24.7572***	23.6471***
	(0.186)	(3.372)	(3.024)	(0.621)	(1.028)
Firm fixed effect	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
No. of obs.	29100	29100	29100	28685	28414
R^2_w	0.169	0.174	0.174	0.650	0.502

Note: ***, **, and * represent the 1%, 5%, and 10% significance level, respectively, and the standard error of double-tailed tests are included in parentheses. This notation applies to all tables below. The last three columns of the table use Driscoll-Kraay standard error adjustments. The standard errors are used below unless otherwise noted. R^2_w denotes between-group R^2.

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From the results of the firm-level control variables in the third column of Table 3, it can be found that the firms themselves perform better in terms of ESG as the size of the firm expands, the age of the firm increases, the debt leverage ratio increases, the money capital decreases, and the equity concentration increases, and the results remain significant at the 1% significance level, and that the change in these indicators suggests that the firms are expanding their production operations and therefore their sustainability performance is improved.

In contrast, the results of control variables in column 4 of the table can be seen that there is a decrease in the factors influencing the ESG performance of the firms on the downstream industry, and the age of the firms, the concentration of equity and the return on assets are the factors that are significant for the ESG performance of the downstream industry. From such results, we can know that for Chinese listed companies, the younger the enterprise, the higher the equity concentration and the higher the return on assets, the better their downstream industry's sustainable development performance tends to be, this is because these enterprises tend to be concentrated in the high-tech industry, with a higher level of production technology and more advanced business model, and at the same time are more likely to be supported by all levels of the government, so they are more important to the Therefore, their influence on downstream industries is relatively high (Wei et al., 2024; Chen et al., 2022).

5.3. Robustness Tests

5.3.1. More Controlling Variables and Alternative Methods

The first column of Table 4 reports results for more control variables, which were added to alleviate the problem of omitted variables. After adding other region-level control variables lngdp and rate3, the proxy variable for digital economic development still contributes to the esg performance of firms' downstream industries at the 1% significance level.

In order to mitigate measurement errors resulting from the choice of measurement method, columns (2) through (4) of Table 4 report the results obtained using PPML, RE, and the population-averaged method (PA). As can be seen from the results in the table, regardless of the methodology used, the increase in the level of digital economy development in the city positively affects the ESG performance of the downstream of the industry chain in which the company is located at the 1% significance level. Such results validate the point in the hypothesis from the perspective of mitigating measurement errors in the methodology.

Table 4.
Results with alternative empirical setups

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	esg_down					
	More control variables	**Alternative empirical methods**			**Alternative ways of computing variables**	**Two-way causality**
	PCA	**PPML**	**RE**	**PA**	**Factor**	**IV**
Digital	1.1963***	0.0233***	0.8281***	0.7397***		1.4175***
	(0.373)	(0.004)	(0.119)	(0.128)		(0.193)
Digitalf					0.1973***	
					(0.013)	
Size	-0.0149	-0.0014	0.0122	0.0175	-0.0219	-0.0287
	(0.049)	(0.001)	(0.028)	(0.029)	(0.026)	(0.038)
Lnage	-0.6138**	-0.0096	0.6328***	0.7139***	-0.6367***	-0.539
	(0.274)	(0.010)	(0.159)	(0.161)	(0.213)	(0.348)
Debt	-0.2566	-0.0049	-0.3587***	-0.3750***	-0.2431	-0.2596*
	(0.265)	(0.005)	(0.124)	(0.133)	(0.194)	(0.148)
Hhi1	0.5686**	0.0088	0.9444***	0.9958***	0.5620***	0.400
	(0.233)	(0.009)	(0.197)	(0.209)	(0.138)	(0.257)
Roa	0.6444**	0.0168**	0.7434***	0.7719***	0.6995***	0.7015***

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	(0.297)	(0.008)	(0.207)	(0.224)	(0.162)	(0.225)
Cash	0.0010	0.000	-0.0038	-0.0049	0.0006	0.0024
	(0.006)	(0.000)	(0.009)	(0.010)	(0.004)	(0.010)
Lngdp	-0.0037					
	(0.157)					
Rate3	-0.6898					
	(0.707)					
Cons	25.0374***	3.3489***	20.7122***	20.3976***	24.9131***	33.1060***
	(2.022)	(0.041)	(0.686)	(0.711)	(0.550)	(1.358)
firm fixed effect	Yes	Yes	No	No	Yes	Yes
year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	28685	28265	28685	28685	28685	24094
R^2_w/R^2_p	0.650	0.127	0.650	-	0.650	0.633

5.3.2. Alternative Variables and Instrument Variables

In order to overcome the endogeneity problem caused by the selection bias of the variable construction method, column (5) of Table 4 reports the regression results of the city's digital economy development indicators calculated using factor analysis. As can be seen from the results, the original findings remain unchanged after using *digitalf* as a proxy variable, with urban digital economy development still driving ESG performance downstream of the industry chain in which firms are located at the 1% significance level.

Two-way causality is one of the most significant sources of endogeneity problems. Finding the right instrumental variables is the key to solving this problem. One period of lag in the development of the digital economy is chosen as an instrumental variable in the choice of time series, and the level of urban entrepreneurship is chosen as another instrumental variable in the cross-section. The last column of Table 4 reports the instrumental variable regression results, from which it can be seen that the conclusions of the paper remain unchanged after adjustments using instrumental variables. It is known from the post-test of instrumental variables that the selected instrumental variables passed the weak instrumental variables as well as the unidentifiable test and the relevance of instrumental variables is recognized. At the same time, the two instrumental variables could not pass the Sargen test at the 10% significance level, indicating that the instrumental variables are indeed exogenous.

5.3.3. Tests for Underlying Mechanisms

Hypotheses 3 and 4 propose that green technology iteration and business model innovation are influential mechanisms for the transmission of corporate ESG performance to upstream and downstream industries, respectively. In order to test the ideas in these two hypotheses, Table 5 reports the results of group testing by using the average business model innovation score and the average number of green patent applications of the downstream industries in which the firms are located as the dividing criteria.

From the test results of the first two columns in Table 5, it can be seen that the development of the urban digital economy produces a higher impact on the ESG performance of the industry chain in which the firms are located when the downstream industry has a more advanced business model. As can be seen from the results of the test of differences between groups in the table, the differences in the impact results in different groups remain significant at the 1% significance level. This result suggests that business model innovation is indeed a mechanism by which the concept of sustainable development can be transmitted between the upstream and downstream of enterprises.

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Table 5.
Mechanism exploration.

Variable	(1)	(2)	(3)	(4)
	esg_down			
	Advanced business model	**Backward business model**	**High No. of green patents**	**Low No. of green patents**
digital	1.3629***	0.5369***	1.0122***	0.5089
	(0.351)	(0.067)	(0.140)	(0.410)
size	0.0193	-0.0193	-0.0107	-0.0419*
	(0.053)	(0.021)	(0.025)	(0.025)
lnage	-1.9357***	1.3934***	-2.7297***	0.4713*
	(0.181)	(0.414)	(0.479)	(0.244)
debt	-0.294	-0.252	-0.8408***	0.0737
	(0.195)	(0.185)	(0.141)	(0.214)
hhi	1.5241***	0.108	1.7313***	0.3640**
	(0.330)	(0.174)	(0.290)	(0.163)
roa	-0.3996***	0.7399**	0.4447***	0.6616***
	(0.092)	(0.338)	(0.149)	(0.152)
cash	-0.0124	0.00100	0.0210***	-0.00160
	(0.009)	(0.003)	(0.003)	(0.011)
cons	25.8024***	20.6543***	29.6363***	22.9188***
	(1.206)	(0.985)	(1.625)	(0.899)
p-value of Intergroup Fisher's permutation test	0.000		0.000	
Firm dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
No. of obs.	13990	14695	9964	15311
R^2_w	0.643	0.685	0.587	0.628

As can be seen from the results in the last two columns of Table 5, the transmission of the impact of digital economy development also has different results in industries with different numbers of green patents. Specifically, when the number of green patents in the downstream industry in which the firm is located is high, the impact of digital economy development on the average ESG performance of the industry is positive at the 1% significance level. By contrast, when the number of green patents in the downstream industry in which the firm is located is low, the impact of digital economic development on industry average ESG performance, while positive, fails to remain significant at a significance level of at least 10%. A further test of the difference in coefficients between groups shows that the results of the subgroup test remain significant at the 1% significance level. Such results suggest that green technological progress is likewise an influential mechanism for the digital economy to achieve transmission in the industry chain. In addition, if we compare the coefficients of business model innovation and green technology progress, we find that the mechanism of business model innovation is higher.

5.3.4. Heterogeneity Analysis

Table 6 reports the results of the heterogeneity analysis for the nature of property rights and for different regions. The results in the first two columns show that although there is a significant impact effect of digital economy development on the overall ESG performance downstream of the industrial chain in both SOEs and other firm type samples, the heterogeneity of the impact across property rights nature is not high as can be seen by comparing their numerical sizes as well as the coefficients of

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variation between groups. The reason for this result is that although state-owned enterprises may be higher than other enterprise types in terms of size and age, the efficiency of state-owned enterprises does not have a clear advantage in areas such as green technological progress and business model innovation, so although the development of the digital economy is more pronounced on the overall ESG performance of the downstream of the state-owned enterprises, the difference between the results of the samples with different property rights cannot be considered very high.

Table 6.
Heterogeneity analysis.

Variable	(1)	(2)	(3)	(4)
	esg_down			
	State-owned firms	**Other firms**	**East region**	**Middle and west region**
digital	1.4372***	1.1019***	1.0496***	0.7726***
	(0.193)	(0.186)	(0.172)	(0.094)
size	0.0727*	-0.0703***	-0.0757***	0.1409***
	(0.042)	(0.027)	(0.021)	(0.052)
lnage	0.1241	-1.1401***	-0.7028***	-0.0576
	(0.800)	(0.151)	(0.153)	(0.264)
debt	-0.8758***	0.113	0.0243	-0.6177**
	(0.213)	(0.129)	(0.110)	(0.301)
hhi	0.1898	1.0307***	0.6541***	0.1191
	(0.183)	(0.160)	(0.174)	(0.143)
roa	0.5895**	0.5773***	0.6708***	0.4853***
	(0.271)	(0.120)	(0.216)	(0.134)
cash	0.0049**	-0.0058	0.0052	-0.0005
	(0.002)	(0.007)	(0.006)	(0.003)
cons	21.4757***	26.6789***	25.8466***	20.8461***
	(1.669)	(0.770)	(0.401)	(1.036)
p-value of Intergroup Fisher's permutation test	0.100		0.199	
Firm dummy	Yes	Yes	Yes	YES
Year dummy	Yes	Yes	Yes	YES
No. of obs.	10231	18454	20388	8297
R^2_w	0.656	0.649	0.635	0.684

From the results of the last two columns, it can be seen that there is a significant effect of digital economy development on the overall ESG performance of the downstream of the industrial chain in both the eastern region and the central and western region samples, and by comparing the magnitude of their coefficients, it can be known that the digital economy has a higher impact on the ESG performance of the downstream of the industrial chain in the sample of the eastern region. However, it can be seen through the test of coefficient difference between groups that the results under both samples cannot remain significant at the 10% significance level. The reason for this result is that, on the one hand, the number of listed companies in the eastern region of China is higher than that in the central and western regions, so the greater impact of the development of the digital economy is on the listed companies in the east, and therefore, in terms of the size of the coefficient, the coefficient value is higher under the

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sample of the eastern region; on the other hand, compared with the enterprises in the central and western regions, the enterprises in the eastern region have higher hardware and software bases.

And the efficiency of the local government is also greatly ahead, and their performance in the ESG field is better, so for the central and western regions, the development of the digital economy is even more important for these enterprises, and if they can have a better level of development of the digital economy, the ESG performance of themselves and the upstream and downstream of the industrial chain in which they are located will also be better, which leads to the fact that in the coefficient difference between the groups, the results under the samples of the two groups do not have a significant difference.

To summarize, the results from Table 2 to Table 6 not only validate the main hypotheses of this paper, which is that the construction of a digital economy platform enhances corporate ESG performance and overall ESG performance downstream of the industry chain in which the company operates, but also two transmission mechanisms are revealed through which the development of the digital economy affects the overall ESG performance downstream of the industrial chain: business model innovation and green technology advancement. The paper also utilizes various standard error to mitigate heteroskedasticity, autocorrelation, and endogeneity problems due to mutual causality, omitted variables, and measurement errors; therefore, the results are more robust.

6. Discussion

6.1. Theoretical Implications

While the literature on the intersection between digital economy platforms and firms' ESG performance is sweaty, there are few studies on the overall ESG performance of firms upstream and downstream of the industry chain in which they are located, and this study contributes to the literature in this area. It is empirically demonstrated that the construction of urban digital economy platforms enhances the environmental, social and governance (ESG) performance of firms, as well as the overall ESG performance of the downstream of the industry chain in which the firms are located, and that this impact effect is more significant under the sample of state-owned enterprises (SOEs), and that there is no significant heterogeneity in terms of regions. Then, the reason why there is a significant impact on the downstream rather than the upstream of the industry chain in which the firms are located is because the target firms are their A-side relative to the downstream industry, and in order to obtain orders, firms in the downstream industry are more incentivized to upgrade their technology and upgrade their business models, which leads to a faster improvement in their overall ESG performance. This study expands the theoretical understanding of how digital infrastructure affects the sustainable development of the entire industrial chain.

6.2. Managerial and Policy Implications

For investors in the capital market, the research in this paper has the following benefits for their investments:(1) Fully understand the positive impact of the development of the digital economy. By studying the impact of urban economic development on corporate ESG performance, investors grasp the relationship between the two and the most popular ESG investment concepts. Investors can combine the digital economy strategy advocated by the state with ESG development concepts to form their own set of unique investment strategies (2) Clearly grasp the investment risks, the digital transformation promoted by the digital economy helps enterprises optimize their production processes, improve the efficiency of energy and resource use, and reduce the risk of environmental pollution and ecological damage. By studying the ESG impact of the digital economy on companies and the upstream and downstream industries in which they operate, investors can better assess the associated risks and adjust their investment strategies accordingly. (3) Investors can more easily identify potential investment opportunities. By understanding the digital transformation strategy, technology drive, and organizational empowerment of an enterprise, investors can better assess the ESG performance and development potential of the enterprise.

The digital economy has a profound impact on the ESG performance of enterprises and their upstream and downstream industrial chains, which has the following important implications for enterprise managers: (1) ESG is currently an advanced investment concept. Corporate managers should

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incorporate ESG management into their strategic planning and daily operations to ensure that their production activities comply with environmental regulations and social responsibility requirements. Establish a comprehensive ESG management system and reporting mechanism, and regularly disclose the ESG performance and improvement measures of the enterprise to stakeholders. (2) The upstream and downstream industries of the enterprise are closely interconnected, and attention should be radiated from individual enterprises to the entire industrial chain. Enterprise managers should actively promote technological innovation and cooperative innovation, and utilize new technologies and new models to enhance the ESG performance of enterprises. At the same time, they should strengthen cooperation with enterprises upstream and downstream of the industry chain to jointly promote ESG improvement and sustainable development of the industry.

From a policy perspective, policy implementers should actively promote the construction of an ESG evaluation system and develop scientific and reasonable ESG evaluation standards and methods. This can help assess the ESG performance of enterprises and identify their strengths and weaknesses in ESG, thus providing targeted guidance for enterprises to improve their ESG performance. At the same time, the ESG evaluation system can also provide investors with decision-making references and reduce investment risks. Policy implementers should improve the ESG disclosure system by requiring enterprises to publish regular ESG reports that disclose in detail their performance in environmental, social and governance aspects. This will help investors, consumers and other stakeholders to better understand the ESG performance of enterprises and make more informed investment and consumption decisions. At the same time, policy implementers should also strengthen the supervision of ESG disclosure to ensure that the information disclosed by enterprises is true, accurate and complete.

6.3. Limitations and Future Research Agenda

While this study makes its own contribution to the field of relevant academic research, there is a degree of limitation. The study of listed companies during the sample period of 2013-2022 may fall short in terms of the extended scope of the study interval. Future research could expand the sample to include listed companies in a longer study interval to validate and extend these results. In addition, exploring the spatial impact of digital economy platform building on corporate ESG performance. This paper has discussed the results of the urban digital economy in upstream and downstream relationships in the industrial chain on the ESG performance of firms and industries, which can provide a deeper understanding of the sustainability trajectory of firms from a spatial perspective. Future research can certainly also explore the most effective specific elements of business model innovation that affect ESG performance, as well as the role of government policies in promoting business model or green technology innovation.

7. Conclusion

In order to examine whether the development of urban digital economy will enhance the ESG performance of enterprises and radiate the impact to the upstream and downstream industries of the supply chain in which the enterprises are located. Through a literature and theory review, this paper first proposes that the development of urban digital economy not only enhances the ESG performance of enterprises, but also leads to the sustainable development of the upstream and downstream industries of the whole supply chain through two mechanisms, namely, green technological advancement and business model innovation. Subsequently, using a sample of 4,482 A-share companies listed on China's Shanghai and Shenzhen stock exchanges from 2013 to 2022, an empirical study was conducted with the fixed-effects model as the main methodology, and the results of the study show that:

First, when the city where the enterprise is located vigorously develops the digital economy, its own ESG performance will be significantly improved. In terms of effect size, when the city where the enterprise is located vigorously develops the digital economy, its ESG score will be increased by 1.8389. It should be said that since the Chinese central government upgraded the digital economy as a national strategy in 2012, its connotation and extension have been highly valued by all walks of life in the society. Under the goal of "peak carbon and carbon neutrality", linking the digital economy to the ESG

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performance of enterprises will undoubtedly be beneficial to the long-term sustainable development of enterprises, which provides an idea for realizing this ambitious goal.

Secondly, when the city where the enterprise is located vigorously develops the digital economy, the overall ESG performance of the industries upstream and downstream of the industry chain in which it is located will also be improved, and the overall ESG performance of the downstream industry chain will rise more significantly. In terms of impact size, when the city where the enterprise is located vigorously develops the digital economy, the overall ESG score of the downstream industries of the supply chain in which it is located will increase by 1.1822. "Accelerating the green transformation of the development mode, and focusing on improving the resilience of the industrial chain and supply chain" is the future development direction proposed by the Chinese government in the context of the rising global trade protectionism and the continuous recession of the world economy. While the Chinese government has put forward the future development direction, the conclusion of this paper affirms the industrial radiance of the pilot green supply chain management policy. Therefore, further expanding the number of enterprises included in the pilot work and enriching the content of the pilot work will contribute to the health and stability of the whole industrial chain and supply chain.

Next, in terms of impact mechanisms, the continuous improvement of green technology and the continuous optimization of business models are the two impact mechanisms by which the development of digital economy positively affects the sustainable development of enterprises and the whole supply chain. In terms of impact size, as the city where the enterprise is located vigorously develops the digital economy, the overall ESG performance of the industry chain in which the enterprise is located will rise more significantly in enterprises with faster green technology and higher business model innovation, with the difference of the coefficient size ranging from 0.50-0.83. From the perspective of the definition of ESG, environment and governance are important components, and both of them are also the meaning of green supply chain management. It can be seen that increasing human, material and financial investment in green technology research and development, and continuously improving the environment of the business model will make the enterprise and its entire industrial chain maximize the non-economic benefits.

Finally, the non-economic impact effect of digital economic development is heterogeneous in the nature of property rights. In terms of the nature of property rights, compared with other types of enterprises, the impact of the development of the digital economy is more significant in state-owned enterprises, and can be very effectively transmitted to the downstream industries of the supply chain in which the enterprise is located, but the effect also has a certain degree of influence in the private enterprises. This is because state-owned enterprises are the mainstay of China's economy, with stronger capital and human capital, while other types of enterprises have higher efficiency and stronger vitality, so they are better adapted to new concepts, ideas and development modes such as industry chain management and ESG. In contrast, there is no significant regional heterogeneity in the impact of the development of the digital economy on the industry chain in which enterprises are located.

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