Heliyon 10 (2024) e30784

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Information infrastructure and corporate green innovation quality incentive

Jianmin Liu [a], Xuan Meng [a], Qin Xia [b,*]

[a] School of Economics and Management, Nanchang University, China
[b] School of Finance, Nankai University, China

ARTICLE INFO

Keywords:
Information infrastructure
The quality of green innovation
Growth effect of innovation resource
Adaptive incentives

ABSTRACT

We use a sample of Chinese firms from 2006 to 2020 to investigate the effect of information infrastructure on the quality of green innovation. Findings show that information infrastructure significantly improves corporate green innovation quality, and information infrastructure improves the pricing efficiency, improves valuation levels, accelerates the flow of innovation resources, and induces the growth effect of corporate innovation resources. Furthermore, we find that executive salary incentives, internal control quality, and market-oriented environmental regulation have adaptive incentives for information infrastructure to improve the quality of green innovation. Our findings provide justification to promote the construction of an information infrastructure and adopt market-oriented environmental regulations to improve corporate green innovation quality.

1. Introduction

One of the problems in realizing green development is coordinating economic benefits and environmental values. Green innovation can solve this problem [1]. Green innovation refers to green technological innovation involving energy conservation [2]. The report of the 19th National Congress of the Communist Party of China [3] emphasizes building a green innovation system, which has become the core task of the country to promote green development to achieve harmonious economic development.

Compared with traditional technological innovation, green innovation contains the attributes of technological innovation, prioritizes environmental and resource protection [4]. Green innovation requires more investment [5], which indirectly hinders the motivation for green innovation. Green innovation shows the so-called "double externalities" [6], which has a positive impact on environmental protection [7]. On the one hand, green innovation has the positive externality of public knowledge.[1] Technological innovation is the process of producing new knowledge [2]. Initially, new knowledge belongs to the private knowledge category of innovative firms. When the private knowledge of innovative firms appears in the market to pursue high profits, other firms gradually spill over into public knowledge through operations such as learning, analysis, imitation, and copying. Public knowledge is nonexclusive and noncompetitive [8]. For other firms, the use of new knowledge related to innovative technology has the advantages of less investment, less risk, and quick income; however, it is difficult for innovative firms to deter other firms from applying new knowledge. The evolution of private knowledge into public knowledge leads innovative firms to bear a large amount of research and development

* Corresponding author.
E-mail address: xiaqin77@163.com (Q. Xia).

[1] Positive externality mean that the economic activities of one economic entity lead other economic entities to obtain additional economic benefits, and the beneficiaries do not have to pay the relevant costs [9].

https://doi.org/10.1016/j.heliyon.2024.e30784
Received 24 August 2023; Received in revised form 26 April 2024; Accepted 6 May 2024
Available online 10 May 2024
2405-8440/

(R&D) funds and personnel investment, but they cannot obtain the benefits, which leads to insufficient motivation for green innovation. By contrast, green innovation has positive externality for environmental protection. Green innovation is an economic activity that needs to commercialize green technological achievements [1], it has its own unique positive externality, that is, the externality of environmental protection that pollution discharge will bring to society and other enterprises. The costs of pollution treatment and environmental compliance that other firms should bear are underestimated; however, they enjoy the benefits of the environmental improvement for free. Other firms do not compensate for the R&D costs incurred by the green innovative firms [10]. Consequently, enterprises do not have enough motivation to participate in green innovation.

Green innovation has obvious positive externality. Under the current imperfect technical knowledge protection and pricing mechanism of environmental compensation, firms constantly invest in R&D funds and personnel; not only can they not enjoy all the due benefits and the cost compensation brought by green technology, but they also bear the risks of R&D failure and uncertain market prospects [11]. Due to the lack of adequate incentives, rational market players may lose motivation to participate in green innovation [4]. Improvement in corporate green innovation continues to face difficulties. It is imperative to research whether and how green innovation quality can be improved.

New infrastructure is one of the key measures for achieving the continuous transformation of Chinese momentum [12]. The Fifth Plenary Session of the 19th Central Committee in communist party of China pointed out to promote the construction of new infrastructure [16] and accelerated the development of digital China. Among them, information infrastructure based on information technology plays a primary role [17], which supports the current digital transformation of China and the transformation of economic growth momentum. New technology is the power for the transformation of old and new momentum, and information infrastructure means that new technology has replaced old technology as an important social, technical, and institutional phenomenon, which builds the operational foundation of the social system, contains new value logic, conventions, and norms, exerts legitimacy pressure on firms[2] [13], and affects corporate behaviors [14,15], encouraging firms to engage in technological innovative activities to avoid being eliminated from market competition. In addition, information infrastructure promotes industrial transformation, and the type of economic growth has changed from extension to connotation, no longer at the expense of the environment. In particular, new technologies, formats, and energy are natural in terms of environmental protection responsibilities, and information infrastructure contains environmental protection responsibilities. Its additional market value logic and norms encourage enterprises to engage in innovative activities. How can information infrastructure motivate firms to enhance innovation quality as an institutional environment? Related research has not been conducted to date.

Existing research on information infrastructure has focused on economic growth [18,19]. Koutroumpis's research confirms that the construction of broadband can promote economic growth [20]. Additionally, information infrastructure promotes knowledge dissemination among cities and is crucial for technological innovation [21,22]. With the deepening of research on the economic consequences of information infrastructure, scholars have gradually expanded their research scope from the macro level to the micro levels and pay attention to the relationship between information infrastructure and industrial innovation efficiency [23]. Li et al. study the influence of regional information infrastructure on the export performance of Chinese enterprises [24], and Lyytinen et al. [25], Wang et al. [26] and Xu et al. [27]discuss the influence of information infrastructure on the corporate innovation. However, research on the impact of information infrastructure on micro enterprises remains in its infancy. There is insufficient research on information infrastructure and green innovation. Given the economic transformation, upgrades, and environmental protection pressures, this problem is particularly urgent.

Our study makes the following contributions. First, from a research perspective, we enriched related research on information infrastructure and green innovation. Although literature emphasizes the significant role of information infrastructure in innovation [29] [-] [31], there is no special study on the quality of green innovation, and research on the related mechanisms, while research on information infrastructure and green innovation is extremely scarce. What is different is that we comprehensively and systematically study them; Secondly, in terms of mechanism, we suggest that the improvement of capital market pricing efficiency, cross-regional innovation resource flow and enterprise innovation resource investment growth are effective mechanisms for information infrastructure to affect enterprises' green innovation. The existing literature has studied how information infrastructure affects enterprises' green innovation based on mechanisms such as breaking space restrictions through knowledge spillovers [32] and reducing the regional flowing cost of green innovation elements [33], but the empirical tests of relevant mechanisms are insufficient. With the help of information infrastructure construction, this study conducts an empirical test, supplements existing theories, and analyzes the adaptive incentives generated by executive compensation incentives, internal control quality, and environmental supervision. We study the mechanism of information infrastructure to improve the quality of corporate green innovation, which provides strong support for whether and how information infrastructure can improve corporate green innovation quality.

2. Theoretical framework and hypotheses

The basis of corporate element input decisions is that the elements can obtain income and cost compensation. However, under the condition of a distorted element market [34], imperfect technical knowledge protection, and a pricing mechanism of environmental

[2] According to the new institutionalism of organizational sociology, legitimacy is the degree to which an organization's actions are accepted and recognized by various internal and external stakeholders in society, and the degree to which it is consistent with universally existing norms, rules, and beliefs [28]. When organizations obey the institutional pressure and follow the social norms of organizational structure and process, they can gain higher legitimacy when operating.

compensation, firms may not enjoy all the benefits and reasonable cost compensation brought about by green technology when investing in element resources for R&D. Therefore, executives tend to allocate fewer resources to high-quality green innovation activities and conduct more strategic innovation activities. The income prospects of high-quality green innovation are relatively unpredictable, R&D is difficult, and short-term performance remains unclear [35]. Particularly, uncertainty in the process of R&D may increase the risk of operations, and the risk of high-quality green innovation is greater than its benefits. Therefore, firms typically reduce their investments in high-quality green innovations.

2.1. Information infrastructure and corporate green innovation quality incentive

Hart finds that green innovation helps enterprises gain the support of suppliers and customers [36]. Enterprises can reduce emissions and produce more green-differentiated products [37], thus gaining new market share and improving green competitive advantage [38]. Consumer' acceptance of green products with green innovation continues to rise, and they can tolerate the product premium brought about by green products to a certain extent [39], further expanding the profit space brought about by green innovation. In the face of green-conscious consumers, downstream enterprises producing environmental-friendly products, and upstream enterprises using green technology, the pressure of green market demand forces enterprises to produce green innovation demand [40]. In this process, information infrastructure can improve the information efficiency and reduce transaction costs [41], thereby achieving green competitive advantage and green innovation in the future.

Information infrastructure is beneficial to realize the function of environmental protection. Information infrastructure aims at industrial upgrading and transformation, realizing a transition from economic extension to connotation growth [42]. It is no longer a traditional economic model at the expense of the environment but contains environmental protection responsibilities, especially new technologies, formats, and energy sources. Information infrastructure improves the transmission efficiency of information and capital flows and minimizes the emission reduction costs of enterprises [43]. Therefore, the information infrastructure is conducive to the realization of environmental protection functions and contains new market competition logic and norms. Enterprises often choose to improve innovative quality to adapt to new market competition logic and norms [44]. In addition, information infrastructure promotes the explosive growth of technical knowledge related to environmental protection, which improves the quality of green innovation.

Information infrastructure improves the income distribution mechanism of cooperative R&D among firms. Firms often adopt cooperative R&D strategy to improve high-quality technical innovation [45], so as to distribute as much income as possible. Information infrastructure helps to weaken the geographical boundary of element market, promote the element docking of cooperative R&D among firms [46], reduce the transaction cost of innovation element resources, and firms inclined to high-quality innovation have more opportunities to match the most advantageous innovation resource in the market and participate in more benefit distribution; on the other hand, information infrastructure can be used as the basis for firms to form new technologies, promote the growth of shared benefits, lower the cost of knowledge search and speed up exchange of data and information knowledge [47], weaken information asymmetry, and strengthen information transmission and cooperation among firms [48,49]. The convenience of technological knowledge diffusion has brought about more shared benefits, and the greater the corresponding contribution, the higher the income shared by the firms.

Information infrastructure is conducive to creating a compensation mechanism for green-technology transactions. With the help of information infrastructure, the transaction cost of technology has been reduced, and the frequency of technology transactions will be increased accordingly. This will improve technology trading systems in various places [50] and enhance the convenience and fairness of technology transactions. The increase in the frequency transactions triggered by information infrastructure is conducive to the formation of a fairer unit price of technical knowledge [43], further easing the resource constraints of R&D funds and personnel of firms and forming the incentives of green innovation quality. Specifically, on the one hand, information infrastructure promotes the pricing and identification of green technologies, and the R&D spending is reasonably compensated. Element suppliers can transfer the final technology to obtain reasonable or even excessive compensation [51], which will change the behavior decision of element suppliers, guide the rational allocation of innovation resources among enterprises, and encourage enterprises to invest in green innovation. Information infrastructure increases the trading frequency of green technology. The transaction price of green technology knowledge and innovation resources have decreased, and the marginal cost of innovation in the market has generally decreased [52]. The difference in green technology price signals the mismatch of external costs and benefits of innovation, and the original innovation cost of green innovation deviates from the general equilibrium level. A non-equilibrium state causes firms to optimize internal resources, improve the mismatch of innovation elements within firms, and encourages firms to improve the quality of green innovation. Therefore, hypothesis 1 is proposed.

Hypotheses 1. Information infrastructure is conducive to encouraging firms to improve the quality of green innovation.

2.2. Capital market response

Green innovation has high risk and uncertain income, which makes it difficult for enterprises to obtain external financing [53]. Green innovation emphasizes low pollution, low emissions, and products can be recycled, with a higher technology and capital threshold, longer payback period, greater uncertainty, and lower salvage value in case of failure [54]. Therefore, it is difficult for enterprises to win the favor of banks and other financial institutions for green innovation. However, to reduce the risk of being imitated or stolen by competitors, enterprises are often reluctant to disclose too many details about their products and technologies to the outside world. Even if the relevant information is disclosed, external investors cannot scientifically evaluate the value of green patents because of a lack of professional knowledge [55]. In addition, investors must spend considerable manpower and material resources when screening green projects. As a weak party in information acquisition, it easily faces adverse selection and moral hazards [56], which further weakens its willingness to invest in green projects. According to Schumpeter's innovation theory, the key to the success of innovation activities is whether sufficient cash flow can be obtained [57]. Green innovation faces financing constraints easily because of the long R&D cycle and high income uncertainty, which is not adverse to the development of innovation activities [58].

In capital markets, fair capital market valuation is often based on idiosyncratic information [59], which is an objective interpretation and evaluation of a corporate green innovation quality in the capital market. As dynamic information flows, idiosyncratic information forms capital market valuation in the capital market valuation system and the market structure [60]. Capital market valuation determines the distribution of interest between two or more parties. When the capital market positively evaluates the future value of the quality of corporate green innovation, the valuation premium increases. Capital market valuation premiums can guide the flow of resources into enterprises with good-quality green innovation, produce incentive effects [][][] [61].

Information infrastructure is conducive to creating a signal transmission mechanism, improving the efficiency of market capital allocation [62], and forming a fair valuation premium for firms. If the stock price reflects real information, the closer it is to the real value of a firm [63]. Nonfinancial information [64], such as corporate innovation, plays an increasingly important role in capital market pricing. High-quality green innovation can send true and credible signals of corporate innovation ability to the capital market, whereas strategic green innovation cannot. Real and credible signals enable investors to accurately identify innovation. The packaging of strategic green innovations into high-quality technological achievements increases the transmission costs of false-positive signals [11]. More importantly, information technology makes that the possibility of identifying false-positive signals has increased, which may improve investors' avoidance psychology. Therefore, hypothesis 2 is proposed.

Hypotheses 2. Information infrastructure is conducive to improving the pricing efficiency of the capital market and the valuation level of firms.

2.3. Information infrastructure, cross-regional innovation resource flow, and green innovation quality

Information infrastructure is conducive to reducing the information asymmetry caused by space-time distance, optimizing the allocation of factor resources between regions, and guiding innovative resources to flow into enterprises that carry out green innovation [65]. Information infrastructure breaks geographical boundaries through knowledge spillover and linking the economic activities of enterprises in different regions [32], and reduces the regional mobility cost of green innovation elements [33]. Therefore, information infrastructure accelerates the flow of R&D funds and personnel (in particular, it reduces information asymmetry between suppliers and demanders of innovation resources, which is conducive to the cross-regional flow of capital and personnel) [65]., optimizes the allocation of innovation elements, and reduces the mismatch of innovation resource elements between regions and enterprises. Information infrastructure has changed the behaviours of enterprises [66]. When enterprises engage in green innovation activities, the information infrastructure may break down spatial barriers, which is conducive to the cross-regional inflow of innovative resources into enterprises.

On the one hand, information infrastructure is conducive to cross-regional capital flowing into green innovation enterprises, and provides financial support. Information infrastructure can produce technology diffusion and information transmission effects, break geographical restrictions [67], enhance the attractiveness of location selection of manufacturers in a region, attract the inflow of innovative capital from other regions, help enterprises increase investment in green innovation, and reduce the cost of environmental violations. However, the information infrastructure can produce cross-regional absorption effects on human resource elements. Information infrastructure helps gather human capital [27], brings about the rational allocation of human resource elements across regions and provides high-quality talents for corporate green innovation. Therefore, hypothesis 3 is proposed.

Hypotheses 3. Information infrastructure breaks down the space barrier, which is conducive to innovation resources flowing into green innovation enterprises.

2.4. Information infrastructure, enterprise innovation resources investment, and green innovation quality

Green innovation has the characteristic of greater investment, longer cycles, and higher uncertainty [68], which hinder enterprises' enthusiasm for green innovation. First, enterprises need to continuously invest considerable human and financial resources. According to accounting standards, the R&D funds needed for innovation must be included in expenses in the current period, which increases current costs, depreciation, and amortization expenses, directly leading to a decline in current income [69]. Second, before green innovation results truly transform into economic benefits, high R&D expenses may increase product prices, lead to a decline in sales, and expand business risks.

Information infrastructure has a network spillover effect, which not only makes the flow of information and knowledge more effective [70], but is also more conducive to the rational allocation of green innovation resources within enterprises. Specifically, information infrastructure provides enterprises with a platform for sharing and exchanging innovative resources, thus comprehensively reducing the transaction cost of resource allocation [71]. Information infrastructure often improves the informatization level of enterprises, which is conducive to the operation and activation of technical resources reserves [72]. Whether an enterprise can successfully innovate depends on whether it has knowledge reserves for absorbing, utilizing, and transforming technology [73]. Therefore, the more funds and personnel an enterprise invests, the more likely it is to use information to activate technical resource reserves. Information infrastructure can reduce the transaction cost of innovation for enterprises, improve the degree of differentiation from competitors, and bring competitive advantages for enterprises in the green product market [39]. To maintain a leading position, enterprises with relative technological advantages must continue to increase investment in R&D, while other enterprises at a relative disadvantage will also increase R&D funds and personnel investment to improve their weak position. Therefore, we propose the following hypotheses.

Hypotheses 4. Information infrastructure produces the growth effect of enterprise innovation resources investment.

H4a. Information infrastructure encourages enterprises to increase their R&D investments.

H4b. Information infrastructure encourages enterprises to increase their investments in R&D personnel.

3. Research design

3.1. Regression specification

We estimate the following baseline regression model:

$$gti_{it} = \alpha_0 + \alpha_1 infra_t + \sum control + \sum year + \sum industry + \varepsilon_{it} \quad (1)$$

Here, gti_{it} represents the quality of green innovation. $Infra_t$ indicates the information infrastructure in a certain area. *control* represents control variables, and ε_{it} is the error term.

3.2. Sample selection

In our study, Chinese firms from 2006 to 2020 were selected and screened according to the following criteria: elimination of the sample with missing relevant data; elimination of ST and *ST firms, eliminate firms in the financial industry, and eliminate samples with abnormal values.

The related data on information infrastructure come from the China Internet Network Information Center, the China Statistical Yearbook. We collected data from 30 provinces; as the data for Tibet, Hong Kong, Macao and Taiwan were incomplete, they were not included in the analysis. Green patent data were obtained from the China Stock Market & Accounting Research database(CSMAR). Other data were calculated using the CSMAR. Missing data were replaced with data from the following year. This yielded a final sample of 10753 observations. All variables have been winsorized in both the lower and upper 1 % quantiles. We first deconcentrated the continuous variables contained in the interaction item and then multiplied them to eliminate the influence of multicollinearity.

3.3. Variable definitions

3.3.1. Dependent variables

Invention patents are usually regarded as important indicators of innovation quality because they have more significant technical improvements and stricter examination procedures than utility model patents [74]. Utility models and industrial designs reflect firms' number of green innovations more accurately [75]. The costs of utility models and industrial design are lower, which can shorten the innovation cycle, reduce innovation risk, and contribute to firms' value growth. Therefore, we design the indicators of green innovation from the dimensions of quantity and quality, which is more in line with the real green innovative behavior of enterprises in China.

Quality and quantity are two important attributes that are inseparable from everything. The quality of things is reflected by their quantity. If there is no quantity, then there is no quality. However, in practice, the green innovation is caught in the dilemma of "emphasizing and neglecting quality" [76]. Enterprises tend to favor strategic activities such as utility models and designs that highlight their performance in a short time [77,78], to obtain government-supported funds and tax incentives, further exacerbating the problem of "a large number and lame quality." In view of this, the variable explained in this study not only adopts the green quality of enterprises but also examines the number of green innovations. In addition, considering that strategic innovation is the main performance measure of Chinese enterprise practices, we examine the strategic green innovation. Based on studying the quality of green innovation, a systematic investigation of quantity and strategic green innovation aims at identifying and supporting enterprises with policy orientation, which is the core issue of enterprise green innovation incentive policy.

Corporate green innovation quality (gti)

Based on Kim et al. [79], we use the citations of authorized green patents as a proxy. The more citations, the greater the application value. Specifically, we take the natural logarithm of one plus the total number of authorized green patents at time t, and exclude the number of self-citations. There were three reasons for this. First, there may be unqualified patents in the applied green patents, so the number of authorized green patents is more scientific. Second, the higher the quality of green patents, the more likely they are to be cited, so the citations of green patents can well represent the quality of corporate green innovation. Third, among the cited patents, there are some patents cited by firms themselves, so eliminating them can truly reflect innovation quality. Considering that some authorized green patents have never been cited during the sample period, we exclude firms whose citations of authorized green patents during our sample period were zero, further enhancing the credibility of the conclusions.

Corporate strategic green innovation (ugp)

We proxy for corporate strategic green innovation by citing authorized green utility model patents. Firms with zero utility model patents during our sample period are excluded [80].

Corporate green innovation quantity (tgp)

We use the total number of authorized green patents as a proxy, following prior research. Firms with zero authorized green patents during this period were excluded.

3.3.2. Independent variables

Information infrastructure (infra). In 1996, China issued the Informatization Level Index (II) to evaluate the levels of informatization development in various regions of China. Röller and Waverman [81], Datta and Agarwal [82] and Koutroumpis [20] studied the selection of information infrastructure indicators (e.g., telephone service price, number of telephone lines per 100 households and fixed broadband speed). Following prior research, considering availability and timeliness, we measured the information infrastructure from four dimensions: construction, platform, application, and development of information infrastructure.

First, modern transportation facility networks often need to apply modern information technology, and the transmission and diffusion of information technology will also be affected by modern transportation facilities, such as high-speed rail. Drawing on Sun and Xu [23], we incorporate transportation infrastructure into the information infrastructure index system. We chose broadband access ratio, broadband access households per capita, highway density, and railway density to measure information infrastructure. Second, the prior indicators failed to reflect the new information technology represented by digital transformation. Digital inclusive finance, domain names, netizens, and websites represent the breadth and depth of the information infrastructure in the digital application platform. Therefore, we chose the digital inclusive finance index, domain names, netizens, and websites to measure the platform level of information infrastructure. We use road freight volume per capita, railway freight volume per capita, mobile phone penetration rate, employment in information, computer and software industries to measure the application level, as well as software revenue, total telecom services, telecommunication traffic, and new product revenue of industrial firms to measure the development level.

After standardization of the indicators, principal component analysis(PCA) was used to measure the information infrastructure. The eigenvalues of the matrix in Table 1 show that there is a strong positive correlation among the original indicators, and that PCA is feasible. The eigenvalues of the first four principal components were all greater than one, and the cumulative contribution was 83.73 %. Therefore, we select the first four principal components as the standard for calculating the information infrastructure index.

3.3.3. Control variables

We control the micro-characteristics that affect corporate green innovation. Considering that Regional GDP, urbanization rate, expenditure on energy conservation affect corporate technological progress and environmental protection, respectively; we add these three macro-control variables. See Table 2.

4. Empirical analysis

4.1. Descriptive statistics

Table 3 shows that the mean of tgp is 0.918, and the sd is 1.077. There are differences in the total number of corporate green patents. The mean of gti is 1.367, and the sd is 1.236. However, corporate green patent citations differed significantly. The mean of ugp is 0.777, and the sd is 0.988. The maximum of the information infrastructure is 4.483, the min is −1.971, and the sd is 1.557. The level of information infrastructure development varies significantly across different regions.

Table 1
Dimensional description of information infrastructure and eigenvalue of matrix.

Aspect	Variables	Eigenvalue	Difference	Proportion	Cumulaitive
Construction	Broadband access ratio (per 100 people)	8.4653	6.0695	0.5291	0.5291
	Broadband access households per capita (households)	2.3958	0.8874	0.1497	0.6788
	Highway density	1.5083	0.4808	0.0943	0.7731
	Railway density	1.0275	0.3715	0.0642	0.8373
Platform	Digital inclusive finance index	0.6561	0.1675	0.0410	0.8783
	ln domain names	0.4886	0.1288	0.0305	0.9088
	ln netizens	0.3597	0.1208	0.0225	0.9313
	ln websites	0.2389	0.0326	0.0149	0.9463
Application	Road freight volume per capita (ton/person)	0.2063	0.0413	0.0129	0.9591
	Railway freight volume per capita(ton/person)	0.1650	0.0103	0.0103	0.9695
	Mobile phone penetration rate (per 100 person)	0.1547	0.0595	0.0097	0.9791
	Employment in information transmission, computer service and software industry (%)	0.0952	0.0130	0.0060	0.9851
Development	ln software revenue	0.0823	0.0100	0.0051	0.9902
	ln total telecom services	0.0723	0.0192	0.0045	0.9947
	ln telecommunication traffic	0.0532	0.0221	0.0033	0.9981
	ln new products revenue of industrial firms above designated size	0.0310		0.0019	1.0000

Note: The data in the table were obtained from the authors' calculations and arrangements.

Table 2
Variable definitions.

Variables	Definition
gti	Corporate green innovation quality, defined as the citations of authorized green patents at time t
ugp	Corporate strategic green innovation, defined as the citations of authorized green utility models
tgp	Corporate green innovation quantity, defined as the total number of authorized green patents
infra	information infrastructure. Principal component analysis of regional data
cash	Cash holdings, defined as the balance of cash/total assets
ppe	Fixed assets ratio, defined as the net fixed assets/total assets
roa	Net profit/total assets
size	Ln total assets
debt	Total liabilities/total assets
ind	Independent directors' percentage
growth	(Current operating income-previous operating income)/previous operating income
duality	A variable that equals one if the chairman concurrently serves as CEO, and zero otherwise
urb	Urbanization rate
energy	Regional fiscal expenditure on energy conservation and environmental protection
gdp	Regional GDP
year	Year fixed effect, the sample period is 2006–2020.
industry	Industry fixed effect, industry code classification of China Securities Regulatory Commission (CSRC) 2012

4.2. Baseline regression

The variance expansion factor (VIF) test indicated that, as shown in Table 4, the variance expansion factors of all variables in the model were less than five, and the average VIF was 1.97, indicating that there was no severe multicollinearity.

We use Ordinary Least Squares (OLS) regression in our main analyses and adopt the fixed effects model of gradually adding year and industry dummy variables. Columns (1)–(2) in Table 5 show that the estimated coefficients on infra are positive at the statistical level of 1 %, suggesting that information infrastructure can significantly improve the quality of corporate green innovation, proving H1. Consistent with a prior study [44], information infrastructure bears the responsibility for environmental protection and contains new market competition logic and norms. Firms often choose to improve innovation quality to adapt to the logic and norms of new market competition.

It is noteworthy that columns (3)–(6) show that the estimated coefficients on infra are all positive, indicating that information infrastructure can also increase the total amount of green innovation and stimulate enterprises for strategic green innovation.

4.3. Information infrastructure and capital market reaction

4.3.1. Pricing efficiency

Stock price synchronicity reflects the explanatory degree of listed corporate characteristic information on stock returns, which is a widely used measure the pricing efficiency of capital market [83–85]. The lower the stock price synchronicity, the higher the pricing efficiency [83]; The higher the stock price synchronicity, the less heterogeneous information of enterprises is reflected, resulting in synchronization between stock prices and market fluctuations, reducing the pricing efficiency, and leading to low the efficiency of resource allocation. Referring to the prior literature [84], we first regressed the return of stock:

$$R_{i,w,t} = \beta_0 + \beta_1 R_{M,w,t} + \beta_2 R_{M,w-1,t} + \beta_3 R_{I,w,t} + \beta_4 R_{I,w-1,t} + \varepsilon_{i,w,t} \quad (2)$$

where $R_{i,w,t}$ is the return rate of stock i in week w of year t, considering cash dividend reinvestment, $R_{M,w,t}$ is the average return rate of

Table 3
Descriptive statistics.

Variables	N	min	max	mean	sd
gti	10753	0.000	5.323	1.367	1.236
ugp	7637	0.000	6.519	0.777	0.988
tgp	8971	0.000	6.900	0.918	1.077
infra	10753	−1.971	4.483	2.175	1.557
cash	10753	0.0110	0.580	0.148	0.109
ppe	10753	0.004	0.695	0.220	0.160
debt	10753	7.210	93.71	45.60	19.70
growth	10753	−0.493	2.028	0.163	0.344
roa	10753	−25.25	18.72	3.528	6.002
size	10753	20.16	28.46	22.59	1.387
duality	10753	0.000	1.000	0.254	0.435
ind	10753	0.333	0.571	0.374	0.054
energy	10753	0.251	7.474	2.349	1.550
urb	10753	38.70	89.30	66.88	12.94
gdp	10753	0.483	11.08	4.645	2.883

Table 4
VIF matrix.

Variables	VIF	1/VIF
infra	4.96	0.201586
cash	1.38	0.723085
ppe	1.26	0.792654
debt	1.84	0.542707
growth	1.09	0.914354
roa	1.35	0.741937
size	1.58	0.633133
duality	1.07	0.934224
ind	1.02	0.975686
energy	2.29	0.435741
urb	2.75	0.363066
gdp	3.08	0.324281
Mean VIF	1.97	

Table 5
Baseline regression.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	gti	gti	ugp	ugp	tgp	tgp
infra	0.152***	0.140***	0.093***	0.102***	0.093***	0.098***
	(8.159)	(7.496)	(4.627)	(5.115)	(4.696)	(5.055)
cash	0.435***	0.433***	0.243**	0.369***	0.232**	0.405***
	(3.812)	(3.958)	(2.162)	(3.418)	(2.117)	(3.963)
ppe	−1.066***	−0.730***	−0.411***	0.055	−0.603***	−0.178**
	(-14.785)	(-8.570)	(-5.305)	(0.653)	(-7.873)	(-2.158)
debt	−0.002***	−0.001	0.003***	0.004***	0.002***	0.003***
	(-3.127)	(-1.121)	(4.155)	(5.197)	(2.648)	(4.449)
growth	−0.021	−0.092***	−0.091***	−0.103***	−0.109***	−0.148***
	(-0.626)	(-2.930)	(-2.810)	(-3.266)	(-3.382)	(-4.762)
roa	−0.004**	−0.000	0.007***	0.008***	0.003*	0.007***
	(-2.182)	(-0.238)	(3.338)	(4.364)	(1.689)	(3.986)
size	0.369***	0.422***	0.209***	0.210***	0.260***	0.253***
	(34.030)	(38.891)	(15.748)	(16.944)	(18.421)	(20.791)
duality	0.057**	0.036	0.144***	0.142***	0.128***	0.131***
	(2.322)	(1.512)	(5.378)	(5.735)	(5.018)	(5.588)
ind	0.406**	0.433**	0.406*	0.619***	0.014	0.368*
	(2.031)	(2.238)	(1.896)	(3.021)	(0.067)	(1.868)
energy	0.063***	0.051***	0.026**	0.025**	0.035***	0.030***
	(5.551)	(4.774)	(2.272)	(2.311)	(2.963)	(2.820)
urb	−0.007***	−0.006***	−0.007***	−0.009***	−0.007***	−0.009***
	(-4.632)	(-3.902)	(-4.562)	(-6.330)	(-4.617)	(-6.242)
gdp	−0.030***	−0.031***	0.006	−0.004	0.009	−0.001
	(-4.150)	(-4.515)	(0.846)	(-0.653)	(1.226)	(-0.211)
_cons	−6.497***	−8.089***	−3.950***	−4.665***	−4.389***	−5.155***
	(-24.080)	(-26.782)	(-12.405)	(-14.666)	(-13.477)	(-16.453)
industry	No	Yes	No	Yes	No	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
N	10753	10753	7637	7637	8971	8971
Adj R^2	0.231	0.327	0.115	0.253	0.127	0.286

Note: The test statistics are reported in parentheses. ***, ** and * represent the statistical significance of 1 %, 5 % and 10 %. The same below.

the circulating market value of all firms, and $R_{I,w,t}$ is the average return rate of other stocks of year t and week w. According to the classification of the CSRC 2012, R^2 was calculated. Ln R^2 to obtain $SYN_{i,t}$, which represents the stock price synchronicity:

$$SYN_{i,t} = \ln(R^2_{i,t} / (1 - R^2_{i,t})), \quad (3)$$

Column (1) of Table 6 shows that the estimated coefficient of *infra* is negative and significant, indicating that the construction of information infrastructure reduces information asymmetry, enables the stock price to fully reflect the firm's characteristic information, reduces SYN, and improves pricing efficiency. H2 is partly supported.

4.3.2. *The valuation level of the firm*

Information infrastructure is conducive to creating a signal transmission mechanism for high-quality green innovation and induces a fair valuation premium in the capital market. Capital market valuation premiums can guide the flow of resources into firms with green innovation. We chose the price-to-book (PB) ratio as an indicator to measure the valuation levels of listed firms. Column (2) shows the estimated coefficient of *infra* is also significantly positive, suggesting that information infrastructure has improved the valuation level of firms and produced a reward effect. Thus, H2 has been confirmed.

4.4. Information infrastructure and the flow of innovation elements

The industrial concentration model uses the total industrial output value, industrial added value, or employees to calculate the industrial share or industrial concentration and judges whether the industry is transferred by comparing the changes in industrial share or concentration in different regions in different years. In a certain period, if the share or concentration of an industry in a certain region increase, it is considered that the industry has shifted to that region [86]. Drawing on the industrial concentration model, this study chooses the proportion of regional R&D expenditure to national in the current year and the proportion of regional R&D expenditure to national in the previous year to measure the flow of capital elements. The results of Table 7 show the estimation coefficient of infra is positive, indicating that the construction of regional information infrastructure is conducive to breaking through geographical boundaries, facilitating the flow of resources into enterprises, and improving the quality of green innovation. Thus, H3 is confirmed.

4.5. Information infrastructure and growth effect of corporate innovation resources

Based on prior literature [87], we proxy R&D capital investment (rd) by the proportion of R&D investment in income and proxy R&D personnel investment (human) by the proportion of R&D personnel among all employees. The significantly positive coefficients of *infra* in Table 8 indicate that information infrastructure encourages firms to increase investments in order to improve the quality of green innovation. Thus, H4 has been confirmed.

4.6. Heterogeneity analysis

Differences in the level of information infrastructure construction and market segmentation form the factor endowment conditions of cities, which are reflected in the differences in urban wealth. In practice, different regions are at different stages of green innovation, which further affects its direction of green innovation. Low-wealth areas are highly dependent on resources and often choose strategic green innovation; middle-high-wealth areas are more inclined to choose to improve innovation quality. The firms were divided into middle- and low-wealth areas for the analysis.

Based on prior literature [88], we construct a comprehensive index of urban wealth from three perspectives: economic, social, and ecological. The economic dimension includes the natural logarithm of regional GDP and the natural logarithm of fiscal revenue, including the number of beds in health institutions, the number of doctors, the number of books in public libraries, the natural logarithm of students in colleges, the road area per capita, and public transport ownership per capita, while the ecological dimension includes the green coverage rate and the harmless treatment rate of garbage. After standardization of the above 11 indicators, a principal component analysis was carried out, and the first two components were selected as indicators to measure urban wealth. We divide the urban wealth value by year and classify the areas below one-third as low-wealth areas and the rest as middle-high wealth areas. Table 9 shows that the estimated coefficient of infrastructure in column (1) is significantly positive, while in column (2) is not significant, showing that information infrastructure has promoted green innovation in middle-to-high wealth areas rather than in low wealth areas. At the same time, as can be seen from columns (3)–(6), information infrastructure has promoted the strategic green innovation activities of firms in different areas and increased the total amount of green innovation.

4.7. Robustness test

4.7.1. Instrumental variable

Terrain relief affects the quality and operational efficiency of information infrastructure, which is correlated, and usually does not directly affect green innovation; it is exogenous and can be used as an IV of information infrastructure. Simultaneously, the information infrastructure between rural and urban areas is relevant and meets the relevant conditions, and the rural information infrastructure does not have a direct impact on innovation. Therefore, rural information infrastructure[3] was also selected as an IV. We use two-stage least squares regression in the analyses.

The DWH estimation results indicate that the model may have endogeneity problems. The results of the first-stage estimation indicate that the IVs are correlated. The Cragg-Donald Wald test show that there is no weak IV. This further demonstrates the effectiveness and robustness of using terrain relief and rural information infrastructure as IVs. The results in column (1) of Table 10 are consistent with the baseline regression.

4.7.2. Differences-in-Differences(DID)

Since the 18th National Congress of the Communist Party of China, China has attached great importance to the construction of an

[3] The principal component analysis is carried out by using seven indicators, namely, the kilometers of delivery lines, the population coverage rate of radio programs, the number of broadband access households, the proportion of television households, the number of village clinics set up by township hospitals, the expenditure of local finance on urban and rural social affairs, and the proportion of villages with clinics.

Table 6
Capital market reaction.

Variables	(1)	(2)
	SYN	PB
infra	−0.047**	0.269**
	(-2.197)	(2.012)
_cons	−5.015***	30.026***
	(-16.657)	(11.241)
controls	Yes	Yes
industry	Yes	Yes
year	Yes	Yes
N	10648	10727
Adj R^2	0.328	0.053

Table 7
R&D capital flow.

Variables	(1)
	Flow
infra	0.004***
	(23.730)
_cons	0.016***
	(5.894)
controls	Yes
industry	Yes
year	Yes
N	10753
Adj R^2	0.517

Table 8
Growth effect of corporate innovation resources.

Variables	(1)	(2)
	rd	human
infra	0.004***	0.696***
	(6.467)	(3.175)
_cons	0.094***	38.210***
	(9.769)	(8.312)
controls	Yes	Yes
industry	Yes	Yes
year	Yes	Yes
N	9918	7057
Adj R^2	0.447	0.436

Table 9
Heterogeneity analysis.

Variables	Middle-high wealth	Low wealth	Middle-high wealth	Low wealth	Middle-high wealth	Low wealth
	(1)	(2)	(3)	(4)	(5)	(6)
	gti	gti	ugp	ugp	tgp	tgp
infra	0.139***	0.102	0.108***	0.346***	0.099***	0.338***
	(6.558)	(1.027)	(4.927)	(2.812)	(4.583)	(3.106)
_cons	−8.604***	−1.172	−4.689***	−3.199**	−5.295***	−2.330**
	(-27.551)	(-1.278)	(-14.413)	(-2.338)	(-16.292)	(-2.287)
controls	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
N	10049	704	7262	375	8463	508
Adj R^2	0.331	0.354	0.250	0.463	0.281	0.488

information infrastructure and identified 117 "Broadband China " demonstration cities. Therefore, we take the establishment of "Broadband China" to represent the construction of information infrastructure, and systematically evaluates the influence of "Broadband China" on green innovation by using multi-period DID method. When a city is approved as a pilot city of "Broadband China" and after that, the variable equals one, and zero otherwise. Column (4) of Table 10 shows that our main results are robust.

4.7.3. Key variables lag by one period

Considering that previous infrastructure has an impact on the current green innovation quality, to address this concern, we lag variables by one period. Columns (1)–(3) of Table 11 show that the estimated coefficients on *infra* have improved to a certain extent and are significantly positive. After the endogeneity problems are alleviated, the information infrastructure has a stronger driving effect.

4.7.4. Change the independent variable

Referring to Sun and Xu[4] [23], we use the weighted average method to calculate the information infrastructure (infra2). The calculation of the information infrastructure indicators is shown in model (4), where $n = 1$, $W_1 = 25$ %, and $m = 16$. The results in Columns (4)–(6) are consistent with our main analyses.

$$\mathbf{infra2} = \sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{W_i} \left(\sum_{\mathbf{j=1}}^{\mathbf{n}} \frac{\mathbf{1}}{\mathbf{m}} \mathbf{P_{it}} \right) \tag{4}$$

4.7.5. Control the fixed effect of provinces and firms

The fixed effects of provinces and firms are further controlled. The resuts of Column (7) further support the conclusion of this study.

5. Further analyses: adaptive incentives

5.1. Adaptive incentives generated within firms

Information infrastructure creates an institutional environment for corporate green innovation and forms new business rules and value networks that require firms to form an adaptive incentive structure [89,90]. The internal adaptive incentive structures of firms cause their willingness to innovate. Therefore, internal adaptive incentive factors such as executive salaries and internal controls influence the incentive effect of information infrastructure on innovation. We add the interaction item of information infrastructure and internal incentive factors to Model (1) and investigate the role of executive salary and internal control quality.

5.1.1. Executive salary incentives

Firstly, executive incentives often lead firms to actively adapt to information infrastructure, reduce the asymmetry of technical information, and improve technical reserves and application capabilities. Second, green innovation is risky and long-term, and executives' opportunism and short-sighted behavior will make them care only about the short-term interests, but not long-term performance [91], thus hindering the improvement of corporate green innovation quality. Therefore, firms should encourage executives to actively promote green innovation, and executive incentives should become the driving force for firms to actively adapt to external information infrastructure and improve green innovation. We use the executive salary to represent the level of executive incentives, which is the natural logarithm of the salaries of the top three executives. Column (1) of Table 12 shows the estimated coefficient of *infra_salary* is significant, indicating that executive salary incentives have enhanced the incentive effect of information infrastructure on green innovation.

5.1.2. Internal control quality

Internal controls can prevent internal personnel from misappropriating green innovation resources. The IC index published by the DIB Database [92] was used to represent the internal control quality of firms, and the interaction item *infra_IC* was added to the model for analysis. Column (4) of Table 12 shows that the coefficient of *infra_IC* is positive, indicating that internal control quality also enhances the incentive effect of information infrastructure on corporate green innovation quality.

5.2. External adaptive incentives generated by environmental regulation

As a policy activity, environmental regulation has certain guiding and restricting effects on the direction of an enterprise's resource allocation. First, national environmental policies seriously affect public consumption orientation. Environmental regulation triggers a growing demand for green consumption in the market, which stimulates enterprises' motivation for environmental protection and emission reduction [93], thus guiding enterprises to actively seek green technology upgrades. Simultaneously, with the gradual in-depth understanding of the low-carbon life' development concept in the social environment, consumers' acceptance of using green

[4] Sun and Xu [23] weighted three indicators, namely, telephone ownership, TV ownership and computer ownership, to calculate the new infrastructure index value.

Table 10
Instrument variables and DID methods.

Variables	IV			DID		
	(1)	(2)	(3)	(4)	(5)	(6)
	gti	ugp	tgp	gti	ugp	tgp
infra	0.175**	0.062	0.047	0.089***	−0.020	0.039
	(1.987)	(0.579)	(0.486)	(3.270)	(-0.673)	(1.416)
_cons	−7.909***	−4.848***	−5.389***	−8.762***	−5.133***	−5.598***
	(-14.976)	(-8.114)	(-9.929)	(-30.639)	(-16.877)	(-18.747)
controls	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
N	10753	7637	8971	10753	7637	8971
Adj R^2	0.326	0.253	0.285	0.324	0.251	0.284

Table 11
Other robustness test.

Variables	Key variables lag by one period			Change the independent variable			Control the fixed effect of provinces and firms		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	gti	ugp	tgp	gti	ugp	tgp	gti	Ugp	tgp
infra	0.148***	0.109***	0.112***	0.064***	0.054***	0.040**	0.127**	0.144**	0.106
	(6.704)	(4.877)	(5.071)	(3.425)	(2.865)	(2.131)	(1.976)	(2.063)	(1.627)
_cons	−8.690***	−5.075***	−5.802***	−8.701***	−5.049***	−5.548***	−4.375***	−2.822**	−2.734***
	(-25.376)	(-14.066)	(-16.678)	(-30.291)	(-16.570)	(-18.509)	(-4.469)	(-2.506)	(-2.626)
controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	8851	6312	7414	10753	7637	8971	Yes	Yes	Yes
Adj R^2	0.349	0.266	0.300	0.324	0.251	0.284	Yes	Yes	Yes

products continues to rise, which can tolerate the product premium brought about by green products, further expanding the profit space and forming a virtuous circle. Second, enterprises are more willing to introduce green technology into production processes in order to slow down the negative impact on the increase in product costs, thus achieving the effect of compressing product costs at both ends and enabling relevant departments to reach the internal "cost-benefit" balance more quickly. Therefore, under the constraints of environmental regulation, enterprises will stimulate their willingness to innovate, whether for the purpose of catering to the government, meeting the market demand for green consumption, or reducing environmental costs.

It is becoming increasingly important to stimulate green innovation through environmental regulations [94]. Under the influence of environmental regulation, firms focus more on high-quality innovation. In addition, information infrastructure is responsible for environmental protection in the transformation of old and new momentum, and information infrastructure is restricted by

Table 12
Adaptive incentives generated within firms.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	gti	ugp	tgp	gti	ugp	tgp
infra	0.149***	0.105***	0.105***	0.141***	0.103***	0.100***
	(7.994)	(5.281)	(5.370)	(7.517)	(5.182)	(5.146)
infra_salary	0.064***	0.021*	0.040***			
	(6.598)	(1.960)	(3.964)			
salary	0.176***	0.122***	0.342***			
	(9.057)	(6.007)	(3.341)			
infra_IC				0.019***	0.003	0.011*
				(3.088)	(0.418)	(1.844)
IC				0.027**	0.010	0.023**
				(2.317)	(0.854)	(2.109)
_cons	−9.592***	−5.638***	−6.258***	−8.018***	−4.659***	−5.119***
	(-28.796)	(-15.399)	(-17.985)	(-26.585)	(-14.521)	(-16.243)
controls	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
N	10753	7637	8971	10680	7588	8909
Adj R^2	0.334	0.257	0.292	0.328	0.254	0.287

environmental regulations in the process of operation. Environmental regulation includes market-oriented and command-oriented. Market-oriented environmental regulations primarily adopt carbon emission rights and environmental rights trading. Command-oriented environmental regulation mainly adopts administrative means such as environmental law enforcement, energy control, and government subsidies [95]. Market-oriented environmental regulation guides the optimal allocation of innovative resources, provide flexible and effective innovation incentives [96,97], and induce normative isomorphism in firms. Command-oriented environmental regulation is usually a supplementary measure to market-oriented environmental regulation that produces the mandatory isomorphism of firms. Based on Model (1), the interaction item of information infrastructure and environmental regulation is added to investigate the role of environmental regulation.

5.2.1. Adaptive incentive generated by market-oriented environmental regulation

In recent years, China has advocated more market-oriented regulation, and guided enterprises to protect the environment by using economic means such as collecting sewage charges. Therefore, we use the provincial sewage charges to represent market-oriented environmental regulation (fee). Column (1) of Table 13 shows that the estimated coefficient of *infra_fee* is positive, indicating that market-oriented environmental regulation positively regulates the relationship between information infrastructure and green innovation. The results of columns (2)–(3) indicate that market-oriented regulation does not stimulate green innovation quantity or corporate strategic innovation.

5.2.2. Adaptive incentives generated by command-oriented environmental regulation

In practice, when market-oriented regulation is imperfect, command-oriented regulation is typically used as a substitute or supplement to encourage firms to innovate. The comprehensive index of environmental regulation (eri) reflects government' control over the total amount of environmental pollution as a proxy variable for command-oriented environmental regulation. The eri was calculated from industrial wastewater, SO_2, and soot discharges. The above three data points were standardized, the weight of each pollutant was obtained, and a comprehensive index of environmental regulation was obtained by multiplying the weight and standardization. Column (4) of Table 13 shows that command-oriented regulation have no significant incentive effect on green innovation.

6. Conclusions

6.1. Research conclusions

Information infrastructure undertakes the dual responsibilities of momentum transformation and environmental protection, creates an institutional environment in which new technologies replace old ones, induces firms to optimize the allocation of innovation resources, and drives them to improve the quality of green innovation. Our studies show that information infrastructure significantly improves innovation quality. Information infrastructure improves the pricing efficiency of the capital market and a firm's valuation level, accelerates the flow of innovative resources, and induces the growth of innovation resources in firms. Moreover, we find that executive salary incentives, internal control quality, and market-oriented environmental regulations provide adaptive incentives for information infrastructure to improve innovation quality. In addition, information infrastructure has significantly improved corporate green innovation quality in middle-to-high wealth areas compared with low wealth areas.

6.2. Policy suggestions

First, maintain information infrastructure construction ahead of schedule and continue to promote the upgrading of regional informatization. The current information infrastructure is still not advanced, even relatively backward, in some areas, and there are problems such as the timely update. Informatization involves the updating of various technologies. If the technology is backward or not updated on time, it will affect the informatization construction process. A reasonable lead can create isomorphic effects, produce adaptive incentive structures, and provide firms with sufficient green innovation space. With the continuous development of green technology, temporarily idle information infrastructure will not only be outdated and eliminated, but will also correctly guide and accelerate the upgrading of green technology.

Second, market-oriented environmental regulation encourages firms to increase green innovation investments. Currently, environmental regulation focuses on command-oriented regulation, whereas market-oriented regulation has not yet played a greater role. The results showed that command-oriented regulation is ineffective. Therefore, efforts should be made to improve the construction of a policy system for green and low-carbon development, establish a long-term management mechanism for emission reduction, and comprehensively promote green economic and social transformation. Make full use of market-oriented regulation, make rational use of policy tools, and effectively improve the efficiency of innovation.

Third, the middle-high- and low-wealth areas promote the construction of information infrastructure at different levels and effectively promote high-quality green innovation cooperation among regions. Given the different elemental endowments in different regions, the incentive effect on green innovation differs. Middle-high wealth regions should play a demonstration and leading role and drive low-wealth regions to realize the transformation of momentum to realize the effect of high-quality green innovation in value creation.

Finally, we improve executive incentives and internal control mechanisms, and establish an internal adaptive incentive structure for corporate green innovation. Corporate organizational structure and governance mechanisms are directly related to green innovation. Firms should reconstruct the governance structure; improve the mechanism of executive incentives and internal control;

Table 13
External adaptive incentives generated by environmental regulation.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	gti	ugp	tgp	gti	ugp	tgp
infra	0.178***	0.092***	0.103***	0.152***	0.092***	0.093***
	(8.397)	(4.057)	(4.629)	(6.723)	(3.806)	(3.981)
infra_fee	0.035***	−0.010	0.005			
	(4.006)	(-1.096)	(0.570)			
fee	−0.020	−0.009	−0.004			
	(-1.283)	(-0.580)	(-0.270)			
infra_eri				0.010	−0.012	−0.007
				(0.699)	(-0.816)	(-0.496)
eri				−0.138***	−0.020	−0.060**
				(-4.947)	(-0.747)	(-2.194)
_cons	−7.762***	−4.592***	−5.087***	−7.885***	−4.676***	−5.092***
	(-22.268)	(-12.754)	(-14.154)	(-26.184)	(-14.645)	(-16.175)
controls	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
N	10753	7637	8971	10753	7637	8971
Adj R^2	0.327	0.253	0.286	0.328	0.253	0.286

promote the cooperation of business, personnel, finance, and other functional departments; improve the efficiency of organization and management; rationally allocate innovative resources.

6.3. Limitations

Our studies have a few limitations: first, there may be defects in the measurement of information infrastructure construction, and it is difficult to measure its relationship with regional endowment and other factors, which is not adequately detailed; second, governments in different regions may focus on different green technology to meet the strategic layout needs of these regions. These policies introduce uncertainty and affect the adjustment needs of enterprises regarding green innovation strategies. Finally, the economic cycle has an important influence mechanism on information infrastructure construction and enterprise green innovation, which is also worthy of further targeted discussion. However, this study lacks empirical evidence of the expected relationship.

6.4. Future prospects

The future research directions are as follows: First, at present, information infrastructure in different regions of China is unbalanced and inadequate, such as backwardness and untimely updating in rural areas, restricting corporate innovation quality. Therefore, future research should consider how to promote the construction of information infrastructure in a tailored and classified manner according to local conditions, how to continuously innovate mechanisms within firms, build an adaptive incentive structure to adapt to the external informatization process. Second, in the process of the continuous transformation of old and new momentum of China, how to coordinate the development of traditional infrastructure and information infrastructure, and how to build a composite index to measure information infrastructure are worthy of future study.

Data availability statement

Links to all data sources.
CNNIC: https://www.cnnic.net.cn/
China Statistical Yearbook:https://www.stats.gov.cn/sj/ndsj/
Ministry of Industry and Information Technology: https://wap.miit.gov.cn/
CSMAR:https://data.csmar.com/
DIB Internal Control and Risk Management Database: http://www.ic-erm.com/pro1.html.

Research support

This research received no external financial or non-financial support.

Relationships

There are no additional relationships to disclose.

Patents and intellectual property

There are no patents to disclose.

Other activities

There are no additional activities to disclose.

Funding

The authors declare that no funds, grants, or other support was received during the preparation of this manuscript.

CRediT authorship contribution statement

Liu Jianmin: Writing – review & editing, Supervision, Methodology, Conceptualization. **Meng Xuan:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Xia Qin:** Writing – review & editing, Writing – original draft, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] R. Kemp, A. Arundel, K. Smith, Survey indicators for environmental innovation, Conference Towards Environmental Innovation Systems 3 (2002) 46–62.
[2] OECD, Technology and the Economy: the Key Relationship, Paris, Organization of Economic Co-operation and Development, 1992.
[3] Xi Jinping, Winning the decisive battle, building a well-off society in an all-round way and winning the great victory of Socialism with Chinese characteristics in the new era —— a report in the 19th National Congress of the Communist Party of China. https://www.gov.cn/zhuanti/2017-10/27/content_5234876.htm, 2017.
[4] L. Han, Z. Xiao, Y. Yu, Environmental judicature and enterprises' green technology innovation: a revisit of the porter hypothesis, J. Asian Econ. (2024), https://doi.org/10.1016/j.asieco.2023.101693.
[5] C. Montalvo, General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990–2007, J. Clean. Prod. 16 (2007) S7–S13, https://doi.org/10.1016/j.jclepro.2007.10.002.
[6] K. Rennings, Towards a theory and policy of eco-innovation - neoclassical and (Co-)Evolutionary perspectives, Zew Discuss. Pap. (1998). http://hdl.handle.net/10419/24575.
[7] Q. Gao, C. Cheng, G. Sun, Big data application, factor allocation, and green innovation in Chinese manufacturing enterprises, Technol. Forecast. Soc. Change (2023) 192, https://doi.org/10.1016/j.techfore.2023.122567.
[8] J.E. Jackson, D.C. King, Public goods, private interests, and representation, Am. Polit. Sci. Rev. 83 (1989) 1143–1164, https://doi.org/10.2307/1961662.
[9] A. Marshall, Priciples of Economics[M], Macmillan, London, UK, 1920.
[10] A. Xu, M. Song, S. Xu, W. Wang, Accelerated green patent examination and innovation benefits: an analysis of private economic value and public environmental benefits, Technol. Forecast. Soc. Change (2024) 200, https://doi.org/10.1016/j.techfore.2023.123105.
[11] Y. Xu, X. Meng, J. Liu, Information infrastructure , market-oriented environmental regulation and high-quality green innovation of enterprises, SCIREA Journal of Economics 8 (2023), https://doi.org/10.54647/economics790424.
[12] K. Wu, Y. Ye, X. Wang, Z. Liu, H. Zhang, New infrastructure-lead development and green-technologies: evidence from the pearl river delta, China, Sustain. Cities Soc. 99 (2023), https://doi.org/10.1016/j.scs.2023.104864.
[13] T.L. Broekhuizen, M. Broekhuis, M. J Gijsenberg, J.E. Wieringa, Introduction to the special issue – digital business models: a multi-disciplinary and multi-stakeholder perspective, J. Bus. Res. 122 (2021) 847–852, https://doi.org/10.1016/j.jbusres.2020.04.014.
[14] J.W. Meyer, B. Rowan, Institutionalized organizations: formal structure as myth and ceremony, Am. J. Sociol. 83 (1977) 340–363. http://www.jstor.org/stable/2778293.
[15] L.J. Hartley, J.W. Sawaya, Tortoise, not the hare: digital transformation of supply chain business processes, Bus. Horiz. 62 (2019) 707–715, https://doi.org/10.1016/j.bushor.2019.07.006.
[16] Xinhuanet.com, What is the new infrastructure? Available from: http://www.xinhuanet.com/politics/2020-04/26/c_1125908061.htm.
[17] Renmin Ribao, The National Development and Reform Commission held a press conference and said: Economic operation is recovering in an orderly manner, Available from: https://www.gov.cn/xinwen/2020-04/21/content_5504561.htm.
[18] R. Ward, L. Zheng, Mobile and fixed substitution for telephone service in China, Telecommun. Pol. 36 (2012) 301–310, https://doi.org/10.1016/j.telpol.2011.12.002.
[19] W. Pan, B. Han, Empirical study on economic growth of urban agglomerations based on informatization, Scientific Research Management 39 (2018) 289–297, https://doi.org/10.19571/j.cnki.1000-2995.2018.ZK.038.
[20] P. Koutroumpis, The economic impact of broadband on growth: a simultaneous approach, Telecommun. Pol. 33 (2009) 471–485, https://doi.org/10.1016/j.telpol.2009.07.004.
[21] X. Huang, W. Liu, Z. Zhang, X. Zou, P. Li, Quantity or quality: environmental legislation and corporate green innovations, Ecol. Econ. 204 (2023), https://doi.org/10.1016/j.ecolecon.2022.107684.
[22] Z. Yu, C. He, Can the construction of information infrastructure improve the level of urban green innovation-an empirical analysis based on 108 prefecture-level cities in the Yangtze River Economic Belt, Resources and Environment in the Yangtze River Basin 32 (2023) 1834–1848.
[23] Z. Sun, Y. Xu, Can information infrastructure construction improve the innovation efficiency of high-tech industries in China? -Empirical analysis based on panel data of 17 high-tech industries from 2002 to 2013, Nankai Economic Research 2 (2018) 72–92, https://doi.org/10.14116/j.nkes.2018.02.005.
[24] K. Li, W. Shao, Y. Wang, Information density, information infrastructure and enterprise export performance-theoretical and empirical analysis based on enterprise heterogeneity, Manag. World 4 (2015) 52–65, https://doi.org/10.19744/j.cnki.11-1235/f.2015.04.006.
[25] K. Lyytinen, Y. Yoo, J.R. B Jr., Digital product innovation within four classes of innovation networks, Inf. Syst. J. 26 (2016) 47–75, https://doi.org/10.1111/isj.12093.

[26] L. Wang, H. Chen, S. Chen, Information infrastructure, technic link and corporate innovation, Finance Res. Lett. 56 (2023), https://doi.org/10.1016/j.frl.2023.104086.
[27] S. Xu, H. Chen, S. Dong, Z. Guo, Can upgrading information infrastructure improve the innovation ability of companies? Empirical evidence from China, Telecommun. Pol. 47 (2023), https://doi.org/10.1016/j.telpol.2023.102569.
[28] M.C. Suchman, Managing legitimacy: strategic and institutional approaches, Acad. Manag. Rev. 20 (1995) 571–610, https://doi.org/10.5465/amr.1995.9508080331.
[29] B. Patrakosol. Interorganizational relationships and innovation: an empirical investigation of the effects of IT infrastructure, Task Characteristics and Tie Strength 67-07(2006) 2651, The University of Nebraska, Lincoln, 2006.
[30] C. Tang, Y. Xu, Y. Hao, H. Wu, Y. Xue, What is the role of telecommunications infrastructure construction in green technology innovation? A firm-level analysis for China, Energy Econ. 103 (2021), https://doi.org/10.1016/j.eneco.2021.105576.
[31] L. Qiu, Does internet infrastructure construction improve corporate green innovation? Evidence from China, Sustainability 15 (2023), https://doi.org/10.3390/su15010807, 807-807.
[32] M. Storper, A.J. Venables, Buzz: face-to-face contact and the urban economy, J. Econ. Geogr. 4 (2004) 351–370, https://doi.org/10.1093/jnlecg/lbh027.
[33] A.B. Bernard, A. Moxnes, Y.U. Saito, Economics - political economics; investigators at dartmouth college discuss findings in political economics (production networks, geography, and firm performance), Politics Government Week 127 (2019) 639–688, https://doi.org/10.1086/700764.
[34] Z. He, N. Hui, Does the distortion of factor market inhibit the improvement of green innovation efficiency —— the moderating effect of high-tech industrial agglomeration, Sci. Technol. Prog. Policy 39 (2022) 75–84, https://doi.org/10.6049/kjjbydc.2022030475.
[35] T. Liu, X. Cao, Going green: how executive environmental awareness and green innovation drive corporate sustainable development, Journal of the Knowledge Economy (2024), https://doi.org/10.1007/s13132-024-01788-1.
[36] O. Hart, Corporate governance: some theory and implications, Econ. J. 105 (1995) 678–689, https://doi.org/10.2307/2235027.
[37] Y. Tu, W. Wu, How does green innovation improve enterprises' competitive advantage? The role of organizational learning, Sustain. Prod. Consum. (2021), https://doi.org/10.1016/j.spc.2020.12.031.
[38] J. Barney, Firm resources and sustained competitive advantage, J. Manag. 17 (1991) 99–120, https://doi.org/10.1177/014920639101700108.
[39] M. Wang, M. Chen, F. Yang, The optimal subsidy scheme and technology innovation strategy considering consumers' green premium, Asia Pac. J. Mark. Logist. 34 (2022) 1573–1595, 10.1108/APJML-05-2021-0351.
[40] Z. Wang, E. Chu, Can information infrastructure construction make "emission reduction" and "efficiency improvement" have both? -From the perspective of green technology innovation, Modern finance and economics 43 (2023) 74–89, https://doi.org/10.19559/j.cnki.12-1387.2023.10.005.
[41] F. Dong, Y. Li, C. Qin, X. Zhang, Y. Chen, X. Zhao, C. Wang, Information infrastructure and greenhouse gas emission performance in urban China: a difference-in-differences analysis, J. Environ. Manag. (2022), https://doi.org/10.1016/j.jenvman.2022.115252.
[42] P. Zhang, J. Wang, M. Li, et al., Research on the mechanism of information infrastructure affecting industrial structure upgrading, Sci. Rep. 12 (2022), https://doi.org/10.1038/s41598-022-24507-9.
[43] F. Dong, Y. Li, C. Qin, et al., Information infrastructure and greenhouse gas emission performance in urban China: a difference-in-differences analysis, J. Environ. Manag. 316 (2022), https://doi.org/10.1016/j.jenvman.2022.115252.
[44] M. Yang, S. Zheng, L. Zhou, Broadband internet and enterprise innovation, China Econ. Rev. 74 (2022), https://doi.org/10.1016/j.chieco.2022.101802.
[45] Y. Wu, F. Gu, Y. Ji, J. Guo, Y. Fan, Technological capability, eco-innovation performance, and cooperative RD strategy in new energy vehicle industry: evidence from listed companies in China, J. Clean. Prod. 261 (2020), https://doi.org/10.1016/j.jclepro.2020.121157.
[46] R. Crescenzi, L. Gagliardi, The innovative performance of companies in heterogeneous environments: the interplay between external knowledge and internal absorptive capacities, Res. Pol. 47 (2018) 782–795, https://doi.org/10.1016/j.respol.2018.02.006.
[47] P. Almeida, B. Kogut, Localization of knowledge and the mobility of engineers in regional networks, Manag. Sci. 45 (1999) 905–917, https://doi.org/10.1287/mnsc.45.7.905.
[48] P. Hendriks, Why share Knowledge?The influence of ICT on motivation for knowledge sharing, Knowl. Process Manag. 6 (1999) 91–100, https://doi.org/10.1002/(SICI)1099-1441(199906)6:2<91::AID-KPM54>3.0.CO;2-M.
[49] A. Kaufmann, P. Lehner, F. Tödtling, Effects of the Internet on the spatial structure of innovation networks, Inf. Econ. Pol. 15 (2003) 402–424, https://doi.org/10.1016/S0167-6245(03)00005-2.
[50] X. He, X. Ji, Building a national digital technology trading platform and speeding up the high-quality development of the national technology trading market, Think Tank of Science & Technology 12 (2022) 12–14, https://doi.org/10.19881/j.cnki.1006-3676.2022.12.02.
[51] B. Cinzia, F. Giovanna, P. Elena, Technology transfer services impacts on open innovation capabilities of SMEs, Technol. Forecast. Soc. Change (2023) 196, https://doi.org/10.1016/j.techfore.2023.122875.
[52] Y. Jiang, J. Xu, G. Wang, Trade in green patents: how do green technologies flow in China? J. Technol. Tran. (2023) https://doi.org/10.1007/s10961-023-10006-0.
[53] Z. Jiang, C. Xu, J. Zhou, Government environmental protection subsidies, environmental tax collection, and green innovation: evidence from listed enterprises in China, Environ. Sci. Pollut. Control Ser. 30 (2023) 4627–4641, https://doi.org/10.1007/s11356-022-22538-3.
[54] Y. Honjo, M. Kato, H. Okamuro, R&D investment of start-up firms: does founders' human capital matter? Small Bus. Econ. 42 (2014) 207–220, https://doi.org/10.1007/s11187-013-9476-x.
[55] J. Wang, The impact of investor communication on enterprise green innovation, Finance Res. Lett. 57 (2023), https://doi.org/10.1016/j.frl.2023.104158.
[56] C. Liu, L. Tian, Can the endorsement of talent policy promote enterprise innovation, China Industrial Economy 3 (2021) 156–173, https://doi.org/10.19581/j.cnki.ciejournal.2021.03.009.
[57] M. Rossi, G. Festa, A. Devalle, J. Mueller, When corporations get disruptive, the disruptive get corporate: financing disruptive technologies through corporate venture capital, J. Bus. Res. 118 (2020) 378–388, https://doi.org/10.1016/j.jbusres.2020.07.004.
[58] D. Aboody, B. Lev, Information asymmetry, R&D, and insider gains, J. Finance 55 (2000) 2747–2766, https://doi.org/10.1111/0022-1082.00305.
[59] Y. Wang, Y. Zhou, Green finance development and enterprise innovation, J. Finance Econ. 49 (2023) 49–62, https://doi.org/10.16538/j.cnki.jfe.20220615.101.
[60] M. Schreder, Idiosyncratic information and the cost of equity capital: a meta-analytic review of the literature, J. Account. Lit. 41 (2018) 142–172, https://doi.org/10.1016/j.acclit.2018.07.001.
[61] G. Feng, P. Niu, J. Wang, J. Liu, Capital market liberalization and green innovation for sustainability: evidence from China, Econ. Anal. Pol. 75 (2022) 610–623, https://doi.org/10.1016/j.eap.2022.06.009.
[62] B.W. Elliott, M.S. Grant, L.J. Hobson, Trader participation in disclosure: implications of interactions with management, Contemp. Account. Res. 37 (2020) 68–100, https://doi.org/10.1111/1911-3846.12524.
[63] H. Fang, Y. Chu, Voluntary disclosure, compulsory disclosure and pricing efficiency of capital market, Business Management Journal 41 (2019) 156–173, https://doi.org/10.19616/j.cnki.bmj.2019.01.010.
[64] Z. Li, C. Li, X. Feng, Non-financial information disclosure and capital market pricing efficiency, Finance & Trade Economics 43 (2022) 38–52, https://doi.org/10.19795/j.cnki.cn11-1166/f.20220906.010.
[65] Y. Huang, Y. Wang, How does high-speed railway affect green innovation efficiency? A perspective of innovation factor mobility, J. Clean. Prod. 265 (2020), https://doi.org/10.1016/j.jclepro.2020.121623.
[66] H. Wen, C. Lee, F. Zhou, Green credit policy, credit allocation efficiency and upgrade of energy-intensive enterprises, Energy Econ. 94 (2021), https://doi.org/10.1016/j.eneco.2021.105099.
[67] K. Shen, J. Lin, Y. Fu, Network infrastructure construction, information availability and enterprise innovation boundary, China Industrial Economics 1 (2023) 57–75, https://doi.org/10.19581/j.cnki.ciejournal.2023.01.014.
[68] T. Kong, R. Sun, G. Sun, Y. Song, Effects of digital finance on green innovation considering information asymmetry: an empirical study based on Chinese listed firms, Emerg. Mark. Finance Trade 58 (2022) 4399–4411, https://doi.org/10.1080/1540496X.2022.2083953.

[69] G. Sun, J. Fang, T. Li, Y. Ai, Effects of climate policy uncertainty on green innovation in Chinese enterprises, Int. Rev. Financ. Anal. 91 (2024), https://doi.org/10.1016/j.irfa.2023.102960.

[70] M.L. Katz, C. Shapiro, Technology adoption in the presence of network externalities, J. Polit. Econ. 94 (1986) 822–841, https://doi.org/10.1086/261409.

[71] H. Chung, ICT investment-specific technological change and productivity growth in Korea: comparison of 1996–2005 and 2006–2015, Telecommun. Pol. 42 (2018) 78–90, https://doi.org/10.1016/j.telpol.2017.08.005.

[72] M. Ebers, I. Maurer, Connections count: how relational embeddedness and relational empowerment foster absorptive capacity, Res. Pol. 43 (2014) 318–332, https://doi.org/10.1016/j.respol.2013.10.017.

[73] G.T. Schweisfurth, C. Raasch, Absorptive capacity for need knowledge: antecedents and effects for employee innovativeness, Res. Pol. (2018) 687–699, https://doi.org/10.1016/j.respol.2018.01.017.

[74] Z. Dong, H. Wang, Local-neighborhood effect of green technology of environmental regulation, China Industrial Economics 370 (2019) 100–118, https://doi.org/10.19581/j.cnki.ciejournal.2019.01.006.

[75] X. Wang, Y. Wang, Research on green credit policy promoting green innovation, Journal of management world 37 (2021) 173–188+11, https://doi.org/10.19744/j.cnki.11-1235/f.2021.0085.

[76] J. Asker, J. Farre-Mensa, A. Ljungqvist, Comparing the investment behavior of public and private companies, National Bureau of Economic Research (2011). http://www.nber.org/papers/w17394.

[77] W. Li, M. Zheng, Substantive innovation or strategic innovation? -the impact of macro-industrial policies on micro-enterprise innovation, Econ. Res. 51 (2016) 60–73.

[78] Z. Lin, X. Long, Can the threat of short selling inspire China enterprises to innovate, World Econ. 42 (2019) (2019) 126–150, https://doi.org/10.19985/j.cnki.cassjwe.2019.09.007.

[79] J. Kim, V. Kristen, The innovation consequences of mandatory patent disclosures, J. Account. Econ. 71 (2020), https://doi.org/10.1016/j.jacceco.2020.101381.

[80] X. Long, J. Wang, Motivation and quality effect of patent surge in China, World Econ. 38 (2015) 115–142, https://doi.org/10.19985/j.cnki.cassjwe.2015.06.007.

[81] L. Röller, L. Waverman, Telecommunications infrastructure and economic development: a simultaneous approach, Am. Econ. Rev. 91 (2001) 909–923, https://doi.org/10.1257/aer.91.4.909.

[82] A. Datta, S. Agarwal, Telecommunications and economic growth: a panel data approach, Appl. Econ. 36 (2004) 1649–1654, https://doi.org/10.1080/0003684042000218552.

[83] R. Morck, B. Yeung, W. Yu, The information content of stock markets: why do emerging markets have synchronous stock price movement? [J]Journal of Financial Economics 58 (2000) 215–260, https://doi.org/10.1016/S0304-405X(00)00071-4.

[84] F.A. Gul, J. Kim, A.A. Qiu, Ownership concentration, foreign shareholding, audit quality, and stock price synchronicity: evidence from China, J. Financ. Econ. 95 (2010) 425–442, https://doi.org/10.1016/j.jfineco.2009.11.005.

[85] N. Li, R. Yuan, M.A. Khan, X. Yang, N. Khalig, X. Zhang, Does investors' site visits improve the capital market pricing efficiency? Heliyon (2023) 1234 https://doi.org/10.1016/j.heliyon.2023.e19100, 19100-19100.

[86] M. Wen, Relocation and agglomeration of Chinese industry, J. Dev. Econ. 73 (2004) 329–347, https://doi.org/10.1016/j.jdeveco.2003.04.001.

[87] J. Xu, H. Li, Managerial human capital and corporate R&D investment, J. Econ. Behav. Organ. 213 (2023) 151–171, https://doi.org/10.1016/j.jebo.2023.07.021.

[88] Z. Dong, H. Wang, Urban wealth and choice of green technology, Econ. Res. 56 (2021) 143–159.

[89] A. Bergek, S. Jacobsson, A.B. Sandén, 'Legitimation' and 'development of positive externalities': two key processes in the formation phase of technological innovation systems, Technol. Anal. Strat. Manag. 20 (2008) 575–592, https://doi.org/10.1080/09537320802292768.

[90] J. Markard, S. Wirth, B. Truffer, Institutional dynamics and technology legitimacy – a framework and a case study on biogas technology, Res. Pol. 45 (2016) 330–344, https://doi.org/10.1016/j.respol.2015.10.009.

[91] X. Sheng, S. Guo, X. Chang, Managerial myopia and firm productivity: evidence from China, Finance Res. Lett. 49 (2022), https://doi.org/10.1016/j.frl.2022.103083.

[92] DIB Internal Control and Risk Management Database, Available from: http://www.ic-erm.com/pro1.html.

[93] X. Shao, S. Liu, R. Ran, Y. Liu, Environmental regulation, market demand, and green innovation: spatial perspective evidence from China, Environ. Sci. Pollut. Res. Int. 29 (2022) 63859–63885, https://doi.org/10.1007/s11356-022-20313-y.

[94] D. Acemoglu, P. Restrepo, Robots and jobs: evidence from US labor markets, J. Polit. Econ. 128 (2020) 2188–2244, https://doi.org/10.1086/705716.

[95] B. Wang, S. Qi, Technological innovation effects of market-based and command-based policy tools on energy saving and emission reduction —— an empirical study based on patent data of China industrial industry, China Industrial Economy 6 (2016) 91–108, https://doi.org/10.19581/j.cnki.ciejournal.2016.06.008.

[96] A.B. Jaffe, S.R. Peterson, R. Portney, R.N. Stavins, Environmental, Regulation and the competiveness of U.S.Manufacturing:What does the evidence tell us, J. Econ. Lit. 33 (1995) 132–163.

[97] A. Blackman, Z. Li, A.A. Liu, Efficacy of command-and-control and market-based environmental regulation in developing countries, Annual Review of Resource Economics 10 (2018) 381–404, https://doi.org/10.1146/annurev-resource-100517-023144.