Heliyon 10 (2024) e23801

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Influence of local governments on the greening of the manufacturing sector: A perspective on environmental governance objectives

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ARTICLE INFO

Keywords:
Environmental governance goals
Green innovation
Fiscal expenditure, manufacturing
Green total factor productivity

ABSTRACT

The green development of manufacturing industries is significantly impacted by local governments. In this study, we focus on assessing the environmental governance effectiveness by examining the tasks assigned by the central government to each province under the Comprehensive Work Program for Energy Conservation and Emission Reduction. By utilizing panel data from 30 provinces and cities in China from 2011 to 2020, we employ the super-efficient SBM model to evaluate China's manufacturing industry's green total factor productivity. Through various models, including the double-fixed effect and the mediation effect, we investigate the influence of environmental governance targets on the green total factor productivity of the manufacturing industry. Our findings reveal a U-shaped relationship between the environmental governance target and the green total factor productivity of the manufacturing industry. When the pressure of environmental governance targets is below a certain critical value, the green total factor productivity decreases as the target pressure increases. However, once the target pressure surpasses this critical value, the green total factor productivity experiences a positive correlation with the target pressure. Further analysis demonstrates that this U-shaped relationship is observed in regions with low and medium marketization, while regions with high marketization remain unaffected. Moreover, the impact of environmental governance target pressure on green total factor productivity in manufacturing is facilitated by the promotion of green innovation. Furthermore, the relationship between environmental governance target pressure and green total factor productivity in manufacturing is moderated by local government fiscal expenditures. In regions where fiscal expenditures are higher, the influence of environmental governance target pressure on green total factor productivity in manufacturing is more pronounced.

1. Introduction

With the growing global recognition of environmental awareness, governments worldwide are implementing a variety of measures to tackle environmental issues and reduce emissions. International agreements, like the Paris Agreement, are leading the charge in reducing greenhouse gas emissions and urging countries to establish more rigorous environmental standards and policies [1]. The

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https://doi.org/10.1016/j.heliyon.2023.e23801
Received 10 April 2023; Received in revised form 9 December 2023; Accepted 13 December 2023
Available online 16 December 2023

pursuit of green and low-carbon development has now become the focal point of the present era's scientific and technological revolution and industrial transformation, as the sphere of global competition shifts toward the realms of the green economy. China, renowned as one of the world's largest manufacturing nations, is still confronted with numerous challenges and dilemmas in accomplishing the green development of its manufacturing industry, despite the Chinese government's prioritization of this endeavor and initiation of an array of policies and measures [2]. According to the China Statistical Yearbook 2021, the manufacturing sector in China consumed 54.80 % of the country's total energy and accounted for 51.64 % of its carbon emissions in 2020. However, the manufacturing sector only contributed 27.84 % of the nation's industrial added value. This suggests that within this new phase of rapid manufacturing, there are unmistakable characteristics of heavy manufacturing, high energy consumption, high emissions, high input, and low efficiency [3,4]. it is urgent to take effective measures to promote the green and low-carbon transformation of the manufacturing Consequently, prompt and effective measures need to be taken to propel the manufacturing industry towards a green and low-carbon transformation, in order to achieve the goals of "carbon peaking" and "carbon neutrality" and bolster the overall development of the sector. Thus, it is imperative to offer an effective response to the challenges entailed in green development, a response that will be instrumental in facilitating the transformation and upgrading of China's manufacturing industry, fostering sustainable growth, and safeguarding the environment.Since the beginning of reform and opening up, Chinese government officials at all levels have been in the mode of economic competition for a long time for the sake of political promotion, which has promoted the rapid growth of the economy in their jurisdictions, and the local government competition has thus been attributed by many scholars to be an important driving force of China's economic takeoff since the reform and opening up [5,6]. However, government competition under the economic appraisal system will form a path dependence on the crude economic development method, which will result in the waste of resources and the destruction of the environment [7–9], and is not conducive to the sustainable and high-quality development of China's economy. With the promotion of China's green concept and the change of development mode, the Chinese government issued the "Decision of the Central Committee of the Communist Party of China on Several Major Issues on Comprehensively Deepening Reform" and other documents in 2013, which put forward the guideline of "not judging heroes based on the growth rate of GDP", and raised the proportion of the assessment of environmental governance in the officials' appraisal system by means of laws and regulations [10]. With the implementation of assessment measures such as the target responsibility system, one-vote veto, one-post double responsibility, party and government responsibility, environmental audits, and lifelong accountability, China's local governments have realized a shift from "inaction" to "active action" in environmental governance. When vying for promotion as a limited asset, local government officials will give greater consideration to the harmonious advancement of the economy, environment, and society [11,12].

The purpose of environmental governance assessment is to incentivize government officials to actively promote environmental protection and the cause of environmental protection through the mechanism of assessment, reward and punishment. This practice can, on the one hand, enhance the environmental awareness of government officials and raise their awareness of environmental protection and responsibility. On the other hand, it can motivate government officials to actively promote environmental protection and the development of the cause of environmental protection. However, when government officials are faced with environmental protection performance assessment, the phenomena of "one-size-fits-all environmental protection" and "blanket shutdown" have emerged in some regions. Does the pressure of government environmental governance targets affect the green total factor productivity of the manufacturing industry? Play a positive promotion or inhibition? How do the motivations and actions of local governments in the process of environmental governance impact the green total factor productivity of the manufacturing industry? This is an issue that needs to be studied and explored in depth.

The remaining sections of this text will be organized as follows: The second part will consist of a literature review; the third part will conduct a theoretical mechanism analysis; the fourth part will elaborate on research methods and data sources; the fifth part will present empirical analysis results; the sixth part will discuss the applicability analysis based on regional marketization levels; the seventh part will involve a discussion; and finally, a comprehensive summary will be provided in the eighth part.

2. Literature review

Goal setting plays an important role in public sector management practices and administrative reforms, a view supported by Latham et al. (2008). China adopts a governance system of "centralized political power and decentralized economic and environmental power" to govern the country, and in order to promote economic and social development, all levels of government set future development goals in different plans and programs and promote their implementation by lower levels of government [13]. L Lower-level governments have strong motivation and willingness to promote the goals of higher-level governments because the leaders of government at the lower levels in China are appointed by the government at the higher level [14–16]. In most federal countries abroad, the executive head is elected by the public [17,18], and various goals set by local governments are greatly influenced by the population within their jurisdiction. The promotion or non-promotion of local government officials largely depends on the fulfillment of the objectives of the lower government [19]. As a result, the various goals set by higher levels of government, including economic growth goals and environmental governance goals, have become the main source of pressure faced by local government officials [20].

The influencing factors for MGTFP industry mainly include policy factors, technical factors and economic factors. In terms of technological factors, it is found that technological progress and green technology progress are the key factors to promote the growth of green total factor productivity, and the growth rate of different manufacturing industries varies [21–23]; Intelligence can affect the green total factor productivity of the manufacturing industry by improving technical efficiency [24,25]. Market and environmental policies can also influence green total factor productivity in manufacturing [26].Ding et al. (2022) found that trade openness can significantly improve GTFP [27].Ye et al. (2022) found that green industrial policy significantly promoted total factor productivity of manufacturing firms, with incentive and monitoring effects playing an important role, and that non-state-owned firms and larger scale smaller firms benefited more [28]. Another study found that the policy mix is more favorable for green total factor productivity growth, and that command-and-control (regulatory) environmental regulations (e.g., energy efficiency and emission reduction actions, air quality regulations), as well as market competitiveness and market-based environmental regulations, also contribute to growth [29–31]. Some scholars have even found that the effect of local environmental regulations on green total factor productivity can be heterogeneous depending on the level of political attributes of the city, being significantly positive in cities with high political attributes and negative in cities with low political attributes [32]. Green credit policy has a negative impact on the total factor productivity of manufacturing firms [33], debt financing can reverse the relationship between green credit policy and total factor productivity of manufacturing firms by suppressing long-term lending and promoting short-term lending [34]; however, there is also a marginal effect of the impact of environmental governance policies on green total factor productivity in manufacturing industry, i.e., the marginal impact of environmental governance on promoting GTFP growth gradually weakened [35,36]. In terms of economic factors, it was found that the digital economy can significantly increase the green total factor productivity of manufacturing industry, but hinders technological progress, while talent aggregation and financial scale play a key moderating role in this relationship [37]. Industrial structure is the factor, aside from technological advancement, that has the most potential to promote low-carbon development in the manufacturing industry [38]. Additionally, increasing the proportion of clean energy sources like hydroelectric and wind power, as well as adjusting the energy consumption structure, can also reduce the energy intensity of manufacturing, thus contributing to its low-carbon development [39,40].In studying the relationship between government target pressure and green total factor productivity in the manufacturing industry (MGTFP), early studies have focused on the impact of economic growth target pressure. When the pressure to achieve economic growth targets is high, local governments are more inclined to adopt relaxed environmental regulations to reduce the intensity of environmental regulations that may exacerbate environmental pollution in local and neighboring areas [41].However, the contribution of economic growth target pressure to environmental pollution can be enhanced by improving environmental monitoring decentralization (EDM) [42]. Several studies have found a significant "U" shaped relationship between economic growth target pressure and air pollution [43], as well as a "U" shaped relationship with carbon emissions [44], and an inverted "U" shaped relationship with eco-efficiency [45]. Economic growth target pressure may negatively affect green energy efficiency (GEE), but environmental regulation can play a positive moderating role between economic growth target pressure and GEE [46]. There is some discussion about the effect of economic growth target pressure on green total factor productivity (GTFP). Excessive competition pressure for inter-regional economic growth targets has a detrimental impact on Green Total Factor Productivity (GTFP), whereas moderate competition does not produce such an effect [47]. When setting targets, the pressure to achieve economic growth goals has a more significant inhibitory effect on Green Total Factor Productivity (GTFP) when strict constraints and public goals are adopted [48]. With the global push for green development, some countries have established environmental management goals to promote sustainable development. The superior government's ranking of environmental performance targets is an incentive mechanism where provinces with lower rankings will compete to improve their future environmental policy performance in the upcoming years [49]. China's environmental management goals can play a role in promoting and adopting energy-saving technologies [50], shutting down and eliminating outdated capacity [51], reducing excess capacity, and ultimately influencing green development [52]. Furthermore, environmental management goals can also facilitate the improvement of Green Total Factor Productivity (GTFP) in cities [53–55].

In summary, previous studies have provided a basis for analyzing the relationship between government target pressure and green total factor productivity, but there are still some shortcomings that require further improvement. First of all, existing studies mainly focus on the relationship between local government economic growth pressure and green total factor productivity and between environmental governance target pressure and regional (e.g., urban) green total factor productivity, while fewer scholars have paid attention to the mechanism of the direct and indirect impacts of environmental governance target pressure on the green total factor productivity of the manufacturing industry from an industrial perspective.Second, previous literature has made greater use of policy shocks (DID) as a dummy variable to measure, and lacks specific quantitative measures of pressure on the government's environmental governance goals, which seems to be unsatisfactory in terms of how to quantitatively measure pressure on environmental governance goals.

The innovations of this paper are as follows: first, from the industrial perspective, this paper investigates the impact of government environmental governance target pressure on the green total factor productivity of manufacturing industry, and explores the impact mechanism thereof, which expands the research scope of the environmental governance target pressure, and enriches the theory of the impact of government environmental governance target pressure on the green development of industry. Secondly, in terms of the measurement of the government's environmental governance target pressure, the local government's environmental governance target pressure is characterized by adopting the ratio of the actual sulfur dioxide emissions to the central task emissions.

This study adds to the policy knowledge on green total factor productivity in regional manufacturing. Existing literature has identified many factors that influence green total factor productivity in regional manufacturing. However, considering the impact of the complexity of local environmental governance objectives on green TFP in regional manufacturing, governments should be more cautious in formulating and adjusting environmental governance objectives, as well as other related objectives and policies, in order to avoid negative impacts on the greening of the manufacturing sector.

3. Theoretical mechanism analysis

3.1. The direct effect of pressure for environmental governance targets on MGTFP

The process of local government environmental governance, the response of manufacturing enterprises to environmental governance will go through several stages stages. The first stage is the rigid constraint stage. In the rigid constraint stage, as the pressure of the government's environmental governance goals increases, manufacturing enterprises need to take on more environmental responsibilities and costs. In this stage, firms tend to take rigid measures, such as shutting down production and reducing emissions, in order to avoid being penalized or criticized by the government, which may lead to a decrease in the firm's production efficiency, and thus a decrease in green total factor productivity [56]. When manufacturing enterprises experience the rigid constraint stage, they will gradually adjust into the second stage, the stage of technological innovation. When the pressure of the government's environmental governance goals is further strengthened, enterprises will adopt more flexible ways in order to seek sustainable development, such as technological innovation, pollutant treatment, etc. These measures can promote the improvement of enterprise production efficiency, and at the same time reduce the pollution of the environment, so that the green total factor productivity will gradually increase [57,58]. In the process of technological innovation, enterprises will gradually pursue the reduction of environmental protection costs, i.e., the third stage. With the increasing pressure of environmental protection, manufacturing enterprises need to invest more resources and funds in the development of environmental protection equipment and technology in order to meet the environmental requirements of the government and consumers, which will lead to an increase in the production cost of enterprises. However, in practice, only when the environmental protection cost reaches a certain level, enterprises will start to look for more effective and economical environmental protection technologies and measures, which will lead to the improvement of green total factor productivity [59,60]. Based on this, this paper proposes the following hypothesis.

Hypothesis 1. The effect of environmental governance target pressure on MGTFP shows a U-shaped relationship.

3.2. Indirect effect of environmental governance target pressure on MGTFP

When the pressure on the government's environmental governance targets is less than a certain threshold, the pressure on the government's environmental governance targets is low, and the government's supervision and punishment of pollutant emissions from enterprises is relatively weak. Enterprises pay relatively low sewage charges, and it is more economical to pay sewage charges than to make green technological innovations. Therefore, enterprises may prefer to pay sewage charges rather than investing more money in environmental protection innovation [61]. On the one hand, it is because investing in environmental protection innovation is risky: environmental protection innovation may require enterprises to invest a large amount of money and time, and it is difficult to ensure that the results of environmental protection innovation will be recognized by the market and commercially successful, so enterprises may perceive the risk of investing in environmental protection innovation to be high. On the other hand, environmental innovation has a long payback cycle: environmental innovation has a relatively long payback cycle, which requires enterprises to invest more time and effort, and the payback may take a longer time to realize, which may also lead to a lack of enthusiasm for investing in environmental innovation. When the government environmental governance target pressure is less than a certain critical point, with the increase of government environmental governance target pressure, the government's regulation of the environment is gradually tightened, and it is possible to enhance the strength of environmental inspections and checks or penalties, which to a certain extent leads to an increase in the payment of sewage charges by enterprises, which in turn inhibits the financial expenditure on green technology innovation [62]. When the government's environmental governance target pressure exceeds a certain critical point, the strengthening of government environmental regulations and policies makes enterprises face greater environmental governance target pressure, at this time, only through green technological innovation can achieve the goals and requirements of environmental protection [63,64]. Therefore, the following hypothesis is proposed.

Hypothesis 2. Environmental governance pressure affects MGTFP through green technological innovation.

4. Methodology and data

4.1. Model

4.1.1. Fixed effect panel model

Fixed effects models are suitable for situations where individual fixed effects are assumed to exist and these effects are uncorrelated with the explanatory variables. Compared with the random effects model, the fixed effects model can better control the fixed effects of individual units and time units, thus eliminating individual and time-specific effects and studying the relationship between variables more precisely [65]. When analyzing the impact of local governments' setting environmental governance goals on green total factor productivity in manufacturing, we usually believe that different provinces and cities have unique environmental characteristics and government behaviors, so the existence of individual fixed effects is reasonable. In addition, this study also conducted the Hausman test before the model setting, and the results showed that the p-value of the Hausman test was less than 0.05, which indicated that the original hypothesis of the random effects model was rejected at the 95 % significance level, i.e., the basic assumption of the random effects model (individual effects are not correlated with the explanatory variables) was not fulfilled, and therefore, this study used a two-way fixed effects model.Specifically, this article sets up the following empirical model:

$$\mathrm{MGTFP_{it}} = \alpha + \beta_1 \mathrm{pressure_{it}} + \beta_2(\mathrm{pressure_{it}})^2 + X'\varphi + \gamma_i + \lambda_t + \varepsilon_{it} \quad (3)$$

Among them, the green total factor productivity of the manufacturing industry and the pressure on government environmental governance in province i during the t period were respectively calculated using MGTFP and $\mathrm{pressure_{it}}$ is used to represent. among γ_i represents the fixed effect of the province, λ_t represents fixed time effects, and X represents other fixed effects, ε_{it} is a random perturbation term. βrepresents the regression coefficient between environmental governance pressure and MGTFP.

4.1.2. Mediation effects model

Mediating effects modeling can help us identify which variables are transferring influence through mediating effects, which in turn can help design more effective interventions and policies [66]. In order to investigate the impact of environmental governance target pressure on MGTFP, we use the mediating effect model. This model can help us explain how environmental governance target pressure affects green total factor productivity through specific mediating variables (e.g., green innovation). By analyzing the mediating effects, we can reveal the potential mechanisms and pathways to gain a deeper understanding of the impact of governmental environmental governance target pressure on green total factor productivity and provide more comprehensive and accurate research conclusions to better answer the research questions. On the basis of the baseline model, the following recursive model is further developed by using the mediation regression analysis based on the Sobel test:

$$\mathrm{M_{it}} = \alpha_0 + \alpha_1(\mathrm{pressure_{it}}) + \alpha_2 X_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \quad (4)$$

$$\mathrm{MGTFP_{it}} = \rho_0 + \rho_1(\mathrm{pressure_{it}}) + \rho_2(\mathrm{pressure_{it}})^2 + \theta \mathrm{M_{it}} + X'\varphi + \gamma_i + \lambda_t + \varepsilon_{it} \quad (5)$$

The following paragraph translated into English is as follows: In the equation, the subscripts i and t represent the province and year, respectively. MGTFP represents the dependent variable, which is the green total factor productivity of the manufacturing industry. "pressure" represents the core explanatory variable, which is the pressure of government environmental governance. M is the mediating variable, representing green technological innovation. γ_i represents the province fixed effects, λ_t represents the time fixed effects, and X represents other fixed effects, while ε_{it} represents the random disturbance term.

4.1.3. Moderating effects modeling

Moderating effects models allow us to better capture the conditional relationships between variables and to develop individualized interventions and policies for different groups and scenarios [67]. In order to verify whether environmental governance target pressure has an impact on MGTFP through the positive moderating effect of local fiscal expenditures, we add an interaction term ($\mathrm{pressure_{it}} \times \mathrm{T_{it}}$) between the core explanatory variables and the moderating variables to the baseline model. By verifying the significance of the interaction term, we can determine whether there is a moderating effect. Based on the above, we can establish the following moderating effect model:

$$\mathrm{MGTFP_{it}} = \tau_0 + \tau_1(\mathrm{pressure_{it}}) + \tau_2(\mathrm{pressure_{it}})^2 + \tau_3 \mathrm{T_{it}} + \tau_4(\mathrm{pressure_{it}} \times \mathrm{T_{it}}) + X'\varphi + \gamma_i + \lambda_t + \varepsilon_{it} \quad (6)$$

In the equation, the subscripts i and t represent the province and year, respectively. MGTFP represents the dependent variable, which is the green total factor productivity of the manufacturing industry. "pressure" represents the core explanatory variable, which is the pressure of government environmental governance. T represents the moderating variable, which is local fiscal expenditure. γ_i represents the province fixed effects, λ_t represents the time fixed effects, and X represents other fixed effects, while ε_{it} represents the random disturbance term.

4.2. Indicator selection

Explained variable:MGTFP. Green Total Factor Productivity (GTFP) is derived from Total Factor Productivity (TFP) and its calculation method incorporates the impact of unexpected output on the TFP calculation model. In comparison to the traditional SBM model, the Super-SBM model takes into account the environmental factors influencing production when measuring green total factor productivity. Furthermore, it is able to further differentiate performance differences among efficient DMUs. Additionally, this model also has a certain tolerance for data noise and errors, thereby reducing the impact of data noise on the results [68,69]. This study refers to the calculation method proposed by Tian and Fen and utilizes the formula derived from the Super-Efficiency SBM model to evaluate DMU (x0, y0, z0), which possesses the characteristic of unexpected output [70]. The expression formula is as follows:

$$\min \rho = \frac{\frac{1}{m}\sum_{i=1}^{m}(\overline{x}/x_{ik})}{\frac{1}{r_1+r_2}\left(\sum_{s=1}^{r_1}\overline{y^d}\Big/y_{sk}^d + \sum_{q=1}^{r_2}\overline{y^u}\Big/y_{qk}^u\right)} \quad (1)$$

$$\begin{cases} \bar{x} \geq \sum_{j=1,\neq k}^{n} x_{ij}\lambda_j, \overline{y^d} \leq \sum_{j=1,\neq k}^{n} y_{Sj}^{d}\lambda_i \\ \overline{y^d} \geq \sum_{j=1,\neq k}^{n} y_{q_j}^{d}\lambda_i, \bar{x} \geq x_k \\ \overline{y^d} \leq y_k^d, \overline{y^u} \geq y_k^u \\ \lambda_j \geq 0, i = 1,2,\dots,m, j = 1,2\dots,n \\ s = 1,2,\dots,r_1, q = 1,2,\dots,r_2 \end{cases} \tag{2}$$

In the calculation process of Green Total Factor Productivity (GTFP), the indicators applied can be broadly divided into input indicators and output indicators. In this study, the output indicators not only include expected outputs (represented by the main business income of the manufacturing industry in the current year), but also take into account unexpected outputs (such as industrial wastewater, industrial exhaust gases, and general industrial solid waste). The inclusion of unexpected outputs in the calculation of green total factor productivity in the manufacturing industry is aimed at more comprehensively reflecting the impact of production activities on the environment. This helps to measure the environmental benefits of economic activities, evaluate the sustainability of production processes, and provide more targeted guidance for environmental protection. At the same time, it also allows for a more accurate assessment of resource utilization efficiency [71]. The specific indicators for measuring green total factor productivity in the manufacturing industry can be seen in Table 1.

Core explanatory variable:Pressure on environmental governance targets.With the promotion of China's green concept and the transformation of its development mode, especially in 2013, the Chinese government issued the "Decision of the Central Committee of the Communist Party of China on a Number of Major Issues Concerning Comprehensively Deepening Reforms" and other documents, which put forward the guideline of "not basing on the heroes and heroes of the GDP growth rate", and raised the proportion of environmental protection appraisal in the officials' appraisal system by means of laws and regulations. This provision implies that the long-standing GDP growth rate is not a criterion for heroism. This regulation implies a fundamental shift from the long-standing GDP-driven economic growth approach, and the assessment of environmental governance targets will have an impact on the incentive orientation of local government officials. In response to the environmental performance targets issued by the central government, local government officials may implement more stringent environmental protection measures, and continuously increase energy saving and emission reduction, in order to maintain a high degree of consistency with the central government [72].Therefore, this paper takes the sulfur dioxide emission reduction task issued by the Chinese central government to each province during the 12th and 13th Five-Year Programs of Comprehensive Work Program on Energy Conservation and Emission Reduction as the main content of the analysis of pressure on environmental protection and governance targets. This task indicator is issued by the State Council to each province (autonomous region), and each province (autonomous region) is then decomposed to prefectural-level cities according to its own situation. Referring to Chen and Miller's idea, the ratio of the actual amount of sulfur dioxide emitted by the sample province in the year and the amount of sulfur dioxide emissions issued by the central government to the province in the year is used to measure the pressure of the environmental governance objectives [73], that is $\text{pressure}_{\text{it}} = \frac{\text{PF}_{\text{it}}}{\text{PO}_{\text{it}}}$, which PF_{it} indicates the actual amount of sulfur dioxide emitted by the sample province in the year, and PO_{it} indicates the amount of sulfur dioxide emissions issued by the central government to the province in the year.

Control variables: Based on existing literature research on MGTFP, this article further controls the impact of other variables on MGTFP. The selected control variables are as follows:

Financing constraints(FS):Financing constraints refer to the limitations or difficulties faced by enterprises in financing. In the manufacturing industry, financing constraints may affect enterprises' investment in green technological innovation, equipment upgrading and environmental governance, which in turn affects green production efficiency.Financing constraints are measured by the ratio of deposits to loans, i.e., the ratio of bank deposits to the amount of loans [74,75].

Research and Experimental Development(RD): Increased RD intensity can drive technological advances, including in production technologies, environmental monitoring technologies and cleaner production technologies. The introduction and application of these technologies can improve the environmental performance, resource utilization efficiency and energy efficiency of the manufacturing sector, thereby increasing green total factor productivity.RD intensity can be measured by the RD R&D expenditure cost to GDP ratio [76].

Table 1
Indicator system for MGTFP.

Category of indicators	Primary indicators	Secondary indicators
Input indicators	labor input	Year-end employment
	capital stock	Capital stock at end of year
	energy consumption	Year-end energy consumption
Output indicators	Expected outputs	Revenue from main operations for the year
	Non-expected outputs	industrial waste water
		industrial waste gas
		Industrial general solid waste

Intensity of environmental regulation(ISR):According to recent studies, environmental regulations play an important role in promoting the development of green economy. Among them, command-and-control regulations help to improve green total factor productivity by incentivizing technological innovation, optimizing industrial structure, improving scale efficiency, and promoting coordinated regional development [77]. Market-based environmental regulations, on the other hand, may inhibit technological innovation, reduce industrial structure, scale and resource allocation efficiency, and adversely affect green total factor productivity. In this paper, we refer to Li (2022) and Lodhia (2012) who assessed the government's efforts in environmental protection by calculating the number of words related to pollution in the government work report of the year as a proportion of the total number of words [78, 79].

4.3. Data sources

This paper takes 30 provinces in China as the research sample from 2011 to 2020 (Tibet, Hong Kong, Macao and Taiwan are excluded). The input and output data for measuring "green total factor productivity in the manufacturing industry" mainly come from the "China Industrial Statistical Yearbook," "China Energy Statistical Yearbook," and "China Environmental Statistical Yearbook." The data for measuring "environmental governance target pressure" consists of two parts, with sulfur dioxide task emission data sourced from the comprehensive work plan for energy conservation and emissions reduction issued by the State Council, and actual sulfur dioxide emission data sourced from the "China Industrial Statistical Yearbook." The data for measuring "financial constraints" in terms of bank deposits and loan amounts are sourced from the "China Statistical Yearbook." The indicator data for measuring "R&D intensity" comes from the "China Science and Technology Statistical Yearbook." The data for measuring "environmental regulation intensity" is sourced from the provincial "Government Work Reports." Linear interpolation and the nearest-year average method are used to fill in some missing values.

The descriptive statistics of relevant variables are shown in Table 2.

5. Results and discussion

5.1. Temporal and spatial changes in MGTFP

5.1.1. Overall trends in MGTFP

Fig. 1 shows the time evolution of green total factor productivity in China's manufacturing industry. As can be seen from the figure, China's MGTFP shows an overall trend of steady growth. However, there are some fluctuations in productivity between years. Between 2011 and 2015, productivity fluctuated slightly but remained relatively stable overall. This feature is largely consistent with Zhang et al. (2022) [80].2016 was a standout year, with the MGTFP rising sharply to 0.323, a significant increase from the previous year's 0.275.The official implementation of the Air Pollution Prevention and Control Act enacted by China in 2016 may have had an impact on the increase in MGTFP. The Act adopts stricter measures and standards for air pollution control and imposes higher emission requirements on enterprises. Beginning in 2017, MGTFP entered a relatively stable phase that lasted until 2020. During this phase, productivity fluctuated between 0.298 and 0.368, remaining relatively stable overall.

5.1.2. Analysis of regional heterogeneity of MGTFP

Fig. 2 presents the ranking of average GTFP in the manufacturing sector across provinces from 2011 to 2020. Based on the provincial rankings in Fig. 2, the following conclusions can be drawn. Firstly, Beijing, Guangdong, and Shanghai occupy the top three positions, indicating that these regions have relatively high overall GTFP in the manufacturing sector. This can be attributed to various advantages such as locational benefits, innovative capabilities, industrial agglomeration effects, policy support, and talent resources in these areas. Secondly, coastal provinces in the eastern part of China (including Guangdong, Fujian, Jiangsu, Zhejiang, etc.) consistently appear in higher positions in the ranking. This suggests that these regions possess competitive advantages in manufacturing development. This may be attributed to the well-established supply chain systems in the southeastern coastal regions, which involve coordination and collaboration among suppliers, producers, and distributors. Such synergistic effects contribute to optimizing logistics and resource allocation, thereby enhancing production efficiency and green total factor productivity. Additionally, some provinces in the central and western regions, such as Chongqing, Sichuan, Hunan, and Shaanxi, have also achieved notable progress, indicating the development potential of manufacturing GTFP in these areas. However, provinces like Qinghai, Shanxi, and Ningxia rank lower, indicating relatively lower levels of manufacturing GTFP development in these regions. The present discourse aligns harmoniously with the findings of Cheng and Jin's (2022) scholarly investigation [81].

Table 2
Descriptive statistics of variables.

Variable	Observations	Mean	Std	Min	Max	Unit
MGTFP	300	.2984	.13863	.1110	1.022	–
pressure	300	.71277	.32690	.03822	1.580	%
FS	300	.61455	.43454	.00146	2.4977	%
RD	300	3.2307	1.1610	1.517	8.131	%
ISR	300	.01671	.01130	.0041	.0644	%

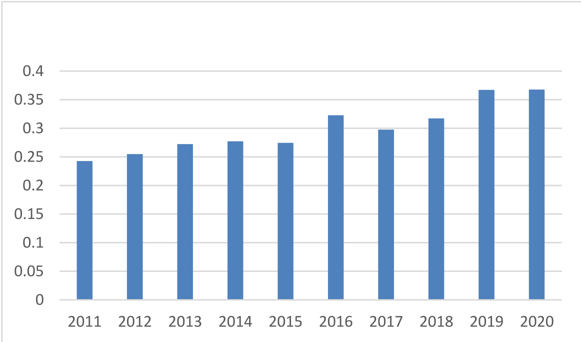

Fig. 1. MGTFP time-varying graph.

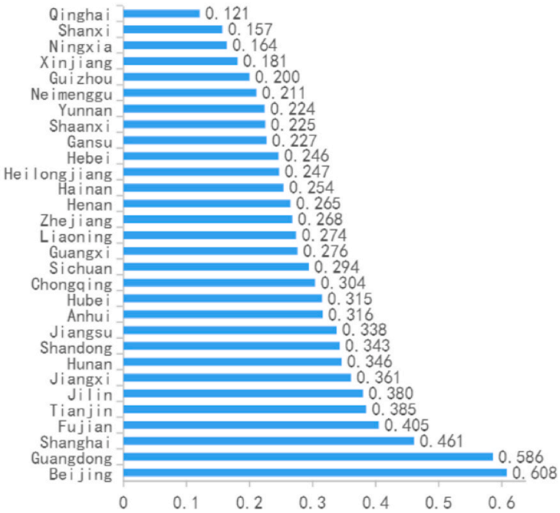

Fig. 2. Ranking of provinces by average MGTFP, 2011–2020.

Table 3
Basic regression results.

	Explained variable:MGTFP			
	(1)	(2)	(3)	(4)
pressure	−0.3497***	−0.3231***	−0.3425***	−0.3372***
	(-2.92)	(-2.83)	(-3.09)	(-3.04)
The square of pressure	0.1209*	0.1103*	0.1189*	0.1161*
	(1.75)	(1.68)	(1.86)	(1.82)
FS		−0.0957***	−0.0972***	−0.0950***
		(-5.31)	(-5.54)	(-5.38)
RD			14.1746***	13.4488***
			(4.04)	(3.75)
ISR				−8.3284
				(-1.02)
Constant term	0.4671***	0.7081***	0.5215***	0.5509***
	(6.94)	(9.02)	(5.85)	(5.88)
Province effect	YES	YES	YES	YES
Time effect	YES	YES	YES	YES
N	300	300	300	300
R^2	0.2339	0.3092	0.3504	0.3531

Note:(1) The brackets are robust standard errors; (2) * * *, * *, * indicate passing statistical tests with a significance level of 1 %, 5 %, and 10 %, respectively; (3) N is the sample size, and R ˆ 2 is the goodness of fit.

5.1.3. Basic regression results

After regression analysis using equation (1), the regression results shown in Table 3 were obtained. Controlling only for time fixed effects and province fixed effects in the first column, the regression coefficient of the primary side of environmental governance target pressure is −0.3497, which passes the statistical test at the 1 % significance level; the regression coefficient of the secondary side of environmental governance target pressure is 0.1209, which passes the statistical test at the 10 % significance level. The research results show that there is a relationship between environmental governance target pressure and green total factor productivity in manufacturing industry that decreases first and then increases. Specifically, when the environmental governance target pressure is small, it will inhibit the green total factor productivity of the manufacturing industry; however, when the environmental governance target pressure is too large, it promotes the green total factor productivity of the manufacturing industry.One possible reason for this is that, at the initial stage, firms take rigid measures, such as shutting down production and reducing emissions, in order to avoid government penalties or criticism. However, these measures may have reduced the productivity of the firms and thus the green total factor productivity. Over time, enterprises gradually enter the technological innovation stage and adopt more flexible methods, such as technological innovation and pollutant treatment, etc., and these measures can both increase production efficiency and reduce pollution to the environment, gradually increasing green total factor productivity.The findings above are consistent with the hypothesized theory presented. The regression results in columns (2)–(4) of Table 2 are based on the successive addition of control variables such as financing constraints, RD intensity, and environmental regulation intensity to column (1). Compared with column (1), columns (2)–(4) of Table 2 show that the primary regression coefficients of environmental governance target pressure are still negative and pass the statistical test of significance level of 1 % after considering these control variables, while the quadratic regression coefficients are positive at the significance level of 10 %.Among the control variables, only "intensity of environmental regulation" is not significant, which may be due to the fact that the intensity of environmental regulation may not be sufficient to have a significant impact on MGTFP. There may be problems such as ineffective policy implementation, lack of supervision or lax law enforcement, resulting in the reduced effectiveness of environmental regulatory measures. It can be seen that there is a U-shaped relationship between the pressure of environmental governance targets and MGTFP, and that reducing the pressure of environmental governance targets and financing constraints and increasing the intensity of research and development can enhance green productivity in the manufacturing industry.

5.2. Impact mechanism testing

The U-shape between the pressure of environmental governance targets and MGTFP is to some extent related to the environmental behavior of manufacturing firms. Among the behaviors of enterprise environmental protection, green technology innovation is one of them. Theoretically, the government's environmental governance target pressure will be transmitted to the manufacturing enterprises, and the manufacturing enterprises, when facing the environmental protection inspections and checks, are likely to take the green technology innovation to reduce the pollutant emissions, and then enhance the green total factor productivity. In order to verify the above logic, we add "green technological innovation" as a control variable on the basis of the regression in Table 4. Referring to the results of existing studies, the green technological innovation indicator is measured by the sum of the number of green utility model patents and green invention patents filed by the manufacturing industry in the same year, so as to examine the robustness of the regression results.

Column (1) of Table 4 presents the same regression results as column (1) of Tables 3 and i.e., the regression coefficients of the primary side of the independent variable environmental governance target pressure are negative, the regression coefficients of the quadratic side are positive, and they pass the statistical test at a significance level of at least 10 %. This implies that there is a relationship between environmental governance target pressure and MGTFP in the absence of other control variables. Column (2) of Table 4 demonstrates the relationship between environmental governance target pressure and green total factor productivity in manufacturing by adding control variables to the previous step. Column (3) further adds "green technology innovation" as a control variable to column (2) and finds that the regression coefficient of green technology innovation is 0.0001, which is statistically significant at the 10 % level.

Table 4
Analysis based on green technology innovation.

	Explained variable:MGTFP		
	(1)	(2)	(3)
pressure	−0.3497***	−0.3372***	−0.3150***
	(-2.92)	(-3.04)	(-2.79)
The square of pressure	0.1209*	0.1161*	0.1078*
	(-1.75)	(-1.82)	(-1.67)
Green technology innovation			0.0001*
			(-1.73)
Other control variables	YES	YES	YES
Provincial fixed effect	YES	YES	YES
Time fixed effect	YES	YES	YES
N	300	360	360
R^2	0.2339	0.3531	0.3587

In the following, we further test whether green technology innovation is affected by the pressure of environmental governance objectives. Through the regression analysis of green technology innovation, controlling other variables constant, we obtain the regression results shown in Table 5 below. Specifically, the effect of environmental governance target pressure on green technological innovation shows a negative correlation and is significant at the 1 % statistical level; at the same time, the squared term of environmental governance target pressure has a positive correlation on green technological innovation and is significant at the 5 % statistical level.

This indicates that there is also a U-shaped relationship between environmental governance target pressure and green technology innovation. Therefore the effect of environmental governance target pressure on green technology innovation becomes a mediating variable of environmental governance target pressure on the green total factor of manufacturing industry. From the micro perspective, when the local government environmental governance target pressure is low, it is more tolerant to the polluting behavior of enterprises. Because the risk of innovation is highly uncertain, under the government's lower environmental constraints, enterprises are more inclined to use for environmental protection expenditures for sewage charges, which in turn has a crowding-out effect on the funding of green technological innovation. When the government is under greater pressure in environmental governance, its constraints on corporate emissions behavior will be stricter and will strengthen its concern for environmental protection. Environmental performance assessment is a long-term work, the local government in the face of greater pressure on environmental governance goals, will strengthen the national policy propaganda. Under the increasingly strict environmental constraints in the future, enterprises are more inclined to increase green technological innovation to meet their long-term development needs.

5.3. Moderating effect test

The green total factor productivity of manufacturing industry is affected by the pressure of the government's environmental governance objectives, but different provinces face different situations, so there may be some factors that may increase or reduce the impact of the pressure of the government's environmental governance objectives on the green total factor productivity of manufacturing industry. In order to explore the answer to the question, this paper uses the level of fiscal expenditure as a regulating variable for testing and obtains the regression results as shown in Table 6. According to the regression results, fiscal expenditure plays a moderating role in the relationship between green total factor productivity and environmental governance target pressure in the manufacturing industry when other moderating variables are kept constant. Specifically, the regression coefficient of fiscal expenditure has a positive trend at the 1 % significance level; the coefficient of the cross-multiplier term of fiscal expenditure and environmental governance target pressure has a negative trend at the 10 % significance level; and the coefficient of the squared cross-multiplier term of fiscal expenditure and environmental governance target pressure has a significant positive trend (the significance level is 5 %). This means that when fiscal expenditure is low, the negative impact of environmental governance target pressure on green total factor productivity in manufacturing industry is greater; conversely, when fiscal expenditure is high, the positive impact of environmental governance target pressure on green total factor productivity in manufacturing industry becomes greater. Therefore, it can be assumed that fiscal expenditure can enhance the impact of environmental governance target pressure on MGTFP.

5.4. Robustness tests

5.4.1. Transforming explanatory variables

In order to further enhance the credibility of the regression results, in this section we will use other alternative indicators to measure the pressure on environmental governance targets and conduct regression tests. In Table 7, we take "the ratio of the actual ammonia nitrogen emissions in the current year/the ammonia nitrogen emissions issued by the central government to the province in the current year" as the target pressure of environmental governance, while keeping other control variables unchanged. The results show that environmental governance target pressure is negatively correlated with the primary term of its regression, which is confirmed at the 1 % significance level. Whereas, environmental governance target pressure is positively correlated with the quadratic term of its regression and was verified at 5 % level of significance. From the regression results of the transformed explanatory variables, it can be seen that the impact of environmental governance target pressure on green total factor productivity of manufacturing industry is always in a U-shape relationship, no matter which index is adopted to measure environmental governance target pressure.

Table 5
Regression results of pressure on green technology innovation.

	Explained variable: green technology innovation
pressure	−4.7e+02***
	(-2.81)
The square of pressure	197.8901**
	(2.07)
Other control variables	YES
Provincial fixed effect	YES
Time fixed effect	YES
N	300
R^2	0.3748

Table 6
Regression analysis based on government fiscal expenditures.

	expenditure
pressure	−0.4626***
	(-3.33)
The square of pressure	0.2267**
	(2.10)
expenditure	0.0000***
	(3.66)
pressure × financial expenditure	−0.0000*
	(-1.72)
Square of pressure × financial expenditure	0.0000**
	(2.39)
Other control variables	YES
province	YES
time	YES
constant	0.3410***
	(4.19)
N	300
R^2	0.4067

Table 7
Tests using different pressure indicators for environmental governance goals.

	Explained variable:MGTFP
	Actual ammonia nitrogen emissions in the current year/ammonia nitrogen emissions issued by the central government in the current year
pressure	−0.6699***
	(-2.83)
The square of pressure	0.3884**
	(2.16)
Other control variables	YES
province	YES
time	YES
N	300
R^2	0.3577

5.4.2. Transforming the Explained variables

In order to verify the regression results in the previous section, we use the method of replacing the explanatory variables to conduct the robustness test. In Table 8, we shrink the "green total factor productivity data" by 1 % and take it as a new explanatory variable. The regression results show that the coefficient of the primary term of the regression is still negatively correlated with the pressure of environmental governance objectives and the significance level is 1 %. Meanwhile, environmental governance target pressure is positively correlated with the coefficient of the quadratic term of its regression, which is verified at the significance level of 5 %.

5.4.3. Endogeneity test

Since environmental governance target pressure may endogenize the regression results, this paper will use the mainstream instrumental variable method of two-stage least squares regression test. We use "the average value of environmental governance target pressure in neighboring provinces" as the instrumental variable of environmental governance target pressure in each province to conduct the least squares regression. The logic is that the pressure of environmental governance target of each provincial government

Table 8
Tests using different MGTFP indicators.

	Explained variable:MGTFP undergoes 1 % microfabrication
pressure	−0.3357***
	(-3.37)
The square of pressure	0.1146**
	(2.00)
Other control variables	YES
province	YES
Time	YES
N	300
R^2	0.3975

is not only referred to the completion of the task assigned by the state, but also affected by the environmental governance effect of neighboring provinces. This is because neighboring provinces and the province in the geographical location, resource endowment, transportation conditions, environmental constraints, industrial development, etc. have more similarity, and environmental governance performance assessment results will exist in the horizontal comparison, not only to complete the central government issued the allocation of the amount of perceived, but also with the neighboring provinces compared to the relatively good is also important. So the pressure on environmental governance targets in neighboring provinces will also be transmitted to the pressure on environmental governance in the sample provinces. Columns (1) and (2) of Table 9 show the panel data regression results after two-stage least squares regression. In the regression results in column (1), the coefficient on the primary term of environmental governance target pressure is negative, while the coefficient on the secondary term of environmental governance target pressure is positive. Both coefficients are statistically significant, indicating a positive U-shaped correlation between environmental governance target pressure and green total factor productivity in manufacturing.

6. Heterogeneity analysis based on market environment

Up to this point, we have found the hypothesis of a U-shaped relationship between environmental governance target pressure and MGTFP to be valid through a variety of tests. Next, we further test whether the relationship between environmental governance target pressure and green total factor productivity in manufacturing industry transforms with the level of marketization.

We group the provinces according to the level of marketization, and then, according to the grouping, we test the relationship between environmental governance target pressure and green total factor productivity in manufacturing. Based on the three quartiles of provincial marketization index scores from the China Sub-Provincial Market Index Report (2018), we divide all provinces into three groups. These three groups represent the high, medium and low levels of marketization. With these three marketization groupings, we perform regression analysis and show the results in Table 10. The first column shows the sample regression results for regions with a high level of marketization, the second column shows the sample regression results for regions with a medium level of marketization, and the third column shows the sample regression results for regions with a low level of marketization. The regression coefficients of environmental governance target pressure in column (1) are insignificant, and the regression coefficients of environmental governance target pressure in columns (2) and (3) are significant, which suggests that the U-shaped relationship between environmental governance target pressure and green total factor productivity in manufacturing industry exists in the regions with medium as well as low degree of marketization, and the regions with high degree of marketization are not affected by it.

Typically, those regions with a high degree of openness and a high level of economic development, especially the southeast coastal regions of China, will also have a relatively higher degree of marketization. These regions have a better economic base, a more optimized and advanced manufacturing industry structure, and manufacturing industries with relatively high technological content. Therefore, when the central government implements environmental policies, these regions are usually better able to adapt and are less affected. However, regions with medium and low marketization are mainly concentrated in central, northeastern, and western regions of China, which lack transportation advantages, coupled with the fact that these provinces themselves are rich in coal, oil, and other energy resources, and their manufacturing industries are more inclined to coal chemical and other related heavily polluting manufacturing industries, coupled with a relatively homogeneous manufacturing structure, which, in the face of greater pressure on environmental governance targets, will inevitably be more sensitive to the impacts of green total factor productivity on the manufacturing industry. productivity is more sensitive to the impact of green total factor productivity in manufacturing.

7. Discussion

The impact of local government environmental governance target pressure on MGTFP is the focus of this paper. It is found that

Table 9
Mean values of pressures on environmental governance targets in neighboring provinces as instrumental variables.

Interpreted variable	GTFP Phase II regression	pressure Phase 1 regression	Thesquare of pressurePhase1regression
	(1)	(2)	(3)
pressure	0.8840*		
	(1.70)		
The squareof pressure	−0.7941*		
	(-1.91)		
IV-: Mean value of environmental governance pressure in neighboring provinces		2.7776***	2.8938***
		(-8.63)	(-5.66)
IV: The square of the mean environmental governance pressure in neighboring provinces		−1.5575***	−1.4566***
		(-5.84)	(-3.45)
Other control variables	YES	YES	YES
province	YES	YES	YES
time	YES	YES	YES
N	300	300	300
R^2	0.8165	0.4223	0.3579

Table 10
Sub-sample regressions based on degree of marketization.

	Marketization (high)	Marketization(Medium)	Marketization (low)
	(1)	(2)	(3)
pressure	−0.4335	0.1114*	0.3178***
	(-1.35)	(1.72)	(3.71)
The square ofpressure	0.0873	−0.0757**	−0.1719***
	(0.39)	(-2.32)	(-4.18)
Other control variables	YES	YES	YES
province	YES	YES	YES
time	YES	YES	YES
N	90	140	70
R^2	0.4410	0.6411	0.7629

there is a U-shaped relationship between local government environmental governance target pressure and green total factor productivity in manufacturing industry, i.e., when the local government environmental governance target pressure is low, the green total factor productivity of manufacturing industry decreases with the increase of government pressure; however, when the local government environmental governance target pressure exceeds a certain critical value, the green total factor productivity of manufacturing industry will increase with the increase of government pressure. This finding sheds important light on our understanding of the impact of local governments' environmental policy implementation efforts on the green development of manufacturing industries. The findings are discussed specifically.

The results of this study differ somewhat from the existing findings in the literature.Zhou et al. (2023) argued that pressure on environmental governance goals promotes green total factor productivity, while the results of this study are inconsistent with this [82]. This discrepancy may be due to the fact that Zhou et al. (2023) regarded the independent variable as a dummy variable (i.e., whether the environmental goals constrain the city) and used the PSM-DID model, which only indicates whether the independent variable affects the dependent variable, and is unable to verify whether there is a nonlinear relationship between the independent variable and the dependent variable. In contrast, this study quantifies the pressure of environmental governance goals, thus better assessing whether there is a nonlinear relationship between the independent and dependent variables.

Controversially, environmental incentive theories differ on the effectiveness of mandatory targets for environmental improvement. Some scholars believe that the provision of significant government incentives can effectively promote environmental improvement; while others hold the opposite view. In this paper, on the other hand, we find through empirical research that the pressure of environmental governance targets exhibits a U-shaped relationship with MGTFP. That is, mandatory targets have the potential to both inhibit and promote environmental improvement. This situation mainly depends on the magnitude of pressure that mandatory targets exert on the government. The findings of this study enrich the theory of environmental incentives and provide a theoretical basis for the government to set mandatory environmental targets in a scientific and rational manner.

8. Conclusions and recommendations

Investigating the impact of government environmental governance goals pressure on the green total factor productivity of the manufacturing industry helps optimize the formulation of environmental governance goals, enhance the targeting and effectiveness of policies.This paper analyzes the data of 30 provinces and cities in China from 2016 to 2020 using panel fixed effects and mediation effects models. Through empirical analysis, this paper draws the following conclusions: first, there is a U-shaped relationship between government environmental governance target pressure and MGTFP, and the conclusion still holds after a series of robustness tests. Second, the environmental governance target pressure affects the green total factor productivity of the manufacturing industry by influencing the path of green innovation in the manufacturing industry, and then has an impact on the green total factor productivity of the manufacturing industry. Third, the impact of environmental governance target pressure on manufacturing green total factor productivity shows more obvious regional differences, in which the impact on the provinces with medium and lower levels of marketization is more significant, and that of the regions with higher levels of marketization is not obvious.

Verify the hypothesis of the impact of government environmental governance goals and pressures on the green total factor productivity of the manufacturing industry, and explore policy tools and mechanisms. This will help further understand the motivations and behaviors of local governments in the process of environmental governance, while providing guidance for the green development of the manufacturing industry. Setting environmental governance goals scientifically and reasonably can avoid policy ineffectiveness and counterproductive effects. Such research not only contributes to improving the green total factor productivity of the manufacturing industry, but also has significant implications for sustainable development and environmental protection. Therefore, policymakers should consider the following measures to promote the green transformation and development of the manufacturing industry.

1. In regions with a low and medium degree of marketization, environmental governance should be stepped up to promote green total factor productivity in manufacturing. In view of the characteristics of these regions, appropriate policy measures should be taken to encourage enterprises to carry out green innovation and improve MGTFP, so as to realize the positive interaction between environmental governance and MGTFP.

2. In regions with a high degree of marketization, regulation and guidance on environmental governance and green total factor productivity in manufacturing should be strengthened to ensure that the environment and industries in these regions maintain a good development trend. At the same time, enterprises should be encouraged to carry out green innovation and improve the green total factor productivity of the manufacturing industry to meet the development needs of regions with a high degree of marketization.
3. Local governments should increase their fiscal expenditures to regulate the relationship between the pressure of environmental governance targets and the green total factor productivity of the manufacturing industry. In regions with greater local fiscal expenditures, they should increase their efforts in environmental governance in order to achieve a win-win situation for environmental protection and economic development, while at the same time increasing support for the manufacturing industry and promoting green total factor productivity.

The following limitations exist in this study. First, our study mainly explores the impact of local government environmental governance target pressure on the green total factor productivity of manufacturing industries from a macro perspective, but has not yet further verified the hypotheses from a micro enterprise perspective. Future studies can utilize the green total factor data of listed manufacturing enterprises at the provincial or municipal level to verify the impact of local government environmental governance target pressure on them. Second, due to the lack of data on energy consumption of provincial manufacturing industries, we adopted an alternative approach in measuring the green total factor productivity of provincial manufacturing industries, i.e., using provincial industrial energy consumption as a substitute. This alternative method may have some impact on the empirical results. The relationship between government environmental governance target pressure and green total factor productivity in manufacturing studied in this paper is more practical in countries characterized by political centralization and environmental decentralization.

Funding statement

Professor Limin Wang has received support from the Qingdao Postdoctoral Project (QDBSH20230202079).
Professor Lv Yanqin has received support from the National Social Science Foundation project, China [22XJY036].
Dr. Shanhong Li received a grant from the Xinjiang University Excellent Doctoral Student Research Innovation Project (XJU2022BS014).

Data availability statement

All data are included in the article and its supplementary information files. These data can also be obtained from the website of the National Bureau of Statistics of China (https://www.stats.gov.cn/sj/).

Ethics declarations

Ethical approval does not apply to this article because no animals or humans were used as subjects in this article.

CRediT authorship contribution statement

Limin Wang: Conceptualization, Data curation, Formal analysis, Funding acquisition. **Shanhong Li:** Investigation, Methodology, Project administration, Resources. **Yanqin Lv:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e23801.

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