Economic Systems 47 (2023) 101011

Contents lists available at ScienceDirect

Economic Systems

journal homepage: www.elsevier.com/locate/ecosys

Rent-seeking, promotion pressure and green economic efficiency: Evidence from China

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ARTICLE INFO

JEL Classification:
H11
Q56
R11

Keywords:
Rent-seeking
Promotion pressure
Green economic efficiency

ABSTRACT

Focusing on the quality and sustainability of urban economic development and using a panel dataset of 263 cities in China from 2004 to 2015, this paper regards each city as a production unit and uses the Epsilon-Based Measure approach to measure green economic efficiency by innovatively regarding labor, capital, land and energy as input factors, GDP as a desirable output, and environmental pollution emissions and land finance as undesirable outputs. Further, this paper examines the effect of rent-seeking on green economic efficiency with a fixed effects model and explores the role of promotion pressure in the relationship between rent-seeking and green economic efficiency with a panel threshold model. Our study finds that: (1) Rent-seeking exerts a significant negative impact on green economic efficiency. (2) Compared to areas of higher promotion pressure, the negative effect of rent-seeking on green economic efficiency is greater in areas facing lower promotion pressure. (3) The relationship among promotion pressure, rent-seeking and green economic efficiency differs in areas facing different "green" promotion pressure.

1. Introduction

A campaign against rent-seeking and for a clean government has been sweeping across China since the 18th National Congress of the Communist Party of China in 2012, resulting in the downfall of several officials involved in illegal activities. Some scholars (e.g., Liu and Mikesell, 2014; Wang and You, 2012) argue that actions against rent-seeking may not only hinder enterprises from gaining more benefits, but could also restrict economic growth. However, the discussions focus on the "quantity effect" of rent-seeking on economic development, while little attention has been paid to the effect of rent-seeking on "economic quality". In fact, "economic quality" is the basis for a country to achieve health and long-term sustainable economic development. If anti-rent-seeking activities

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https://doi.org/10.1016/j.ecosys.2022.101011

Available online 17 June 2022
0939-3625/

improve "economic quality", there is no reason to believe that combating rent-seeking is unfavorable to economic development. Thus, broadly speaking, this paper focuses on the relationship between rent-seeking and "economic quality".

In existing studies, regional economic efficiency is a common method to measure "economic quality", regarding each city as an independent production decision-making unit and choosing appropriate input and output factors to evaluate each city's production efficiency. Influenced by a traditional development model focused purely on GDP growth, the estimation of economic efficiency often takes labor and capital as input factors and GDP as an output factor. However, this long-term development pattern of "high input and high consumption" results in a heavy burden on the ecosystem and serious environmental problems. At the 2015 World Summit on Sustainable Development (WSSD), the United Nations put forward 17 specific "Sustainable Development Goals", aiming to comprehensively resolve contradictions between economic and environmental goals to achieve sustainable development. With China's economy entering the new normal, local governments would also follow these "Sustainable Development Goals" and are expected to play a critical role in this process (Yu and Huang, 2020).

Inspired by this transformation of development goals, we make an effort to measure economic efficiency from the "sustainable" and "green" perspective, defined as green economic efficiency (GEE). Specifically, two main aspects are considered in the efficiency estimation model setting of input and output factors. (1) We estimate GEE under energy and environmental constraints, i.e. besides labor, capital and GDP as in the traditional estimation model, this paper also regards energy as an input factor and environmental pollution emissions as an undesirable output to better reflect economic and environmental issues in a unified framework. (2) Further, we also innovatively include land issue in the estimation model by regarding land as an input factor and land finance as an undesirable output. On the one hand, urbanization has led to a heavy use of land for city construction, causing serious energy-use and environmental problems. Inspired by the interplay among energy, environment and land, land is also considered as an input factor in the production process. On the other hand, as the largest asset owned by local governments, land has become the most important collateral for local governments' debt financing (Zheng et al., 2014) and the fiscal revenue obtained by transferring land-use right is called "land finance". "Land finance" with Chinese characteristics causes a series of negative influences and externalities, such as rising property prices, distorted resource allocation, increased financial risk and social inequality. Therefore, land finance is also regarded as an undesirable output in the estimation model.

This paper attempts to answer the following questions. (1) Does rent-seeking restrict sustainable economic efficiency, that is, does rent-seeking reduce the "quality" of economic development? If so, some research in support of rent-seeking being beneficial to economic development from the perspective of the "quantity effect" will be challenged. (2) Does local officials' promotion pressure play an important role in affecting the relationship between rent-seeking and GEE? This idea is inspired by the opinion that "the effect of rent-seeking activities on economic development may depend on the specific institutional environment" (Dong and Torgler, 2012), while officials with different promotion pressure empowered by China's promotion tournament are facing different institutional environments. (3) Will the relationship among promotion pressure, rent-seeking and GEE have significant differences in areas facing different "green" pressure? Different from the calculation method of promotion pressure based purely on economic performance, "green" promotion pressure incorporates environmental indicators into the officials' assessment system.

There are three possible contributions of the present article. (1) By manually collecting data to build a database of rent-seeking officials, this paper provides higher quality data for measuring the degree of rent-seeking from the new perspective of local officials' integrity. (2) Different from the existing literature focusing on traditional input-output factors in the production process, this article innovatively regards labor, capital, land and energy as input factors, GDP as a desirable output, and environmental pollution emissions and land finance as undesirable outputs to measure economic efficiency, which could better reflect the sustainability and high quality of economic development. (3) This paper combines an assessment system of officials with Chinese characteristics, that on the one hand uses "promotion pressure" as a moderating variable to explore the heterogeneous effect of rent-seeking on GEE, and on the other hand puts forward "green" promotion pressure to test the nonlinear relationship among rent-seeking, promotion pressure and GEE.

The remainder of the paper is organized as follows. Section 2 illustrates the related literature, mainly focusing on the effect of rent-seeking on GEE. Section 3 proposes the research hypotheses. Section 4 presents our data, variables, econometric methodology and some current facts based on raw data. Section 5 reports our results. Section 6 concludes and provides policy suggestions.

2. Literature review

Whether rent-seeking would lead to distortions in social institutions and hinder economic development still remains unsolved. To verify the relationship between rent-seeking and green economic efficiency, we explore the mechanism of how rent-seeking may impact GEE from six dimensions: the resource allocation effect, the time cost effect, the economic cost and financial constraint effect, the social innovation effect, the energy and environment effect and the land finance effect. Among these, the first four pay more attention to the impact of rent-seeking on "traditional" economic efficiency, while the last two emphasize the impact of rent-seeking on GEE, adding energy, land and environmental factors on the basis of traditional efficiency measurement methods.

2.1. Resource allocation effect

According to Bhagwati (1982), because of the existence of rent-seeking, resources cannot be allocated in a reasonable order and field. First, a large proportion of productive resources (e.g. labor, capital and land) are transferred to non-productive areas that are more rewarding and profitable. Second, entrepreneurs with potential innovation capability will abandon technology research activities and engage in rent-seeking activities, resulting in the distortion of human resource allocation (Murphy et al., 1993). Third, rent-seeking distorts the allocation of public expenditures since governments pursuing rent-seeking profits are more likely to invest in

projects that have more room for rent-seeking. Thus, public sectors like health care and education cannot obtain the investment and protection they deserve because of narrow rent-seeking feasibility (Tanzi and Davoodi, 1997).

In contrast, Leff (1964) believes that there exist unavoidable distortions in the resource allocation system. As the feedback on this market failure, rent-seeking can effectively compensate for the shortcomings of the system, helping individual investors to avoid inefficient laws and administrative regulations, reducing distortion costs, and ultimately showing an increase in economic efficiency. Lui (1985) adds that even if the system is not defective, the supply of rent may also push governments to improve the efficiency of work and resource allocation.

2.2. Time cost effect

As mentioned by Mahagaonkar (2008), the hierarchical structure of official decision-making systems increases the time for approval processes and officials may deliberately delay the issuance of licenses to obtain enough rent, leading to a rise of the time cost of enterprises. The higher the time cost, the lower the economic efficiency. In contrast, Bardhan (1997) argues that while governments engage in rent-seeking activities, they may have an incentive to improve administrative efficiency and simplify certain political procedures. Furthermore, Beck and Maher (1986) hold the view that the more rent is paid by enterprises, the higher their time value, since they are more eager to minimize the time cost. To this end, rent-seeking can help governments allocate resources to companies with the highest efficiency.

2.3. Economic cost and financial constraint effect

Some research confirms that higher economic costs caused by rent-seeking lead to enterprises facing financial constraints. If facing higher rent-seeking space, private sectors need to pay much rent to government departments. The existence of rent increases enterprises' initial fixed costs and restricts their available funds and investments in new products and technology, resulting in a decline of production efficiency because of the lack of technological innovation (Paunov, 2016). However, Wang and You (2012) verify that rent-seeking is likely to contribute to reducing enterprises' financial burden and constraints. By offering bribes to officials, enterprises have the opportunity to enjoy some policy support, such as gaining credit loans at lower interest rates, subsidies from governments, which are beneficial for enterprises to invest in more efficient research and development projects with more relaxed capital constraints.

2.4. Social innovation effect

According to Boldrin and Levine (2008) and Claessens and Laeven (2003), rent-seeking can dampen the enthusiasm of enterprises to invest and innovate. Firstly, rent-seeking breaks the protection of intellectual property rights, leading companies to curb the investment and development of intangible assets. Second, since the government has the right to price and allocate the main productive resources, some enterprises could reduce production costs by obtaining resources at lower prices through rent-seeking, while other companies' enthusiasm to innovate will be curbed. Some opposing views, such as Mahagaonkar (2008), find that a long-term political relationship is established between enterprises and the government by rent-seeking, which is helpful for enterprises to reduce information asymmetry and avoid political risk. Accordingly, the information advantage enables enterprises to devote more energy and time to promoting self-innovation capabilities and engaging in entrepreneurship activities (Jiang and Nie, 2014). In addition, because some investment activities, like the introduction and application of new techniques, are related to government permission. Enterprises with rent-seeking activities are more likely to enjoy priority in initiating innovation projects, taking advantage of promoting new technologies and applying for related patents at a late stage of projects, which may also offer a way for rent-seeking to ultimately increase economic efficiency.

2.5. Energy and environment effect

Considering that the excessive concentration of administrative power and dependence on government products with low demand elasticity make energy and environmental factors more vulnerable to rent-seeking, rent-seeking may ultimately influence GEE through energy and environment. Many scholars stress the negative impact of rent-seeking on energy and the environment, which can be explained by two mechanisms. One is the policy and regulation mechanism. Fredriksson and Svensson (2003) discuss the negative impact of rent-seeking on energy and environment efficiency by reducing the effectiveness of related policies or regulations. If energy and environment policies become a target of rent-seeking, the government will choose "inaction" while implementing and supervising environmental policies. The other is the foreign trade investment (FDI) mechanism. In an open international environment, a country seeking competitive advantages to attract FDI may deliberately reduce the environmental regulation intensity for foreign companies (Keller and Levinson, 2002). As a result, cities with looser policies and regulations are more likely to become channels for foreign enterprises to transfer high energy consumption and high pollution industries, and are called "pollution havens". However, as input-output factors of GEE, a reduction of energy and environmental pollutants caused by rent-seeking will hinder the improvement of GEE.

2.6. Land finance effect

The reform of the tax-sharing system in China leads to unequal pressure between the financial and administrative powers. Revenues from land conversion and land mortgage loans constitute the main source of funds for local governments to seek extra-budgetary income and alleviate the financial gap. These revenues are "land finance" (Zheng et al., 2014). "Land finance" has negative impacts on GEE. Li (2010) argues that land finance not only overdraws future land revenue, but also distorts the allocation efficiency of land. Such distortions not only hinder the upgrading of the industrial structure, but also aggravate the phenomenon of overcapacity in the manufacturing industry. Meanwhile, Chen and Zhang (2014) verify that land finance problems indeed reduce economic efficiency.

Rent-seeking aggravates the above impacts of land finance on economic efficiency. A lot of research shows that fiscal decentralization in China bring about a series of problems in the process of land selling, such as low financial transparency and social inequality. Meanwhile, Liang (2009) puts forward that competition incentives, fiscal revenue and government interests would invisibly "encourage" government officials to break the law on land issues. Since local governments have important autonomous decision-making powers in land disposal and management, rent-seeking can negatively affect GEE by inducing land financial problems in China.

3. Mechanisms and hypothesis

Based on the literature, rent-seeking may influence RESS through six aspects. The two competing views "rent-seeking promotes the economy" and "rent-seeking harms the economy" both reveal the impact of rent-seeking on green economic efficiency. Therefore, the first hypothesis is put forward as follows.

Hypothesis 1. : Rent-seeking would have a significant impact on green economic efficiency.

Besides the two opposing views of "rent-seeking promotes the economy" and "rent-seeking harms the economy", Dong and Torgler (2012) put forward the idea of "neutral rent-seeking", pointing out that the impact of rent-seeking on economic development depends on the specific institutional environment. In a perfect institutional environment, rent-seeking exerts a negative impact on economic development. But if the economic system and the resource allocation system have some defects, rent-seeking can act as a "lubricant", which is helpful for the promotion of economic efficiency (Sekkat and Méon, 2005). However, in order to explore this different impact of rent-seeking on GEE, this paper includes local officials' promotion pressure as one facet, since local leaders' promotion pressure reflects the institutional environments in different regions to a certain extent.

In China, the traditional officials' promotion tournament is a GDP assessment system, i.e. the assessment and evaluation of local officials' political achievements is mainly based on regional economic performance with GDP as the core (Li and Zhou, 2005). Provinces, cities, counties, townships and villages are ranked by their performance in growth, output and foreign investment, and this ranking is closely related to officials' promotion opportunities (Maskin et al., 2000). Under this system, local officials are not only "political participants" but also "economic participants". Local officials are enthusiastic about improving the regional economic performance to meet their promotion needs. Xu (2011) points out that officials with poor regional economic performance and relatively lower ranking are under greater promotion pressure.

The promotion tournament provides a strong incentive for ambitious leaders to use their political rights to respond. Usually, local leaders of lower ranking are under higher promotion pressure, the cities they govern have a poor economic performance in the market system. This dilemma favors rent-seeking activities to have greater space to function as a "lubricant" of economic activities and make up for the defects of the system to improve resource allocation efficiency, i.e. higher promotion pressure may alleviate the negative effect of rent-seeking on green economic efficiency (Méon and Weill, 2010).

On the contrary, benefiting from a better economic performance, local leaders ranking higher face lower promotion pressure and the rents they get from rent-seeking activities flow more into personal consumption rather than economic construction. To get more rent to realize their personal interests, local leaders are more likely to use public rights. On the one hand, since local leaders have the right to manage public projects and products, they have opportunities to divert investments into areas with more rent-seeking but unnecessary space, which leads to inefficient investment. On the other hand, since local leaders also have the right to allocate resources to society, they may deliberately delay the approval of related licenses or certificates to take more rent, resulting in a distorted allocation of resources and low economic efficiency. Such behaviors abuse public power for personal interests and become a "stumbling block" for economic activities. Based on the above analysis, the following hypothesis is suggested.

Hypothesis 2. : In areas of lower promotion pressure, rent-seeking exerts a greater negative impact on green economic efficiency.

Li and Zhou (2005) point out that environmental pollution is related to officials' promotion tournament with GDP as the core. The pursuit of promotion opportunities encourages local leaders to utilize their political rights and various resources to support local enterprises' development and indeed achieve great high-speed economic growth in China, but it also brings high costs, such as wasting resources and environmental pollution problems. As a result, in recent years, the central government has adopted a "green" performance appraisal system to align environmental protection with local leaders' private interests. Inspired by this, we also construct a "green" promotion pressure index to measure the environmental pressure faced by officials.

Similar to Cole (2007), many studies have verified the negative effects of rent-seeking on energy and the environment mainly caused by the government's excessive relaxation or inaction in energy and environment policies and regulations. Since the 1980 s, China has experienced political decentralization reform allowing local governments to allocate their regional resources, including

energy and environment. Political decentralization reform leaves room for local leaders to lower environmental protection standards and increases their scope in making decisions about pollution projects' supervision and evaluation. Liang and Gao (2014) also argue that the collusion between governments and enterprises mainly accounts for the difficulty in controlling environmental pollution.

Thus, we speculate that, compared with areas of lower "green" promotion pressure, the negative effects of rent-seeking on energy and the environment may be further amplified in areas of higher green promotion pressure. First, higher "green" promotion pressure means a poor local environment, so local leaders may have more opportunities to formulate energy policies and regulate polluters, making lower economic efficiency. Second, areas of higher "green" promotion pressure are more fragile and often cannot tolerate further damage to the environment caused by rent-seeking. On the contrary, areas of lower "green" promotion pressure benefit from a better environment and less rent-seeking space in formulating, implementing and auditing environmental policies, the negative impact of rent-seeking on GEE is relatively smaller. Thus, the following hypothesis is set forth.

Hypothesis 3. . In areas of higher "green" promotion pressure, rent-seeking exerts a greater negative impact on green economic efficiency.

Based on the above hypothesis, in areas of higher "green" promotion pressure, rent-seeking has a greater negative influence on GEE, and the alleviating effect of promotion pressure on rent-seeking may be relatively insignificant. According to Freedman and Jaggi (2005), administrative intervention plays a vital role in corporate responsibility fulfillment of environmental protection. Areas of higher "green" promotion pressure are faced with more serious ecological and environmental problems. To solve these, local leaders would inevitably divert their efforts and attention to regional economic development, which weakens the "alleviating effect" of higher promotion pressure on the negative influence of rent-seeking. Therefore, based on the aforementioned arguments, the following hypothesis is suggested.

Hypothesis 4. . In areas of higher "green" promotion pressure, the "alleviating effect" exerted by higher promotion pressure on the negative impact of rent-seeking is less significant.

4. Data and methodology

4.1. Data and sample description

Our research sample includes 263 cities in China from 2004 to 2015. The data used to construct rent-seeking indicators and identify officials' characteristic variables are derived from the website of the Ministry of Supervision of the Central Discipline Commission, the database of local leaders, People's Daily Online and Xinhua website. Moreover, other used raw data including input-output factors in the efficiency estimation and control variables in the empirical model come from *China City Statistics Yearbook*, *China Land & Resource Almanac*, *China Urban-Rural Construction Statistical Yearbook*, *China Environment Statistical Yearbook*, *China Statistical Yearbook* and the WIND database.

4.2. Main variable measurement

4.2.1. Dependent variable

GEE_{it} is the dependent variable indicating green economic efficiency in city i in year t. To estimate economic efficiency, data envelopment analysis (DEA) is widely used because there is no need to establish a specific production function or master input and output prices, and the decomposed efficiency of inputs and outputs can be calculated. However, traditional DEA methods (e.g. BCC and CCR) can't calculate the efficiency of undesirable outputs and only improve outputs and inputs with the same proportion. If the factors are relaxed, they often overestimate the objects' efficiency. Moreover, although purely non-radial models such as SBM (slack-based measure) overcome the above shortcomings, they lose the original proportion of the efficiency front's projection value, which may underestimate the objects' efficiency. Thus, following Tone and Tsutsui (2010), EBM (Epsilon-Based Measure) is adopted to estimate GEE in this paper, combining the ideas of CCR and SBM.

Specifically, assuming that the total number of decision-making units (DMUs) in period t is N. $x \in R^m$, $y \in R^{q1}$, $b \in R^{q2}$ represent input vectors, desirable output vectors and undesirable output vectors of DMU. m, q_1, q_2 are the numbers of input variables, desirable output variables and undesirable output variables. Matrix X, Y and B are defined as follows: $X=[x_1, ...,x_N] \in R^{m\times N}$, $Y = [y_1, ...,y_N] \in R^{q_1\times N}$, $B=[b_1, ...,b_N] \in R^{q_2\times N}$. Thus, the possibilities set of production has the following form:

$$P = \{(x, y, b) | x \geq X\lambda, y \leq Y\lambda, b \geq B\lambda, \lambda \geq 0\} \quad (1)$$

Efficiency values of each DMU ($k \in \{1,2...,N\}$) can be obtained by solving the following programming problems, with ε (value range between 0 and 1) as a key parameter to indicate the importance of the non-radial part.

$$GEE^{t}_{EBM}\left(x^{t}_{k}, y^{t}_{k}, b^{t}_{k}\right) = \min\left\{\frac{\theta - \varepsilon^{-}\left(1/m\right)\sum_{f=1}^{m}\left(s^{x,-}_{f}/x^{t}_{f,k}\right)}{\varphi + \left(\varepsilon^{+}/q_1\right)\sum_{r=1}^{q_1}\left(s^{y,+}_{r}/y^{t}_{r,k)}\right) + \left(\varepsilon^{-}/q_2\right)\sum_{l=1}^{q_2}\left(s^{b,-}_{l}/b^{t}_{l,k}\right)}\right\}$$

$$\text{s. t.} \quad X\lambda + s^{x,-} - \theta x_k = 0,\ Y\lambda - s^{y,+} - \varphi y_k = 0,\ B\lambda + s^{b,-} - \varphi b_k = 0$$

$$s^{x,-} \geq 0,\ s^{y,+} \geq 0,\ s^{b,-} \geq 0,\ i'\lambda = 1,\ \lambda \geq 0 \tag{2}$$

In Eq. (2), *GEE* represents green economic efficiency, and $s^{x,-}$, $s^{y,+}$ and $s^{b,-}$represent slack variables of inputs, desirable outputs and undesirable outputs, respectively. λ is the vector of the weight coefficient. Under the assumption that the variable returns to scale, the sum of all DMUs' weight coefficients is equal to 1. In order to solve Eq. (2), we treat it as a linear programming problem according to the following steps. First, we set t equal to Eq. (3).

$$t = \frac{1}{\varphi + \left(\varepsilon^{+}/q_1\right)\sum_{r=1}^{q_1}\left(s^{y,+}_{r}/y^{t}_{r,k)}\right) + \left(\varepsilon^{-}/q_2\right)\sum_{l=1}^{q_2}\left(s^{b,-}_{l}/b^{t}_{l,k}\right)} \tag{3}$$

Then, Eq. (2) is transformed as follows:

$$GEE^{t}_{EBM}\left(x^{t}_{k}, y^{t}_{k}, b^{t}_{k}\right) = \min\left\{\theta t - \varepsilon^{-}\left(1/m\right)\sum_{f=1}^{m}\left(ts^{x,-}_{f}/x^{t}_{f,k}\right)\right\}$$

$$\text{s. t.} \quad Xt\lambda + ts^{x,-} - \theta t x_k = 0, \quad Yt\lambda - ts^{y,+} - \varphi t y_k = 0, \quad Bt\lambda + ts^{b,-} - \varphi t b_k = 0$$

$$s^{x,-} \geq 0, \quad s^{y,+} \geq 0, \quad s^{b,-} \geq 0, \quad i'\lambda = 1, \quad \lambda \geq 0 \tag{4}$$

Second, we make the following settings as in Eq. (5), and then Eq. (4) can be transformed as Eq. (6).

$$S^{x,-} = ts^{x,-},\ S^{y,+} = ts^{y,+},\ S^{b,-} = ts^{b,-},\ \Lambda = t\lambda \tag{5}$$

$$GEE^{t}_{EBM}\left(x^{t}_{k}, y^{t}_{k}, b^{t}_{k}\right) = \min\left\{\theta t - \varepsilon^{-}\left(1/m\right)\sum_{f=1}^{m}\left(S^{x,-}_{f}/x^{t}_{f,k}\right)\right\}$$

$$\text{s. t.} \quad X\Lambda + S^{x,-} - \theta t x_k = 0,\ Y\Lambda - S^{y,+} - \varphi t y_k = 0,\ B\Lambda + S^{b,-} - \varphi t b_k = 0 \tag{6}$$

Let the optimal solution of linear programming be$(GEE^{*}_{EBM_L}, S^{x,-,*}, S^{y,+,*}, S^{b,-,*}, t^{*}, \Lambda^{*})$, and finally, we can find the optimal solution of the original non-linear programming problem as follows.

$$GEE^{*}_{EBM} = GEE^{*}_{EBM\_L}, \quad \lambda^{*} = \Lambda^{*}/t^{*}$$

$$s^{x,-,*} = S^{x,-,*}/t^{*},\ s^{y,+,*} = S^{y,+,*}/t^{*},\ s^{b,-,*} = S^{b,-,*}/t^{*} \tag{7}$$

To measure economic efficiency accurately and comprehensively from the "sustainable" and "green" perspectives, this paper regards labor, capital, land and energy as input factors, GDP as a desirable output, environmental pollution emissions and land finance as undesirable outputs to measure green economic efficiency by EBM. Referring to the existing research on measuring regional economic efficiency (Chen and Zhang, 2014; Lin and Tan, 2019; Managi and Kaneko, 2006; Tu and Liu, 2011), the selection of specific indicators is described below. (1) Labor input is measured by the number of employed workers at the end of the year. (2) Capital input is capital stock, based on the perpetual inventory method (Reinsdorf and Cover, 2005; Zhang et al., 2004). (3) Energy input is measured by full-year industrial electricity consumption. (4) Land input is measured by the area of urban construction land. (5) Desirable output factor is the real value of regional GDP, calculated by using the GDP deflator and nominal GDP. (6) Undesirable output factors include environmental pollution emissions and land finance, among which industrial wastewater discharge, industrial dust discharge and industrial SO_2 discharge are used as undesirable environmental pollution outputs, and actual value of land transfer income based on the GDP deflator index measures land finance output.

4.2.2. Independent variables

Independent variables include RS_{it} and $Cross_{it}$, which is obtained by multiplying RS_{it} and $Promotion_{it}$. As for RS_{it}, following Xu and Liu (2013), whether a city has illegal local leaders (mayor and secretary of the Municipal Committee) is taken as the proxy index of rent-seeking in this paper. There are two reasons for the indicator selection of rent-seeking. First, city leaders' (mayor and secretary of the Municipal Committee) decision-making and illegal activities can directly affect resource allocation and urban economic development, especially considering that areas with illegal officials have more rent-seeking opportunities and greater rent-seeking costs for enterprises (Xu and Liu, 2013). Second, in terms of sample selection, considering that not all officials' illegal activities are related to rent-seeking activities, this paper only retains serious illegal cases, mainly those involving seeking and accepting bribes and more directly related to rent-seeking.

For data collection, we manually collect information on illegal local leaders and proceed with the following three steps. (1) We sort out the list of all local leaders in China from 2004 to 2015 based on the information provided by the database of local leaders. (2)

From the Ministry of Supervision of the Central Discipline Commission website, People's Daily Online and Xinhua website, we collect information on every illegal case investigation and make a list of illegal local leaders. (3) To further identify the heterogeneity of local officials, we research resumes provided by the database of local leaders and collect officials' personal information, including gender, age, educational background, learning experience, work experience, etc.

As for the construction of officials' promotion pressure ($Promotion_{it}$), according to Xu (2011), we choose the GDP growth rate as the most important evaluation indicator in the measurement of promotion pressure. Moreover, due to the growing attention to people's wellbeing and livelihood, fiscal surplus and unemployment rate are also considered to measure promotion pressure faced by local leaders (Qian et al., 2011), among which fiscal surplus is equal to fiscal revenue minus fiscal expenditure divided by GDP. Let e_{it}^{k} (k = 1,2,3) be the k-th evaluation indicator in region i in year t and E_{it}^{k} be the pressure score. Since provincial leaders have the right to reward, punish, appoint and remove prefectural officials (Xu, 2011), a comparison will be made among the cities in the same province rather than among all cities across the country.

Specifically, taking each province as a unit, we sort the e_{it}^{k} values of each city from small to large within the province. GDP growth rate and fiscal surplus are positively correlated with economic performance and negatively correlated with promotion pressure. For these two indicators, if the value of e_{it}^{k} belongs to the first 25% interval, the first 25%− 50% interval, first 50%− 75% interval and first 75%− 100% interval, assign 3, 2, 1, 0 to E_{it}^{k}. Conversely, higher unemployment means worse economic performance and higher promotion pressure, after sorting values of e_{it}^{k} from small to large within the province, assign 0, 1, 2, 3 to E_{it}^{k} if the value of e_{it}^{k} belongs to the first 25% interval, 25%− 50% interval, 50%− 75% interval, 75%− 100% interval, respectively. Then, giving the same weight to E_{it}^{k} of GDP growth rate, fiscal surplus and unemployment rate, $Promotion_{it}$ is constructed as $Promotion_{it} = \sum_{k=1}^{3} E_{it}^{k}$, where $Promotion_{it} \in [0,9]$. The higher the value of $Promotion_{it}$, the higher the promotion pressure faced by local leaders of city i.

4.2.3. Threshold variable

As mentioned in the hypothesis section, there are two different orientations of the official evaluation system, giving officials different promotion incentives. One links the promotion opportunities purely to the regional economic performance, providing intrinsic incentives for officials to stimulate economic growth in their region (Tsui and Wang, 2004). The other focuses on the local environmental quality and adopts a "green" performance appraisal system (Qian et al., 2011).

As for the "green" promotion pressure indicator ($GrePromotion_{it}$), following the measurement method put forward by Qian et al. (2011), industrial electricity consumption, industrial wastewater discharge, industrial dust discharge and industrial SO_2 discharge are the four main indicators in the construction of $GrePromotion_{it}$ to reflect the ground and air environment. Similarly, let i_{it}^{k} (k = 1,2,3,4) be the k-th environmental indicator reflecting the environmental condition in region i in year t and let I_{it}^{k} be the "green" pressure score based on the k-th eco-environmental indicator. We assign a value among 0, 1, 2, 3 to I_{it}^{k} if the value of i_{it}^{k} belongs to the first 25% interval, 25%− 50% interval, 50%− 75% interval and 75%− 100% interval. Weighting the green promotion pressure score of the above indicators, for local leaders in region i, $GrePromotion_{it}$ is constructed as $\sum_{k=1}^{4} I_{it}^{k}$, where $GrePromotion_{it} \in [0,12]$. The higher the value of $GrePromotion_{it}$, the greater the "green" promotion pressure faced by local leaders of city i.

4.2.4. Control variables

Regarding control variables, $E\_controls_{it}$ and $O\_controls_{it}$ respectively reflect the situation of urban development and the experience of local leaders. Referring to relevant research on economic efficiency (Li and Lin, 2017; Lin and Tan, 2019; Song et al., 2011; Tu and Liu, 2011), $E\_controls_{it}$ is set as a vector of control variables that may affect GEE from the economic level, including: (1) $Urbanization_{it}$, measured by the growth rate of the share of urban population; (2) IS_{it}, which measures the industrial structure of city i by the proportion of the secondary industry in GDP; (3) $Open_{it}$, measuring the proportion of total import and export trade in GDP; (4) $Fiscal_{it}$, calculated as the proportion of local government expenditure in GDP; (5) $Marketization_{it}$, measured by the proportion of non-state-owned enterprises' fixed asset investment in total fixed asset investment; (6) HR_{it}, measured by the proportion of education fiscal expenditure in GDP; (7) RD_{it}, calculated as the proportion of internal expenditure of R&D funds in GDP; (8) $Greeninvest_{it}$, measured by the proportion of pollution control projects' investment in GDP.

$O\_controls_{it}$ is a vector of local leaders' personal characteristics that may influence GEE, such as the following. (1) Considering that local leaders' firm experience determines the difficulty of establishing a rent-seeking relationship between the government and enterprises and then affects GEE, $Firm\_experience_{it}$ is a dummy control variable to identify whether at least one local leader in city i in year t has enterprise working experience. (2) Given that the energy sectors' working experience enables leaders to accumulate experience in formulating energy policies and enhance their environmental awareness, which is important to improve GEE, $Energy_{it}$ is used to control whether city i *in year* t appoints local leaders with working experience in the energy sector or not.

The descriptive statistics for each variable used in our empirical model are presented in Table 1. Overall, 15.74% of the cities in the sample have had illegal local leaders. The mean value of IS_{it} is 49.6670, showing that, in general, cities in China are dominated by the secondary industry. The mean values of $Energy_{it}$ and $Firm\_experience_{it}$ are 0.1180 and 0.5188, suggesting that 51.88% of cities have local leaders with corporate experience, while only 11.80% have experience in the energy sector.

4.3. Models

4.3.1. Benchmark model

First, as our main objective in this paper is to identify the relationship between rent-seeking and green economic efficiency, we estimate the fixed effect model as Eq. (8) to verify Hypothesis 1. Further, to examine the role of promotion pressure in the relationship between rent-seeking and GEE, we take the cross term $Cross_{it}$ of RS_{it} and $Promotion_{it}$ in Eq. (9), which is used to verify Hypothesis 2.

Table 1
Descriptive statistics of the main variables.

Variable	Observations	Mean	Std. Dev.	Min.	Max.
GEE_{it}	2974	0.7767	0.1796	0.3086	1.0000
RS_{it}	2974	0.1574	0.3642	0.0000	1.0000
$Cross_{it}$	2937	0.6524	1.7232	0.0000	9.0000
$GrePromotion_{it}$	2965	5.2651	3.4234	0.0000	12.0000
$Urbanization_{it}$	2896	0.0337	0.0406	0.0000	0.7670
IS_{it}	2974	49.6670	10.7474	9.0000	90.9700
$Open_{it}$	2974	8.0924	19.9647	0.0858	327.9379
$Fiscal_{it}$	2974	0.1515	0.0794	0.0405	0.8582
$Marketization_{it}$	2974	0.7125	0.1047	0.3914	0.8855
HR_{it}	2974	0.0281	0.0158	0.0012	0.1656
RD_{it}	2974	0.0017	0.0060	0.0001	0.3180
$Greeninvest_{it}$	2974	0.0320	0.0306	0.0007	0.3281
$Energy_{it}$	2974	0.1180	0.3227	0.0000	1.0000
$Firm\_experience_{it}$	2974	0.5188	0.4997	0.0000	1.0000

$$GEE_{it} = \alpha_1 + \alpha_2 RS_{it} + \alpha_3 E\_controls_{it} + \alpha_4 O\_controls_{it} + \mu_i + \nu_t + \varepsilon_{it} \tag{8}$$

$$GEE_{it} = \alpha_1 + \alpha_2 RS_{it} + \alpha_3 Cross_{it} + \alpha_4 E\_controls_{it} + \alpha_5 O\_controls_{it} + \mu_i + \nu_t + \varepsilon_{it} \tag{9}$$

$$Cross_{it} = RS_{it} \cdot Promotion_{it} \tag{10}$$

where the cities are indexed by i ($i = 1,2,., N$) and time by t ($t = 1,2,., T$). GEE_{it} represents green economic efficiency and $Promotion_{it}$ is promotion pressure faced by local leaders. RS_{it} represents local leaders' (mayor and secretary of the Municipal Committee) rent-seeking variable. If the mayor or the secretary of the Municipal Committee in city i in year t is an illegal official, RS_{it} is equal to 1, if not, RS_{it} is equal to 0. The coefficients of interest to us are α_2 in Eq. (8) and α_3 in Eq. (9). Coefficient α_2 in Eq. (8) measures the impact of rent-seeking on GEE. Coefficient α_3 in Eq. (9) reflects the impact of promotion pressure on the relationship between rent-seeking and green economic efficiency. If α_3 is positive, that means rent-seeking exerts a greater negative impact on green economic efficiency in areas of lower promotion pressure. If α_3 is negative, that means rent-seeking exerts a greater negative impact on green economic efficiency in areas of higher promotion pressure. $E\_controls_{it}$ contains $Urbanization_{it}$, IS_{it}, $Open_{it}$, $Fiscal_{it}$, $Marketization_{it}$, HR_{it}, RD_{it}, $Greeninvest_{it}$; $O\_controls_{it}$ includes $Firm\_experience_{it}$ and $Energy_{it}$; μ_i controls the city fixed effect and ν_t controls the year fixed effect; ε_{it} represents the error term.

4.3.2. Panel threshold model

Hypotheses 3 and 4 further detect how Hypotheses 1 and 2 change if "green" promotion pressure is considered, i.e. the non-linearity of (1) the relationship between rent-seeking and GEE, (2) the impact of promotion pressure on the relationship between rent-seeking and GEE. Thus, using $GrePromotion_{it}$ to measure the environmental pressure faced by local leaders, we adopt it as a threshold variable to carry out the panel threshold model and verify its threshold effect in the relationship among rent-seeking, promotion pressure and GEE. Based on Hansen's (1999) method, Eq. (11) is set to test Hypothesis 3 and Eq. (12) is set to verify Hypothesis 4.

$$\begin{aligned} GEE_{it} = {} & \alpha_1 + \alpha_2 RS_{it} \cdot I(GrePromotion_{it} \le \gamma) + \alpha_3 RS_{it} \cdot I(GrePromotion_{it} > \gamma) \\ & + \alpha_4 Cross_{it} + \alpha_5 E\_controls_{it} + \alpha_6 O\_controls_{it} + \mu_i + \nu_t + \varepsilon_{it} \end{aligned} \tag{11}$$

Fig. 1. Comparison of green economic efficiency and real GDP growth ratio from 2004 to 2015.

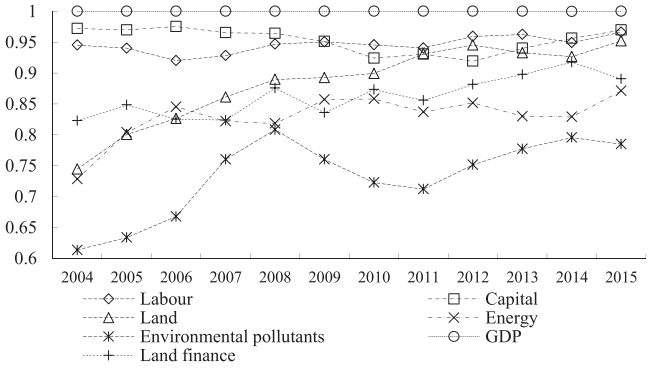

Fig. 2. Comparison of input-output factors' efficiency from 2004 to 2015.

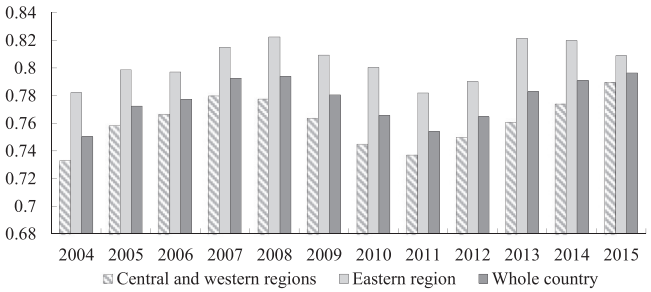

Fig. 3. Differences in green economic efficiency in different regions from 2004 to 2015.

$$GEE_{it} = \alpha_1 + \alpha_2 RS_{it} + \alpha_3 Cross_{it} \cdot I(GrePromotion_{it} \le \gamma) + \alpha_4 Cross_{it} \cdot I(GrePromotion_{it} > \gamma) + \alpha_5 E\_controls_{it} + \alpha_6 O\_controls_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (12)$$

$$Cross_{it} = RS_{it} \cdot Promotion_{it} \quad (13)$$

where γ is the threshold value to be estimated and $I(\bullet)$ represents the indicator function. If the expression in parentheses is true, the value of $I(\bullet)$ is 1, if not, $I(\bullet)$ is equal to 0. Other variables in Eq. (11) and Eq. (12) are set in the same way as in Eq. (8) and Eq. (9).

4.4. The situation of green economic efficiency in China

Figs. 1–3 make a comparative analysis on the trends of average GEE, the decomposition efficiency of input-output factors and regional differences of GEE, reflecting the sustainable development situation of cities in China from different perspectives, and can be summarized with the following three main conclusions. (1) The curves of "economic quality" (average GEE) and "economic quantity" (average real GDP growth ratio) in Fig. 1 show almost opposite development trends, which means the growth of the GDP-oriented economy in quantity is not equal to the improvement of economic quality, and it is necessary to take economic efficiency into consideration when analyzing economic development. (2) If input and output efficiency are decomposed (Fig. 2), we find that the efficiency of capital is the highest and relatively stable, the average efficiency of environment pollutants (0.7322), energy (0.8293), and land finance 0.8622) are generally lower in each year, indicating that they are the main factors restricting GEE. (3) GEE in eastern cities is significantly higher than in central and western cities (Fig. 3), maybe benefitting from their advantages in talent and technology, sufficient funds and resources, and advanced policy orientation.

Table 2
Single variable test.

	Q1	Q2	Q2-Q1	Wilcoxson	t-value
RS_M_{it}	0.7809	0.7273	0.0536	0.0000 ***	4.3272 ***
RS_S_{it}	0.7859	0. 6886	0.0973	0.0000 ***	8.6682 ***
RS_{it}	0.7898	0.7065	0.0833	0.0000 ***	9.3448 ***

Notes: *, ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

Table 3
The relationship between rent-seeking and green economic efficiency.

Variables	(1)	(2)	(3)	(4)
RS_{it}	-0.0157 **	-0.0149 *	-0.0143 *	-0.0143 *
	(0.0077)	(0.0078)	(0.0078)	(0.0078)
$Urbanization_{it}$	-0.1437 **	-0.1331 **	-0.1560 **	-0.1559 **
	(0.0609)	(0.0622)	(0.0629)	(0.0629)
IS_{it}	-0.0013 **	-0.0015 ***	-0.0014 **	-0.0013 **
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
$Open_{it}$	-0.0004	0.0003	0.0000	0.0000
	(0.0003)	(0.0005)	(0.0005)	(0.0005)
$Fiscal_{it}$		-0.0444	-0.0262	-0.0258
		(0.0634)	(0.0640)	(0.0640)
$Marketization_{it}$		0.0769 *	0.0894 *	0.0867 *
		(0.0465)	(0.0483)	(0.0483)
HR_{it}		-0.0416	0.3015	0.2972
		(0.3164)	(0.3985)	(0.3984)
RD_{it}			-2.3528 *	-2.3475 *
			(1.3959)	(1.3958)
$Greeninvest_{it}$			0.2396 *	0.2445 *
			(0.1292)	(0.1293)
$Energy_{it}$				-0.0077
				(0.0094)
$Firm\_experience_{it}$				-0.0076
				(0.0058)
Constant	0.9054 ***	0.8630 ***	0.8340 ***	0.8386 ***
	(0.0294)	(0.0397)	(0.0419)	(0.0421)
City fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Observations	2894	2894	2894	2894

Notes: Robust standard errors are reported in parentheses; *, ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

Table 4
The relationship among rent-seeking, promotion pressure and green economic efficiency.

Variables	(1)	(2)	(3)	(4)
RS_{it}	-0.0575 ***	-0.0559 ***	-0.0555 ***	-0.0550 ***
	(0.0155)	(0.0155)	(0.0155)	(0.0155)
$Cross_{it}$	0.0098 ***	0.0096 ***	0.0097 ***	0.0096 ***
	(0.0032)	(0.0032)	(0.0032)	(0.0032)
$Urbanization_{it}$	-0.1390 **	-0.1283 **	-0.1511 **	-0.1507 **
	(0.0610)	(0.0622)	(0.0630)	(0.0630)
IS_{it}	-0.0012 **	-0.0014 ***	-0.0013 **	-0.0012 **
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
$Open_{it}$	-0.0004	0.0002	-0.0001	-0.0001
	(0.0003)	(0.0005)	(0.0005)	(0.0005)
$Fiscal_{it}$		-0.0526	-0.0351	-0.0345
		(0.0634)	(0.0640)	(0.0641)
$Marketization_{it}$		0.0744	0.0872 *	0.0846 *
		(0.0465)	(0.0483)	(0.0483)
HR_{it}		0.0179	0.3475	0.3422
		(0.3166)	(0.3992)	(0.3991)
RD_{it}			-2.2719	-2.2650
			(1.4004)	(1.4003)
$Greeninvest_{it}$			0.2376 *	0.2422 *
			(0.1291)	(0.1291)
$Energy_{it}$				-0.0074
				(0.0094)
$Firm\_experience_{it}$				-0.0076
				(0.0058)
Constant	0.9026 ***	0.8617 ***	0.8329 ***	0.8374 ***
	(0.0295)	(0.0398)	(0.0420)	(0.0421)
City fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Observations	2857	2857	2857	2857

Notes: $Cross_{it}$ is the cross of RS_{it} and $Promotion_{it}$; robust standard errors are reported in parentheses; *, ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

5. Results and discussion

5.1. Single variable test

In this part, samples are divided according to the values of the dummy variables RS_M_{it}, RS_S_{it} and RS_{it} to test the difference of the mean value of GEE_{it} between different samples. RS_M_{it}, RS_S_{it} and RS_{it} measure whether city i has an illegal mayor, an illegal secretary of the Municipal Committee and an illegal local leader in year t. In Table 2, Q1 represents the mean value of GEE_{it} in samples without illegal local leaders and Q2 reports the mean value of GEE_{it} in samples with illegal local leaders. The results of three sample divisions show that Q1 is always higher than Q2, and these differences between groups pass the T-test and the Wilcoxson test for significance, suggesting that there is a negative relationship between rent-seeking and GEE.

5.2. Estimation of the baseline model

Table 3 gives an overview of our baseline model's regression results based on Eq. (8). Columns (1)-(3) report the estimation results controlling for some economic-level variables, the city fixed effect and the year fixed effect. We can see that the coefficient of RS_{it} is statistically significant and negative, suggesting that rent-seeking exerts a significant negative impact on GEE. We further control for the official characteristics of local leaders in column (4), we can see that the coefficient of RS_{it} is -0.0143 and significant at the 10% level, i.e., GEE of the cities with illegal local leaders is on average 0.0143 lower than that of cities without illegal local leaders. This finding confirms the negative impact of rent-seeking on GEE (Hypothesis 1) and the existence of the theory of "rent-seeking harms the economy" from the perspective of sustainable economic efficiency, that is, although some previous studies point out that rent-seeking may be beneficial to efficiency in different ways (Asiedu and Freeman, 2010; Jiang and Nie, 2014; Wang and You, 2012), on the whole, rent-seeking exerts a negative impact on economic efficiency if we add economy and resource environment into the measurement of efficiency.

With respect to other control variables, the estimated results are basically consistent with the existing literature (Li and Lin, 2017; Lin and Tan, 2019; Tu and Liu, 2011). Take the results of column (4) as an example, which adds all the control variables from the economic and official levels. $Urbanization_{it}$ is significantly negatively correlated with GEE_{it} at the 5% significance level, indicating that

Table 5
Test of the non-linear relationship between rent-seeking and green economic efficiency: Different balanced panel samples.

Variables	Balanced Panel A	Balanced Panel B	Balanced Panel C
	(1)	(2)	(3)
RS_{it} (< threshold = 3)	-0.0095	-0.0132	-0.0119
	(0.0187)	(0.0183)	(0.0176)
RS_{it} (≥ threshold = 3)	-0.0617***	-0.0588***	-0.0615***
	(0.0154)	(0.0144)	(0.0138)
$Cross_{it}$	0.0086***	0.0095***	0.0096***
	(0.0031)	(0.0030)	(0.0029)
$Urbanization_{it}$	0.0230	-0.0645	
	(0.1607)	(0.0497)	
IS_{it}	-0.0008*	-0.0012**	
	(0.0005)	(0.0005)	
$Open_{it}$	-0.0009*	-0.0016	-0.0003
	(0.0005)	(0.0013)	(0.0004)
$Fiscal_{it}$	-0.0852*	-0.0355	-0.0314
	(0.0498)	(0.0560)	(0.0517)
$Marketization_{it}$	0.0904	0.1407***	0.0304
	(0.0616)	(0.0536)	(0.0475)
HR_{it}	0.1039	0.2937	0.4711
	(0.3772)	(0.4002)	(0.3621)
RD_{it}	-2.4125	-5.6196***	-1.6241
	(1.5980)	(2.1722)	(1.5867)
$Greeninvest_{it}$	0.3084***	0.2532**	0.0369
	(0.1144)	(0.1161)	(0.0996)
$Energy_{it}$	-0.0046	-0.0022	-0.0023
	(0.0081)	(0.0080)	(0.0075)
$Firm\_experience_{it}$	-0.0080	-0.0120**	-0.0098**
	(0.0050)	(0.0052)	(0.0048)
Constant	0.7645***	0.7369***	0.7491***
	(0.0474)	(0.0374)	(0.0305)
City fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	2140	2160	2496
P-value for threshold test	0.0000	0.0000	0.0000

Notes: $Cross_{it}$ is the cross of RS_{it} and $Promotion_{it}$; robust standard errors are reported in parentheses; *, ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

Table 6
Test of the non-linear relationship between cross terms and green economic efficiency: Different balanced panel samples.

Variables	Balanced Panel A	Balanced Panel B	Balanced Panel C
	(1)	(2)	(3)
$Cross_{it}$ (< threshold = 3)	0.0171 ***	0.0173 ***	0.0178 ***
	(0.0035)	(0.0032)	(0.0031)
$Cross_{it}$ (≥ threshold = 3)	0.0042	0.0051	0.0050
	(0.0033)	(0.0032)	(0.0031)
RS_{it}	-0.0454 ***	-0.0443 ***	-0.0459 ***
	(0.0152)	(0.0144)	(0.0137)
$Urbanization_{it}$	0.0190	-0.0636	
	(0.1603)	(0.0495)	
IS_{it}	-0.0008 *	-0.0012 ***	
	(0.0005)	(0.0005)	
$Open_{it}$	-0.0009 *	-0.0017	-0.0003
	(0.0005)	(0.0013)	(0.0004)
$Fiscal_{it}$	-0.0844 *	-0.0372	-0.0325
	(0.0497)	(0.0558)	(0.0516)
$Marketization_{it}$	0.0881	0.1424 ***	0.0314
	(0.0615)	(0.0534)	(0.0474)
HR_{it}	0.0902	0.2847	0.4645
	(0.3764)	(0.3991)	(0.3612)
RD_{it}	-2.3990	-5.5605 **	-1.5848
	(1.5946)	(2.1662)	(1.5829)
$Greeninvest_{it}$	0.3162 ***	0.2573 **	0.0405
	(0.1141)	(0.1158)	(0.0993)
$Energy_{it}$	-0.0043	-0.0020	-0.0022
	(0.0081)	(0.0080)	(0.0075)
$Firm\_experience_{it}$	-0.0086 *	-0.0127 **	-0.0105 **
	(0.0050)	(0.0051)	(0.0048)
Constant	0.7662 ***	0.7370 ***	0.7490 ***
	(0.0473)	(0.0373)	(0.0304)
City fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	2140	2160	2496
P-value for threshold test	0.0000	0.0000	0.0000

Notes: $Cross_{it}$ is the cross of RS_{it} and $Promotion_{it}$; robust standard errors are reported in parentheses; *, ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

overinvestment and repeated projects in the process of urbanization reduce the efficiency of urban development. IS_{it} is significantly negatively correlated with GEE_{it} at the 5% significance level, mainly because that secondary industry is the main source of industrial pollution and energy consumption, which has a negative effect on the "green" development of cities. The estimation coefficient of $Marketization_{it}$ is significantly positive at the 10% level, indicating that the increase of marketization will speed up the diffusion of technology (Song et al., 2011), which is helpful for firms to gain advanced experience and improve GEE eventually. The significantly negative coefficient of RD_{it} is unexpected. The reason may be attributed to the fact that most R&D funding flows to heavy industry rather than "green" industry, imposing a burden on the environment and stimulating excessive consumption of energy and land. Thus, if we take energy, land and environmental pollutants into account, higher research and development expenditure may play a negative role on GEE. $Greeninvest_{it}$ is significantly positively correlated with GEE_{it} at the 10% significance level, showing that increasing investment in environmental governance projects can also promote GEE.

In order to further test Hypothesis 2, we put the cross term ($Cross_{it}$) of RS_{it} and $Promotion_{it}$ into Eq. (9). Table 4 shows the relationship among rent-seeking, promotion pressure and green economic efficiency. The results show that after controlling for all economic-level and official-level variables that may have an impact on GEE (column (4)), the coefficient of RS_{it} is significantly − 0.0550 at 1% level and the coefficient of $Cross_{it}$ is significant 0.0096 at 1% level, and this result is robust in controlling different variables (columns (1)-(3) in Table 4). Since the absolute value of RS_{it} is greater than that of $Cross_{it}$, in general, rent-seeking has a negative impact on GEE even considering officials' promotion pressure. But the coefficient of $Cross_{it}$ is positively correlated with GEE, indicating that compared to areas of lower promotion pressure, the negative effect of rent-seeking on GEE is weaker in areas facing higher promotion pressure. The result confirms that higher promotion pressure alleviates the negative impact of rent-seeking and supports Hypothesis 2. The possible reason is that in areas of lower promotion pressure, the bribes obtained by officials through rent-seeking are more likely to flow to areas of personal consumption and activities with more space for rent-seeking but lower efficiency.

5.3. Estimation of the panel threshold model

Since the panel threshold model requires a balanced panel without missing values, we change the unbalanced data to a balanced sample. Tables 5 and 6 present the results of Hypotheses 3 and 4 using different balanced panel samples. Column (1) excludes the

Table 7
Robustness test: changing the measurement of RS_{it}.

Variables	(1)	(2)	(3)	(4)	(5)
RS_M_{it}	-0.0570 ***	-0.0561 ***			-0.0577 ***
	(0.0204)	(0.0206)			(0.0214)
$Cross\_M_{it}$	0.0091 **	0.0089 * *			0.0085 *
	(0.0044)	(0.0045)			(0.0047)
RS_S_{it}			-0.0457 **	-0.0480 **	-0.0473 **
			(0.0192)	(0.0192)	(0.0194)
$Cross\_S_{it}$			0.0092 **	0.0102 **	0.0096 **
			(0.0040)	(0.0040)	(0.0040)
$Urbanization_{it}$	-0.1520 **	-0.1496 **	-0.1467 **	-0.1377 **	-0.1406 **
	(0.0631)	(0.0641)	(0.0631)	(0.0634)	(0.0642)
IS_{it}	-0.0013 **	-0.0012 **	-0.0014 **	-0.0014 **	-0.0012 **
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
$Open_{it}$	-0.0000	-0.0000	-0.0000	0.0001	0.0000
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
$Fiscal_{it}$	-0.0351	-0.0286	-0.0315	-0.0474	-0.0468
	(0.0641)	(0.0646)	(0.0641)	(0.0646)	(0.0650)
$Marketization_{it}$	0.0895 *	0.0794	0.1002 **	0.0590	0.0344
	(0.0482)	(0.0488)	(0.0483)	(0.0493)	(0.0500)
HR_{it}	0.3543	0.3755	0.3301	0.2263	0.2535
	(0.3996)	(0.4022)	(0.3998)	(0.4046)	(0.4067)
RD_{it}	-2.3505 *	-2.6379 *	-2.2809	-1.4603	-1.6692
	(1.4006)	(1.4132)	(1.4027)	(1.4237)	(1.4346)
$Greeninvest_{it}$	0.2409 *	0.2700 * *	0.2387 *	0.1856	0.2198
	(0.1292)	(0.1318)	(0.1293)	(0.1353)	(0.1384)
$Energy\_M_{it}$		-0.0077			-0.0138
		(0.0123)			(0.0127)
$Firm\_experience\_M_{it}$		-0.0091			-0.0081
		(0.0063)			(0.0064)
$Energy\_S_{it}$				0.0104	0.0100
				(0.0102)	(0.0103)
$Firm\_experience\_S_{it}$				-0.0073	-0.0068
				(0.0062)	(0.0063)
Constant	0.8308 ***	0.8346 ***	0.8249 ***	0.8595 ***	0.8710 ***
	(0.0417)	(0.0424)	(0.0420)	(0.0427)	(0.0435)
City fixed effect	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	2857	2803	2857	2747	2693

Notes: 'M' means Mayor of the Communist Party of China, *'S'* means Secretary of the Municipal Committee of the Communist Party of China; $Cross\_M_{it}$ is the cross of RS_M_{it} and $Promotion_{it}$; $Cross\_S_{it}$ is the cross of RS_S_{it} and $Promotion_{it}$; robust standard errors are reported in parentheses; * , * * and * ** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

years 2004 and 2005, which have relatively more missing data, containing 214 cities with complete data from 2006 to 2015 (Balanced Panel A). Column (2) includes all the control variables in the model, 180 cities with complete data from 2004 to 2015 (Balanced Panel B). Column (3) excludes $Urbanization_{it}$ and IS_{it}, which have missing data, including 208 cities with complete data from 2004 to 2015 (Balanced Panel C).

To check the number of thresholds, we estimate the single, double and triple threshold in turn, and the results support a single threshold at the 5% significance level. The regression results show that the threshold values estimated by Eqs. (11) and (12) are all 3.

Table 5 shows the regression results of the panel threshold model that takes RS_{it} as the core explanatory variable, i.e. Eq. (11). As shown in Table 5, we can see that: (1) for three different balanced panel samples (columns (1) - (3) of Table 4), the coefficients of RS_{it} are all significantly negative at the 1% level if $GrePromotion_{it}$ is above the threshold value ($GrePromotion_{it} \geq 3$), implying that rent-seeking has a significant effect on GEE if the region is facing higher "green" promotion pressure. (2) The negative impact of rent-seeking on GEE is not significant and relatively smaller while $GrePromotion_{it}$ is below the threshold value ($GrePromotion_{it} < 3$), which verifies Hypothesis 3. Namely, in areas of higher "green" promotion pressure, rent-seeking exerts a greater negative impact on GEE.

Table 6 reports the estimation results of the panel threshold model with $Cross_{it}$ as the core explanatory variable, i.e. Eq. (12). It can be seen from Table 3 that: (1) if $GrePromotion_{it}$ is below the threshold value ($GrePromotion_{it} < 3$), the coefficients of $Cross_{it}$ are positive at the 1% significance level for all samples (see columns (1)-(3) in Table 5), indicating that the "alleviating effect" exerted by higher promotion pressure on the negative impact of rent-seeking is significant in areas with lower "green" promotion pressure. (2) If $GrePromotion_{it}$ is over the threshold value ($GrePromotion_{it} \geq 3$), the coefficients of $Cross_{it}$ all turn insignificant. Further, compared to the estimation results when $GrePromotion_{it} < 3$, the absolute value of the coefficients of $Cross_{it}$ is much smaller when $GrePromotion_{it} \geq 3$. This shows that the "alleviating effect" exerted by higher promotion pressure on the negative impact of rent-seeking turns much smaller and even insignificant when "green" promotion pressure is greater than the threshold value. Thus, Hypothesis 4 is confirmed.

Table 8
Robustness test: changing the efficiency estimation method.

Variables	*SuperSBM1*		*SuperSBM2*	
	(1)	(2)	(3)	(4)
$SuperSBM1_{it-1}$	0.6091 ***	0.5978 ***		
	(0.0235)	(0.0229)		
$SuperSBM2_{it-1}$			0.6303 ***	0.6143 ***
			(0.0206)	(0.0217)
RS_{it}	-0.0297 ***	-0.0297 ***	-0.0951 ***	-0.0918 ***
	(0.0083)	(0.0091)	(0.0147)	(0.0151)
$Cross_{it}$	0.0050 ***	0.0044 ***	0.0179 ***	0.0174 ***
	(0.0015)	(0.0016)	(0.0026)	(0.0025)
$Urbanization_{it}$	-0.0453	-0.0435	0.0918	0.0620
	(0.0414)	(0.0404)	(0.0745)	(0.0742)
IS_{it}	-0.0014 ***	-0.0016 ***	-0.0015 ***	-0.0011 **
	(0.0004)	(0.0004)	(0.0005)	(0.0005)
$Open_{it}$	-0.0004 *	-0.0009 **	-0.0005	-0.0007
	(0.0002)	(0.0004)	(0.0004)	(0.0005)
$Fiscal_{it}$		-0.0830		-0.0810
		(0.0514)		(0.0622)
$Marketization_{it}$		-0.2389 ***		-0.0448
		(0.0631)		(0.1061)
HR_{it}		0.2852		1.0506 ***
		(0.2854)		(0.3698)
RD_{it}		0.4269		-3.2858 ***
		(1.0267)		(1.2605)
$Greeninvest_{it}$		0.2036		0.1616
		(0.1342)		(0.1880)
$Energy_{it}$		0.0024		-0.0101
		(0.0067)		(0.0096)
$Firm\_experience_{it}$		-0.0058		-0.0032
		(0.0049)		(0.0060)
Constant	0.2492 ***	0.0000	0.0000	0.2645 ***
	(0.0279)	(0.0000)	(0.0000)	(0.0936)
AR(2) -P value	0.729	0.699	0.376	0.355
Hansen-P value	0.235	0.340	0.624	0.618
City fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Observations	2610	2610	2610	2610

Notes: $Cross_{it}$ is the cross of RS_{it} and $Promotion_{it}$; robust standard errors are reported in parentheses; *, ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

5.4. Robustness test

It can be seen from the empirical results that: (1) rent-seeking is harmful to GEE. (2) In areas of lower promotion pressure, rent-seeking exerts a greater negative impact on green economic efficiency. In the following, we aim to ensure the credibility of the above research results with some robustness tests by changing the measurement of RS_{it}, changing the efficiency estimation method, using balanced panel subsamples and considering endogeneity. Tables 7, 8, 9 and 10 show different robustness tests of the regression in Table 4.

5.4.1. Changing the measurement of RS_{it}

Table 7 distinguishes rent-seeking behaviors between mayors and secretaries of the Municipal Committee. Columns (1) and (2) take mayors as the research objects, adding control variables at the economic level and all control variables to estimate, respectively. Columns (3) and (4) take secretaries of the Municipal Committee as the research objects, adding control variables at the economic level and all control variables to estimate, respectively. Column (5) reports the estimated results with RS_M_{it}, $Cross\_M_{it}$, RS_S_{it}, $Cross\_S_{it}$ and all control variables are added to the model. We can see that: (1) the coefficients of RS_M_{it} and RS_S_{it} are both negatively correlated with GEE, indicating that rent-seeking behavior of mayors and secretaries of the Municipal Committee both restrict improvements in GEE; (2) the coefficients of $Cross\_M_{it}$ and $Cross\_S_{it}$ are significantly positive, confirming that in areas of lower promotion pressure, rent-seeking behavior of mayors and secretaries of the Municipal Committee both exert a greater negative impact on green economic efficiency. The above results further verify the credibility of the relationship between rent-seeking, promotion pressure and green economic efficiency.

5.4.2. Changing the efficiency estimation method

In the estimation of economic efficiency, traditional models of DEA (e.g., BCC, CCR, SBM, EBM) take all DMUs into account while constructing the effective production frontier. Thus, the efficiency value of DMUs estimated by traditional DEA models can range from 0 to 1, and DMUs at the production frontier have the same highest efficiency (value = 1). Here, we change the efficiency

Table 9
Robustness test: using different balanced panel subsamples.

Variables	Balanced Panel A	Balanced Panel B	Balanced Panel C
	(1)	(2)	(3)
RS_{it}	-0.0623***	-0.0662***	-0.0669***
	(0.0186)	(0.0176)	(0.0171)
$Cross_{it}$	0.0102***	0.0126***	0.0125***
	(0.0038)	(0.0036)	(0.0035)
$Urbanization_{it}$	-0.0652	-0.0823	
	(0.2073)	(0.0691)	
IS_{it}	-0.0011*	-0.0012**	
	(0.0006)	(0.0006)	
$Open_{it}$	-0.0005	-0.0021	0.0001
	(0.0006)	(0.0014)	(0.0005)
$Fiscal_{it}$	-0.1044	-0.0538	-0.0472
	(0.0638)	(0.0719)	(0.0674)
$Marketization_{it}$	-0.0059	0.0885	-0.0225
	(0.0718)	(0.0629)	(0.0574)
HR_{it}	0.4250	0.6476	0.8591*
	(0.4675)	(0.4916)	(0.4610)
RD_{it}	-1.6884	-5.4335**	-1.0236
	(2.0913)	(2.7303)	(2.1393)
$Greeninvest_{it}$	0.3343**	0.2849*	0.0294
	(0.1446)	(0.1468)	(0.1280)
$Energy_{it}$	-0.0086	-0.0027	-0.0036
	(0.0107)	(0.0105)	(0.0101)
$Firm\_experience_{it}$	-0.0075	-0.0130**	-0.0096
	(0.0065)	(0.0066)	(0.0062)
Constant	0.8808***	0.8063***	0.8151***
	(0.0596)	(0.0477)	(0.0406)
City fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	2140	2160	2496

Notes: $Cross_{it}$ is the cross of RS_{it} and $Promotion_{it}$; robust standard errors are reported in parentheses; *, ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

estimation method by further using the Super-SBM (Super Slack Based Measure) model to re-estimate the economic efficiency. This model excludes the evaluated DMU while constructing the effective production frontier so that efficiency values of DMUs in this model may be greater than 1.

Table 8 reports the results of changing the measurement of GEE_{it} by adopting the Super-SBM model. Columns (1) and (2) take $SuperSBM1_{it}$ as the dependent variable with labor, capital and energy as input factors, GDP as a desirable output, and environmental pollution emissions as undesirable outputs. Columns (3) and (4) take $SuperSBM2_{it}$ as the dependent variable with labor, capital, energy and land as input factors, GDP as a desirable output, and environmental pollution emissions and land finance as undesirable outputs. All regressions in Table 8 employ the two-step systems Generalized Method of Moments (GMM) to better consider dynamic changes and alleviate endogeneity. We can see that the P-values of AR (2) and the Hansen test are all over 0.1, indicating that there is no second order autocorrelation in the random error term and the instrumental variables are effective. The coefficient estimation of RS_{it} and $Cross_{it}$ is also consistent with the results of Table 4.

5.4.3. Using balanced panel subsamples

Table 9 gives the results using different balanced panel subsamples. The samples used in columns (1)-(3) of Table 9 are the same as columns (1)-(3) of Tables 5 and 6. As can be seen from Table 9, no matter which subsample is replaced for the regression, RS_{it} is negative at the 1% significance level and $Cross_{it}$ is positive at the 1% significance level. This result is close to the baseline regression results, i.e. after using balanced panel subsamples, the estimated coefficients of the baseline model are still robust.

5.4.4. Consider endogeneity

Endogeneity caused by reverse causality and missing variables is a common problem in empirical research. On the one hand, although this paper attempts to control for some variables that may affect GEE from the economic and official levels, there are still many variables that are difficult to quantify and observe. On the other hand, the officials may also face greater rent-seeking space while green economic efficiency is low, causing reverse causation between GEE and rent-seeking. In terms of these problems, first, the lag term of RS_{it}, $Cross_{it}$ and all control variables are used as independent variables for re-estimation. Second, we add more control variables trying to avoid endogenous problems caused by the omission of important variables. Third, we employ Propensity Score Matching (PSM) to re-estimate.

In Table 10, column (1) reports the results of one period lag of RS_{it}, $Cross_{it}$ and all control variables, and the results show that RS_{it} is significantly negatively correlated with GEE_{it+1} and $Cross_{it}$ is significantly positively correlated with GEE_{it+1}. Column (2) shows the

Table 10
Robustness test: considering endogeneity.

Variables	GEE_{it+1}	GEE_{it}	GEE_{it}
	(1)	(2)	(3)
RS_{it}	-0.0489 ***	-0.0553 ***	-0.0972 ***
	(0.0158)	(0.0160)	(0.0270)
$Cross_{it}$	0.0064 **	0.0100 ***	0.0148 ***
	(0.0032)	(0.0033)	(0.0041)
$Urbanization_{it}$	-0.1347 **	-0.1457 **	-0.1077
	(0.0647)	(0.0633)	(0.1620)
IS_{it}	-0.0009	-0.0014 **	-0.0016
	(0.0006)	(0.0005)	(0.0010)
$Open_{it}$	0.0003	0.0003	0.0010
	(0.0006)	(0.0005)	(0.0007)
$Fiscal_{it}$	-0.0258	-0.0364	0.0588
	(0.0645)	(0.0649)	(0.1760)
$Marketization_{it}$	0.0407	0.0069	-0.0396
	(0.0588)	(0.0534)	(0.0995)
HR_{it}	-0.3151	0.5175	0.7075
	(0.4502)	(0.4385)	(0.9416)
RD_{it}	-0.4529	0.7640	-10.0983 * *
	(2.1242)	(1.8741)	(4.8329)
$Greeninvest_{it}$	0.1663	0.2582 *	0.2308
	(0.1324)	(0.1354)	(0.2522)
$Energy_{it}$	0.0004	-0.0097	-0.0059
	(0.0098)	(0.0097)	(0.0197)
$Firm\_experience_{it}$	-0.0069	-0.0081	0.0056
	(0.0061)	(0.0060)	(0.0121)
$Finance_{it}$		-0.0151 **	
		(0.0075)	
$Education_{it}$		0.0083	
		(0.0056)	
$Crossprovincial_{it}$		0.0089	
		(0.0079)	
Constant	0.8695 ***	0.8709 ***	0.9035 ***
	(0.0441)	(0.0469)	(0.0850)
City fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	2576	2732	911

Notes: $Cross_{it}$ is the cross of RS_{it} and $Promotion_{it}$; robust standard errors are reported in parentheses; * , ** and *** stand for $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

results of adding more control variables. Specifically, we add $Finance_{it}$, $Education_{it}$ and $Crossprovincial_{it}$. $Finance_{it}$ represents the financial development level and is measured by the proportion of financial institutions' loans in GDP, $Education_{it}$ is used to measure the education background of local leaders, and $Crossprovincial_{it}$ is a dummy control variable to identify whether at least one local leader in city i in year t had cross-provincial governance experience. The regression results show that the coefficient of RS_{it} is significantly negative at the 1% confidence level and the coefficient of $Cross_{it}$ is significantly positive at the 1% confidence level. In addition, $Finance_{it}$ is significantly negatively correlated with GEE_{it}, which may be due to more loans going to industrial enterprises with high pollution and energy consumption.

The result of PSM is shown in Column (3). According to the value of the dummy variable RS_{it}, we divided the sample into two groups: the treatment and the control group. Then we do matching work, with the matching variables including $Urbanization_{it}$, IS_{it}, $Open_{it}$, $Fiscal_{it}$, $Marketization_{it}$, HR_{it}, RD_{it}, $Greeninvest_{it}$, $Firm\_experience_{it}$ and $Energy_{it}$. Next, we pair two samples with similar values of matching variables in different groups. The result shows that the coefficient of RS_{it} is -0.0972 and significant at the 1% level, indicating that the GEE of the subsample with illegal local leaders is relatively lower than that without illegal local leaders. Moreover, $Cross_{it}$ is also positive and significant at the 1% level. These results confirm the robustness of the core conclusions.

6. Conclusions

Integrating economic development, energy, land use and the ecological environment into the same framework from the perspective of "economic quality", this paper estimated green economic efficiency by using the EBM (Epsilon-Based Measure) model, which reflects the efficiency situation in the process of urban development as follows. (1) A GDP-oriented development model can't comprehensively reflect the situation of economic development because GEE and GDP growth in China show an almost opposite trend. (2) If input and output factors are decomposed, the efficiency of capital is the highest and relatively stable, while the efficiency of energy, environment pollutants and land finance need to be improved to a large extent. (3) The GEE of the eastern region is significantly higher than that of the central and western regions.

In the empirical part, using panel data from China's 263 cities for the period of 2014–2015, we explored the relationship among rent-seeking, promotion pressure and GEE. First, we explored the relationship between rent-seeking and GEE, with the result indicating that rent-seeking has a significant negative impact on GEE. Second, we added promotion pressure to the baseline model to test its role in affecting the relationship between rent-seeking and GEE and found that rent-seeking exerts a greater negative impact on green economic efficiency in areas of lower promotion pressure, i.e. higher promotion pressure exerts an "alleviating effect" on the negative impact of rent-seeking. The above conclusions still robust when changing the measurement of the core explanatory variable or the method of efficiency estimation, using balanced panel subsamples and considering endogeneity. Third, to study the nonlinearity of the relationship among rent-seeking, promotion pressure and GEE, this paper used "green" promotion pressure as a threshold variable and employed a panel threshold model. The analysis indicates that, in areas of higher "green" promotion pressure, rent-seeking exerts a greater negative impact on GEE, and the "alleviating effect" exerted by higher promotion pressure on the negative impact of rent-seeking is less significant.

According to the main conclusions outlined above, we arrive at the following policy recommendations. First, it is necessary to allocate resources reasonably and improve the efficiency of production factors. Based on our efficiency estimate, the efficiency of energy and environment factors urgently needs to be improved. The following three aspects can be tackled simultaneously. (1) The government should formulate strict laws and regulations on energy utilization and environmental protection, strengthen the daily supervision of enterprises, curb environmental pollution and excessive energy consumption in production processes. (2) Pushing the transformation and upgrading of traditional industries is an urgent task, the government should make great efforts to adjust the energy structure and control the total amount of energy use. (3) Using advanced technologies to control and fight pollution can help enterprises to improve efficiency. Therefore, the government should encourage and support enterprises in introducing and carrying out technological innovation.

Second, it should be considered that rent-seeking can significantly hinder the improvement of GEE and a clean political environment can provide a fair order for resource allocation and help achieve a coordinated development of economy and environment. We suggest that the government should strengthen supervision for a better political environment and work to reduce the space for collusion and rent-seeking between local officials and enterprises by allocating resources more transparently and fairly.

Third, the government needs to establish a reasonable political promotion evaluation system to encourage officials to develop sustainable economic development. According to our research, appropriate promotion incentives for local officials can alleviate the negative impact of rent-seeking on GEE to some extent. Hence, we suggest that while assessing local officials' performance, the government should add energy and environmental indicators to link local officials' promotion to the local environmental and economic performance at the same time to mobilize local officials' enthusiasm of environmental protection.

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.

Acknowledgments

This work was supported by the "National Natural Science Foundation of China", "China" (grant numbers 71603056) and "Humanities and Social Sciences Projects of the Ministry of Education of China", "Chin"" (grant number 21YJC790107).

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