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Role of R&D investments and air quality in green governance efficiency

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ABSTRACT

This article measures the impact of R&D investment and carbon dioxide (CO_2) emission of the Shanghai and Shenzhen stock market listed companies on the green governance efficiency (G.G.E.). An econometric analysis based on the data from 2015 to 2019 is used to measure the impact. The study's findings reveal that research and development (R&D) investments significantly boost G.G.E. On the other hand, CO_2 emission and energy intensity reduce G.G.E. The study results show that the listed companies' performance would have a significant role in achieving the Chinese government's carbon neutrality goal. The study provides policy recommendations to promote green governance performance in China and other developing countries.

1. Introduction and background

China's rapid economic growth highly relied on energy consumption has resulted in significant ecological imbalances, particularly concerning air quality (Dai et al., 2021; Guoci, 2020; Niu & Du, 2021; Yan & Su, 2020; Zhou et al., 2021). Based on the Paris agreement on climate change, the Chinese government committed to reducing CO_2 emissions per unit of G.D.P. by 65% to 70% within 2050, using 2005 as the baseline. The Chinese government seems to be quite concerned about resource shortages and the environmental pressures of economic growth. China requires more green investments because of its aggressive growth goals and environmental concerns. Specifically, the country needs to consider green governance efficiency (G.G.E.) to simultaneously promote economic growth and environmental development (Sueyoshi et al., 2017), resulting in better economic growth with nominal environmental loss in limited resources. Green governance is vital for achieving global sustainable goals for future growth, and policymakers should keep this in mind when making environmental policy decisions (Debbarma & Choi, 2022).

One of the main components of efficient green governance is stable finance and investments in green infrastructure (Taghizadeh-Hesary & Yoshino, 2020; Tran, 2021;

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Ngo et al., 2021). Several studies support the impact of green financing, green investments, and financial inclusion on CO_2 emissions and green performance (Le et al., 2020; Tran, 2021, Zhang et al., 2021); however, the researchers' findings are inconsistent. The studies of Ozturk and Acaravci (2013) Saidi and Mbarek (2017), Charfeddine and Kahia (2019), Chandio, Jiang, Akram et al. (2021) and Otek Ntsama et al. (2021) show a positive correlation between financial development and CO_2 emissions, whereas studies such as Alemzero, Sun et al. (2020), Sun, Pofoura et al. (2020) and Alemzero, Iqbal et al. (2020) exhibit a negative relationship. Similarly, the environmental Kuznets curve (E.K.C.) is used for developed (Dogan & Seker, 2016) and developing (Charfeddine & Kahia, 2019) countries to exhibit nonlinear or inverted -U relationships between the two components. CO_2 emission and per capita income are the major components of the conventional E.K.C. Hence, the level of CO_2 emission needs to be considered as a possible determinant of the G.G.E.

Research and development (R&D) in green technologies and energy efficiency investments may all be used as mediating variables to quantify green technological innovation and G.G.E. Various empirical studies utilise total R&D inputs as a proxy for modern technology and argue how they can be regarded as a proposed integrated to limit energy usage. R&D is implemented in different sectors, and total R&D inputs may not yield new technologies in the green energy industry; using total R&D expenses in the analysis is improper.

According to major studies, the most crucial factor to consider when discussing green governance and growth is the G.D.P. level (Chen et al., 2019). G.D.P. is one of the main drivers of energy consumption; higher economic growth requires more energy consumption in the firms and households. Another determining factor of G.G.E. is energy efficiency (or, in the simplest definition 1/energy intensity). China's energy efficiency has risen rapidly in tandem with the country's economic and technical advancements. There has been an improvement of up to 42% in the average energy efficiency of regions in China between 2000 and 2016. However, considerable disparities in regional and temporal patterns still exist in improvements in provincial energy efficiency. An increase in the renewable energy demand and fostering new green technologies requires more investment and financial development (Charfeddine & Kahia, 2019; Huang et al., 2021; Mirza, Naqvi et al., 2020; Rizvi et al., 2020; Sun, Awan et al., 2020; Sun, Jiang et al., 2020). Therefore, when considering the G.G.E., investment is another factor that needs to be considered. The previous studies were on a group of countries, such as Asia Pacific countries (Khezri et al., 2021), panel data for 42 countries (Xu et al., 2021), panel data from 97 countries worldwide (Lv & Li 2021), Ghana (Abokyi et al., 2019), high-income countries and lower-income countries (Khan et al., 2018), O.E.C.D. countries (Zaidi et al., 2019) evaluated the role of green finance and others factors on energy efficiency, carbon emissions, sustainable growth, and green governance.

This study aims to measure the influence of R&D, energy intensity, and air pollution of the Shanghai and Shenzhen stock markets listed companies on the G.G.E. The study utilises econometric analysis using the data from 2015 to 2019 to quantify this impact.

The remaining structure is organised as follows, the following section contains a literature review, section 3 shows data and empirical model, section 4 explains the

results and discussion and section 5 concludes the study and provides policy recommendations.

2. Literature review

China's greenhouse gas (G.H.G.) emission reduction objectives increase energy supply and consumption conflict. Recently, studying the energy efficiency and low-carbon economy's driving elements has become an essential topic. Particularly, the determinants of the firms' energy efficiency investment have been extensively studied recently (Gao et al., 2021; Liu et al., 2021; Lei et al., 2021; Mohsin, Hanif et al., 2021; Sun et al., 2021; Wu et al., 2022; Xiang et al., 2021) empirically explore the drivers of energy efficiency in different sectors. They classify these drivers into internal and external controls (firm size and sector). Market pressures (trade, client requirements, industrial network, and professional technical assistance), governmental tools, external drivers (Mirza, Rahat et al., 2020; Naqvi et al., 2021). They include policy and legislation (legal compliance, subsidies, taxes, agreements, and other policy interventions) (Ji et al., 2021; Shao, 2020; Umar et al., 2021a). Not only has government involvement been justified due to market failures, but data from Europe shows that energy efficiency has increased slowly since 2008, with minimal gain in most industries and no progress in others like steel and cement. Despite these minimal gains, the industry has enormous potential to raise energy efficiency (Umar et al., 2021b; Wu, 2020). Canli and Karaşar (2020) stress the significance of strengthening policy initiatives to increase energy efficiency in the industry.

According to Kordej-De Villa and Slijepcevic (2019) and Khosravi et al. (2019), policies can help improve energy efficiency and achieve green growth by lowering investment costs, such as subsidies, lower loan interest rates, and tax deductions. Some countries, like Spain, offer subsidies to encourage energy-efficient devices. Subventions lower investment costs and payback times, encouraging enterprises to adopt new green technologies.

A review of the literature shows a bidirectional relationship between finance and green governance. Easier access to cheaper and stable finance enhance the G.G.E. On the other hand, firms with better green governance structures face lower financing constraints (Li et al., 2020).

Mohsin, Ullah et al. (2021) propose categorising commercial energy efficiency approaches as unbending, monetary, and supportive. Governments can utilise energy management systems to help private investors decide what actions to take and what investments to make to improve energy efficiency. Government policies also define instruments, provide technical information, and encourage coordinated efforts. Yang et al. (2021), He et al. (2020) and Mohsin et al. (2021) provide a qualitative assessment of these instruments. Quantitatively, some studies have analyzed the elements that promote energy efficiency and green growth using various policy instruments (Anh Tu & Rasoulinezhad, 2021; Cao et al., 2021); However, they have not included R&D investments as the determinant of green governance. Numerous studies have examined the aspects that determine the growth of eco-innovations and energy efficiency. Sun, Cao et al. (2020) and Baloch et al. (2020) incorporate the role of

environmental rules and governmental subsidies in promoting energy efficiency and eco-innovations. Chandio, Jiang, Rehman et al. (2021) found a direct correlation between government R&D subsidies and energy efficiency. Sun, Awan et al. (2020) and Alemzero, Sun et al. (2020) indicate an optimistic influence of governmental initiatives on energy-saving and energy-efficient innovations.

According to Li et al. (2021), Chien et al. (2021) and Iqbal et al. (2021), the lack of government policies is a major concern for enterprises to promote energy efficiency and green growth. Their research show that existing rules and regulations do not prevent the adoption of energy-efficient devices. Taghizadeh-Hesary and Taghizadeh-Hesary (2020) stressed the role of carbon taxation in green performance. According to Taghizadeh-Hesary and Yoshino (2019) and Taghizadeh-Hesary and Yoshino (2020), green finance's role in promoting green growth and performance is significant.

A most recent study by Debbarma and Choi (2022) show that the taxonomy of green governance – global governance, adaptive governance, climate governance, ecological governance, self-governance, energy governance, and information technology (IT) governance – are related to each other and can work on the same objective by pursuing different activities.

3. Data and empirical model

3.1. Data

The sample of enterprises in this study was drawn from all registered companies in Shanghai and Shenzhen A-shares, except those with incomplete data. Given the considerable changes in China's air quality, the study used only data from 2015 to 2019 to maintain consistency in calculating the degree of air pollution. The majority of the data in this article comes from the China Stock Market & Accounting Research (C.S.M.A.R) database, while the macroeconomic statistics have been taken from the Statistical Yearbook of Chinese Cities. Patent data is derived from the State Intellectual Property Office and is included in the city's technical complexity data.

3.2. Empirical model

This research uses an extensible benchmark measurement model (1) to examine the determinants of G.G.E. the explanatory variables will be treated as logarithms to avoid erroneous regression. G.G.E. is the dependent variable and is measured based on the G.G.E. index developed by Chen et al. (2019). In contrast, CO_2 and R&D are the main independent variables, whereas energy intensity, trade, G.D.P., and industrial structure are control variables.

$$LnGGE_{it} = \beta_0 + \beta_1 CO2_{ijt} + \beta_2 R\&D_{ijt} + \beta_3 X_{it} + Dummy + \varepsilon_{it} \qquad (1)$$

Where β_0 is a constant term, β_1, β_2 and β_3 denote regression coefficients, i signifies the selected company, t denotes the year, j represents the professional-level city where the listed company i is situated, RD_{it} indicates investment in R&D i in the t

Table 1. Symbol and definition of variables.

Acronyms	Explanation
GGE	Green governance efficiency
EI	Energy intensity
TRADE	Trade activity
INVEST	Investment
GDP	Gross domestic product
CO2	Carbon dioxide emission
INDUST	Industrial Structure
RD	Research & Development

Source: Authors' compilation.

period, CO_2 shows the CO_2 emission, X_i shows control variable and ε_{it} represents the error term.

Table 1 lists the variables presented in this work, together with their associated symbols and definitions. We inspired by López-Bernabé et al. (2021), Dranka et al. (2020) and Doukas et al. (2021) for selection of the variables.

This study substitutes R&D expenditure/primary business income for innovation variable (R.D.) (Bourcet & Bovari, 2020). Control variables in this study include the energy intensity (*EI*), trade activity (*Trade*), Investment (*Investment*), G.D.P. growth rate (*GDP*), Industrial Structure (*INDSTR*). Dummy variables were used to examine a wide range of study topics. Dummies indicate whether the mentioned company is a key air quality management enterprise (key pollution monitoring enterprises have a value of 1 and the rest have a value of 0), a state enterprise (government enterprises have a value of 1 and the rest have a significance of 0), or even a polluting firm (polluting enterprises have a value of 1 and the remainder have a value of 0). There are only a few sectors of high-tech complexity, as well as the rest are zero.

4. Results and discussion

4.1. Data analysis and empirical results

This section selects the most appropriate econometric method by estimating the Hausman test's random effects (R.E.) and fixed effects (F.E.). The Hausman test results show that in this study, the performance of the F.E. model is better than that of the R.E. model.

Next before running the regressions, we need to check for the presence of unit roots. Table 2 shows the unit root test results using the second-generation unit root test, including cross-sectionally augmented Im-Pesaran-Shin (C.I.P.S.) and Covariate Augmented Dickey-Fuller (C.A.D.F.). The results confirm the presence of unit root at level and stationarity results in the first differences. This means the series are integrated of order 1. Hence we need to run the co-integration test.

The co-integration test by Westerlund and Edgerton (2008) was employed that addresses the structural breaks. The co-integration test results confirmed that there is no co-integration. This study uses the ordinary least squares (O.L.S.), F.E., R.E and generalised method of moments (G.M.M.) regression models to determine the effects of R&D and air quality (CO_2 emission) on G.G.E. The regression results are shown in Table 3:

Table 2. Unit root tests results.

Variables	CIPS		CADF	
	Level	First-Difference	Level	First-Difference
CO_2	−1.423	−5.426***	−2.776	−3.537***
EI	−1.915	−4.371***	−2.587	−3.423***
INVEST	−2.045	−3.323***	−1.667	−2.634**
TRADE	−2.194	−3.864***	−2.365	−3.075***
INDUST	−2.243	−5.135***	−1.834	−3.951***
GDP	−1.773	−3.526***	−2.186	−2.954***
RD	−1.912	−4.377***	−1.921	−2.922**

Note: ** and *** represents 5% and 1% significance level, Note: CIPS = cross-sectionally augmented Im-Pesaran-Shin (CIPS) and CADF = Covariate Augmented Dickey-Fuller; Source: Authors' calculation.

Table 3. Regression results (Determinants of G.G.E.).

Factors	Model (1)	Model (2)	Model (3)	Model(4)
GGEit-1				0.863***
EI	−0.051***	−0.121***	−0.122**	−0.071***
R&D	0.023***	0.022***	0.029***	0.001
CO_2	−0.031*	−0.043***	−0.011**	−0.010*
Trade	−0.312***	−0.223	−0.102	0.062
InvesT	0.050**	−0.001	0.021	0.055***
GDP	0.035***	0.010***	0.009***	0.002***
INDUST	0.501***	−0.411***	−0.546***	0.033**
COnstant	0.082	0.424***	0.389***	0.037***
N	472	472	472	472

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively Model 1–4 are OLS, FE, RE, GMM, respectively. Source: Authors' calculation.

Empirical results in Table 3 depict a positive association between R&D investments of the Chinese listed companies and the G.G.E. The coefficient of energy intensity is negative in all models, meaning there is a negative association between energy intensity and G.G.E. This shows the importance of enhancing energy efficiency and reducing the energy intensity to achieve green performance goals. Moreover, the investments promote G.G.E. There is a negative association between the level of CO_2 emissions of Chinese listed companies and the G.G.E.; this shows their significant causing role in the general pollution level of the country.

5. Conclusions and policy recommendations

This article measures the influence paths of R&D investment, pollution, and energy intensity of Shanghai and Shenzhen's listed companies on the G.G.E. Government supervision and support are critical in synchronising the market, fostering stockholder confidence, and alleviating R&D businesses' funding challenges.

The empirical results show that R&D investment is a significant determinant of the G.G.E. On the other hand, energy intensity and pollution level (CO_2 emission) negatively affect the G.G.E.

Our empirical results confirm that if China aims to achieve carbon neutrality and meet sustainable development goals, the performance of the listed companies, mainly large enterprises is crucial. Large companies need to set their objective not only based on profit making but also consider green performance and sustainability.

Based on the empirical findings herewith, we provide bellow policy recommendations:

1. Increasing green credit provision for renewable energy projects and energy efficiency by introducing new measures such as low-interest loans, easing financing approvals, green credit guarantee scheme and shortening the approval cycle. At the same time, granting preferential financings such as low interest loans, green credit guarantee, tax reductions, and voluntary write-offs of bad debts for renewable industries.
2. The function of the securities market must be clarified. Listing of the green small- and medium-sized enterprises (S.M.E.s) and sci-tech innovation markets should be easier. In addition, a market for renewable energy enterprises that contains many green enterprises specialising in non-fossil energy fields should be established.
3. Easing the application for green finance and green investments in the carbon market. By encouraging investment in the carbon market, efficient financialisation will contribute to the sound construction of the carbon market and improve emission reduction projects.

Future research should consider introducing the green finance indicator to assess its impact on the G.G.E. In addition, different approaches and models can be employed for deeper analysis and perspectives of the relationships between the studied variables.

Conflicts of interest

The authors declare no conflict of interest.

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