Research on the Influence of Government Intervention on Energy Intensity

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Abstract. In recent years, the mismatch between the economic growth rate and the degree of environmental protection has intensified, and the problems of resource consumption and environmental pollution have become serious. Driven by a large amount of energy, the development mode featuring high energy consumption and high growth is unsustainable. And it brings tremendous pressure to realize the strategic goal of sustainable development. In this case, energy saving becomes a basic strategic guideline for economic and social development in various countries, which is also an extremely urgent task at present. This paper firstly analyses the low possibility of enterprises to carrying out energy-saving behaviours conscientiously. And then the enterprise's energy-saving behaviours are empirically studied by constructing a game model between enterprises. Besides, the government behaviours are divided into economic means, administrative means and legal means, and Energy-saving behaviour are quantified as energy intensity, which form a panel regression model to further analyse the specific impact of the three methods on energy empirically.

1. Raise of problem
Throughout historical development, the replacement of energy is driving the progress of social civilization. The increase in urban population and the expansion of the industrial economy are driving the rising energy consumption and energy dependence. The problems of resource shortage, environmental degradation and insufficient energy supply are becoming increasingly prominent. From 2000 to 2018, the annual average growth rate of my country's energy production was 5.83%, significantly lower than the annual average growth rate of energy consumption by 6.70%, and the energy supply gap also expanded from 83.94 million tons to 87 million tons. Moreover, (Figure 1) China's energy consumption per unit of GDP and carbon dioxide emissions are large, far exceeding the world average. This data also confirms that my country's rapid economic development is mostly at the expense of resources and the environment. Compared with developed countries, my country's energy saving potential is still huge, and it is expected to further decouple environmental protection and economic growth.
Figure 1. Distribution of energy consumption per unit of GDP and carbon dioxide emissions per unit in some countries in 2018

Data sources: 《BP World Energy Statistical Yearbook》《World Bank》

As an environmental resource, energy has the characteristics of public goods, which means that there is low cost to obtain the goods, and personal use within a certain time period will not exclude the use by other people. Hence, a large amount of energy resources will be consumed in a short period of time. In addition, there is a double market failure in energy utilization, which also requires government intervention. First, energy consumption, especially fossil fuels, will produce a large number of pollutants. These emissions will cause serious damage to the surrounding environment, threaten people's health and produce negative external influences. Under the market mechanism, the producers of the enterprise will not pay for the pollution generated, resulting in excess output and ecological deterioration. Second, the development of new energy or clean technologies by companies has positive externalities. The research and development of these technologies requires a lot of capital, however, the companies do not obtain the benefit compensation generated by this external effect, which will eventually lead to insufficient technological innovation. Therefore, the dual market failure to correct the negative externalities caused by energy consumption and make up for the positive externalities of clean technology supports the government to carry out a reasonable intervention. In recent years, the government has used a variety of policy tools, including administrative, legal, and economic tools, to control the energy consumption of our country's economic development to a certain extent in its efforts to promote energy conservation and emission reduction. And different policy tools have different degrees of effectiveness and acceptability. Therefore, the following questions are raised: Will the main body of economic activity take the initiative to save energy? Is government intervention necessary? What are the differences between the constraints of different types of interventions and which is better?

2. Literature review and basic concept

2.1. Literature review

Government intervention plays a role as an alternative mechanism for market forces in achieving the goal of environmental constraints. (Fu 2018) [1] Jianya G (2011) believed that the government needs to comprehensively use economic, legal and administrative means to formulate and improve a series of energy conservation and emission reduction policies in the implementation of energy conservation and emission reduction. [2] Fabrizi A (2018) argued that the environment regulation is
not only to send the signals of low efficiency of energy utilization to enterprises, but also to give companies the pressure to make progress in energy-saving technology innovation. At the same time, it reduced the instability of enterprises’ investment in energy conservation and avoided the speculation. [3] Chang C-P (2018) believed that a well-designed energy policy can save energy greatly, but if the government’s policy cannot play its expected role, the positive effect of the policy will hardly appear. [4] Han H (2018) believed that the financial subsidy in energy facilities can change the backward technologies used in the current infrastructure, thus changing energy usage habits and ultimately affecting energy intensity. [5] Currently, some achievements have been made in the research on promoting energy conservation and emission reduction, but there are still some aspects to be improved. There are relatively few literatures focus on energy intensity. Moreover, the existing literatures on government intervention usually use the comprehensive index. Hence, different means of government policies on energy conservation and emission reduction needs further detailed research.

2.2. Basic concept

2.2.1. Energy intensity

Energy intensity refers to the energy consumption of GDP per unit of output in this article. It is a relative indicator of the comprehensive utilization of energy in a country or region, and reflects the resource and environmental costs paid by a country or region in the process of economic development. Under the background of sustainable development, reducing energy intensity is an important measure to alleviate the contradiction between economic development and ecological environment. High energy intensity indicates low efficiency of energy conversion into GDP. The continuous decline in energy intensity means that economic development and energy consumption are gradually decoupling, indicating that a country’s economic activities are developing in a more sustainable direction.

2.2.2. Government intervention

Government intervention mainly refers to a series of policy measures adopted by the government to regulate the national economy in order to make up for the shortcomings of the market. The government intervention in this paper specifically refers to a series of measures that the government has taken to reduce energy intensity in order to protect the ecological environment, achieve sustainable economic development, and increase economic and social benefits. The intervention measures include economic, legal and administrative means. The legal and administrative means is that the state makes use of the supreme right, and directly imposes punishment on the enterprises that violate the laws and standards. Economic means usually refer to fiscal and tax policies which guide polluters’ behavior through market signals such as price increases, subsidies, and tax exemptions.

3. The necessity of government intervention to save energy

3.1. Crux analysis of energy-saving subjects

The enterprise is the main body of economic activity and energy consumption. When the external mandatory restraint mechanism of the enterprise is missing, the behaviour of the enterprise, as a rational economic person, will depend entirely on the contest between the potential benefits it can obtain and the production costs it pays. From the perspective of the production and management process of an enterprise, on the one hand, it needs to invest key production factors such as energy resources in the production process. However, energy resources, as an environmental resource with the characteristics of public products, will lead to uncontrolled mining by enterprises, causing waste and depletion of environmental resources. On the other hand, the pollution, produced by the enterprise during the production and operation process has not been included in the direct cost of the products produced by the enterprise, resulting in a deviation between the enterprise’s production cost and the social production cost. Moreover, enterprises do not bear the environmental treatment cost of pollution which is unavoidable in the production process, so they will not take the initiative to restrict their own emissions, resulting in the continuous aggravation of local pollution. Therefore, the commonality of
resources and the negative externality of pollution will cause problems such as resource mismatch in the "invisible hand" of the market, which will lead to excess production of enterprises. In short, under any type of economic system, as long as there is no restriction on the use of energy resources and the discharge of environmental pollutants, all companies will spare no effort to develop and use environmental resources for the principle of maximizing their own interests, and discharge pollution without restraint, in order to maximize their private interests by occupying public resources with lower costs as much as possible.

3.2. “Prisoner’s dilemma” of energy-saving behaviour

Here, a simple game model is constructed to analyse the strategic behaviour and decision dilemma of enterprises in the process of environmental resource use and governance. Suppose that there are only two competing enterprises A and B in a completely competitive market. The production technology, scale, and products of the two companies are all the same. At the same time, the production energy consumption and sewage levels of these two companies are also equivalent. Both enterprises have two strategies to choose from in their production processes: implementing energy saving and emission reduction; and not implementing energy saving and emission reduction. If both enterprises choose not to implement energy conservation and emission reduction, the use of environmental resources will quickly exceed the limit, which will in turn affect the production and operation of the companies, resulting in insufficient energy supply and deterioration of the ecological environment, resulting in a rapid decline in revenue. However, if both choose to implement energy conservation and emission reduction, the good environmental resources jointly created by the two enterprises can make the two enterprises have sufficient energy supply and ensure the sustainable development of the company. At the same time, due to the large amount of capital required by the enterprise for its own energy-saving emission reduction research and development and technology upgrade and reconstruction in the early stage, it is assumed that the research and development and transformation costs paid by the enterprise for energy-saving emission reduction within a certain period of time are greater than the cost reduction caused by energy-saving technology. That is, when the decisions of the two enterprises are different, the profitability of the enterprises implementing energy saving and emission reduction in the short term is less than that of companies that do not implement energy saving and emission reduction, and enterprises that have not undergone transformation can also enjoy the high-quality environment provided by the implementing party. Based on the above assumptions, the following parameters are set: that is, if the two enterprises do not implement energy saving and emission reduction, the gain of each enterprise is R1; if the two enterprises implement energy saving and emission reduction, the gain of each is R4; if only one enterprise implements energy conservation and emission reduction, the income of the one that implements energy saving and emission reduction is R2, and the income of the one that does not implement energy saving and emission reduction is R3; and it is assumed that R2<R4<R1<R3. Then the revenue matrix of the game is shown in Table 1 as below:

**Table 1. Revenue matrix of energy-saving behaviours of various enterprises without government intervention**

| Enterprise A | Enterprise B |
|-------------|-------------|
| Energy-saving | (R1,R1) | (R2,R4) |
| Non-energy-saving | (R3,R2) | (R4,R4) |

In this game model, the information of enterprises A and B is completely symmetrical, and the decisions of both parties are made at the same time, and neither party can accurately obtain
information about the actions of others. Therefore, as a rational economic person pursuing their own profit maximization, enterprises A and B will choose the most beneficial actions to implement in two strategies. That is, when enterprise A chooses to implement energy conservation and emission reduction, the income $R_1$ of enterprise B for energy conservation and emission reduction is less than the income $R_3$ of enterprise B without energy conservation and emission reduction, so enterprise B will choose not to perform energy conservation and emission reduction; when enterprise A chooses not to conduct energy conservation and emission reduction, the income $R_2$ of enterprise B for energy conservation and emission reduction is still less than the income $R_4$ of enterprise B without energy conservation and emission reduction, so enterprise B will definitely choose not to carry out energy conservation and emission reduction. In the same way, regardless of the strategy made by enterprise B, enterprise A will choose not to carry out energy conservation and emission reduction. In the process of competition between Enterprise A and Enterprise B, a Nash equilibrium $(R_4, R_4)$ will be formed, that is, both companies will choose not to save energy and reduce emissions. On the whole, the equilibrium result of the game between the two parties is not optimal, because if both parties implement energy conservation and emission reduction, the gains of the two will be greater, but under the premise of satisfying individual rationality, Pareto improvement cannot be achieved, which formed the conflict between individual rationality and collective rationality. As a result, enterprises A and B finally only got lower returns, and the entire society only realized lower benefits. If the results of the two enterprises are extended to N companies, indicating that without the intervention of the government, each company has the goal of pursuing profit maximization in a completely competitive market, and generates internal incentives that do not save energy and reduce emissions. The result of the game eventually forms a typical 'prisoner's dilemma'. It also confirms that in the implementation of energy saving and emission reduction reforms, reformers need to bear the risks and pay the costs, but the results of the reforms often have a significant positive externality, which is conducive to the production and life of other enterprises. This feature helps other enterprises achieve hitchhiking easily. Therefore, enterprises have no inherent motivation to reform, which also verifies the necessity of government intervention.

4. Empirically analyze on the influence of government intervention on energy intensity

4.1. Variable selection and data sources
This article selects provincial panel data from 2007 to 2017 in China. The financial subsidy in the energy industry, the number of people in the environmental protection system, the cost of environmental monitoring, the number of environmental standards, the number of administrative punishments and the number of environmental laws in each province are all taken from the China Statistical Yearbook and China Environmental Yearbook. Due to the lack of data in Tibet, the data of Tibet Autonomous Region was excluded, and only 30 provinces were retained. In addition, linear interpolation is adopted to complete the partially missing data.

4.1.1. Energy intensity
Energy intensity is expressed by the ratio of primary energy consumption to the gross regional product of each province. Primary energy consumption is taken from China's Statistical Energy Yearbook, GDP is taken from China's Statistical Energy Yearbook, and price fluctuation is excluded through deflator.

4.1.2. Financial subsidy
Energy subsidy refers to the fixed investment activities carried out by the government in the fields of energy production, circulation and consumption to achieve future benefits. Energy subsidy has the characteristics of high risk and high cost, and needs to rely on the government's policy support, and the government's support policies are generally realized through direct investment or subsidy in regions or projects, so it chooses fixed investment of the government's energy industry and related industries as The economic means of government intervention. It is believed that the greater the number of financial
subsidies in the energy sector, the lower the energy consumption per unit of economic output in my country.

4.1.3. Administrative supervision
In order to comprehensively consider the administrative supervision power of government intervention in unit energy consumption, it is planned to comprehensively evaluate from the four aspects of supervision manpower, financial resources, existing supervision standards and the punishment situation based on supervision. Because the dimensions and units of the four variables are different, this paper uses the averaging method such as formula (1) to process the variables of the four dimensions to eliminate the dimension, and finally take the arithmetic average of the four variables. Such as formula (2). The stricter the administrative regulation, the lower the energy consumption per unit of economic output.

\[ x_{i}^{t} = \frac{x_{i}^{t}}{x_{t}} \quad (i=1,2,3,4) \]  
\[ x_{\text{supervision}} = \frac{x_{1}^{t}+x_{2}^{t}+x_{3}^{t}+x_{4}^{t}}{4} \] (2)

4.1.4. Environmental laws
Environmental laws can directly intervene the environmental behaviour, which belongs to the pre-control behaviour in the intervention and has the characteristics of convenient operation. This paper refers to the green index proposed by Low[6], selects the number of effective environmental laws as the legal means to constrain unit energy consumption. Environmental laws are generally considered to have a lag period of 1-3 phases. Therefore, the lag period of local environmental laws should be considered.

Hence, financial subsidy, administrative supervision and environment laws are taken as independent variables to describe the means of government intervention. And then energy intensity is taken as dependent variable to carry out the panel regression. The specific variable description, symbol and its meaning are shown in the following table 2.

**Table 2. Indicator meaning and description**

| Variable description | Variable symbol | Variable meaning | Indicator description |
|----------------------|----------------|------------------|----------------------|
| Explained variable   | energy         | Energy intensity | Primary energy consumption |
| Exploratory variables| subsidy        | Financial subsidy| Government Energy Industry Investment |
|                      | supervision    | Administrative supervision | Number of environmental protection systems |
| Control variable     | law            | Environment laws | Environmental monitoring costs |
|                      | innovation     | Technological innovation | Effective environmental regulations and standards |
|                      | industry       | Industrial structure | Number of environmental administrative punishment cases |
|                      | fdi            | Foreign direct investment | Effective environmental laws |

4.2. Empirical analysis and results discussion
Table 3 lists the results of three panel model regressions that only include the three control variables of technological innovation, industrial structure, and foreign direct investment on energy intensity. Regarding the selection of the three panel regression models, according to the results of the F test, it indicates that mixed effects should be rejected; according to the results of the BP test, it indicates that mixed effects should be rejected a; according to the results of the Hausman test, it should reject random effects and choose fixed effects. From the regression results of the table 3, technological innovation, industrial structure, and foreign direct investment have a negative correlation with the energy intensity of various provinces in China, indicating that the stronger the technological innovation capability, the higher the industrial structure, and the higher the amount of foreign capital actually utilized, The lower the energy consumption per unit of local output value. Among them, technological innovation and industrial structure have passed the 1% significance level, and their constraint coefficients are -0.2841 and -0.3216, respectively, indicating that the two have a stronger constraint on energy consumption per unit output, and the constraint effect on the industrial structure is better. The actual absorption of foreign investment has passed the 5% significance level, indicating that foreign direct investment has realized the overflow of advanced management experience and science and technology to a certain extent, exerted the energy-saving effect, and rejected the hypothesis of 'pollution paradise'.

Table 3. Results of the national panel regression model with only control variables

| model variable | POOL       | FE         | RE         |
|----------------|------------|------------|------------|
| lninnovation   | -0.0897*** | -0.2814*** | -0.2695*** |
|                | (-0.024)   | (-0.0271)  | (-0.0312)  |
| lnindustry     | -0.4732*** | -0.3216*** | -0.3381*** |
|                | (-0.0379)  | (-0.0343)  | (-0.0354)  |
| lnfdi          | -0.1609*** | -0.0323**  | -0.0358*** |
|                | (-0.0198)  | (-0.0137)  | (-0.0135)  |
| Constant       | 5.9911***  | 6.2624***  | 6.2218***  |
|                | (-0.0628)  | (-0.1444)  | (-0.1674)  |
| N              | 330        | 330        | 330        |
| R²             | 0.7395     | 0.8127     |            |
| F test         |            |            |            |
|                | 87.45***   |            |            |
| BP-LM test     |            |            |            |
|                | 1034.56*** |            |            |
| Hausman test   |            |            |            |
|                | 14.70***   |            |            |

Note: ***, **, and * are significant at the levels of 1%, 5%, and 10%, () is t value.

Table 4. Results of the national panel regression model of all explanatory variables

| model variable  | POOL       | FE         | RE         |
|-----------------|------------|------------|------------|
| lnsubsidy       | 0.1814***  | 0.0672**   | 0.0821***  |
|                 | (-0.0238)  | (-0.0282)  | (-0.0308)  |
| lninsupervision | -0.0862*** | -0.0466**  | -0.0479**  |
|                 | (-0.0309)  | (-0.0197)  | (-0.0193)  |
| lnlaw           | -0.0797*** | -0.0334**  | -0.0378*** |
|                 | (-0.0136)  | (-0.0150)  | (-0.0144)  |
| lninnovation    | -0.1592*** | -0.2492*** | -0.2372*** |
|                 | (-0.0209)  | (-0.0425)  | (-0.0420)  |
| lnindustry      | -0.0939**  | -0.2921*** | -0.3005*** |
|                 | (-0.0406)  | (-0.0401)  | (-0.0410)  |
| lnfdi           | -0.1315*** | -0.0238*   | -0.0317**  |
From the regression results in Table 4, the impact of the lag phase of environmental regulations on energy intensity has passed the 5% significance level. When the legal means of environmental resource constraints increases by one unit, the energy consumption per unit of output decreases 0.0334 units. This shows that the legal means represented by environmental laws have a programmatic effect and can effectively restrain energy consumption. The agency variable of administrative supervision also has a significant negative correlation with energy intensity. When the administrative order means constrained by environmental resources increases by one unit, the energy consumption per unit of output decreases by 0.0460 units. This shows that the series of administrative measures taken by the government for environmental protection have indeed exerted energy-saving effects. The economic means represented by financial subsidies passed the 5% significance level, showing a significant positive correlation, which is inconsistent with the expectation theory. This shows that the financial subsidies in the energy sector have not played an ideal role in supporting it. On the contrary, this fixed investment in the energy industry has increased energy consumption. Judging from the economic, legal and administrative means of government intervention, economic measures have not been able to achieve the desired energy-saving effect. Administrative means and legal means have a significant negative relationship with the energy intensity, and administrative means have a stronger binding effect on energy intensity than legal means. The reason may be that the actual amount of financial subsidies for new energy is not in place, and there may be resource distortions and mismatch problem. However, administrative and legal means have a coercive effect on the behavior of enterprise subjects.

5. Conclusion
According to game analysis, companies usually do not actively save energy, and government intervention mechanisms are essential for energy use. Currently, government intervention methods are mainly divided into economic means, administrative means and legal means. Among them, legal means and administrative means play a significant role in energy constraints. However, economic means have not played an effective role. The possible reason is that economic means are not mandatory, and economic subjects usually make decisions on the comparison of their costs and benefits. Compared with economic means, legal and administrative means are often mandatory, which can achieve the goal of energy conservation constraint in a short time.

6. Reference
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