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The Impact of China's Low-Carbon City Pilot Policy on the Green Technology Innovation of Pilot Cities

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Abstract:

In response to the increasing focus on green development, the Chinese government has fine-tuned the low-carbon city pilot policy to bolster low-carbon development. The DID model is utilized in this study to empirically analyze the influence of the LCCP policy on green technology innovation in China's pilot cities. The findings indicate that the LCCP policy has indeed promoted green technology innovation in these cities.

Keywords: LCCP policy, GTI, DID

1. Introduction

Green development is an economic development trend that meets global concerns about a series of challenges and problems brought by environmental issues like climate change or the lack of natural resources. In order to form a green and economic society, enterprises also take action to respond to the demand for sustainability and contribute to green economic circular development. Enterprises, especially in manufacturing or renewable energy industries, would actively put efforts into green technology innovation (GTI) and improve their products in a more environmentally beneficial way. Therefore, an international trend of constructing green society flows on a worldwide scale from developed countries to developing countries gradually.

In order to achieve an effective and stable transition to a green society, a number of environmental protection-related policies have been implemented by the Chinese government to construct a green circular economy (GCE) and promote innovation of green technology. Low-carbon city pilot (LCCP) policy is an effective and directed policy that achieves an obvious outcome in reducing carbon emissions in pilot cities. The reduced carbon emission plays an important role in not only the environmental sustainability aspect but also promotes the economy in cities (Yang & Li, 2013). In addition, with the stimulation of low-carbon progression, GTI is facilitated as well. The LCCP policy was initially launched in 2010, with early pilot cities such as Guangdong included in the first batch. Subsequent batches of pilot cities were announced in 2012 and 2017. It encourages to implementation low a carbon economy, including producing and consuming in a low-carbon way. A low-carbon city aims to maintain production and consumption in a low-carbon manner, create a resource-conscious and environmentally aware community, and establish a long-term sustainable energy ecological system(Luo, 2008; Xia, 2008). Low-carbon cities restrict carbon emissions to reduce the negative influence on the environment and improve the ability to deal with climate change problems to a certain extent. In this way, the cities can create an energy-saving and environmental-beneficial society to construct a sustainable energy ecosystem.

Low-carbon city pilot policy functions crucially in

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the stimulation of green technology innovation as well. According to the relevant research conducted by Zou et al. (2022), which used 268 prefecture-level cities' innovation index as a database concludes that LLCP policy has effects of promoting technology innovation ability via increasing government investment. Besides, LCCP policy improves enterprises' innovation competition by establishing and increasing public awareness of the importance of low-carbon. In this way, companies have to reposition the market niche of their products and put more effort into investing in low-carbon materials or machines with less energy consumption. The productivity of innovation of enterprises is thus improved in order to maintain their social acceptance and sustainability. Therefore, sustainable development should be the foundation of low-carbon development. It is critical to stick to sustainable development principles and seek more green technology innovation to support long-term development (Mulugetta & Urban, 2010). Furthermore, according to Cheng et al. (2019), a diminishing effect on low-carbon innovation from small cities to big cities is found with the promotion of LCCP policy. Due to the different technological levels and economic levels of pilot cities, it is reasonable and common that large cities can develop and transition into low-carbon development more smoothly and easily.

In order to conduct and further analyze the effects of the LCCP policy with efficiency and accuracy, this paper will use the method of Difference-in-Difference (DID) to calculate and observe the concrete influence and impacts of LCCP policy on GTI and the economic development of pilot cities. DID model is a powerful statistical tool for rating the causal effects of policies or interventions on the differences between experimental and control groups. It clearly and effectively shows the effects of policies with comprehensive considerations of potential factors such as the carbon emission amount, the energy consumption amount, or the research and development (R&D) spending that will affect the GTI and the economic development.

The research analysis and literature review above show that, at the moment, there is a lack of literature analyzing the specific impacts of the LCCP policy on the GTI of China's pilot cities. As such, by providing empirical data and an analysis using the DID model, this paper advances our understanding of how LCCP policy affects GTI.

2. Conceptual Framework

In the pilot cities, the promotion of low-carbon development has varying effects on different factors at different levels. This paper utilizes the DID model to empirically analyze the effects of the LCCP policy on GTI in the pilot cities. The dependent variable, the principle focus of this study, and the independent variables are depicted in Figure 1, showcasing the evolution of innovation.

The most obviously influenced factor in the LCCP policy is the amount of carbon emissions of industries in the pilot cities. China is the global leader in low-carbon innovation patent numbers, green energy policies, and subsidies for the production of wind and solar power, according to Deloitte 2018 and WIPO 2020. Thus, take the carbon emission as the main variable which shows the direct relations with the policy effects. However, it is difficult and inaccurate to research on and conclude the exact impact of LCCP policy on innovation with a single variable of carbon emission. Therefore, it is important to search for other factors that are indirectly related to the influence of LCCP policy but have impacts on GTI. Firstly, the energy consumption efficiency level would reduce carbon emissions if the energy consumption is more effective and decreased. Then, the sum of funds allocated to research and development (R&D) and technology is crucial to determine the innovation as well. When there is increasing investment in reducing carbon emissions, the GTI will be motivated. Hence, R&D spending and technological spending are also influential to innovation (Pan et al., 2021). Besides, the technological developed level and the economic developed level are important and influential to the GTI. On the other hand, since innovation is an abstract concept, it is usually difficult to observe its progress directly. Therefore, by collecting the data of applying amounts of the green patents in the pilots cities, it will show quantified and observable data results of the impact of LCCP policy.

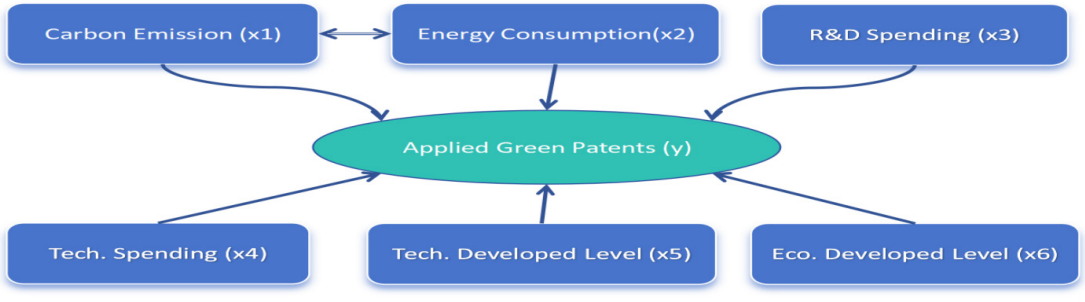

Figure 1. Independent variables

3. Data Results and Empirical Analysis

3.1 Data Resources

To show the GTI in a quantified number, one approach is to collect the total amounts of green patents that applied in each of the pilot cities during the policy years. The data on applied green patents, energy consumption, R&D spending, technological spending, technological development level (expressed as numerical values), and economic development level were obtained from the China City Statistical Yearbook. Additionally, the carbon emission data was collected from the CEADS database, which contains carbon emission statistics from various locations globally. Any missing data in each dataset was supplemented using the mean value.

As shown in Table 1, the descriptive statistics for every variable are provided, including the total number of observations, the mean, standard deviation, minimum, median, and maximum values for each variable.

Table 1: Summary Statistics

VarName	Obs	Mean	SD	Min	Median	Max
DID	6900	0.201	0.401	0.000	0.000	1.000
ln_emission	6900	3.244	0.643	0.668	3.244	6.129
ln_Energy	6900	11.102	1.183	0.000	11.162	13.601
ln_RD	6900	11.412	2.196	0.000	11.558	17.185
ln_Techspending	6900	9.413	1.770	0.000	9.413	15.529
ln_Tech	6900	0.013	0.013	0.000	0.012	0.188
ln_Eco	6900	2.422	0.068	1.722	2.422	2.643

3.2 Empirical Model

In this paper, it conducts Difference-in-Difference (DID) model to empirically research the impact of LCCP policy on the GTI of pilot cities.

The formula of DID model in this research is defined as follows

$$y_{it} = \beta_0 + \beta_1 DID_i + \gamma x_i + \varepsilon_i$$

where t is the observation year and i is the observation city. Since the LCCP policy was implemented gradually, it doesn't have a specific year as a start year of this policy. Thus, in this study, it will choose 2012 when the policy began to expand, to be the year of the policy implementation. y_{it} refers to the green technological innovation (GTI). β_0 is the expected value when other variables equal to zero, in this research β_0 is supposed to be the amount of applied green patents of pilot cities. β_1 refers to the net distinction between the treatment group and the control group. DID_i is a dummy variable that represents whether the observation city is the treatment group or not. It usually equals 0 or 1; when the observation city is the pilot city, then it equals 1; otherwise, it is 0. This refers to the control variables, including carbon emissions, energy consumption, R&D spending, technological spending, technological development level, and the economically developed level of pilot cities. γ here is a coefficient vector related to x. ε_i is the error term which represents the other potential influential factors to GTI that are not considered in this research.

3.3 Result of the DID Regression

As shown in table 2 shows the data result of the regression of the DID model, and we can see that DID is significant in every situation, which means the LCCP policy has effects on promoting GTI. The first column reports the regression result of the impact of the carbon emission amount on the amount of applied green patents without any fixed effect of year or city. Apparently, the carbon emission turns out to be significantly influential to GTI in this situation. In the second column, it shows the regression result of carbon emission with fixed effects of year and city and it still turns to be significant. The third column shows regression results, including other control variables without fixed effects, and we can see that all of the other control variables are very significantly influential to the GTI in this situation. Furthermore, as is shown in the fourth column, the other control variables still turn out to be significant with fixed effects.

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Table 2: Regression result of DID model

	(1)	(2)	(3)	(4)
	y	y	y	y
DID	0.162**	0.319***	-0.193***	0.278***
	(2.79)	(5.83)	(-3.62)	(5.45)
Carbon Emission	0.429***	0.184***	0.0178	0.00169
	(11.86)	(5.40)	(0.52)	(0.05)
Energy Consumption			0.166***	-0.147*
			(7.50)	(-2.46)
R&D Spending			0.323***	0.0378*
			(29.09)	(2.44)
Tech. Spending			0.174***	0.556***
			(7.47)	(23.37)
Tech. Develop Level			27.08***	-7.942***
			(11.59)	(-4.04)
Eco. Develop Level			-7.329***	2.391***
			(-15.46)	(4.27)
Constant	6.656***	7.419***	18.29***	-1.700
	(55.85)	(66.47)	(17.66)	(-1.27)
Year FE	NO	YES	NO	YES
City FE	NO	YES	NO	YES
N	6900	6900	6900	6900

t statistics in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.4 Parallel Trend Test

The parallel trend hypothesis of the DID model is likely to hold true if the treatment group and control group exhibit consistent trends over time. To align with Gao et al. (2020), the first year preceding the 2012 policy implementation is excluded from the analysis to avoid complete collinearity. From the "current" time point onwards, a significant treatment effect would be indicated by observable changes in the trend or level of points in the "las" stage compared to before. By comparing the points at the "current" and "las" time points, we can see from Figure 2 that there is an increasing trend from las_1 to las_6, indicating a meaningful impact of the policy implementation.

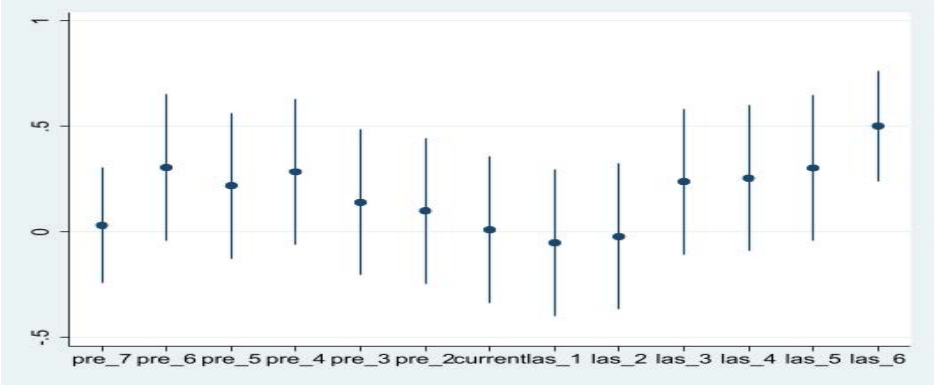

Figure 2. Parallel trend test result

4. Conclusion

As shown from the data results and analysis above, we can see that LCCP policy has a profound and lasting effect on the GTI of the pilot cities. From the table 2, it shows that wit the fixed effects of years and cities, technological spending, technological developed level and economical developed level have the most impact on the GTI. This paper uses the DID model to perform an empirical analysis based on data from the pilot cities and concludes that the LCCP policy boosts the GTI of the pilot cities.

Although there are several literature and researches paying attention on the impacts of environmental policies such as LCCP policy, there are still plenty of unknown and unclear points about the influence relationship between green development and environmental policies. There is much room for future studies and research to further explore relevant aspects.

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