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Industrial Policy and Innovation Capability of Strategic Emerging Industries: Empirical Evidence from Chinese New Energy Vehicle Industry

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Abstract: Industrial policy is an important tool for developing countries to protect their own industries and improve innovation capabilities. This paper takes China's new energy vehicle industry as an example, and uses the number of invention patents as a measure of independent innovation capability in order to analyze the impact mechanism of industrial policy on innovation. The estimation results of difference-in-differences and propensity score matching estimations show that the "Ten Cities Thousand Vehicles Project" for promoting the new energy vehicle industry has indeed increased the number of invention patents filed in new energy automobile manufacturers, as compared with traditional automakers. This paper also provides empirical evidence and statistical support for the implementation of industrial policies.

Keywords: Industrial Policy; Innovation Capability; Difference-in-differences; Propensity Score Matching; New Energy Vehicles

1. Introduction

In recent years, China has entered a key period of economic transformation. Encouraging innovation to drive the structural transformation from the traditional industries to hi-tech industries has become the government's main task. In order to seize a new round of high ground for competition and promote the transformation of economy from a factor-driven model to an innovation-driven model, the Chinese government clearly proposed that it would foster and support several industries as strategic emerging industries, and give priority to the enhancement of independent innovation capability. In 2002, the Sixteenth National Congress of the Communist Party of China made a series of great strategic decisions to enhance independent innovation capability and build an innovative nation. After that, the State Council also issued "The Outline of the National Midterm Plan for the Development of Science and Technology (2006–2020)" (hereinafter as "The Outline"), which was the first complete policy system proposed systematically for promoting independent innovation. "The Outline" aims to turn China into an innovative country in the new era. Additionally, the Chinese government has introduced a large number of industrial policies aimed at stimulating enterprise innovation. It puts forward the establishment of the coordination mechanism of government procurement and independent products innovation. For example, the government implements the first-purchase policy for important high-tech equipment and products with independent intellectual property rights developed by domestic enterprises, and provide related support policies for enterprises purchasing domestic hi-tech equipment.

However, whether these industrial policies that promote innovation have really played a role still remains a problem that needs to be explored. As the sum of various policies that the state intervenes in the formation and development of the industry, industrial policy has been widely used for a long time in nearly all countries around the world. In the past 20 years, although many countries have been steadily carrying out the reform agenda of the industrial policy, there still exists controversy about the impact of industrial policy [1]. Fan and Watanabe [2] believe that new technological process needs industrial policy, because the market failure caused by technology spillover effect requires government coordination. In addition, innovation is not a mere technical act, but a combination of broad political, scientific, and social behaviors that requires the government to use policy tools to coordinate [3]. Pack and Saggi [4] argue that, based on the limitations of human cognition and the distortion of the incentive mechanism, the problem of government failure is much more serious in reality, although there is certain rationality in industrial policies, which leads to the ineffectiveness of industrial policies.

This paper tries to conduct an empirical evaluation of the industrial policy of strategic emerging industries represented by the new energy vehicle industry, which is still in the early stage of development, and the technological application and market demand market in China are not mature. Form the view of government, support and guidance are considered to be urgently needed. By setting up a control group and an experimental group in quasi-natural experiments, the difference in innovation capabilities between new energy vehicle and traditional automobile manufacturers before and after the implementation of relevant industrial policies can be clearly described. Moreover, unlike other industries, the subsidy policy for new energy vehicles is mainly aimed at the demand market, and the effect of technological innovation will also be reflected by the changes in the sales volume of automobiles. Therefore, this paper attempts to reflect the mechanism of industrial policy on the innovation capabilities of the new energy vehicle industry.

The full text structure is as follows. The second section provides a brief literature review. The third section presents the conceptual framework. In the fourth section, we will sort out the development of China's new energy vehicle industry and related industrial policies. The fifth section sets up the empirical model and analyzes the results. The final section concludes the full article.

2. Literature Review

Current literature generally divides industrial policies into selective industrial policy and functional industrial policy [5]. About the selective industrial policy, i.e., the effectiveness of Japanese and Korean industrial policies, there is much controversy in both academia and policy practical areas. Beason and Weinstein [6] studied the industrial policy support of important industrial sectors in Japan from 1955 to the end of twentieth Century. Their research found that Japan's industrial policy did not promote the growth of the target sector. In contrast, those industries had received little support exhibited fastest development. According to the analysis of Lee [7] and Powell [8], the direct intervention, restriction of competition and selective support of industrial policies have reduced the efficiency of industrial production. However, Johnson believed that the development of heavy industry in Japan is closely related to the industrial policy of the Ministry of International Trade and Industry [9]. Taking the semiconductor industry as an example, Mathews and Cho [10] demonstrated that the advancement of Asian science and technology plays an important role, thanks to the country's policy-led mobilization strategy, which has accelerated the transfer, diffusion and absorption of new technologies. Edler and Fagerberg [11] took stock of rapidly growing area of public policy, with particular focus on innovation policy, and mentioned that modern state had always, as part of its core policy missions, supported the generation of scientific knowledge, technology, and innovation. Aghion et al. [12] also indicated that industrial policy could promote competition among enterprises and drive enterprise to achieve productivity improvement through quality-improving innovation.

According to the perspective of new structural economics, the institutional system and policy design in developed countries are not necessarily applicable to developing countries.

Hence, industrial policy should be designed according to the development and resource endowment of the industries in this country [13], because economic development is not a static optimization resources allocation but rather a structural optimization process of continuous innovation of technology, and the continuous improvement of hard infrastructure and soft institutional environment. For the emerging industries in developing countries, innovative forerunners need to be given enough incentive compensation because of the heavier risks and costs on their shoulders. This compensation cannot only rely on the market and the entrepreneurs themselves, but more on the external support from the government's industrial policies, such as financial subsidies, the legal environment, the financial system and so on, that is, a "facilitating state" is needed [14]. Even though the normative theories of industrial policy on innovation is currently relatively complete, empirical studies are still quite scarce [15].

Currently, although there are many studies discussing the impact of entrepreneurs' innovation activities, those studies mainly focused on description of industrial status and other influencing factors, including regional agglomeration, education and economic development, etc., rather than policy evaluation [16,17]. By analyzing the impact of industrial policies on research and development (R&D) investors, Pack and Saggi [4] and Clausen [18] put forward that the specificity of the policy, the design of incentive mechanism and the follow-up supervision would affect the implementation results. From the few new energy policy evaluation studies in other countries [19–21], the stability of local government policies is an important prerequisite for obtaining industrial investment, and the policy encouragement on this basis can often stimulate industrial development [22–24]. However, the existing research lacks the empirical evaluation of innovation activities in China's new energy industries. This paper also tries to make a useful attempt in this regard.

In fact, there also exists an important technical issue in how to measure the effects of industrial policies in many empirical studies. A number of existing studies have attempted to define the dummy variables of industrial policy incentives to comprehensively examine the impact of industrial policies by interpreting the industrial policies and government regulations [25–28]. However, due to the timing and missing variables that may exist in the empirical analysis, it is difficult to establish a direct link between industrial policies and technological innovations by using only dummy variables. Falck, Heblich and Kipar [29] used a difference-in-differences approach to analyze the "Cluster Initiative" introduced in 1999 by the Bavarian State Government. They found that introducing the Bavarian-wide cluster policy increased the likelihood of innovation by a firm in the targeted industry. Copeland and Kahn [30] did a simple difference-in-differences estimation, comparing the changes in sales and production patterns for eligible versus ineligible vehicles before and after the "Cash-for-Clunkers" program of America in 2009. Their findings revealed that the program did prompt a large spike in sales, but led to only a modest and fleeting impact on production. Arima et al. [31] also used difference-in-differences method to capture the impact of environmental policy enforcement between two time periods. They addressed the recent reduction of deforestation rates in the Brazilian Amazon by conducting a statistical analysis to ascertain if different levels of policy enforcement between two groups had any impact on this reduction. Similar to the methods of these studies, this paper also attempts to use the difference-in-differences method to measure the impact of China's new energy vehicle policy on the innovation capability of Chinese automobile manufacturers.

3. Conceptual Framework

The strategic new industries are usually high-tech industries which are knowledge intensive. The international competitiveness of such industry depends on the overall innovation capability, in order to keep independent in the market competition and achieve the high added-value position of the industrial value chain. However, the R&D activities are always unpredictable for enterprises, which may bring uncertainty risks and a certain amount of sunk costs. Industrial policy can provide financial support to enterprises through subsidies or tax deduction, which may reduce the external risks. Montmartin and Herrera [32] found that as government provides subsidies to enterprises, the enterprises could be relieved from the financing constraints in the process of innovation practice, and the risk expectations for R&D activities could be significantly reduced as well. Therefore, at the initial stage of the industrial development, government subsidies can provide initial assets for enterprises, which may lead to reducing their production costs and gaining greater profitability advantages. Romer [33] proposed an important theoretical hypothesis saying that the production of new technology is mainly the result of the final profit of new technology and driven by market interest. Therefore, the excessive total cost of the initial investment is an important mechanism to limit technological innovation, and sharing the cost of R&D can increase the expected level of innovation profitability. The cost of technological innovation mainly comes from two aspects, the loss suffered from innovation failure, and the fixed costs of innovation success. In fact, the failure rate of technological innovation is very high. Mansfield [34] made a statistical study that only about 20% of research projects on chemical, pharmaceutical, petroleum and electronic products on the U.S. market can be finally commercialized. Because of the high failure rate and the massive fixed cost, technological innovation could be considered a high risky investment. Hence, this study proposes the first hypothesis:

Hypothesis 1: Industrial policies can improve the technological innovation level of the enterprises in government encouraged industries.

Conversely, industrial policies can often provide producers with certain incentives to promote industrial development, including information supplementation, credit incentives, financial subsidies, tax deductions, and land resource preferences. It will result in a large number of new enterprises and funds entering the encouraged industries, which may lead to overcapacity. In addition, the vicious competition of local governments on preferential conditions may also result in the real market demand not being correctly reflected, which also increase the possibility of overcapacity. Therefore, if the support of industrial policies cannot correctly guide enterprise innovation, it will cause huge waste of resources. Under the background of local protectionism and Chinese local officials' promotion tournament [35], the resource, repeated capacity building and new energy vehicle fraud compensation may significantly reduce the effectiveness of policy implementation. Hence, this study puts forward the second hypothesis:

Hypothesis 2: Industrial policies can inhibit the technological innovation level of enterprises in government encouraged industries.

4. Industrial Policies of China's New Energy Vehicle Industry

4.1. The Development and Expansion Stages

China's new energy vehicle industry began in the early twenty-first century. In 2001, the new energy vehicle research project was listed as the "863" major scientific and technological project during the national "10th Five-year" period, and planned the strategy of taking gasoline vehicles as the starting point and advancing to the target of hydrogen-powered vehicles. Since the "11th Five-Year", China had put forward the strategy of "energy-saving and new energy vehicles", which represented the great concern from the government to the R&D and industrialization of new energy vehicles. In 2016, the production and sales of new energy vehicles increased by more than 50% over the same period last year, which was a significant slowdown in growth rate compared with that in 2015. Under the strong stimulation of policies, the production and sales of new energy vehicles in China reached 517,000 and 507,000 in 2016, with growth rates of 51.7% and 53%, respectively. The production and sales of pure electric vehicles were 417,000 and 409,000, respectively, with an increase of 63.9% and 65.1% compared with the same period in the previous year. The production and sales of plug-in hybrid vehicles were 99,000 and 98,000 respectively, up 15.7% and 17.1% respectively over the same time period of the previous year.

New energy vehicles accounted for 1.8% of vehicle sales in the whole year. The production and sales goals of "700,000 vehicles for the whole year" had not been completed by the adjustment of the "national subsidy" policy, the fermentation of "fraud subsidy inspection", and the overthrow of the promotion catalogue (see, Figure 1).

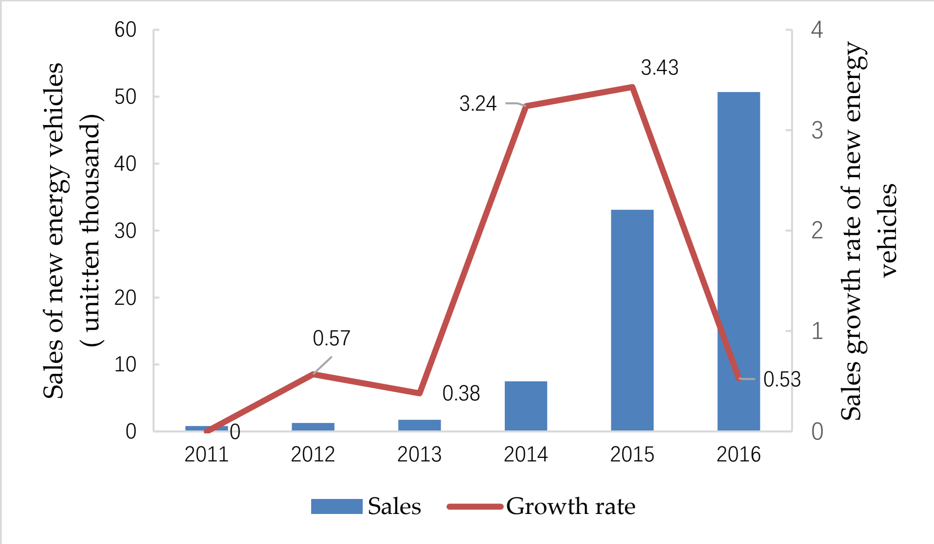

Figure 1. Sales of new energy vehicles and its growth rate in 2011–2016. Data source: China Association of Automobile Manufacturers.

The number of electric vehicles (EV) produced in 2016 was 409,000, accounting for 80.7%, with a proportion increased for two consecutive years. At present, the policy is the main driving force for the development of the new energy vehicle industry: the subsidy policy is obvious to EV. In addition, there is no license welfare for the plug-in hybrid electric vehicles in key test cities of the new energy vehicle (such as Beijing), and the owners still need to participate in the small passenger car plate lottery. Under the influence of these factors, the proportion of electric vehicles has increased by more than 20 percentage in 2015–2016. The author believes that, influenced by the policy, the dominant position of electric vehicles will continue to be maintained (see, Figure 2).

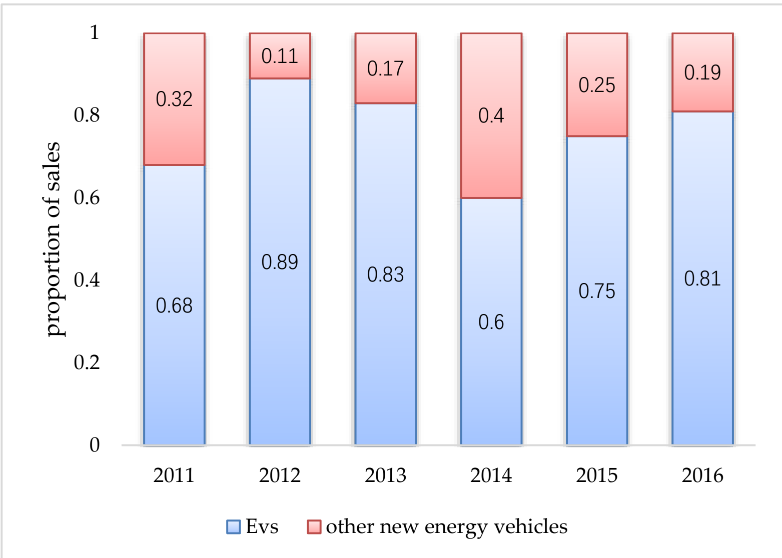

Figure 2. The proportion of electric vehicles (EV) in new energy vehicles in 2011–2016. Data source: China Association of Automobile Manufacturers.

4.2. Key Policies on New Energy Vehicle Industry

In 2008, the sales growth of new energy vehicles in the whole year was mainly the growth of passenger cars. A total of 899 new energy passenger vehicles were sold, up 117% from the previous year, while 1536 new energy commercial vehicles were sold, with a 17% decline by the previous year. In 2009, the supporting policies were introduced frequently, and the new energy vehicle industry has entered a rapid development track in China. Although the proportion of new energy vehicles in China's automobile market was still very small, its growth potential had begun to release. In 2016, the sales of new energy passenger vehicles decreased to 310, by 62% compared to that in 2015, while the sales of new energy commercial vehicles (LPG vehicles, LNG vehicles, hybrid vehicles, etc.) increased to 4,034, by 179% compared to the same period in the last year. Compared with the cold market in the passenger vehicles market, the "new energy vehicles" have begun to grow rapidly in China's commercial vehicle market.

New energy vehicles have provided a breakthrough for alleviating China's energy crisis, achieving the goal of energy-saving and emission reduction, improving the atmospheric environment and the catching-up strategy of the automotive industry. In 2009, since the carried-out **"Ten Cities Thousand Vehicles Project"**, the relevant government departments have introduced some policies in order to promote the development of the new energy vehicle industry. The main policies are in Table 1.

Table 1. Major Industrial Policies on New Energy Vehicle Industry.

Serial No.	Policy Name	Release Time	Issue Department
1	Notice on launching pilot projects For demonstration and popularization of energy-saving and new energy vehicles	23 Jan 2009	Ministry of Treasury and Ministry of Science and Technology
2	Notice on launching pilot projects for private purchases of new energy vehicles	31 May 2010	Ministry of Treasury, Ministry of Science and Technology, Ministry of Industry and Information, National Development and Reform Commission
3	Decision on accelerating the cultivation and development of strategic emerging industries	10 Oct 2010	The State Council
4	Development plan on energy-saving and new energy vehicle industry	28 Jun 2012	The State Council
5	Notice on the continuing popularization and application of new energy vehicles	10 Sep 2013	Ministry of Science and Technology, Ministry of Industry and Information, National Development and Reform Commission
6	Notice on exemption of purchase tax on new energy vehicle	1 Aug 2014	Ministry of Treasury, Administration of Taxation, Ministry of Industry and Information
7	Notice on the award about construction of new energy vehicle charging facilities	8 Nov 2014	Ministry of Science and Technology, Ministry of Industry and Information, National Development and Reform Commission
8	Made in China 2025	8 May 2015	The State Council
9	Notice on strengthening the planning and construction of charging facilities for electric vehicles in cities	15 Jan 2016	Ministry of Housing and Urban-Rural Construction

Source: Authors' collection.

In 2010, China had increased its support for new energy vehicles. Since June 2010, the state had launched a subsidy pilot project for private purchase of new energy vehicles in 5 cities, including Shanghai, Changchun, Shenzhen, Hangzhou and Hefei. In July 2010, the government increased the number of energy-saving and new energy vehicle popularization pilot cities in the **"Ten Cities Thousand Vehicles Project"** from 20 to 25.5 cities were selected to pilot the subsidy private purchase of energy-saving and new energy vehicles, which meant that the new energy vehicle was entering the stage of comprehensive policy support.

In 2011, it began to enter the industrialization stage. The new energy city vehicles, hybrid vehicles and small electric vehicles were launched throughout the country. On April 18, 2012, the premier of the State Council, chaired the standing meeting of the State Council, which decided to achieve the accumulating production and sales of 500,000 of electric and plug-in hybrid vehicles in 2015, and more than 5 million in 2020. The average fuel consumption of passenger vehicles produced in 2015 to fall to 6.9 liters per hundred kilometers, to fall to 5 liters in 2020. The technology of new energy vehicles, power batteries and key components reached the international advanced level as a whole.

In May of the same year, in order to speed up the development of new energy vehicles, the new energy vehicle project would receive 1–2 billion yuan annually. In 2014, 78,499 new energy vehicles were produced in China, and the production volume increased nearly 3.5 times over the same period of the last year. The sales of 74,763 vehicles in the overall market share of the automobile increased from 0.08% in 2013 to 0.32%, and the sales volume increased by nearly 3.2 times over the same period of the last year. By the end of March 2015, 39 application programs had promoted 97,700 new energy vehicles cumulatively.

Since 2016, the new energy vehicle fraud compensation incidents have continued. Firstly, the Four Ministries and Commissions including the Ministry of Industry and Information, the Ministry of Treasury jointly conducted verification, then in April it was said to be led by the State Council. In the meantime, relevant government departments also introduced a series of new energy vehicle related policies: for example, introduced The Recommended Model Catalogue for Promotion and Application of Energy-saving and New energy Vehicles, abolishing the original catalogue since January 1, 2016; suspended ternary lithium-ion battery vehicles for new energy vehicles in order to better evaluate the related risks. It was also said that the 1–3 batch of recommended catalogue published in 2016 would be returned and rechecked, all the battery enterprises that had not been included in the catalogue of the standard conditions for the automotive power battery industry, and those complete vehicle recommendation catalogue promotion were not to be passed.

In the long run, both the fraud compensation verification and the introduction of such series of policies are beneficial to the sustainable development of the industry, but in the short term, it may also suppress the industry. In 2016, the ratio of new energy vehicle piles decreased for the first time, which indicated that the charging pile industry was in the outbreak stage in a way. According to "The plan for the development of electric vehicle charging pile infrastructure (2015–2020)", around 4.8 million new dispersed charging piles are needed in 2015–2020 to meet the demand for more than 5 million electric vehicles at the end of the period, of which 500,000 new dispersed public charging piles are needed. By the end of 2016, China had built 150,000 public charging piles, up 206% from the end of last year, and in 2015–2017, about 222,000 public charging piles had been built in China (see, Figure 3). Based on the accelerating construction of charging piles, the vehicle pile ratio has dropped from 9.13:1 in 2015 to 6.36:1 in 2016.

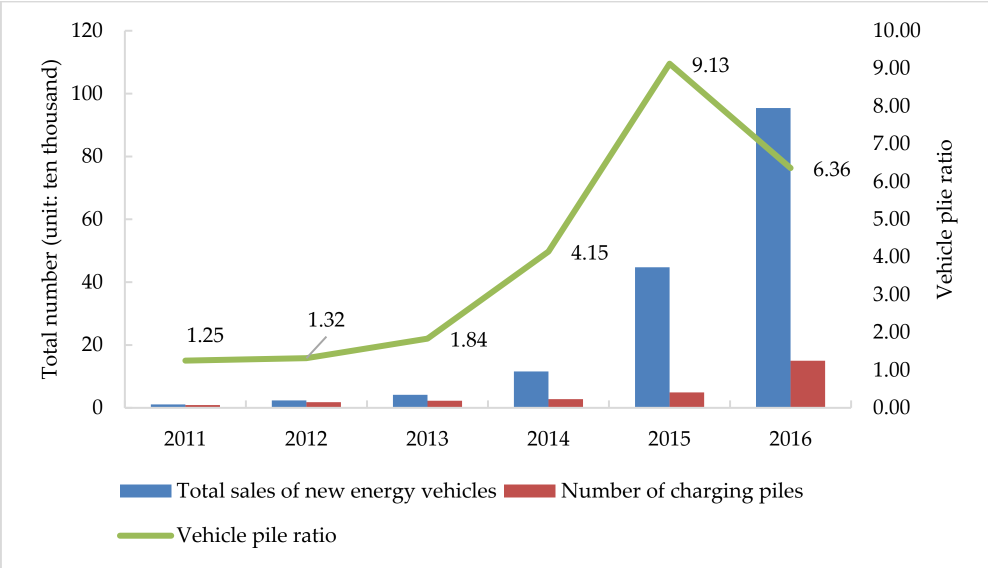

Figure 3. Total number and proportion of new energy vehicles and charging piles in 2011–2016. Data source: Summarized by the author according to the relevant data.

5. Empirical Analysis

5.1. Model Setup

(1) Difference-in-Differences Model

Studying the influence of industrial policy on the development and innovation of new energy automobile industry is an important way to evaluate the effectiveness of industrial policy. We pay attention to the changes of the development and innovation of new energy automobile industry after the implementation of industrial policy. Difference-in-differences method can not only control the influence of unobservable factors changing with time, but also control individual heterogeneity, which has been widely used in the research of evaluating the effect of policy implementation. This approach treats new policies or institutions as an exogenous shock, akin to a "quasi-natural experiment".

The industrial policy of new energy vehicles first started in the National 15th Plan. In order to promote the sales of new energy vehicles and gradually cultivate the consumer market for new energy vehicles, several Chinese ministries jointly launched the "**Ten Cities One Thousand Vehicles**" project for the development of new energy automotive industry in 2009. The "**Ten Cities Thousand Vehicles Project**" is considered as the demonstration and promotion application project of 1,000 new energy vehicles in ten cities, was jointly launched by the Ministry of Science and Technology, the Ministry of Finance, the National Development and Reform Commission, and the Ministry of Industry and Information Technology in January 2009. The main content includes providing financial subsidies to develop 10 cities each year, and each city launches 1,000 new energy vehicles to carry out demonstration operations involving public transport, rental, public service, municipal administration, and postal services in these large and medium-sized cities. The main purpose of this policy is to make the whole country's new energy vehicles operating scale account for 10% of the automotive market share by 2012. Hence, we use the year of 2009 as the specific policy invention date, take the observation from 2010 to 2015 as the treatment group and the observation from 2006 to 2009 as the control group. Intuitively, we expect to look at the direct stimulating effect of policies on production and sales, and new energy vehicles have entered a fast-growing channel. Hence, this paper also takes the new energy automobile industry as the treatment group, and the traditional automobile industry as the control group. Here, the traditional automobile industry means the automobile industry which has not been benefited by state subsidies and other policies. New energy vehicles and traditional cars are consistent in their use, and there is commonality in the automotive industry itself, including R&D activities.

Meanwhile, the main differences between the two industries are as following. Firstly, the traditional car market has a large share, but the growth rate is relatively slow. On the contrary, even though the market share of new energy vehicles is small, the growth rate is faster in the recent years. Secondly, the Chinese government introduced a pilot policy for the promotion of new energy vehicles, mainly through subsidies, in order to open the consumer market for new energy vehicles in 2009. The demand-side subsidy policy is the most distinct difference between the development of traditional automobile and new energy automobile industries. This also allows us to estimate the impact of subsidy policies on innovation in the new energy automobile industry after controlling for the impact of region characteristic variables. The Difference-in-Differences (DID) model can be constructed as follows:

$$Lnpatent_{i,t} = \beta_0 + \beta_1 \mathrm{Nev} * \mathrm{Year} + \beta_3 Nev + \boldsymbol{x_{i,t}} + \mu_i + \varepsilon_{i,t}$$

where $patent_{i,t}$ means the number of new-type invention patent applications in province i at year t. The period is from 2006 to 2015. $Nev = 1$ if in treatment group, and $Nev = 0$ if in control group. $Year = 1$ if post-treatment (2010–2015) and $Year = 0$ if pre-treatment group (2006–2009). The coefficient on the interaction term (β_1) measures the DID estimate of the treatment effect. $\boldsymbol{x_{i,t}}$ is other control variables affecting the innovation of new energy automobile industry, including Growth, GDP and Population. μ_i is region dummy variable, and $\varepsilon_{i,t}$ is random disturbance item.

(2) Propensity Score Matching

Because the initial conditions of the experimental group and the control group are not completely the same, the DID method based on the simple linear regression model may have the problem of "selection bias", and the results are not robust. We used the "Treatment Effect" method of policy evaluation to further study. The basic idea is to find and match observable variables as similar as possible to the treatment group in the control group, average the treatment effect of each individual, and obtain the "matching estimator". The idea of Propensity Score Matching (PSM) is to compute the propensity score of a processing group variable and a control group variable, and to use the propensity score as a distance function for matching. The PSM method constructs the multi-dimensional factors representing individual characteristics into the comprehensive propensity score, and searches for the similar individuals for matching, which can overcome the difficulty of matching caused by the dimension problem [36].

This paper assesses the impact of government support on industry innovation by matching provinces enacting new energy vehicles industry with other provinces. The evaluation of the implementation effect of the new energy vehicle industrial policy can be regarded as a "treatment effect" problem. The provinces that implement the new energy industrial policy constitute the "treatment group", while the provinces that do not implement the new energy industrial policy constitute the "control group". Rubin [37] proposed a counterfactual framework to solve the problem of processing effects. The implementation of new energy vehicle industrial policy can be represented by the processing variable Nev_i, $Nev_i = 1$ for implementation, and $Nev_i = 0$ for non-implementation. For province i, use y_i to represent the innovation ability $(y_i = y_{1i}, Nev_i = 1; y_i = y_{0i}, Nev_i = 0)$, where, y_{1i} represents the innovation ability of provinces that implement new energy automobile industrial policy, y_{0i} represents the innovation ability of provinces that do not implement new energy automobile industrial policy, and $(y_{1i} - y_{0i})$ represents the processing effect of new energy automobile industrial policy implemented by province i.

Assuming that the selection of new energy vehicle industrial policy implementation Nev_i meets "Ignorability", that is, given factors x_{it} affecting the implementation of new energy vehicle industrial policy of a province, innovation ability (y_{1i}, y_{0i}) is independent of Nev_i, then the evaluation model of innovation ability for the implementation of new energy vehicle industrial policy can be defined:

$$y_i = \boldsymbol{x_i'}\boldsymbol{\beta} + \gamma Nev_i + \varepsilon_i$$

In essence, the PSM method ensures the observation data is as close as possible to the random experiment data through the combination of matching and resampling, so as to overcome the "self-selection" problem and directly compare the sample selection results of the treatment group and the control group. After matching, the average treatment effect of provinces implementing the new energy vehicle industry policy (Average Treatment Effect on Treated, ATT) can be estimated as:

$$\widehat{ATT} = \frac{1}{N_1}\sum_{T_{i=1}}(y_i - \hat{y}_{0i})$$

The average treatment effect of provinces that have not implemented the new energy vehicle industry policy (Average Treatment Effect on the Untreated, ATU) can be estimated as:

$$\widehat{ATU} = \frac{1}{N_0}\sum_{T_{j=0}}\left(\hat{y}_{0j} - y_j\right)$$

The Average Treatment Effect (ATE) of all provinces is:

$$\widehat{AT}\mathrm{E} = \frac{1}{N}\sum\nolimits_{i=1}^{N}(\hat{y}_{1i} - \hat{y}_{0i})$$

$N = N_1 + N_0$ is the total sample size. If $Nev_i = 1$, then $\hat{y}_{1i} = y_i$; if $Nev_i = 0$, then $\hat{y}_{0i} = y_j$.

PSM is divided into global matching method and nearest neighbor matching method. Global matching method matches individuals in the whole sample through distance weight function, while nearest neighbor matching is the arithmetic average of the nearest individuals. The selection of matching methods and parameters depends on specific data. If the results of different matching methods are similar, robust estimation results can be obtained. Therefore, multiple methods should be adopted in this study to conduct sample matching for provinces implementing new energy vehicle industrial policies. After the matching is completed, we need to calculate the standard deviation of $\boldsymbol{x_i}$ **and** $\boldsymbol{x_j}$ for the balance test, to investigate whether the $\boldsymbol{x_i}$ of the provinces that implement the new energy vehicle industry policy and the $\boldsymbol{x_j}$ of the provinces that do not implement the new energy vehicle industry policy are close enough to each other. Rosenbaum and Rubin [38] believe that the standard deviation is generally less than 10%. Otherwise, a new match is required.

(3) Difference-in-Differences Propensity Score Matching Model

The PSM estimator relies on the "ignorability assumption", that is, the selection of measurable variables is not applicable to the selection of unobservable variables. When the unobservable variables that affect the processing, variables do not change with time and the data is panel data, the Difference-in-Differences Propensity Score Matching estimation (DID-PSM) can be used. The estimation of the average treatment effect of new energy industrial policy is:

$$\widehat{ATT} = \frac{1}{N_1}\sum_{i:i\in I_1\cap S_p}\left[(y_{1ti} - y_{0t'i}) - \sum_{j:j\in I_0\cap S_p} w(i,j)\left(y_{0tj} - y_{0t'j}\right)\right]$$

where, t is before the experiment, which is 2006–2009; t' is the experimental stage, which is 2010–2015. S_p is the common value range, $I_1 = i : Nev_i = 1$ is the processing group, $I_0 = i : Nev_i = 0$ is the control group. N_1=$I_1 \cap S_p$ is the number of treatment group, $w(i,j)$ is the weight of corresponding to the pairs $w(i,j)$, $(y_{1ti} - y_{0t'i})$ is the change for individuals in processing group before and after the policy, $(y_{0tj} - y_{0t'j})$ is the change for individuals in control group before and after the policy.

5.2. Data Sources and Variables Description

This paper selects the number of patent applications in China to measure independent innovation. In general, indicators for measuring innovation include number of patents, R&D expenditure, sales of new products, etc. [39]. Among these indicators, patents as an intermediate output indicator of innovation activities can provide information on the firm's innovation capability. In contrast, R&D expenditure is considered as a prerequisite for the formation of independent innovation capabilities. However, R&D expenditures may not always lead to independent innovation success, due to the high probability of failure. In addition, sales of new products may also be due to the introduction of new technologies rather than independent innovation.

China's State Intellectual Property Office granted three types of patents, new-type invention patent, utility model patent, and layout design patent. Such three types of patents are successively decreasing in degree of innovation. In this paper, we use the most innovative one new-type invention patent to measure innovation capability. Specifically, we measure independent innovation from the perspective of the number of new-type invention patent applications and the success rate of applications.

The descriptive statistics of each variable are shown in Table 2. We can find that 58.82% of the selected samples in this paper are in the experimental group, that is, more than half of the provinces have implemented the new energy vehicle industry policy. The average lnpatent value of provinces implementing new energy automobile industrial policy is 2.7287, while the average patent value of provinces without implementing new energy automobile industrial policy is 4.7854. This is contrary to the previous hypothesis of this paper, which needs to be proved by empirical test.

Table 2. Statistics Summary.

Variable	Obs	Mean		Standard Deviation		Min		Max	
		Treated	Control	Treated	Control	Treated	Control	Treated	Control
Lnpatent	391	2.7287	4.78544	1.42149	1.480021	0	0	5.69	7.834
Growth	391	99	16.39	131.960	13.71849	-45	2.45	343	45.46
GDP	391	19100.77	19100.77	13952.9	13952.92	2338.98	2338.98	72812.6	72812.6
Population	391	5233.221	5233.221	2506.77	2506.774	1075	1075	10724	10724

5.3. Results

(1) Difference-in-Differences Results Analysis

Table 3 reports the estimated impact of the new energy automobile industry policy on the number of invention patents. Table 3 shows that the results of ordinary least-squares regression, maximum likelihood regression, semi-parametric regression, DID and PSM estimation all meet our expectations. It can be found that the coefficient of the interaction term *Nev*Year* is significantly positive, which means the number of invention patents for the provinces enact new energy automobile industry policy has increased significantly, compared to the provinces do not.

Table 3. The estimated impact of the new energy automobile industry policy on the number of invention patents.

	(1)	(2)	(3)	(4)	(5)
	OLS	**ML**	**Nonpara**	**DID**	**PSM**
Nev*Year	-	-	-	0.644793 ***	-
	-	-	-	(4.51)	-
Nev	−2.066665 ***	−1.304 ***	1.392 ***	−2.424591 ***	-
	(−19.81)	(−5.83)	(4.15)	(−18.76)	-
Growth	0.000876 ***	0.00124 *	−0.0028 ***	0.000106	0.0091568 ***
	(1.909)	(1.83)	(4.43)	(0.16)	(4.97)
GDP	0.000109 ***	−0.000092 ***	0.000060 ***	0.000095 ***	-1.78×10^{-6}
	(18.45)	(16.30)	(3.43)	(17.10)	(−0.25)
Population	−0.000248 ***	−0.000218 ***	−0.724 ***	−0.000229 ***	5.27×10^{-6}
	(−11.23)	(−7.93)	(−0.031)	(−10.49)	(0.15)
Constant	4.146 ***	3.375 ***	-	3.289 ***	−0.363442 **
	(35.24)	(14.38)	-	(35.29)	(−2.28)
N	391	391	391	391	391

Note: (1) Figure in bracket is t value or z value; (2) ***, **, * represent 1%, 5%, 10% significant level, respectively.

The validity of the DID estimation is premised on the assumption that the experimental group and the control group satisfy the parallel trend hypothesis before being processed. Figure 4 shows that before the policy shock point of 2009, the number of invention patents in the experimental group of the control group maintained the same growth trend, while after the policy shock point, the number of invention patents in the experimental group and the control group changed significantly. Therefore, the results obtained through applying double difference estimation in this paper are consistent with the assumption of parallel trend.

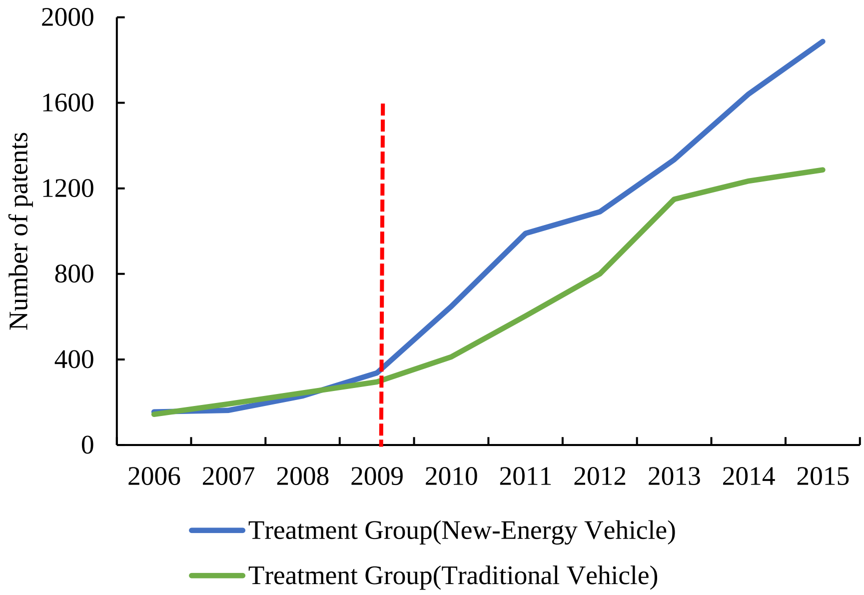

Figure 4. Parallel trend assumptions.

As Table 4 shown, although the DID estimator of the number of invention patents is not significant, the sign is positive, which indicates that the number of invention patents can be increased after the implementation of the new energy vehicle policy, and such industrial policy can promote the improvement of the innovation capability of the new energy vehicle industry.

Table 4. Estimated effect of Difference-in-Differences (DID) method.

Lnpatent	Change in innovation capability						
	Treated		Control		DIFF		DIFF-IN-DIFF
	Base Line (1)	Follow Up (2)	Base Line (3)	Follow Up (4)	(5) = (1) − (3)	(6) = (4) − (2)	(7) = (6) − (5)
Mean	1.691	2.401	3.821	4.440	−2.130 ***	−2.038 *	0.092
N	92	115	69	115	161	230	391

Note: ***, * represent 1%, 10% significant level, respectively.

(2) Propensity Score Matching Results Analysis

Table 5 is the result of studying the influence of new energy vehicles on innovation using the PSM method. The first, second, third and fourth columns in table are the results of using k-nearest neighbor matching, radius matching, core matching and spline matching respectively. It can be seen from Table 5 that the results obtained by various matching methods are the same, which indicates the robustness of the estimation results by PSM method.

Table 5. The results of the impact of innovation using Propensity Score Matching (PSM) method.

	K-nearest neighbor matching (k = 5)	Radius matching (ε = 0.05)	Kernel matching (epan kernel; bw = 0.06)	Spline matching
Growth	0.0091568 *** (4.97)	0.0091568 *** (4.97)	0.0091568 *** (4.97)	0.0091568 *** (4.97)
GDP	-1.78×10^{-6} (−0.25)	-1.78×10^{-6} (−0.25)	-1.78×10^{-6} (−0.25)	-1.78×10^{-6} (−0.25)
Population	5.27×10^{-6} (0.15)	5.27×10^{-6} (0.15)	5.27×10^{-6} (0.15)	5.27×10^{-6} (0.15)
Constant	−0.3634429 ** (−2.28)	−0.3634429 ** (−2.28)	−0.3634429 ** (−2.28)	−0.3634429 ** (−2.28)
N	391	391	391	391
LR chi2	53.62	53.62	53.62	53.62
Pseudo R2	0.0992	0.0992	0.0992	0.0992

Note: ***, ** represent 1%, 5% significant level, respectively.

After the PSM estimation, the distribution of each variable in the experimental group and the control group should be testified whether they are balanced. Table 6 shows the results of data balance test. It can be seen from Table 6 that, the mean differences of the covariates between the experimental group and the control group are relatively small, indicating that PSM method and DID-PSM method can be used for our data.

Table 6. Data balance test.

	Mean			t-test	
Variable	**Treated**	**Control**	**Bias**	**t**	**Pr(T>|t|)**
growth	68.5	29.139	52.2	4.99	0.000 ***
GDP	19083	19685	−4.6	−0.40	0.689
population	5252.2	6468.2	−48.4	−4.80	0.000 ***

Note: *** represent 1% significant level.

Figure 5 shows that the data after PSM is relatively balanced, and that the samples basically meet the requirement of common range, that is, most of the observed values of provinces that implement new energy automobile industrial policy and provinces that do not implement new energy automobile industrial policy are within the common value range, and only a small number of samples are lost in the PSM.

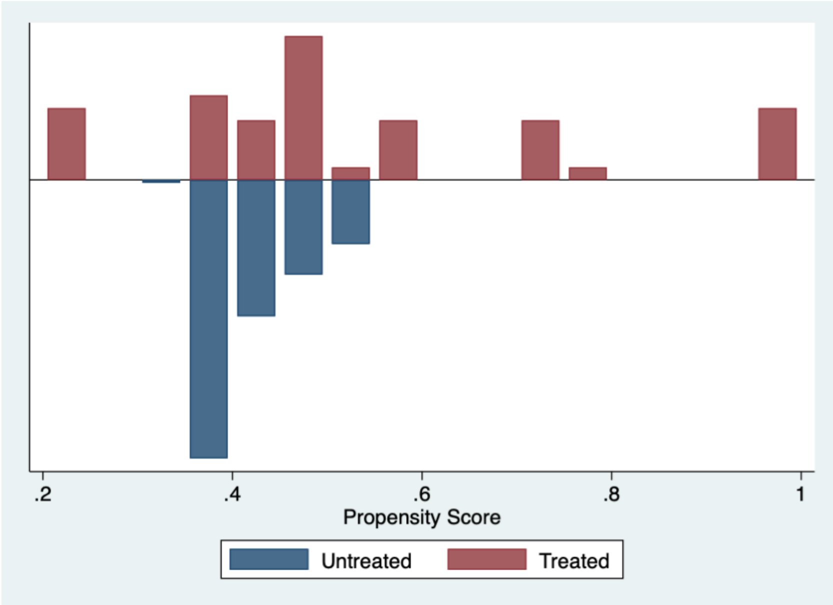

Figure 5. Common support domain of PSM (proximity matching).

(3) Difference-in-Differences Propensity Score Matching Results Analysis

From Table 7, we can find that, after the implementation of the new energy automobile industry policy, the number of invention patents was improved to some extent, while the DID estimator was not significant, but the symbol is positive, it shows that the new energy automotive industry policy has a role in promoting innovation ability to automotive industry. The result estimated by DID-PSM method is consistent with DID method.

Table 7. The results of the impact of innovation using Difference-in-Differences Propensity Score Matching (DID-PSM) method.

Lnpatent	Change in innovation capability						
	Treated		Control		DIFF		DIFF-IN-DIFF
	Base Line (1)	Follow Up (2)	Base Line (3)	Follow Up (4)	(5) = (3) − (1)	(6) = (4) − (2)	(7) = (6) − (5)
Mean	1.681	3.429	3.885	5.411	−2.204 ***	-1.982 ***	0.223
N	89	138	89	132	178	270	448

Note: *** represent 1% significant level.

6. Conclusions

Sustainable transportation means that the source of energy must be renewable and environmentally friendly, such as solar energy, wind energy, bio-power generation, etc. However, these renewable energy sources are not enough to support the current demand of travel. Therefore, the innovation capability of new energy vehicle industry, especially for energy power systems, becomes very important. Taking the new energy vehicle industry as an example, this paper empirically examines the impact of industrial policies on industry innovation capability by using the number of invention patents to measure the innovation capability. It is found that the results of difference-in-differences estimation show that China's related industrial policies in 2009 can significantly improve the number of invention patents filed in China's new energy vehicle industry, which provides solid evidence to reflect that industrial policies can promote the innovation capabilities of new energy vehicle manufacturers.

We believe that China's new energy vehicle industry policies can play an important role by the following ways. First, the industrial policies on new energy vehicles has increased enterprises' risk resistance, through subsidies on demand side. For the early development stage of a strategic new industry, the government subsidies can provide the initial assets of the enterprise development, return on investment will also improve the innovation incentives of the enterprise.

Second, the emergence and sustainability of new energy vehicles require adjustments in old vehicle platforms, which will take time for customers to accept. The consumption subsidy, product marketing support and infrastructure promotion could facilitate the market scale of the new energy vehicle, and the increasing market demand will help manufacturers to reduce the risk of reduce the production cost, which brings it a greater profit advantage. The increase of the rate of technological innovation, and provide the reliable expected profit to offset the costs of technological innovation.

Finally, the rise of new energy vehicles has broken the high entry barrier of the traditional automobile industry. Industrial policy support for new energy vehicle industry can enhance competition in the entire automotive industry. The market competition is becoming increasingly fierce, and more innovative manufacturers are entering this area. It has also prompted the traditional automobile manufacturing enterprises to switch to the production of new energy vehicles, and has been forced to accelerate the pace of innovation to ensure survival in the competitive market.

The limitations of this paper have to be mentioned here. The first is that the effect of certain policies cannot be analyzed specifically because the difficulty of collecting data, the other is about the impact of the future subsidy decline. We currently do not have the corresponding resources to support such analysis, and the further researches are still needed.

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