Which incentive instruments do well for expanding the installed capacity of wind power: the empirical study in China

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Abstract: China has made significant progress in pursuing its wind power policy in terms of cumulative installed capacity. This study investigated the effects of different incentive policies on the expansion of installed capacity of wind power. Local planning support, cost allocation, concessionary tendering system and benchmark pricing are selected as policy variables and the individual fixed-effects model is applied to perform a quantitative analysis given the characteristics of the data series. Empirical results indicate that the effects of cost allocation, benchmark price and local planning support are decreasing gradually. We also find that concessionary tendering has no evident impact on the increase in installed capacity. This investigation on incentive policies provided evidence to further the design of an incentive mechanism that can optimize the supply structure of energy.

1. Introduction
Increasing environmental concerns have driven China to gradually rebuild its energy structures by substituting fossil energy with renewable energy. The cumulative installed capacity of wind power in China reached 169 MKW, which topped world rankings. The government has formulated incentive policies to solve problems in the development of the wind power industry[14]. Besides, the increasing gap of subsidies reached 35.1 billion yuan at the end of 2017[5], which stimulates the relevant questions include: are all incentive policies effective in driving the growth of installed wind capacity? how about the degrees of the effects of incentive policies?

The incentive policies for wind power expansion have drawn wide attention from researchers. Current methodologies of investigating the effects of the incentive instruments can be classified into case study and empirical research. Case investigations identified the factors that had driven development of wind power, analysed the obstacles for expanding and then presented the suitable conditions for corresponding policy adoption[14–17], Which helped us understand the existing incentive instruments well while providing limited empirical evidence for the optimal policy design.

Empirical studies on the analysis of effects could lead to improve policy designs. Menz F. C. et.al (2006) was the first study to use multivariate techniques to assess the effectiveness of different state policies. Carley (2009) adopted fixed effects model to indicate that RPS does not result in a remarkable increase in the proportion of renewable energy. Manuel González-Gómez (2017) indicated that guaranteed prices had a positive effect on the installed power capacity of the wind and solar power. Baldwin, E., et. al. (2016) mainly compared the effects of FIT and RPS under different income level, and Poisson Regression Models (PRM) had been adopted since the dependent variable was a count variable. The research mentioned above had adopted the proper statistical model to find the degree of effectiveness according to the characters of the variables. The researches levels were from the country (region) to state. The relative research had enlightened our work under the Chinese scenario. In this
paper, we analyse the incentive policies of expanding wind power installed capacity and quantify their effects based on provincial level panel data.

2. Policy Discussion And Model Formation

2.1. Combing the incentive policies and selecting variables

In China, there are mainly five forms of incentive instruments: tax discount, discount interest on loans, fixed prices included benchmark electricity price and cost-sharing and wind power concessionary tendering. Yu Yanyan (2015) claimed that the feed-in tariff (FIT) was amended and perfected without further quantitative analysis. The quantitative researches about the incentive instruments for wind power installed capacity can be tracked back to Yu Lihong. (2008). Hu Z., et. al. (2013) proved that the growth of wind power capacity completely relied on power subsidies. Zhao X, et. al. (2016) found that price policy positively affected the expansion of wind power installation. Zhang, X, et. al (2016) revealed that the adoption of wind energy policies and a general energy plan at the provincial level are having positive effects on the growth of wind capacity in Chinese. We establish a comprehensive model, which investigates the effects of incentive policies from provincial level data. Extract four variables from the incentive instruments: policy planning, cost sharing, concessionary tendering and benchmarking of electricity pricing defined as follows:

Policy planning (pplan) refers to the relative energy planning that encourages the expansion of wind power. The value of pplan can be defined as follows:

\[
p_{\text{plan}} = \begin{cases} 
0, & \text{if policy planning exists.} \\
1, & \text{if some policy planning exists.} 
\end{cases}
\]

Cost sharing (cshare). The access cost of wind power should be shared amongst wind power enterprise, power grids and regional users. Various enforcement techniques for cost sharing have evolved during the period in different regions of the country. cshare can be evaluated as follows:

\[
c_{\text{share}} = \begin{cases} 
0, & \text{if no cost sharing exists.} \\
1, & \text{if cost sharing exists.} 
\end{cases}
\]

Concessionary tendering (ctender) refers to the commitment of the Grid Power Group to purchase the wind power at lowest bid price during the concessionary tendering period. ctender can be evaluated as follows:

\[
c_{\text{tender}} = \begin{cases} 
0, & \text{if no concessionary projects exist.} \\
1, & \text{if concessionary projects exist.} 
\end{cases}
\]

Benchmarking electricity price (bprice) refers to the fixed price for purchasing wind power. The benchmarking prices have been determined by the State Council Department in accordance with the tender size. bprice is evaluated as follows:

\[
b_{\text{price}} = \begin{cases} 
0, & \text{if no benchmarking price exists.} \\
1, & \text{if benchmarking price exists.} 
\end{cases}
\]

These variables are explanatory variables while the effects can be measured by the scale of wind power installed capacity (icapacity). The natural logarithm of the installed capacity (lnicapacity) replaces icapacity as the explained variable to narrow the magnitude and distance between the installed capacity and the other variables in value, which does not change the original co-integration relationship.

2.2. Data collection

Data on the installed capacity of wind power and the four incentive instruments in 31 provinces (cities) in China from 2005 to 2015 are collected according to the structure of variables. Table 1 shows the statistical results.
Table 1. Statistics Of Wind Power Installed Capacity In China: Incentive Policies From 2005 To 2015

| Variable name | lnicapacity | pplan | cshare | ctender | bprice |
|---------------|-------------|-------|--------|---------|--------|
| Average       | 3.7378      | 0.4252| 0.6246 | 0.02053 | 0.53079|
| Median        | 5.7015      | 0     | 1      | 0       | 1      |
| Maximum       | 10.1530     | 1     | 1      | 1       | 1      |
| Minimum       | -6.9078     | 0     | 0      | 0       | 0      |
| Std deviation | 5.4395      | 0.4951| 0.4849 | 0.1420  | 0.4998 |
| Skewness      | -1.2068     | 0.302 | -0.51478| 6.7628  | -0.1234|
| Kurtosis      | 2.9511      | 1.0915| 1.2650 | 46.7352 | 1.01523|
| P-value       | 0           | 4.2955e-13| 2.778e-13| 0       | 4.5508e-13|
| Observations  | 341         | 341   | 341    | 341     | 341    |
| Sections      | 31          | 31    | 31     | 31      | 31     |

Table 1 shows that the kurtosis of concessionary tendering is very large (larger than 3) and the distribution is steep. On the contrary, the kurtosis of the remaining variables is very small (less than 3) and the distribution is gentle. The skewness coefficient of concessionary tendering and policy planning is greater than 0, revealing a distribution that deviates to the right. The skewness coefficients of the remaining variables are less than 0, showing a distribution that deviates to the left.

2.3. Adoption of statistic model
The panel data framework naturally services this aim due to the better power properties than univariate methods in finite samples. This power gain is a crucial feature of the existing empirical studies, given the difficulty of constructing a balanced panel across N provinces over T periods. To avoid false regression, the unit root test is applied. The results of this test showed that the P-values of the explanatory variables are greater than 0.05 at a significant level of 5%, indicating that these variables are non-stationary. Meanwhile, the P-value of the explained variable lncapacity is less than 0.05 at a significance level of 5%, indicating that it is stationary. The unit root test is applied to the first-order differences of the explanatory variables, and the results satisfy the requirement of the co-integration test because the P value is less than 0.05 at a significance level of 5%. The stationary relationships amongst the variables have been tested through the co-integration test, which indicates that all variables are co-integrated stationary regression residuals of the equations observed. To select the statistical model of the panel data, individual and time fixed-effects models are considered. From the heterogeneity test is conducted, and the cross-section F and cross-section chi-square are less than 0.05. Thus, the individual effect must be considered. The random-effect model is excluded according to the results of the Hausman test as follows: Prob. = 0.0001, and P values < 0.05. The fixed-effects model is adopted because the span of the data series does not satisfy the sample capacity requirement of the varying coefficient model. In summary, the individual fixed-effects model is adopted to quantify the effect of incentive policies as follows:

\[
\lnicapacity = \alpha_i + \sum_{t=1}^{4} \beta_i x_{it} + \epsilon_{it}
\]

Where intercept \( \alpha_i \) denotes all the unobservable factors that affect the explained variable, which does not change over time and reflects the individual differences resulting from missing variables. \( \epsilon_{it} \) denotes the error of the unobservable variable, which varies over time. In addition, the four incentive instruments are exogenous variables, which avoid the simultaneous error in the explained variables.
2.4. Model estimation and analysis of results

We adopt the in-group method to estimate the regression coefficients of the four variables. Table 2 shows the results.

Table 2. Estimation results of individual fixed effects model under variable intercept

| Variables | Regression coefficients | Standard deviation | T test value | P value |
|-----------|-------------------------|--------------------|-------------|---------|
| Intercept | -0.960891               | 0.284646           | -3.375743   | 0.0008  |
| pplan     | 1.941330                | 0.497755           | 3.900174    | 0.0001  |

Table 2 shows that the P values of policy planning, cost sharing and benchmarking electricity price are far less than 0.05, showing a remarkable impact on wind power installed capacity. However, the P value of concessionary tendering is greater than 0.05, indicating that no evident effect is detected on the installed capacity. Then concession bidding is removed from the explanatory variable list and the estimated regression coefficients of the remaining variables in the model, as shown in Table 3.

Table 3. Estimation results after excluding "concession bidding"

| Variables | Regression coefficients | Standard deviation | T test value | P value |
|-----------|-------------------------|--------------------|-------------|---------|
| Intercept | -0.986645               | 0.280218           | -3.520998   | 0.0005  |
| pplan     | 1.953561                | 0.496651           | 3.933472    | 0.0001  |
| cshare    | 4.316949                | 0.491349           | 8.785908    | 0.0000  |
| bprice    | 2.255548                | 0.480484           | 4.694324    | 0.0000  |

The final model is then built according to Table 4, as follows:

\[
\ln(\text{icapacity}) = 1.953561 \times \text{pplan} + 4.316949 \times \text{cshare} + 2.255548 \times \text{bprice} - 0.986645
\]  

Equation (1) shows that policy planning, cost sharing and benchmarking electricity price play important roles in promoting wind power installation. The degrees of the effects rank as planning, benchmarking electricity price and cost sharing gradually while the corresponding coefficients are increase from 1.953561 to 4.316949. To test the robustness of the model, the dependent variable converts to the installed capacity (icapacity), the final model is established as:

\[
\text{icapacity} = 1362.542 \times \text{pplan} + 1198.698 \times \text{cshare} + 1712.032 \times \text{bprice} - 299.5282
\]  

According to the Equation (2), the degrees of the effects rank as cost sharing, planning, benchmarking electricity price and gradually while the corresponding coefficients are increase from 1198.698 to 1712.032. From the two statistical models, the concessionary tendering has not worked obviously. Comparing the coefficients from model (1) and (2), there is subtle distinction between the effects, FIT still the most effective measurement than the others. The robustness of model (1) can be testified.

Noticeably, benchmarking electricity price and cost sharing are the main forms of FIT. So, FIT is the most efficient incentive policy, which is consistent with the expansion practice of the wind power industry. FIT guarantees a fixed rate of return for investors over a long period of time, thereby attracting investments for the wind power industry. The effect of local policy planning ranks third in wind power expansion. A scientific local policy planning is expected because renewable energy projects are mainly designed by the local governments. Nevertheless, the impact of the concessionary tendering system is insignificant. This finding is attributed to the fact that the tendering price of an onshore wind power project is lower than the project’s FIT, which is approved by the NDRC. Concessionary tendering price
has not been attractive to investors. Thus, in the beginning of 2016, the tendering of onshore wind power was no longer listed.

3. Summary And Future Work
This study quantitatively analysed the effects of different incentive policies on the expansion of wind power installed capacity by using a statistic model. We collected panel data involving wind power installed capacity and policy implementation from 2005 to 2015 in 31 provinces and regions in China. The individual fixed-effects variable intercept model was selected for analysis through heterogeneity along with the Hausman tests. Results showed that policy planning, cost sharing and benchmark tariffs contributed to the expansion of wind power. The cost-sharing system was the most effective factor, followed by benchmark electricity price and local policy planning. The influence of concessionary bidding was insignificant.

Although the effect of FIT has been remarkable in recent years, the rapid expansion of wind power installed capacity has resulted in a huge subsidy funding gap. Therefore, an adjustment of the benchmarking pricing is required to ensure reasonable profits for wind power projects and narrow the gap of the subsidy fund requirement. Consequently, reasonable wind power policy planning can be expected. This policy should be designed by the local administration to form a system of special benefits, interest subsidies and other incentives according to local wind resources, equipment and technology.

With the development and establishment of the Green Power Certificates Market Transaction System and the Carbon Transaction Market Union in 2017, we should pay close attention to the effects of the relative market instruments to the development of the wind power industry. RPS is expected to become one of the powerful incentive instruments for renewable energy in the future even if it is still in its infancy in China. The mixed of these policies, the heterogeneity of the support mechanisms underlying them, the amount of capital needed to sustain their long-term deployment and the increasing tightening of government budgets naturally raises the question of how to identify optimal frame of instruments and of how to assess their deployment, so our future research will focus on the more complicated incentive instruments from the market and government, mainly comparing the differences of these two types of instruments from the perspective of wind power integrated the process of installing, transferring and consuming.

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