We investigate the effect of the COVID-19 pandemic on energy production in 30 Chinese provinces. Using data for the January 2018 to December 2020 period, we conclude that the pandemic has negatively influenced energy production. Moreover, we show that the negative impact of COVID-19 on traditional energy production is more than on renewable energy production. Our results pass robustness tests.

I. Introduction

The outbreak of the novel coronavirus (COVID-19) has threatened human life and halted economic and social growth globally. To control its spread, the global response has been lockdowns (resulting in factory closures), travel bans, and social distancing (Alfano & Ercolano, 2020; Phan & Narayan, 2020). While these policies have contained the spread of the virus, they have also exerted heavy social and economic costs, creating greater economic uncertainty and challenging global economic recovery (He, Niu, et al., 2020; Lan et al., 2020; Yan & Qian, 2020).

In this paper, we focus on China’s energy sector and evaluate how it responded to the COVID-19 pandemic. Our motivation has roots in the role of the energy sector in economic recovery in the post-epidemic era. Understanding China’s energy sector is important because China is the world’s largest energy producer, consumer, and a significant importer and exporter of renewable energy equipment (Cornelius & Story, 2007).

Our hypothesis is that COVID-19 has had a negative impact on China’s energy production. We argue that there is a theoretical connection between COVID-19 and energy production for the following reasons. First, the COVID-19 pandemic has caused great uncertainty to the economic recovery (Ilyke, 2020b; Narayan, 2020a). This uncertainty has disrupted economic activity globally. As far as China is concerned, in the first quarter of 2020, the growth rate of national GDP fell by 6.8% year-on-year, and China’s energy consumption is expected to decline too (Alfano & Ercolano, 2020). Second, economic slowdown has caused unemployment, significant reduction in transportation activities, which have reduced the demand for energy. Thus, energy production has declined.

Using data for 30 Chinese provinces, we conclude that the COVID-19 pandemic negatively impacted China’s energy production. We show that the negative impact of COVID-19 on traditional energy production has been more than on renewable energy production. The robustness test based on a different econometric approach (namely the generalized method of moments (GMM) estimator) confirms this conclusion.

Our main contribution is to show how that COVID-19 has led to a fall in traditional energy production and renewable energy production by 14.5% and 9.8%, respectively. It follows that while both types of energy production have been impacted by the pandemic, the effect on renewable energy production has been less than traditional energy production. These results complement existing research on the impact of COVID-19 on the economy (Dash et al., 2021; Haldar & Sethi, 2020a; Tisdell, 2020) and the impact on energy (Devpura & Narayan, 2020; Fu & Shen, 2020; Gil-Alana & Monge, 2020; Gu et al., 2020; He, Sun, et al., 2020; Huang & Zheng, 2020; Ilyke, 2020a; Liu et al., 2020; Narayan, 2020b; Qin et al., 2020; Salisu et al., 2020).

II. Data and Methodology

Our panel dataset contains monthly data for 30 Chinese provinces from January 2018 to December 2020. The variable symbols, measurement and data sources are shown in Table 1.

We construct the panel fixed effects regression model to test the impact of COVID-19 on energy production because this model helps overcome the endogenous problem caused by missing variables to a certain extent. The model is as follows:
How Does Energy Production Respond to the COVID-19 Pandemic? Evidence From China

Table 1: Variables Symbols Measurement and Data Source

| Variable Symbols | Measurement | Data source |
|------------------|-------------|-------------|
| lnTEP            | Logarithm of the total energy production | National Bureau of Statistics |
| lnTREP           | Logarithm of the traditional energy production | National Bureau of Statistics |
| lnREP            | Logarithm of the renewable energy production | National Bureau of Statistics |
| COVID-19         | The number of COVID-19 confirmed cases | Wind database |
| CPI              | Consumer price index | National Bureau of Statistics |
| PPI              | Producer price index | National Bureau of Statistics |
| IAV              | Fixed asset investment completed amount | National Bureau of Statistics |
| INA              | Industrial added value growth rate | National Bureau of Statistics |
| Trade            | Import and export trade amount | National Bureau of Statistics |

This table reports the variable symbols, measurement, and data sources. The traditional energy mainly includes oil, coke, kerosene, gasoline, fuel oil, and raw coal, while renewable energy mainly includes solar energy, water conservancy, firepower, and wind power. The total energy production is the sum of all types of energy production. We convert different energy units into standard coal, in which the unit is ten thousand tons.

\[
\ln EP_t = \alpha_0 + \alpha_1 \text{COVID}-19_t + \alpha_2 \text{CPI}_t
+ \alpha_3 \text{PPI}_t + \alpha_4 \text{IAV}_t + \alpha_5 \text{INV}_t
+ \alpha_6 \text{TRADE}_t + \mu_t + \varepsilon_t
\]

EP is energy production (i.e. TEP, TREP, or REP). Here, in addition to those variables defined in Table 1, $\mu_t$ is the individual fixed effect of the provinces; the subscripts $i$ and $t$ represent the province and year, respectively; $\alpha_0$ represents the constant term; and $\alpha_1$, $\alpha_2$, $\alpha_3$, $\alpha_4$, $\alpha_5$, and $\alpha_6$, represent the regression coefficients.

III. Empirical results

A. Empirical results of the total energy production

In Table 2, Panel A presents descriptive statistics. In Panel B, the first column shows the effect of COVID-19 on the total energy production. We see that the pandemic has a negative effect on China’s total energy production. For each additional confirmed case of COVID-19, the total energy output decreases by 14.9%. This means that COVID-19 reduces total energy production. The potential reason is that the pandemic has made economic recovery uncertain, prompting energy producers to reduce production consistent with the subdued demand. The outbreak of COVID-19 has also led to the introduction of a variety of pandemic prevention and control policies (Haldar & Sethi, 2020b). These efforts have affected social and economic development, thereby reducing the demand for energy. Meanwhile, COVID-19 has increased the transportation and storage costs of energy, such as oil and coal, due to the stagnation in transportation. This led to energy producers reducing energy production to order to reduce production costs.

B. Empirical results of traditional energy production and renewable energy production

From results in Panel B, we see that COVID-19 has a significantly negative effect on traditional energy production and renewable energy production. By comparison, traditional energy production and renewable energy production fall by 14.5% and 9.8% for each COVID-19 confirmed case, respectively.

We, therefore, arrive at an interesting conclusion that the negative impact of COVID-19 on traditional energy production is more than that on renewable energy. This finding is likely to be related to the characteristics of the different types of energy. Traditional energy production, for instance, includes kerosene, fuel oil, and coal, which are resource-intensive and labor-intensive, requiring a large amount of labor to complete energy production. Strict COVID-19 prevention and control measures made it difficult for workers to return to work, and a large number of workers became stranded, resulting in insufficient operating efficiency of enterprises. By contrast, renewable energy includes solar energy, wind energy, and water energy. These are technology-intensive energy types and they are less dependent on labor.

To stimulate recovery of the renewable energy industry, the Chinese government introduced the subsidy policies, such as promoting fuel cell vehicles to “replace subsidies with rewards”, extending the period of the crude oil subsidy policy and easing financial pressure within the new energy industry chain. All these factors may have assisted in mitigating the negative impact of the pandemic on renewable energy production. Further research on this is warranted.

C. Robustness Test

We adopt the GMM estimator to confirm the robustness of the regression results. From Table 3, the Wald values indicate the regression results are significant. The Hansen test results show the validity of the instruments. In addition, the values of first and second order autoregressive coefficients reject and accept that the null hypothesis, respectively, indicating that the model does not have a second-order serial correlation problem. We find that COVID-19 has a negative effect on total energy production, traditional energy production, and renewable energy production, which is consistent with the results from our earlier panel regression model. Overall, therefore, our conclusions on the effect of COVID-19 on energy production are robust.
Table 2: Summary of the variables and main results of fixed effect estimation

| Variable | N   | S.D. | Mean  | Max   | Min   | Median |
|----------|-----|------|-------|-------|-------|--------|
| lnTEP    | 1080| 2.5126| 5.0626 | 8.9545 | 0     | 5.5817 |
| lnTREP   | 1080| 2.5024| 5.0153 | 8.9501 | 0     | 5.5094 |
| lnREP    | 1080| 1.3427| 2.4291 | 4.1950 | 0     | 2.8556 |
| COVID-19 | 1080| 1832.229 | 80.3232 | 59754 | 0.0000 | 0.0000 |
| CPI      | 1080| 1.2752| 102.4238 | 106.9100 | 98.1 | 102.3 |
| PPI      | 1080| 3.9673| 100.507 | 116.7  | 82.1  | 100    |
| IAV      | 1080| 12.054 | 1.1212 | 28.6000 | -82.8000 | 3.9    |
| INA      | 1080| 5.0317| 4.6826 | 22.5000 | -46.9000 | 5.2    |
| Trade    | 1080| 14600000 | 7967799 | 108000000 | 4056.18 | 2458526 |

Panel B: Results of the fixed effect estimation method

| Variable | Model 1: lnTEP | Model 2: lnTREP | Model 3: lnREP |
|----------|---------------|----------------|---------------|
| COVID-19 | -0.149**      | -0.145**       | -0.098***     |
|           | (-2.34)       | (-2.28)        | (-3.16)       |
| CPI      | -0.192***     | -0.189***      | -0.111***     |
|           | (-2.92)       | (-2.89)        | (-3.47)       |
| PPI      | -0.279***     | -0.276***      | -0.156***     |
|           | (-4.48)       | (-4.46)        | (-5.15)       |
| IAV      | -0.131*       | -0.127*        | -0.082**      |
|           | (-1.76)       | (-1.72)        | (-2.28)       |
| INA      | 0.900***      | 0.891***       | 0.446         |
|           | (13.23)       | (13.18)        | (13.51)       |
| TRADE    | 1.004***      | 0.991***       | 0.555***      |
|           | (9.02)        | (8.96)         | (10.29)       |
| Cons     | 5.063***      | 5.015***       | 2.429***      |
|           | (82.94)       | (82.73)        | (82.09)       |
| F        | 11***         | 11.48***       | 17.87***      |

This table has two parts. Panel A reports the descriptive statistics of our variables. We report observations (N), mean (Mean), standard deviation (S.D.), minimum (Min), median (Median), and maximum (Max) values. Panel B has the results of the fixed effect estimation: Model 1 presents the results of the impact of COVID-19 on lnTEP, while Model 2 and Model 3 present the results for lnTREP and lnREP, respectively. The values in brackets are the p-value. Lastly, ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

IV. Conclusion

As the largest energy producer in the world, China’s energy production is undergoing profound changes due to the COVID-19 pandemic. Therefore, this paper aims to solve the research problem of how does energy production respond to the COVID-19 pandemic. We find that COVID-19 has significantly reduced energy production, especially traditional energy production.

Governments thus need to speed up the distribution and development of the energy industry in the post-epidemic era and enhance the stability of the energy industry system. The transformation and upgrading of the traditional energy industry need to take technological transformation and human substitution as the main directions.

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| Variable     | Model 4 | Model 5 | Model 6 |
|--------------|---------|---------|---------|
| InTEP(-1)    | 0.400*** (38.57) |         |         |
| InTREP(-1)   | 0.400*** (22.63) |         | 0.415*** (16.27) |
| InREP(-1)    |         |         |         |
| COVID-19     | -0.218* (-1.68) | -0.215* (-1.83) | -0.088** (-2.11) |
| CPI          | -0.007 (-1.05) | -0.002 (-0.17) | -0.023*** (-2.71) |
| PPI          | -0.182*** (-11.31) | -0.167*** (-6.67) | -0.090*** (-7.82) |
| IAV          | -0.034 (-1.24) | -0.030 (-0.87) | -0.071*** (-5.15) |
| INA          | 0.410*** (25.53) | 0.399*** (12.26) | 0.200*** (15.65) |
| TRADE        | 0.062* (1.76) | 0.067 (1.27) | 0.119*** (4.55) |
| Cons         | 3.467*** (46.34) | 3.420*** (33.69) | 1.629*** (22.14) |
| Wald         | 4635.8*** | 5390.02*** | 1499.47*** |
| AR(1)        | -5.045 (0.000) | -4.941 (0.000) | -4.897 (0.000) |
| AR(2)        | -0.275 (0.783) | -0.254 (0.799) | 0.869 (0.385) |
| Hansen       | 25.14 (0.156) | 24.05 (0.194) | 26.64 (0.113) |

This table reports the robustness test results. Models 4 to 6 present results of the impact of COVID-19 on lnTEP, lnTREP, and lnREP, respectively. (-1) represents the one period lag of the variable. The Hansen test is used to determine whether the instrumental variables are valid. We report the z-values for the null hypothesis of instrument validity. The Arellano-Bond autoregressive (AR) test is used to determine whether there is a serial correlation problem in the residual term. The values in brackets are the p-value. Lastly, ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

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