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Energy Revolution and Security Guarantee of China's Energy Economy

Huang Weihe [1], Mei Yingdan [2], Wu Lili [2], Liang Yunling [2], Zhao Xiaoli [2]

1. PetroChina Planning & Engineering Institute, Beijing 100083, China
2. School of Economics and Management, China University of Petroleum-Beijing, Beijing 102249, China

Abstract: Energy is fundamental to economic operations. Energy structure adjustments may significantly impact the macroeconomic operations of a country. This study quantitatively estimated the effect of energy structure adjustment on energy prices. In addition, the impact of the resulting price changes on macroeconomic operations was examined using an econometric model and statistical methods. The results indicated that a 1% increase in the proportion of natural gas consumption in the total energy consumption raised energy prices by 0.8%, whereas a 1% increase in the coal consumption ratio lowered energy prices by 0.2%. Moreover, technological progress, energy investment growth, increased marketization, and energy efficiency improvement were determined to be conducive to reducing energy prices. We concluded that China's energy revolution is less likely to affect the security of the energy economy, and the energy price increase remains within the acceptable range of the national economy and energy consumption. To ensure the security of the energy economy in the process of China's energy revolution, we suggest that China should focus on technological innovation and deepen reforms in the energy market to improve its energy market competitiveness. These measures will be beneficial for mitigating the energy price increase pressure as a consequence of the energy revolution.
Keywords: energy revolution; security of energy economy; energy structure; energy price; national economy

1 Introduction

Since China first proposed the energy revolution concept in 2014, the substitution rate of clean and low carbon energy (e.g., renewable energy and natural gas) for coal has significantly accelerated. Owing to the different production inputs, production costs, and the scarcity of all energy types, energy structure adjustment is expected to lead to a change in energy prices. As an essential production factor, the energy price is likely to adversely impact China's economy, Therefore, consideration of the relationship between the energy revolution and energy economic security should be undertaken.

Recent studies on the relationship between energy and economic growth have mainly concentrated on two aspects. The first is the relationship between energy consumption and economic growth. The general conclusion is that the former has an important influence on the latter [1]. The second is the impact of energy prices on economic growth. Some research suggests that rising energy prices, including those of coal and oil, boost domestic GDP growth in the short term but lead to a decline in the long term [2–4]. Overall, the impact of energy structure adjustment on economic development is less well established.

This paper is organized into three innovative aspects. First, given the background of China's energy revolution,

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Corresponding author: Zhao Xiaoli, professor of School of Economics and Management of China University of Petroleum-Beijing. Major research field is energy economy and strategy. E-mail: email99zxl@vip.sina.com
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we quantitatively estimate the effect of energy structure adjustment on energy prices. In addition, we evaluate the impact of the resulting price changes on macroeconomic operations using an econometric model and statistical methods. Accordingly, we elucidate the relationship between the energy revolution and energy economic security. Second, based on the fixed effect model, we quantitatively estimate the main factors affecting China's energy prices and suggest relevant measures to mitigate energy price increase pressure. Our study thus advances research on energy economic security under the energy revolution process. Finally, based on a statistical analysis in terms of the rapid development of China's economy, we assess the bearing capacity of the national economy and energy consumption per capita on rising energy prices. Our findings provide theoretical support for promoting the rapid development of clean energy, such as renewable energy and natural gas, while enabling the scientific formulation of energy revolution objectives.

2 Impact of energy industries on economic development

2.1 Analysis based on the energy industry spreading effect

The industrial spreading effect coefficient is an important index for investigating the influence of an industry on economic development. It refers to the change in the total output when a unit of industrial output changes. Multiplying the industrial spreading effect coefficient by the GDP value-added coefficient (GDP/total domestic output) determines the impact of changes in the industrial output value on the GDP. These two methods were adopted in this study as follows. First, we used the result-based industrial spreading effect algorithm (directly calculating the total industrial spread effect) and the process-based industrial spreading effect algorithm (computing the sum of the direct, indirect, and induced effects) to obtain the total industrial spread effect. We then used the mean value of the two methods as the final spreading effect coefficient. Finally, the spreading effect coefficient was multiplied by the GDP value-added coefficient to obtain the coefficients of energy industries to the GDP.

Based on input–output data from 2002 to 2015, different energy sectors were merged, and the spreading effect coefficients of energy industries to GDP were calculated accordingly (Table 1). The relevant energy sectors included coal mining and beneficiation products, oil and gas extraction products, oil and coking products, nuclear fuel processing products, electricity and thermal production and supply, and gas production and supply.

Table 1. Spreading effect coefficients of energy industries to the GDP.

Year	Impact of energy industries on total output (based on results)	Impact of energy industries on total output (based on process)	Mean value of two methods	GDP value-added coefficients	Spreading effect coefficients of energy industry to GDP
2002	2.3730	2.3614	2.3672	0.3888	0.9204
2005	2.9117	2.9142	2.9130	0.3407	0.9923
2007	3.1386	3.1562	3.1474	0.3249	1.0226
2010	3.2096	3.2288	3.2192	0.3222	1.0373
2012	3.1097	3.1514	3.1305	0.3352	1.0492
2015	3.5004	3.4858	3.4931	0.3268	1.1416

Source: Calculated from the national input–output table published by the National Statistics Bureau.

As shown in Table 1**,** the spreading effect coefficients of energy industries to the GDP are much higher than those of the GDP value-added coefficients, and the spreading coefficients are approximately 1. This indicates that the energy industry can greatly promote economic growth by means of its own development and impact on related industries. As the total output of the energy industry increases by one unit, the GDP increases by approximately one unit. Because the total output has the problem of double counting, it has an amplification effect for one unit. The change in the coefficients of energy industries to the GDP shows a continuous upward trend (from 0.9204 in 2002 to 1.1416 in 2015), which indicates the growing influence of energy industries on the GDP.

2.2 Annual increase of impact of energy imports on international trade

For a long time, China has been a net energy importer. Its energy trade has mainly focused on importing oil and natural gas and exporting coal. Based on the historical data of the total trade in goods published by the General

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Administration of Customs, we used an auto-regression model to predict the net exports of China's long-term trade in goods. Combined with long-term projections of China's energy trade benchmark scenarios by the International Energy Agency (IEA) in the *World Energy Outlook* (2018), we analyzed the impact of energy imports on China's international trade (commodity trade) (Fig. 1). China's energy imports offset the surplus of commodity trade. By 2025, the energy trade deficit is likely to extrude a commodity trade surplus. However, as China's energy industry continues to upgrade, the energy consumption structure will also be further optimized, and the offsetting effect will be eased.

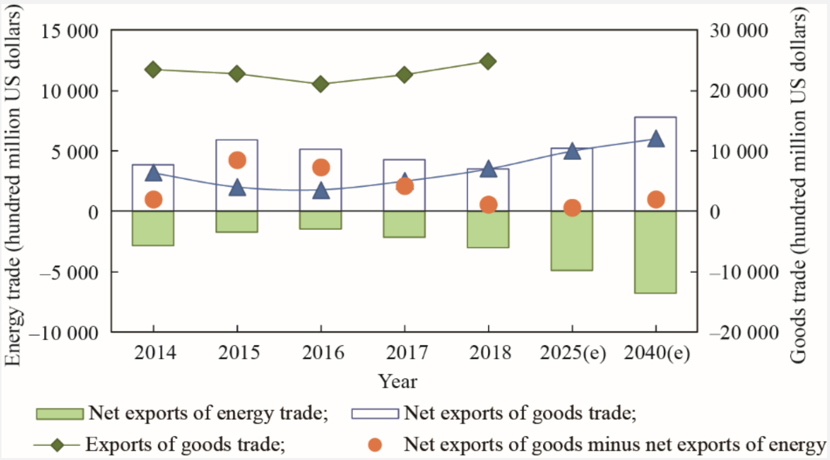

Fig. 1. Impact of China's energy imports on net exports of goods.

Note: The data before 2018 were sourced from IEA and General Administration of Customs of China. (e) refers to predicted value.

3 Impact of energy structure on energy prices

3.1 Factors affecting energy prices

3.1.1 Energy consumption and energy prices

In our research on energy prices, the purchasing price index of fuel and power was used instead of the energy price. The data were obtained from the *China Statistical Yearbook* and *New China Compendium of Statistics 1949–2004*. According to economic principles, when energy prices rise, the energy demand should be reduced. This means that the energy price is theoretically inversely related to the demand. However, the correlation between comparable fuel, power price index, and total energy consumption was 2.73, which means there was a positive correlation between the energy price and demand (Fig. 2). This is because, since 1993, the ex-factory price of major energy products in China has increased substantially. The rise in energy prices should have dampened the energy demand. However, owing to the low elasticity of energy prices and the lack of elasticity of the entire economic system, the correlation of the price mechanism to the energy demand was not obvious. Meanwhile, the energy price system has not been determined, and the conscious energy-saving mechanisms of the main market players have not yet been established. Thus, the increase in energy prices appears to have limited the inhibition of energy demand.

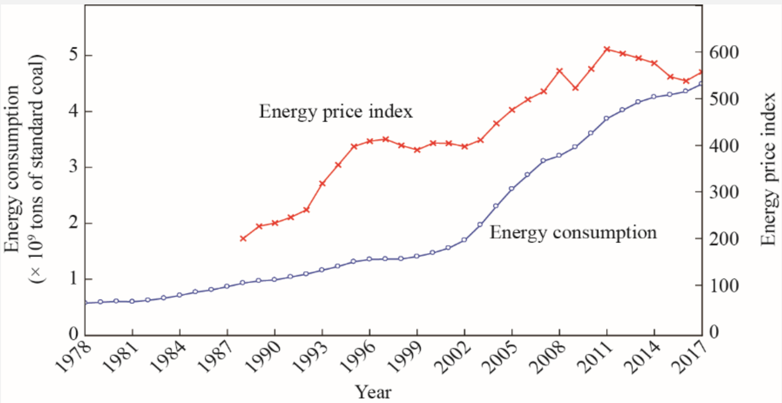

Fig. 2. Energy consumption and energy price trends from 1978 to 2017.

3.1.2 Market, regulation, and energy prices

In theory, energy pricing is mainly determined by the relationship between the supply and demand, and government regulation determines marketization, that is, the sensitivity of the energy price to the energy supply. Improving marketization can increase the energy efficiency and affect the energy supply structure [5]. Since the reform of coal price marketization, the surge of coal demand and tax changes has led to a sharp increase in coal prices and coal mining profits. Consequently, China has transformed from a net exporter to a net importer of coal since 2009. However, since 2012, coal prices have reversed and declined for four consecutive years as coal demand growth has slowed. To reverse the large-scale loss caused by the decline in coal prices, the government began to control these prices. They controlled coal production by closing sustained loss-making and low-productivity coal companies and by reducing employee working hours. In turn, coal prices began to increase after March 2016.

From the perspective of the whole industry chain, China's natural gas market is strictly regulated, which is not conducive to attracting investment, increasing supply, and making natural gas prices remain high. In April 2015, stock gas and incremental gas prices were merged. In July 2015, the Shanghai Petroleum and Natural Gas Trading Center was established. Through these market-oriented reform measures, the uniform retail price of natural gas has been reduced and gradually approaches the price of imported liquefied natural gas.

3.1.3 Energy investment and energy prices

Growing investment in energy industries will increase energy use intensity in various regions and affect the energy supply structure, which will lead to changing energy prices [5]. Energy investment usually reduces energy prices by promoting an increased energy supply.

3.1.4 Technological progress and energy prices

Technological progress has both broad and narrow definitions. The former only refers to scientific and technological innovation. The latter includes management innovation, institutional innovation, and other soft technological progress besides scientific and technological innovation. Technological advances have transformed the energy supply structure by increasing energy efficiency and influencing energy prices. From the purchasing price index of fuel and power and the price trend of liquefied natural gas from 1989 to 2017 (Fig. 3), it is evident that significant technological breakthroughs engender lower energy prices in most cases.

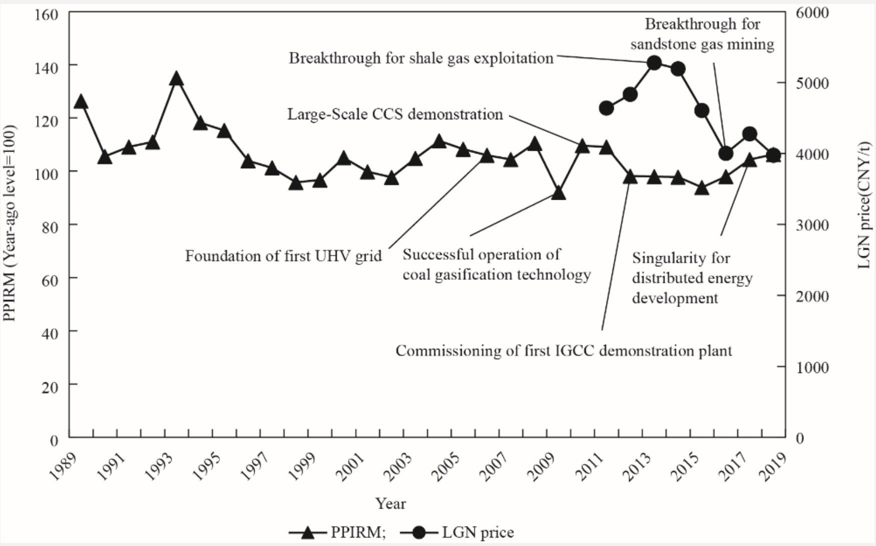

Fig. 3. China's energy price index, liquefied natural gas price, and technological progress.

Note: The data is sourced from China Macroeconomic Database (2018); UHV: ultrahigh voltage; IGCC: integrated gasification combined cycle; PPIRM: purchasing price index of raw material, fuel, and power.

3.2 Empirical analysis for the impact of energy structure on energy price

3.2.1 Model building and data sources

Based on the above analysis, it can be concluded that the factors affecting energy prices are energy consumption,

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marketization, technological progress, and investment. The energy consumption structure transformation causes a substitution effect, which leads to changes in energy prices. Economic growth and urbanization also affect energy prices by impacting the energy consumption and energy consumption structure. The energy consumption structure is denoted by the ratio of natural gas consumption to the total energy consumption and the ratio of coal consumption to the total energy consumption. Economic growth is measured as the GDP per capita.

The basic model is set as follows:

$$\begin{aligned} P_{it} = & \alpha_0 + \alpha_1 \times Q_{it} + \alpha_2 \times MARKET_{it} \\ & + \alpha_3 \times Tech_{it} + \alpha_4 \times Invest_{it} + \alpha_5 \times GDPC \\ & + \alpha_6 \times Urban_{it} + \alpha_7 \times Structure_{it} + \mu_{it} \end{aligned} \quad (1)$$

where *P* is the energy price index, *Q* is the energy consumption, *MARKET* indicates marketization, *Tech* denotes technological progress (measured by the number of patents and scientific inputs), *Invest* represents investment (expressed by fixed assets investment), *GDPC* is captured as GDP per capita, *urban* denotes urbanization, *Structure* represents the energy consumption structure, and μ, *I*, and *t* denote random disturbance term, province, and year, respectively.

The sources of the data in the study are shown in Table 2. Table 3 displays the descriptive statistics for all variables.

Table 2. Data sources for the impact of energy structure adjustment on energy prices in the study.

Variables	Unit	Definition	Source
Energy price index	1988 as the base year	PPIRM	China Macroeconomic Database
Technical patent		Number of energy-related patents	http://www.pss-system.gov.cn/sipopublicsearch/portal/index.shtml (Patent examination at China National Intellectual Property Administration)
Marketization index		Regional marketization level	China’s Provincial Marketization Index Report (2016)
Fixed asset investment	100 million yuan	Fixed asset investment	China Statistical Yearbook
Scientific research input	10000 yuan	Provincial expenditure on scientific research	China Statistical Yearbook
Proportion of energy supply	%	Proportion of different types of energy supply	China Energy Statistical Yearbook
GDP per capita	yuan	Ratio of total provincial GDP to total population	China Statistical Yearbook

Table 3. Descriptive statistics of energy price impact.

Variables	N	Mean	Var	Min	Max
Energy price index	270	101.29	8.632	81.000	130.800
GDP per capita	279	5.47	3.099	1.172	16.774
Energy investment	274	948.05	721.533	21.122	4021.259
Energy patent number	217	121.17	174.242	0.000	840.000
Energy consumption	270	13 779.57	8331.091	1135.000	38 899.000
Marketization index	279	5.99	2.011	−0.300	9.950
Proportion of urban population at year-end	279	53.18	14.136	21.900	89.600
Proportion of natural gas consumption	270	0.05	0.048	0.002	0.287
Proportion of coal consumption	270	0.01	0.020	0.000	0.127
Proportion of electricity consumption	270	0.12	0.040	0.060	0.261
Proportion of crude oil consumption	270	0.13	0.103	0.000	0.488

3.2.2 Results and analysis

During the process of model recognition, we first used ordinary least squares (OLS) to estimate the parameters of the model. We then used the fixed effect and random effect models to investigate the factors affecting energy prices. Our final sample contained observations from 31 provinces between 2008 and 2018. The number of years was less than the number of provinces, which could be considered short panel data.

There are three types of regression models in common short panel models: the mixed model, fixed effect model, and random effect model. After the Lagrange multiplier test and Hausman test, we used the fixed effect model. Table 4 reports the regression results of the three models:

Table 4. Regression results of energy price impact in three models.

	OLS	Fixed Effect	Random Effect
Log GDPC	−0.0605**	0.2490***	−0.0605***
Log Q	0.0442**	0.0166*	0.0442***
Log Invest	−0.0267*	−0.0244*	−0.0267***
Log (R & D)	−0.0055	−0.1967***	−0.0055
Marketization index	−0.0087	−0.0367***	−0.0087**
Proportion of urban population at year-end	0.0020**	−0.0034	0.0020***
Proportion of natural gas consumption	0.0006	0.0082**	0.0006
Proportion of coal consumption	0.0006	−0.0024*	0.0006*
Proportion of crude oil consumption	0.0003	0.0045	0.0003
Constant	5.0171***	4.9704***	5.01714***
Hausman test		Wald chi2(9)=313.97 Pro>chi2=0	
Observations	265	265	265

Note: ***,**, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

(1) Impact of supply-side factors

Marketization and technological progress have a significant impact on energy prices. For every 1% increase in marketization, energy prices will be reduced by 3.67%, which is consistent with our expectation: with increased marketization, energy prices will continue to decline. For every 1% increase in technology, the energy price is reduced by 19.67%, and the impact of technological progress on the energy price is often irreversible. Energy investment increases the energy supply and reduces the energy prices. For every 1% increase in total energy investment, energy prices will decrease by 2.44%.

(2) Impact of energy consumption

For every 1% increase in energy consumption, the energy price will increase by 1.66%, which is in line with the market law; that is, other things being equal, rising consumption will inevitably lead to price increases.

(3) Impact of energy consumption structure

The proportion of energy consumption represents the influence of the energy consumption structure on the energy price. The results showed that the energy price will increase by 0.82% for each increase in natural gas consumption and will decrease by 0.24% for each increase in coal consumption. This may result from lower coal prices and higher natural gas prices. Compared with coal and natural gas, the impact of crude oil consumption on energy prices is not obvious.

(4) Impact of demand-side control variables

Demand-side control variables include the GDP per capita and urbanization. The GDP per capita is positively correlated with the energy price. For every 1% change in the GDP per capita, energy prices will change by 24.90%. It can be observed that the change in energy prices on the demand side is largely based due to income. Although there is a negative correlation between urbanization and energy prices, the statistical results are not obvious.

4 Impact of energy price fluctuation on energy economic security

4.1 Impact of energy price fluctuation on the GDP

The impact of energy price fluctuations on the GDP is complicated, and the related transmission mechanism and effectiveness have been a continued focus of academic research. The transmission mechanism described by domestic scholars varies on account of varying perspectives, whereas more scholars describe the influence of energy price fluctuations on the GDP in terms of the product chain [5,6]. In this study, we used an impulse response function based on the vector autoregression model. The advantage of this process is that it is not necessary to assume the endogeneity or exogeneity of each variable in the model.

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Fig. 4 shows the impulse response diagram. The Y-axis represents pressure fluctuations caused by the unit impulse (as a percentage); the X-axis indicates the duration of the pressure fluctuations. The figure shows the dynamic effect of energy prices on the percentage increase in the GDP: rising energy prices reduce the GDP growth rate over the next five years. In the first year, it is expected to decline rapidly; for instance, the GDP growth rate would reduce by 1.46%. In the next four years, it is expected to gradually decrease and will eventually tend to 0. In the short run, the decrease in production input caused by rising energy prices will constrain economic growth. However, higher energy prices will promote energy-saving applications and energy efficiency, thereby reducing the adverse effects of energy prices on the economy in the long term. We further determined that 87% of the forecast variance for the previous eight years came from the GDP percentage increase and the remaining 13% came from the energy price. This means that the GDP growth rate was more likely to be independently affected, and the results and theoretical expectations were consistent.

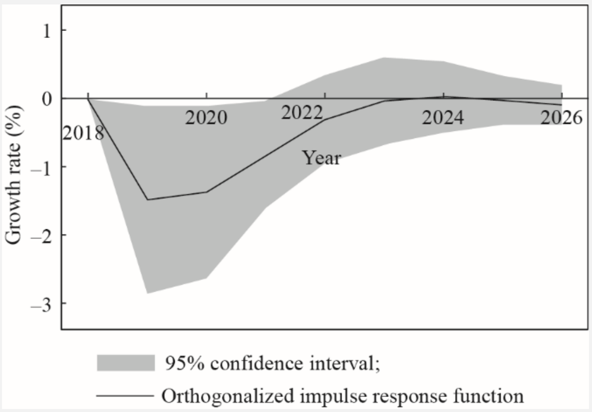

Fig. 4. Impulse response of energy price index to the GDP growth rate.

Note: The energy price index is the raw material, fuel, and power price index based on 1998 from the China macroeconomic database. The GDP figures were collected from the National Statistical Yearbook.

4.2 Impact of energy price fluctuation on the labor market

According to market allocation principles, energy price fluctuations will reallocate market resources (including capital and labor), which will have an impact on the labor market. Fig. 5 shows the dynamic effect of energy prices on the unemployment rate. The results show that an increase in energy prices will reduce the unemployment rate by 1.17% in the next two years. However, in the long run, an increase in energy prices will increase the unemployment rate by 1.23%.

It was further determined that 57% of the forecast variance for the previous eight years came from the unemployment rate itself and the remaining 43% came from energy prices, which means that the unemployment rate was closely affected by itself and by the energy prices.

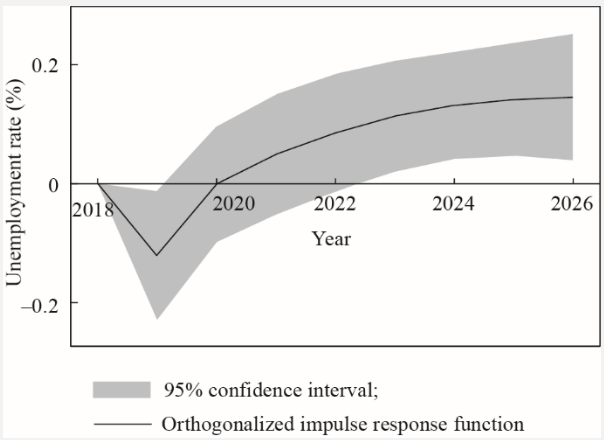

Fig. 5. Impulse response of the energy price index to unemployment rate.

Note: The energy price index is the raw material, fuel, and power price index based on 1998 from the China macroeconomic database. The unemployment rate figures were collected from the National Statistical Yearbook.

5 Impact of energy revolution on energy economic security with energy efficiency change

The energy revolution process is usually accompanied by energy efficiency improvement. To more accurately reflect the impact of future energy structure changes on China's energy economic security, this study further considered the impact of energy efficiency improvement on energy prices by affecting energy consumption.

5.1 Impact of energy efficiency change on energy demand

5.1.1 Model building and data sources

The model is set as follows:

$$Y_{it} = \beta_0 + \beta_1 \mathrm{EI}_{it} + \beta_2 R2_{it} + \beta_3 R3_{it} + \beta_4 \log(\mathrm{IM})_{it} + \beta_5 \mathrm{FIX}_{it} + \mu_5 \quad (2)$$

where Y represents energy consumption, i denotes provinces, t indicates time, μ is random disturbance, EI is energy intensity, and $R2$ and $R3$ are measured as the ratio of secondary and tertiary industries to the GDP, respectively. Moreover, IM is calculated as imports and exports, and FIX represents the fuel power index.

The data were sourced from *the China Statistical Yearbook*, province statistical yearbooks, and province panel data from 1990 to 2015. The method used was a dynamic panel data model, which can analyze the dynamic relationship, cover individual differences, and reduce the biased errors caused by adding data.

5.1.2 Results and analysis

Table 5 reports the results of the fixed effect model. The higher is the energy efficiency, the lower is the total energy consumption, and no rebound effects are found.

Table 5. Regression results of fixed effect models using panel data.

Variables	Total energy consumption growth	Electricity consumption growth	Coal consumption growth	Crude oil consumption growth	Natural gas consumption growth
Energy intensity	0.178***	0.183***	0.164***	0.203***	0.130***
Log(GDP)	0.715***	0.517***	0.636***	0.940***	0.632***
Proportion of secondary industry	1.232***	1.614***	1.947**	−1.519***	2.006***
Proportion of tertiary industry	−0.1220	0.0273	−2.074**	0.516	1.521***
Log(imports and exports)	−0.0191	0.0724***	0.158***	−0.0838**	0.0824***
Fuel power index	0.000 432	0.001 86	−0.000 692	0.004 98**	0.000 881
Constant	2.247***	1.916***	−2.170***	−1.948***	−2.028***
Observations	456.000	378.000	378.000	378.000	368.000
R-squared	0.946	0.863	0.697	0.755	0.963

Note: ***,**, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

5.2 Impact of energy efficiency on energy prices

Using similar data and methods, we tested the influence of energy efficiency on energy prices (purchasing price index of fuel and power). Table 6 displays the results from OLS, the fixed effect model (FE), and the dynamic panel-data regression model (DPD). It is evident that the energy price index declines as the energy intensity increases, and the energy price decreases as the energy efficiency increases. These results are significant at the 1% level. Meanwhile, a one standard deviation decrease in GDP energy consumption leads to a 3.1% decrease in the energy price index. This indicates that the energy efficiency improvement can slow the energy price increase.

5.3 Energy price change within an acceptable range

Energy efficiency improvement can slow the adverse impact of energy structure changes (mainly reflected in the increase in natural gas consumption and the decline in coal consumption) on energy prices. It thereby alleviates the impact of rising energy prices on macroeconomic operations. As China's economy continues to grow, the affordability of energy prices will increase as well. China's unit GDP energy price is decreasing year by year, indicating that the ability to withstand energy price increases engendered by energy transformation is enhanced in China.

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Table 6. Impact of energy efficiency on energy prices.

Variables	OLS	FE	DPD
Energy intensity	2.470***	3.303***	3.102***
Energy consumption	−4.39e-05	0.000 354	0.000 271
Log(GDP)	−1.754	−9.813***	−18.160***
Proportion of secondary industry	−4.723	40.38**	120.100***
Proportion of tertiary industry	−32.380***	4.622	25.190
Log(imports and exports)	2.608***	6.004***	9.564***
Log(energy investment)	−0.254	1.760**	3.324***
Constant	92.160***	45.830***	−0.177
Observations	450.000	450.000	450.000
R-squared	0.186	0.276	—

Note: ***,**, and * indicate the significance at the 1%, 5%, and 10% levels, respectively.

Some developed countries, such as the United States, the United Kingdom, Germany, and Japan, are also actively engaged in energy transformation. In contrast, it can be found (Fig. 6) that China's energy price change is expected to remain within the acceptable range of the national economy and energy consumption. European countries have decided to phase out fossil energy by 2050 in accordance with the *Paris Climate Agreement*. The shale gas revolution in the United States has also made its energy consumption structure cleaner. Japan's domestic energy dependence is high; thus, renewable energy is being vigorously developed there to ensure energy supply security. Compared with these countries, China's GDP per capita is relatively low, and integrated energy prices are also relatively low. As China's economy is developed in the future, its GDP per capita will continue to increase, and the rise in integrated energy prices should remain within an acceptable range.

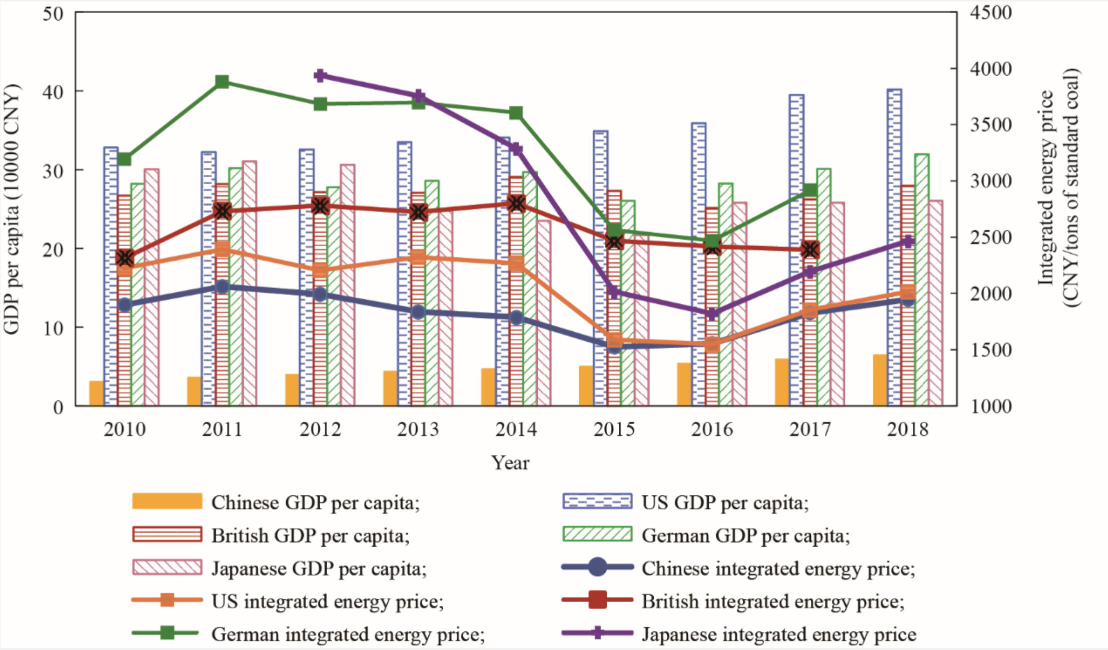

Fig. 6. GDP per capita and integrated energy prices in different countries.

Source: BP Statistical Yearbook 2018, Eurostat, METI, and the Professional Knowledge Service System for Energy.

6 Concluding remarks

6.1 Research conclusions

First, with the future increase in natural gas consumption and the decrease in coal consumption, China's energy price is expected to show an overall upward trend. Specifically, the results of this study indicated that a 1% increase in the proportion of natural gas consumption to the total energy consumption will increase energy prices by 0.82%, while a 1% coal consumption ratio will lower energy prices by 0.24%.

Second, among other factors affecting energy price changes, economic growth and energy consumption increases are crucial factors. Technological progress, energy investment growth, and increased marketization will reduce energy prices, with technological progress anticipated to have the greatest impact on energy price reduction followed by marketization.

Third, energy price changes will have a great impact on the GDP. An increase in energy prices will cause GDP growth to decline in the next five years, especially in the first year. The GDP will be more affected independently. 87% of GDP growth will come from its own factors, while the energy price change will be relatively small.

Fourth, energy price changes will affect the labor market as well. In the long term, rising energy prices will increase the unemployment rate; however, the impact will be relatively limited.

Fifth, considering energy efficiency changes, the adverse effects of the energy revolution on energy economic security will be further weakened. Increased energy efficiency will be conducive to reducing energy consumption and lowering energy prices.

In sum, the energy revolution will increase China's energy prices. Nevertheless, with the increasing market openness, technological progress, and energy efficiency improvement, the increase in energy prices caused by the energy revolution will be generally within control. Meanwhile, the energy price rise will have a limited impact on China's macro economy and will remain within the acceptable range of the national economy and energy consumption.

6.2 Policy implications

It is necessary to promote the close combination of technological progress and energy transformation and to bolster the development of technology-intensive clean and low-carbon energy industries. Energy technology innovation helps reduce energy prices in the energy revolution process, and relevant measures have a positive influence on decreasing the impact of the energy revolution on energy prices.

Moreover, it is recommended to advance energy power market reform and improve the competitiveness of the energy market. Increasing market openness can help reduce energy prices and more effectively introduce market mechanisms, which is crucial for reducing the risks of rising energy prices in the energy revolution.

References

[1] Yuan J H, Kang J G, Zhao C H, et al. Energy consumption and economic growth: Evidence from China at both aggregated and disaggregated levels [J]. Energy Economics, 2008, 30(6): 3077– 3094.

[2] Ding Z H, Li W B, Zhou M H, et al. Impact of coal price fluctuation on China's real economy [J]. Journal of Beijing Institute of Technology (Social Science Edition), 2014, 16(2): 18–23. Chinese.

[3] He N R, Zhu R L. Analysis of the impact of world oil price on China's economy [J]. World Economy Studies, 2006 (2): 47–53. Chinese.

[4] Wei T Y. The influence of a rise in world oil price on Chinese economy [J]. The Journal of Quantitative & Technical Economics, 2002, 19(5): 17–20. Chinese.

[5] Guo J, Zhang L. Empirical analysis of the relationship between China's energy consumption and economic growth [J]. Journal of Liaoning Technical University (Social Science Edition), 2008, 10(3): 248–251. Chinese.

[6] Shen M, Cai H B. Impact of energy cost changes on heterogeneous industries [J]. Journal of Nanjing University (Philosophy, Humanities and Social Sciences), 2014, 51(6): 27–35. Chinese.