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Empirical Research on the Relationship between China Export and New Energy Consumption

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ABSTRACT: With the development of the reform and opening-up, China's volume of export trade has grown rapidly; meanwhile the new energy consumption has risen vigorously. Export trade plays extremely important role in China's national economy, and consumption of clean energy provides significant support to China's export. Cointegration analysis of new energy consumption is adopted based on the data from 1979 to 2011, with the result showing that there exists bi-directional Grand causal relationship between China's export trade and new energy consumption. According to the impulse response and variance decomposition, the contribution of exports to consumption of new energy is more than that of new energy consumption to export trade.

Keywords: New energy consumption; Export trade; Grand Causal relationship; Impulse response; Variance decomposition
JEL Classifications: C32; Q43

1. Introduction

It is well acknowledged that investment, consumption and export are three driving forces in promoting China's economic development, of which export is particularly important aspect. China's export trade volume reached $2.05 trillion in 2012, simultaneously its new energy consumption[①] accounted for 9%. China's export trade has been facing unprecedented challenges in the post financial crisis era. Therefore, drawing lessons from successful energy development strategies of developed countries and exploring the strategy of new energy development in China will contribute to the optimization of export industry and product structure, which also has important theoretical and practical significance in expediting the shifting of export trade pattern with the characteristic of energy-extensive consumption.

Existing research literatures at home and abroad are mainly based on the relationship between China's export trade and energy discharge. Nnaji et al. (2013) used Nigeria's statistical data of 1970-2009 to conduct the empirical analysis, showing that significant relationship exists between energy consumption and exports. Sultan (2012) suggested that conserving electricity as a climate policy may not be conducive for exports and economic growth. The use of renewable sources for electricity could be the right option. Kahrl and Roland-Holst (2008) used China's input-output table of 2002 to analyze the impact of export on energy demand, indicating that export is the vital source of rapid growth of energy demand in China. Xu (2011) concluded that a country's export trade and energy consumption is influenced and decided by each other. It is necessary to boost the research and development of new energy and upgrade the technical content of export products. Wang (2012) used the method of regression analysis and factor decomposition analysis to conclude that export trade influences energy consumption and carbon emissions in China. Chen (2008) conducted co-integration and causality analysis of export trade and energy prices and established the dynamic econometric model. On the basis of empirical analysis, he further elaborated the influence of energy constraint on export trade cost. Zhu (2007) performed the integration and Granger causality test on the relationship between energy consumption and export trade in Shandong province and the conclusion was that there

[①]New energy consumption: The article selects the total consumption of hydropower, nuclear power and wind power as statistics index for new energy consumption given the availability of the data.

existed strong correlation between the scale of export trade and energy consumption in Shandong province. Li (2003) used sub-models of macroeconomic, energy and environment to future study China's economy, energy and environment, and found that expected continuation of rapid growth will lead to the modernization of energy source switching and the change of consumption by sector. Wang (2011) pointed that the increase of embodied energy[②] in China's export trade is completely caused by the expansion of export trade. Moreover, structure and technology effect of export trade plays a positive role to slow the growth of embodied energy. Lan and Ning (2010) carried on an empirical research on China's export trade of 22 trade industry departments and energy consumption, and pointed out that embodied energy of China's net exports in 2030 will exceed 8 times than that of the total energy output, which will go against the sustainable development of China's export trade. Zhang and Shi (2011) calculated China's implicit carbon emissions of the product exported to the United States from 2003 to 2007 through the method of input and output, and indicated that with the increase of China's export to United States, implicit carbon emissions of the export products are also increasing.

As for the research about new energy consumption, the relationships between new energy and employment, trade along with economic growth have been widely discussed. Kammen et al. (2004) analyzed the economic and employment impacts of the clean energy industry in the United States and Europe, indicating that expanding the use of renewable energy has a significant positive impact on employment. Lehra et al. (2008) adopted the approach of input-output analysis and explicit modeling of export and foreign trade effects to draw a conclusion that net employment effects in the new energy sources sector will be positive. Brander and Taylor (1997) examined a small open economy with an open-access renewable resource, indicating that gains from trade are eroded by ongoing resource depletion and major renewable resource stock is a significant policy issue. Then Espey (2001) discussed the main support mechanism named renewables portfolio standard (RPS)for enhancing the deployment of renewable energies (RE), and the result revealed that RPS could only ease the problem of enhancing the use of RE and trading systems like the emissions trading are proposed in the Kyoto protocol. Examples of this line of research include Steenblik (2006), Ringel (2006), Birda et al. (2008), Nilsson et al. (2009), Lilliestam and Ellenbeck (2011), Mőst and Fichtner (2010) that mainly analyzed the relation between new energy and one country or region's import and export trade. Chien and Hu (2008) analyzed the effects of renewable energy on GDP for 116 economies in 2003 and confirmed the positive relationship between renewable energy and GDP through the path of increasing capital formation, but not for the path of increasing trade balance. Bugaje (2005) suggested appropriate infrastructural support should be provided for the sustainability of renewable energy resources in Nigeria and the Africa continent at large. Mathiesen et al. (2011) designed an hour-by-hour energy system analyses and revealed that implementing energy savings, renewable energy and more efficient conversion technologies will have positive socio-economic effects, create employment and potentially lead to large earnings on exports. Rütter (2009) presented a complete analysis of the employment and economic growth impacts of renewable energies, covering past, present and future prospects in Europe, and the verdict was that benefits of RES for securing supply and mitigating climate change can go hand in hand with economic benefits. Besides, Foxon et al. (2005), Jacobsson and Lauber (2006) introduced renewable energy technologies of UK and German from the perspective of energy system transformation and gave us new advice on solving China's existing energy problem.

Based on the above review, we can see that the existing research literature mainly concentrates on the development situation of traditional energy such as coal, oil, natural gas as well as the relationship between export trade and traditional energy emissions. However, there is little discuss about the present situation of new energy such as hydroelectric, nuclear power and wind power and the relationship between China's export trade and new energy consumption, and this is what the paper's research purpose and the importance of selecting the topic.

[②]Embodied energy: It is also called "implied energy", referring to the total energy consumed in the whole process of products' upstream processing, manufacturing, transportation and other links.

2. Research Method and Data Selection

2.1 Research method

On the basis of building the VAR model, the paper conducts the Granger causality test, impulse response function and variance decomposition. Take China's export trade volume of 1979-2011 and the new energy statistics data as sample, GDP as explained variable to carry out the regression analysis in order to explore the dynamic causality between China's export trade and new energy consumption(the total consumption of hydropower, nuclear power and wind power).

2.1.1 Establish the model of VAR

Vector autoregressive model (VAR) is a kind model of unstructured. Each endogenous variable in the system is regarded as a function of all the endogenous variables' lag item in the system to construct the model. When every variable plays a role to predict the remaining variables, this set of variables is suitable for using the VAR model. VAR model is usually used to forecast time series related to system and research on the effects of random dynamic disturbance on the variable system, so that the effects of economic shocks on economic variables can be explained, its general form is:

$$Y_t = A_1Y_{t-1} + A_2Y_{t-2} + \ldots + A_pY_{t-p} + B_0X_t + \ldots + B_rX_{t-r} + \varepsilon_t \quad (1)$$

Y_t is endogenous variable vector with k dimension, Y_{t-i} (i = 1, 2,..., p) is the lagged endogenous variable vector, X_{t-i} (i = 0, 1, r) is a exogenous variable vector with k dimension or lagged exogenous variable vector, p and r respectively are the lag order number of endogenous and exogenous variable. A_i is the coefficient matrix of k*k dimension, B_i is the coefficient matrix of k*d dimension, the matrixes are all the parameters matrix to be estimated. ε_t is the random perturbation term (Gao,2009). The bigger the lag order p and r in VAR model, the more complete the dynamic characteristics of the constructed model can be reflected, but the more parameters for estimation, and the smaller the degree of freedom of the model. Generally the optimal lag order number of the model can be determined based on the principle of minimum values in AIC and SC information rules.

2.1.2 Granger causality test

Granger causality test is used to determine whether there is a causal relationship between economic variables and the direction of this influence. Its inspection thought is that if the prediction effect of economic variable Y is better when the model contains the past information of X and Y at the same time than solely contains the past information of Y, variable X helps to improve prediction accuracy of variable Y, thus X is the Granger reason of Y.

For non-stationary time series, there may produce a false cause and effect, so it is necessary to determine whether it keeps stability. This paper first uses ADF unit root test to test whether economic variables are the same order integer variables, then uses the co-integration method to test whether there is a long-term equilibrium relationship between variables, then adopts Granger causality test to verify the causal relationship between them. If the time series is stable, and there is a cointegration relationship, Granger causality test can be conducted. To eliminate the phenomenon of autocorrelation of error term, variables in the model takes their logarithmic form. In this paper, the new energy consumption (EN) and the export trade take logarithm (EX), written as LOGEN and LOGEX, vector autoregressive model is set up as follows:

$$LOGENt = \alpha_0 + \alpha_1 LOGEN_{t-1} + \ldots + \alpha_k LOGEN_{t-k} + \beta 1 LOGEX_{t-1} + \ldots \beta_k LOGEX_{t-k} + \varepsilon_{1,t} \quad (2)$$

$$LOGEXt = \alpha_0 + \alpha_1 LOGEX_{t-1} + \ldots + \alpha_k LOGEX_{t-k} + \beta_1 LOGEN_{t-1} + \ldots \beta_k LOGEN_{t-k} + \varepsilon_{2,t} \quad (3)$$

K is the maximum lag order number. The original hypothesis of test is that LOGEN(LOGEX) is not the Granger reason of LOGEX(LOGEN), namely $\beta_1=\beta_2=\ldots=\beta_k=0$

2.1.3 Impulse response function

Impulse response function is used to measure the impact of a standard deviation of the random disturbance of an endogenous variable on the current and future value of the endogenous variable in the VAR model. It can intuitively reflect the dynamic interaction among all the endogenous variables. In the VAR dynamic model constituted by the equation (2) and (3), if $\varepsilon_1$changes, it will make the current value of the variable LOGENt immediately change, at the same time, through the model of the effect also makes values of variable LOGEXt change in the next period .Because of the lagged effect, changes of LOGEXt will cause the value of LOGENt to change in the future. The changes of LOGENt in each period could be described by a trace.

2.1.4 Variance decomposition

Another analysis approach of studying the dynamic characteristics of VAR model is to make each exogenous decompose into components associated with endogenous variables. Analysis the contribution of each structural's impact on endogenous variable could learn about the relative importance of structural impact to endogenous variables. Through decomposing the standard errors of EX, EN and calculate the proportion random shock of EX and EN shared in the total contribution so as to analysis the interaction effect of China's new energy consumption and export trade.

2.2 Data selection

The data of export trade and new energy consumption are all taken from China's national bureau of statistics statistical yearbook (1979-2011), and the time span is 33 years. The structure variable, that is the proportion new energy consumption accounted for in the total energy consumptions and gross domestic product (GDP) are added as the control variables in order to better illustrate the relationship between China's new energy consumption (it means the total consumption of hydropower, nuclear power and wind power) and export trade. In order to make sequences more smoothly, take indicators' logarithm respectively and noted as LOGEN, LOGEX, LOGGDP and LOGPROP.

3. Empirical Analysis of the Relationship between China's Export Trade and New Energy Consumption

3.1 Analysis of causal relationship between China's export trade and new energy consumption

3.1.1 Unit root test

Conduct stationary test of LOGEX, LOGEN, LOGGDP and LOGPROP as well as their first-order differential variables respectively, the results are set out as table 1. At 5% significant level, we accept the hypothesis of sequence LOGEX, LOGEN, LOGGDP and LOGPROP all having a unit root statistics according to t values of the sequences; meanwhile, ADF test rejects the hypothesis that the four first-order difference sequence has a unit root, and accepts LOGEX, LOGEN,LOGGDP and LOGPROP are stationary series. Therefore, Sequence LOGEX, LOGEN, LOGGDP and LOGPROP are the integration sequence of order list I (1), namely LOGEX ~ I (1), LOGEN ~ I (1), LOGGDP ~ I (1), and LOGPROP~ I (1).

Table 1. The result of stationary test

Varible	Lag phase	ADF value	0.05 critical value	Conclusion
LOGEX	0	-1.837858	-3.557759	Accept the null hypothesis
LOGEX	1	-5.463931	-3.562882	Reject the null hypothesis
LOGEN	0	-2.284483	-3.557759	Accept the null hypothesis
LOGEN	1	-6.990027	-3.562882	Reject the null hypothesis
LOGGDP	0	-2.826662	-3.562882	Accept the null hypothesis
LOGGDP	1	-3.779779	-3.580623	Reject the null hypothesis
LOGPROP	0	-1.721937	-2.957110	Accept the null hypothesis
LOGPROP	1	-6.816834	-2.960411	Reject the null hypothesis

3.1.2 Co-integration test

Unit root test results shows LOGEN, LOGEX, LOGGDP and LOGPROP are all I (1) sequences. The model of regression coefficient co-integration test (i.e., Johansen co-integration test) is then adopted. Under the assumption of zero collaborators, trace statistic is greater than the 5% critical value, then reject the null hypothesis and accept there exists at least one cointegrate vector.Under the assumption of at most one cointegrate vector, trace statistic is less than the 5% critical value, so accept the null hypothesis that there is at most one cointegrate vector, namely the trace statistic inspection results reveals that at the level of 5%， there is only one co-integration relationship, which is set out as table 2. It is suggested that the long-term equilibrium relationship lies between China's new energy consumption and export trade volume, which means there exists co-integration relationship between them.

In the presence of one co-integration relationship, regression equation is obtained by using logarithmic form of OLS estimation equation as table 3.

Table 2. The result of sequences' co-integration test

Hypothesize	Eigenval	Trace	5% critical value	P value
None co-integrate vector *	0.580891	31.68663	29.79707	0.0299
Almost one co-integrate vector	0.167647	5.597894	15.49471	0.7425
* denotes rejection of the hypothesis at the 0.05 level.				

Table 3. The result of OLS regression result

Variable	Coefficient	Std. Error	P value
C	-12.966 (-5.124)***	2.531	0.0000
LOGEN	2.144 (3.464)***	0.619	0.0023
LOGGDP	1.448 (2.399)**	0.603	0.0258
LOGPROP	-3.673 (-2.721)**	1.349	0.0128
Adj.R^2	0.996		
D.W-stat	1.976		
F-stat	1059.229		

Note: t statistics are shown in brackets, ** and *** represent the level of significance at 1% and 5%.

The adjustment coefficient of the regression result shows that the fitting degree of the equation is high enough, and every variable passes test of significance level. From the estimated equation we can see that every 1% of increase in new energy consumption can make the export volume increase by 2.144% in China. At the same time, the growth of GDP plays positive role in driving the export trade. This shows that the expansion of export trade in China is related to the gross domestic product (GDP), and is more closely related to the increase of new energy consumption. China's export trade has certain dependence on new energy consumption.

3.1.3 Conduct Granger causality test for LOGEN and LOGEX

There exists a co-integration relationship between China's new energy consumption and export trade, so the Granger test of LOGEN and LOGEX can be conducted.

Table 4 shows results of Granger causality test with 1-4 lag length. From F statistical values in the table, when the lag length is 1 under the significance level of 5%, the original assumption of "LOGEX is the Granger cause of LOGEN changes" is rejected, so there is a single causal relationship; Lag length is 2, refuse the original assumption, there are bidirectional causal relationship between LOGEN and LOGEX; Lag length is 3 and 4, refuse the null hypothesis of "LOGEX is not the Granger cause of LOGEN change", namely that there is a single causal relationship between LOGEN and LOGEX. According to the results of the analysis, it is generally believed that there exists the single causality between export trade and new energy consumption under the significance level of 5%, namely the scale of China's export trade change is the cause of the change of the new energy consumption.

When choosing the significance level of 10%, choose 1 as the lag order number, the null hypothesis is refused. There is a single causal relationship between export trade (LOGEX) and new energy consumption (LOGEN), namely the export trade can Granger cause the increase of new energy consumption. Choosing the lag order 2, 3 and 4, there presents bidirectional Granger causality between China's new energy consumption and export trade. China's export trade could granger cause new energy consumption, and new energy consumption in turn can also granger cause the expansion of export trade.

Table 4. Granger causality test of China's export trade and new energy consumption

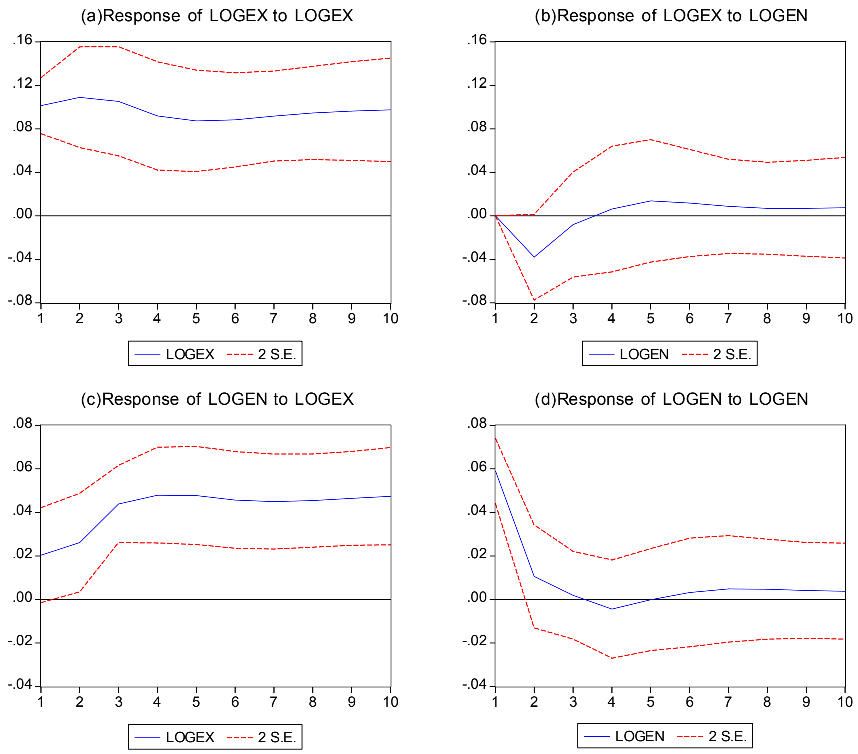
Hypothesize	Lags	F-statistic	Probability	Judge for hypothesize
LOGEX does not Granger Cause LOGEN	1	18.4603	0.00018	Reject the null hypothesis
LOGEN does not Granger Cause LOGEX	1	0.88905	0.35352	Accept the null hypothesis
LOGEX does not Granger Cause LOGEN	2	8.39492	0.00154	Reject the null hypothesis
LOGEN does not Granger Cause LOGEX	2	3.68971	0.03885	Reject the null hypothesis
LOGEX does not Granger Cause LOGEN	3	5.33954	0.00612	Reject the null hypothesis
LOGEN does not Granger Cause LOGEX	3	2.50401	0.08445	Accept the null hypothesis
LOGEX does not Granger Cause LOGEN	4	3.18934	0.03523	Reject the null hypothesis

3.2 Dynamic analysis of China’s export trade and new energy consumption

3.2.1 Analysis of impulse response function

Through the Granger causality test, when the significance level is 10%, China’s export trade and new energy consumption have two-way Granger causality. In order to further reveal the dynamic changes in the interaction between them, this article analyzes impulse response of standard deviation rate of China’s export trade and new energy consumption, as shown in figure 1.

Figure 1. Impulse response of China’s export trade and new energy consumption

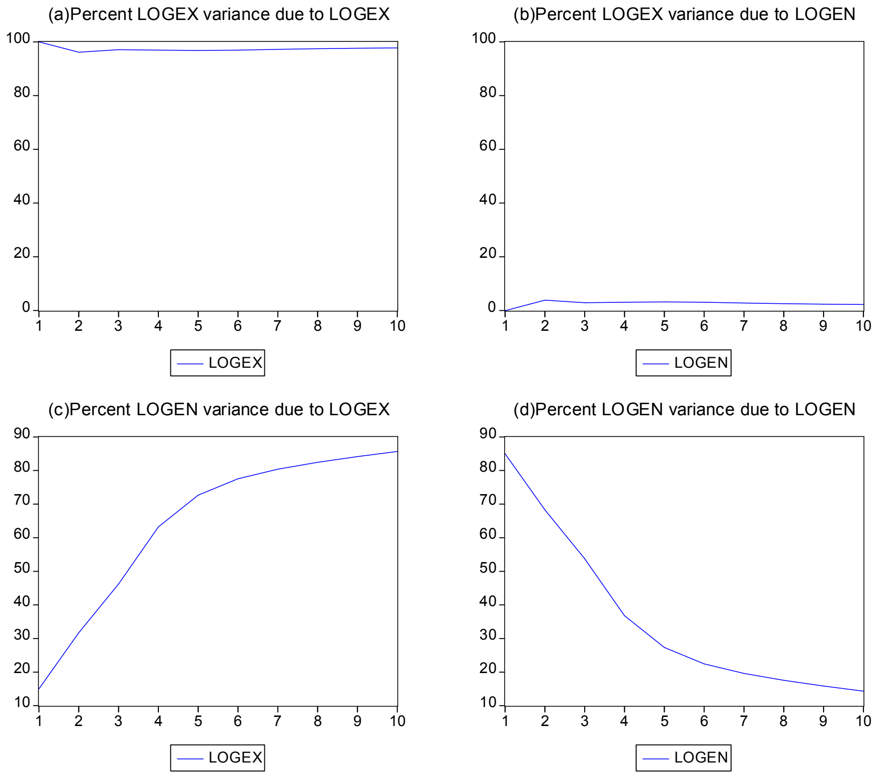


As can be seen from figure 1, new energy consumption (LOGEN) immediately makes a negative response of the impact of export trade (LOGEX), and the negative response reaches the maximum in the second phase. In the 4th phase, positive response appears, and the maximum positive effect occurs in the 5th phase, and then levels off. This suggests that after export trade suffering the influence of the external, the larger negative impact on energy consumption will occur in the short term, and there is a steady positive impact in the long-term. Export trade (LOGEX) makes an immediate positive response of the impact of new energy consumption (LOGEN), and the response reaches the maximum in the 4th phase, and then levels off in the future. This shows that external shock of new energy consumption has bigger positive impact on new energy consumption in the short term, and the influence takes on in stable situation in the long-term. Deviations of two standard deviations are relatively stable, suggesting that the response errors of LOGEX caused by LOGEN which is suffered from the external shock and that of LOGEN caused by LOGEX both level off over time.

3.2.2 Analysis of variance decomposition

For further analysis mutual influence between China's export trade and new energy consumption, this paper conducts the variance decomposition of standard error of LOGEX and LOGEN in the established VAR model, as shown in figure 2. Standard error of 1-10 phase are broken down into the proportional changes what LOGEN and LOGEX have contributed. The contribution proportion of new energy consumption impacting on export trade change is about 5% at 2^{th} period, and then the proportion declines and levels off. The contribution proportion of export trade's contribution to new energy consumption is about 15% at 1^{st} period, then increases in the following phases, and the proportion in 4^{th} phase reaches more than 50%, indicating that the driving effect of the increase in export trade on the new energy consumption is particularly obvious.

Figure 2. Variance Decomposition



4. Conclusion

After Granger causality test, impulse response function and variance decomposition, empirical test and analysis are carried out for the relationship of China's export trade and new energy consumption (it means the total consumption of hydropower, nuclear power and wind power) based on the data of China's export trade volume of 1979-2011 and new energy consumption, and the conclusion and revelation are as follows:

Firstly, Granger causality test shows that China's export trade scale and new energy consumption takes on bi-directional causation relationship. Export trade changes directly affect the change of new energy consumption, while the new changes in energy consumption will also cause the change of export trade, and the new energy consumption in China is closely dependent on export trade scale.

Secondly, the analysis of impulse response function shows that the export trade has a negative impact on new energy consumption firstly, and then produces the stable positive influence; In the meantime, the change of new energy consumption has continuously positive influence on export trade. It is the effective to transform the mode of China's trade growth, accelerate the pace of industrial restructuring and upgrading. By virtue of enhancing the development of new energy and innovation of renewable energy technology, China's unreasonable foreign trade structure and tight supply of energy will be improved efficiently.

Thirdly, variance decomposition result shows that China's export trade and energy consumption impact on each other after suffering the shock. Export's contribution to the new energy consumption shows a continuously rising trend, which is bigger than new energy consumption's contribution to export trade change. As a result, the increase of China's export trade will cause new energy consumption to increase in the medium and long term, which to some extent can optimize the current energy consumption structure in China. In addition, under the financial crisis there exists an increasingly severe energy supply gap in China. The urgent task is to adjust the commodity structure of export trade, compress production of high-energy consumption and restrict its export to alleviate China's heavy rely on traditional energy consumption, so as to better boost the pull effect of new energy consumption on China's export trade.

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