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Clean Energy Trade Cooperation between USA and China and its Economic Impacts

Yaowu Dong[1], Li You[2], and Denghui Duan*

Yaowu Dong: Guizhou University of Commerce, Guiyang, China 550014
Li You: Guizhou University of Commerce, Guiyang, China 550014

Abstract. We study bilateral trade cooperation between the USA and China, along with its economic impacts. Trade Intensity Indices (TII) and Revealed Comparative Advantage indices (RCA) are investigated in six different clean energy categories including natural gas, solar, wind, biomass, hydro, and nuclear energy between 1992 and 2017. Data from TII and RCA indicate that clean energy trade cooperation between the USA and China needs to be strengthened. A Vector Autoregressive model (VAR) is established with one exogenous variable (oil price) and five endogenous variables including US TIIu, Chinese TIIc, US Gross Domestic Product (GDP), Chinese GDP and CO2 emissions. After verifying the model stationarity, impulse responses are obtained by applying positive impacts from TIIu and TIIc. The overall CO2 emissions will be reduced, and US GDP will increase. However, Chinese GDP will decrease as China is at early stages of clean energy development. To overcome the obstacles in the bilateral clean energy trade, both countries should coordinate their trade measures and devise effective policies beneficial to both countries.

1 Introduction

As the entire world is facing challenges in climate changes, clean energy development and utilization has become number one priority in energy policies for many countries. In 2017, China and the USA ranked top two countries in primary energy consumptions, accounted for 23.2% and 16.5% of the world's total consumptions respectively (BP,2018). Their combined energy consumptions were 5,367 Mtoe, reaching 40% of the total world consumptions. From 2007 to 2017, China's annual energy consumption increased from 2,150 Mtoe to 3,132 Mtoe. China's great achievement in economic development is largely driven by energy consumptions (Bian, et al., 2017). If Chinese energy demands follow such growth pattern in the future, it will be extremely difficult to sustain primary energy supplies for China. By contrast, the total energy consumption in USA barely changed between 2007 and 2017; while its energy profiles changed drastically. For example, coal decreased from 23% to 14%; oil decreased from 39% to 38%, and clean energy increased from 38% to 48%, which includes natural gas, solar, wind, biomass, hydro, and nuclear energy. During the same period, Chinese clean energy increased from 12% to 20%; coal decreased from 77% to 61%, and oil increased from 11% to 19%. In 2017, CO_2 emissions from USA were 5270 Mt or 14.5% of world emissions; and that from China were 9839 Mt or 27.2% of the total emissions. While both countries have improved their energy profiles, there are substantial gaps in clean energy developments.

Broadly speaking, energy development and economic growth are closely related (Yemane, 2004; Dolgopolova and Hye. 2014). The change in the energy profiles will affect the economic growth. Statistically, there are wide differences in the thermal efficiency between different energy resources. If coal percentage is relatively high in Chinese energy profiles, its thermal efficiency will be relatively low (Meng and Zhou, 2014). When China heavily relies on coal during its economic growth, CO2 emissions will be inevitably increased, which in turn will slow down the economic growth (Tiba and Omri, 2017; Chen et al. 2016). If energy profiles can be optimized, there is a possibility to reduce total energy consumptions and CO2 emissions while maintaining economic growths (Wu L Y, Zeng W H.2013). For China, increasing clean energy penetrations and reducing energy consumptions may lead to sustainable economic growths. If the US and China strengthen the trade cooperation in clean energy between them, it will promote the development of clean energy industry and bring about the change of energy profiles in both countries.

2 Methods and Data

2.1 Methods

In bilateral trades, the Trade Intensity Index (TII) can be used to measure the degrees of trade interdependences between two countries. After collecting data in

*Corresponding address: 17212001@qq.com

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subsection 2.2, we can describe the clean energy trade cooperation between US and China and analyze impacts on economies and CO2 emissions. In Equation (1), TII formula is calculated as (WTO, 2017):

$$TII=\frac{\chi_{ij}}{\chi_i} \div \frac{\chi_{wj}}{\chi_w} \quad (1)$$

where χ_{ij} is the export amount from i-th country to the j-th country, χ_i is the total export amount of i-th country; χ_{wj} is the value of world exports to the j-th country, and χ_w is the total export amount for the entire world. If TII<1, it indicates the lower degree of bilateral trade between the partner countries. The index with a value greater than1 indicates the high intensity of trade between the partner countries (Maryam, et al., 2017). To study bilateral clean energy trade relationships between US and China, two indices can be proposed based on Equation (1): TIIu for the US and TIIc for China.

In this paper, VAR (Vector Auto-Regression) models will be established to study relationships among relevant variables such as TIIu, TIIc, GDPs and oil prices, and analyze the impacts of clean energy trade cooperation on economic growth and CO2 emissions. The VAR model is provided in Equation (2).

$$Yt = C + A1\ Yt - 1 + \cdots + An\ Yt\text{-}n + HXt + Ut \quad (2)$$

where Yt refers to five endogenous variables (TIIu, TIIc, GDPu, GDPc and CO2) matrix (5×1), and subscript t represents the most recent year or present time (t); Xt is the exogenous variable (OPRICE) for the present time (t); H is the coefficient matrix (5×1) for the exogenous variable; Ut is the white noise matrix (5×1); A is the coefficient matrix (5×5), and n is the maximum number of lagging times; and C is the constant matrix (5×1).

2.2 Data

In this paper, we focused on merchandise trades, and selected clean energy items from United Nations Comtrade Database (1992–2017). The general categories included natural gas, solar, wind, biomass, hydro, and nuclear energy. Other data such as OPRICE, CO2, GDPu and GDPc were from BP Energy Statistics Yearbook, World Bank Database, US Energy Information Administration and China National Bureau of Statistics.

3 Results

3.1 USA-China Clean Energy Trade Intensity Indices

In order to have an in-depth study of the clean energy trade between the USA and China, the annual Trade Intensity Indices (TII) are calculated for solar energy, wind energy, biomass energy, water energy, natural gas and nuclear power in both countries according to Equation (1). From the perspective of the USA, Most TIIu values of biomass energy are greater than 1 and TIIu values of nuclear energy are greater than 1 in recent years, indicating that USA has close trade relationships with China in these areas. In terms of solar energy, wind energy, water energy and natural gas, TIIu values are less than 1. Among them the TIIu value of solar energy reached its maximum in 2010 and began to decline year by year. In fact, trade frictions between the USA and China over solar products have increased in recent years. In 2012 the U.S. Department of Commerce confirmed that China exports of crystalline silicon photovoltaic cells and components to USA were dumped and subsidized, and imposed an anti-dumping duties and countervailing duties on Chinese enterprises, which resulted in a decline in solar product trade between the U.S. and China. As to wind energy, TIIu has been on the rise since 1992. Although the value has not exceeded 1, the bilateral trade has been continuously strengthened. The TIIu values of water energy began to decline after reaching its maximum in 2000, and has shown a rebound in recent years, but most of the time are less than 1.0. The reason is related to the slowdown of hydropower construction in China in recent years. Considering the impact of hydropower stations on local ecology, China has slowed down the investment in hydropower. In terms of natural gas, similar to wind energy, TIIu values began to decline after reaching its maximum value in 2000. The trade relation between USA and China in natural gas products is not close. The Liquefied Natural Gas (LNG) trade between the two countries only started in 2016, and with just a small amount.

From the perspective of China, the TIIc values of wind energy, biomass energy and nuclear power are greater than 1 in recent years, which indicates that China has close trade relationships with US in these areas. Although USA has a distinctive advantage in nuclear power key technologies and equipment, China has a cost advantage in the middle and low-end manufacturing field, which makes it possible to have trade exchanges and maintain close trade cooperation with USA. The TIIc value of the solar energy started to decline after reaching its peak in 2011, which is similar to the trend of the TIIu value after 2011. It also demonstrates that the solar trade has become fragile after trade frictions between the USA and China. In terms of water energy, the TIIc values fluctuate a lot, and have been less than 1 in most years. In terms of natural gas, TIIc value has been low all the time, because China has been a big importer of natural gas products for many years, but its export resources are very limited.

3.2 Revealed Comparative Advantage

At present, the measurement of comparative advantage is mostly based on Balassa's Revealed Comparative Advantage (RCA) (Balassa, 1965), which is often adopted to analyze the international export competitiveness of a country's products (Jing, et al., 2018; Gholamreza and Pratibha, 2018). Balassa's RCA index is useful to evaluate whether a certain country has comparative advantages in the exports of a given commodity with regard to a certain group of countries (Veselin, 2014; Gupta and Kumar, 2017). Therefore, we use RCA to analyze the comparative advantages of clean energy between the USA and China, and to further analyze the trade cooperation between the two countries. The specific calculation formula is as follows:

$$RCA_{ik}=\frac{\chi_{ik}}{\chi_i}\div\frac{\chi_{wk}}{\chi_w} \quad (3)$$

Where RAC_{ik} represents RCA of industial k in country i; χ_{ik} represents the export amount of industrial k from country i; χ_{wk}represents the world export amount of industrial k; χ_i represents the total export from country i; $\chi_w$represents the total world exports. In general, if RCA<0.8, it means this commodity owns little world competitiveness; if RCA is between 0.8 and 1.25, it starts to show certain comparative advantages; if RCA is between 1.25 and 2.5, the competitiveness is considerable strong; if RCA>2.5, this commodity is strongly competitive (Zheng, et al., 2018).

Based on Equation (3), the Revealed Comparative Advantages are calculated for solar energy, wind energy, biomass energy, water energy, natural gas and nuclear power of the US and China. It can be seen that the US has the largest revealed advantage in biomass energy. The RCAu shows an ever-increasing trend, and has been greater than 2.5 in recent years, which indicates that the US has a strong competitiveness in the export of biomass energy. Such competitiveness is reflected in biomass trades with China. In nuclear power, in recent years, the RCAu has always been between 1.25 and 2.5, which can be concluded that USA is considerable competitive around the world in the export of nuclear energy products. While USA is expanding exports of nuclear energy, China is also expanding imports correspondingly, and the trade between the US and China is becoming closer. In terms of solar energy and wind energy, the RCAu values have declined in recent years, now are around 0.8, indicating that there are still certain competitive advantages, but these advantages are weakening. Among them, the RCAu value of solar has fluctuated around 0.8 since 2011, and started to recover after reaching the lowest point in 2015, while the RCAu of wind has continued to decline. But the trend of RCAu value of wind energy is generally opposite to TIIu value. Although the trade cooperation with China has been weak in wind energy (TIIu value is less than 1), this cooperation is growing closer in recent years (TIIu value is in upward trend). The competitiveness of the USA in terms of water power and natural gas energy is relatively weak. For many years, RCAu values of water and natural gas have been less than 0.8 and began to rise after reaching their lowest levels in 2011 and 2013, respectively. The TIIu value has been very low, which indicates that the improvement of the international export competitiveness of American natural gas is not reflected in the trade exchanges between China and the USA.

3.3 Analysis based on VAR Model

The annual TIIc and TIIu values of each clean energy product are obtained through previous calculation. In order to build the VAR model, the values are weighted and summed according to the proportion of the export quantity of each product in the total export quantity, and then the TIIc and TIIu values of the total clean energy are obtained. At the same time, in order to eliminate the possible heteroscedasticity, logarithm values of TIIu, TIIc, GDPu, GDPc and OPRICE are utilized, and the corresponding variables will be LTIIu, LTIIc, LGDPu, LGDPc. Before building the VAR model, it is necessary to examine the stationarity of time series data. The unit root test is conducted by using the ADF (Augmented Dickey Fuller) through Eviews 6 (Table 1). It is found that all sequences have first-order single integration, that is, after the first difference operations, each new time series (DLTIIu, DLTIIc, DLGDPu, DLGDPc or DLOPRICE) displays the stationarity. It is found that the sequences DLTIIc, DLTIIU and DLOPRICE are stable at 1% significant level, while DLGDPc, DLGDPu and DLCO2 are stable at 10% significant level.

Table 1. ADF Unit Root Test

	DLTIIc	DLTIIu	DLGDPc	DLGDPu	DLCO_2	DLOPRICE
ADF-value	-5.459	-4.364	-2.835	-2.689	-2.658	-4.593
P-value	0.000	0.002	0.068	0.091	0.096	0.001

Furthermore, according to equation (3), VAR model can be built with first-order difference sequence data. Among them, DLTIIc, DLTIIU, DLGDPc, DLGDPu and DLCO2 are endogenous variables, and DLOPRICE is exogenous variables. Then, the optimal lag order of the model should be selected. If the lag order is too small, it may lead to the autocorrelation of the residuals; if the lag order is too large, the freedom of the model will be reduced due to too many parameters to be estimated, thus affecting the effectiveness of parameter estimation. According to Table 2, The lag order selected by both the LR and FPE methods is one. AIC and HQ are two, and SC is zero. For a comprehensive consideration, one is selected as the optimal lagging order for this VAR model, that is VARTII(1), which is used in the following calculation.

Table 2. Lag Orders of VARTII(1) Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	213.8507	NA	1.38e^{-14}	-17.72615	-17.23246*	-17.60199
1	246.5311	45.46835*	7.81e^{-15}*	-18.39401	-16.66608	-17.95944
2	275.9506	28.14043	8.51e^{-15}	-18.77832*	-15.81616	-18.03334*

*indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

To examine overall effectiveness, VARTII(1) model is subjected to stability test via AR root graphical method. If the reciprocal values of the characteristic roots are all within the unit circle, that is, the reciprocal values are all less than 1, it indicates that VAR(1) is stable. Otherwise, it indicates that the model is unstable, and we need to reset and test the lag orders of the model. As is illustrated in Figure 1, reciprocal values of the characteristic roots are all within the unit circle, indicating that VARTII(1) is stable and lag order is selected properly. Thus, the impulse responses can be analyzed.

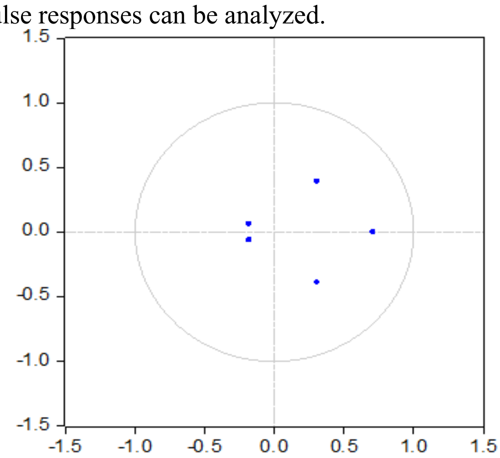

Fig. 1. Inverse roots of AR characteristic polynomial

The Gross Domestic Product (GDPc and GDPu) and total carbon dioxide (CO2) emissions may be affected by the clean energy trade cooperation. Therefore, next we analyze the impulse response of VARTII(1) model. The impulse response functions are shown in Figure 2 to 4. In the Figures, the vertical axis is the impulse responses, and the horizontal axis is the lag time (year) after the initial positive impacts are applied to DLTIIu or DLTIIC. The impact value is the respective standard deviation value in the data. In the beginning, the clean energy Trade Intensity Index (DLTIIC) will cause a positive response for DLCO2. However, DLCO2 began to decline rapidly from the second phase, and reached the minimum value at the end of the third phase, and then gradually converged. As China's clean energy technology is not mature at first, it needs to increase investment for the development, which leads to the increase of total energy consumption and the increase of CO2 emissions. With the use of clean energy, part of the traditional energy will be replaced, thus curbing CO2 emissions. However, since the first phase, the DLTIu index will cause negative response for DLCO2. Obviously, USA has relatively rich experience and mature technology in clean energy production, and the cooperation in clean energy trade will help to reduce CO2 emissions. Cumulatively, the negative DLCO2 responses due to DLTIIu and DLTIIC are -0,005293 and -0.004255 respectively. As tabulated in Table 3. Figure 3 illustrates the impulse responses of DLGDPu due to DLTIIu and DLTIIC. The clean energy Trade Intensity Index (DLTIIu or DLTIIC) may cause a positive impact on DLGDPu. This is because China lacks the experience and technologies to develop clean energy, and it has to buy key equipment from the USA. As a result, trade cooperation in clean energy between the two countries will boost GDP growth in the US. Cumulativeness, the DLGDPu responses due to DLTIIu and DLTIIC are 0.002280 and 0.005729, respectively, as tabulated in Table 3. Referring to Figure 4 and Table 3, DLTIIu or DLTIIC may cause a negative impact on DLGDPc and the cumulative responses due to DLTIIu and DLTIIC are -0.010490 and -0.011629, respectively. This is because US-China trade cooperation in clean energy is in its infancy. It is difficult for China to invest in and develop clean energy without cooperation with USA. Key technologies and equipment critically need be introduced. The increased investment in clean energy has a certain crowding-out effect on other investments, so the trade cooperation in clean energy cannot stimulate China's economic growth in the initial stage.

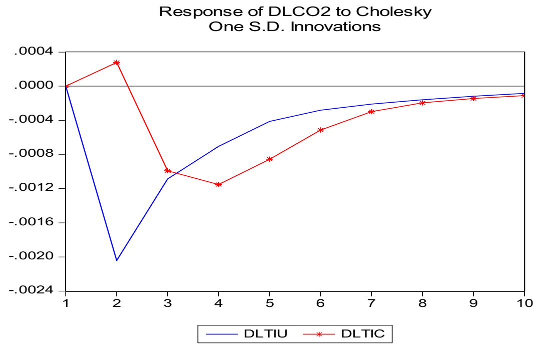

Fig. 2. Response of DLCO2 in VARTII(1)

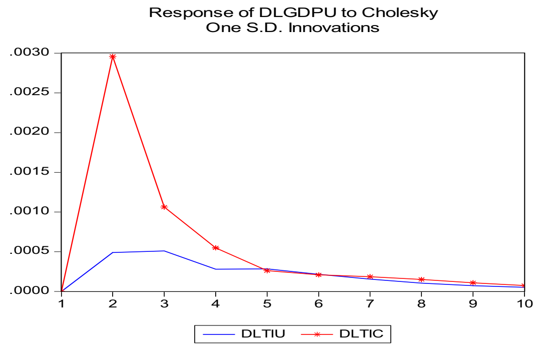

Fig. 3. Response of DLGDPu in VARTII(1)

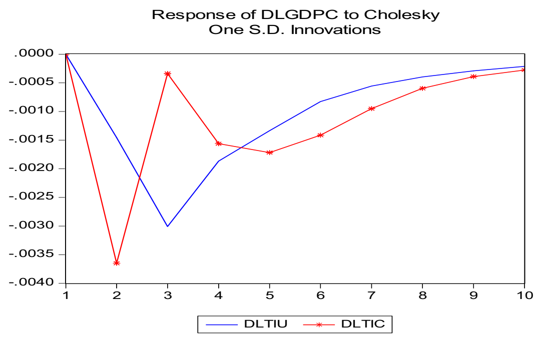

Fig. 4. Response of DLGDPc in VARTII(1)

Table 3. Total Impulse Response

Response / Impulse	DLCO₂	DLGDPu	DLGDPc
DLTIIu	-0.005293	0.002280	-0.010490
DLTIIc	-0.004255	0.005729	-0.011629

4 Conclusion and Policy Implications

In this article the Trade Intensity Index (TII) is used to measure the trade relations in clean energy between the USA and China. The TIIu values are greater than 1 in biomass energy and nuclear power. That shows the trade complementarity between American exports and China's imports is obvious, and the trade cooperation relationship is relatively close. In biomass energy, nuclear power and wind energy, TIIc values are greater than 1, which indicates that there is a close trade and cooperation relationship between China's exports and America's imports. In terms of solar energy, water energy and natural gas, TIIu and TIIc are all less than 1. According to the RCAu and TIIu value, the USA has obvious competitiveness in biomass energy and nuclear power, and close trade cooperation with China. The US has certain comparative advantages in solar energy, but such advantages are not reflected in the trade cooperation with China. It also has certain comparative advantages in wind energy, and its trade cooperation with China is strengthening, but it is still weak. China has an obvious comparative advantages in solar energy, wind energy and hydropower, and shows international competitiveness. However, its close trade cooperation with USA can only be found in wind energy (TIIu value is greater than 1). Although China does not have a comparative advantage in biomass and nuclear power, it has a better trade relationship with USA. The only resource that neither country has obvious comparative advantage is natural gas energy, and bilateral trade cooperation is also weak. To conclude, the clean energy products in which USA and China have comparative advantages have not been fully transformed into the close trade cooperation between them. In terms of solar energy and hydropower, the two countries have not yet formed trade complementarity, and the trade cooperation remains to be strengthened. In terms of natural gas, although USA began to export LNG to China in 2016, the trade volume was relatively small, and there are no signs of the strengthening trade cooperation relationship in the TIIu values.

Obviously, bilateral trade cooperation is beneficial to both countries and has an obvious complementary effect. At present, USA and China should improve the intellectual property and relevant legal systems recognized by both sides. In this regard, USA has a mature management system and relevant experience, so it is advisable to refer to the existing practices of the USA in patent protection, or develop a mutually agreed management system based on the American practices to ensure the standardization of application and review. At the same time, USA and China should strictly enforce laws on patent protection, strengthen cooperation and communication, strike cross-border intellectual property violations and crimes, and maintain bilateral trade order. With the improvement of the protection of intellectual property rights, USA and China will naturally open their doors to each other. USA should consider technology transfers, and China will also open market access. This is conducive to the formation and development of clean energy trade cooperation based on the different division of labor in the industrial chain, that is, high-end products from the USA enter the Chinese market, while low-end products from China enter the American market. At the same time, the mechanism of capital access and withdrawal should be improved to ensure the legalization and transparency of capital investment and protect the legitimate rights and interests of enterprises. In addition, coordination and communication in the areas of tariffs and price subsidies should also be strengthened to actively promote bilateral trade cooperation. In the specific operation, first of all, we can work on the policies at the federal government level for USA and the central government level for China. Both countries should clearly define their prospects of clean energy development for future decades based on available domestic resources and bilateral trades. Secondly, initial collaboration at the state/province level to fully explore clean energy based on similar development goals can be carried out. For example, states such as New York and California may be able to work with metropolises such as Beijing and Shanghai. In the beginning, it may be beneficial to developed states or cities. After accumulating certain experience in these areas, we can expand the scope of cooperation and continuously promote the bilateral trade between the two countries.

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