Study on the Clean Energy Cooperation of Northeast Asia Based on Dynamic Game Theory

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Abstract. In face of the tension of climate change and energy shortage, all countries endeavor to explore and utilize clean energy for sustainable development and accelerate regional clean energy cooperation. Not only big energy exporting countries but also big energy importing and carbon emission countries are distributed in Northeast Asia, thus laying a favorable foundation for the regional energy cooperation. Northeast Asia has witnessed lots of sticking points over history, territory and big powers out of the region. Therefore, the cooperation on energy is progressing at a slow pace. By virtue of dynamic game model, this paper analyzes the strategies adopted by Northeast Asian countries in the regional clean energy cooperation, setting out a reliable path for the regional clean energy cooperation of Northeast Asia.

Keywords. Northeast Asia, clean energy, dynamic game

1. Introduction

In face of the tension of climate change and energy shortage, all countries endeavor to explore and utilize clean energy for sustainable development. However, the United States announced the withdrawal from the Paris Agreement in 2017, accelerating the regional governance. China, Japan and ROK of Northeast Asia take the first, fifth and eighth place in terms of carbon emissions [1]. Carbon emissions from the energy industry of Japan and ROK respectively accounted for 3.2% and 1.8% of the global total carbon emissions in 2020. However, this proportion was as high as 30.9% for China [2]. Moreover, these three countries are the world’s major energy importing countries. Russia and Mongolia are two big energy exporting countries in the region. However, they have been fully aware of the significance of developing new energy. In the context of global climate change since the 21st century, the Russian Government has promulgated a series of laws and regulations on energy conservation [3]. Mongolia has promulgated the Policy on Green Development in 2014 [4]. The clean energy cooperation among Northeast Asian countries enjoys remarkable geographical advantages. In detail, Russia is a major supplier of natural gas; Japan and ROK are competitive in terms of new energy

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technology and capital; China has advanced technologies in wind energy. However, the regional clean energy cooperation is progressing at a slow pace due to the related historical and political factors as well as the intervention of other big powers out of the region [5]. The study on the conditions of clean energy cooperation among Northeast Asian countries will be of great significance to boost the regional clean energy cooperation and achieve the regional carbon neutrality.

2. Current Status of Clean Energy Cooperation in Northeast Asia

2.1. Clean Energy Trades among Different Northeast Asian Countries

Most direct energy trades in Northeast Asia are commercial fossil energy and natural gas is the direct commodity in the field of clean energy. The cooperation on hydropower, nuclear energy and renewable energy is achieved as the technical cooperation on energy development and utilization, in which direct commercial trade is only the cooperation on electric energy conservation in small scale [6]. The amount of natural gas export by Russia to Northeast Asia accounted for 53.59% of its total natural gas export amount in 2020. Russia exported the most natural gas to Japan, up to 32.86% of its total natural gas export volume. In 2020, Russia exported 3.9 billion m³ of natural gas to China through pipelines (Table 1). The natural gas trade of Northeast Asia plays an important role in the global natural gas trade.

<table>
<thead>
<tr>
<th></th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>467.59</td>
<td>670.27</td>
</tr>
<tr>
<td>Japan</td>
<td>2792.51</td>
<td>2216.74</td>
</tr>
<tr>
<td>ROK</td>
<td>906.73</td>
<td>727.68</td>
</tr>
<tr>
<td>Mongolia</td>
<td>0.02</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

Data source: UN Comtrade Database (UN Commodity Trade Statistics Database).

2.2. Clean Energy Investment Cooperation Among Different Northeast Asian Countries

The gas and oil cooperation project between China and Russia was officially initiated in 1994. Both the countries sign an energy cooperation agreement in 1996 to advance the cooperation in the field of natural gas, including natural gas exploration, exploitation and processing, pipeline operation, trade and establishment of joint ventures. Russia has started transporting crude oil and natural gas to China, Japan and ROK through China-Russia Crude Oil Pipeline since 2011. The cooperation between Russia and China on electric power and new energy is progressing. Phase I and II of Tianwan Nuclear Power Station were completed in 2018. This project marks the cooperation between China and Russia on high technology in the field of nuclear energy. It is also the largest technological and economic cooperation project between the two countries so far, which offers significant support to the bilateral energy cooperation.

Russia and Japan conducted the cooperative exploitation of oil and natural gas by jointly implementing “Sakhalin-2” project. About 60% of the LNG produced by this
project will be transported to Japan. In this way Japan’s LNG resources are guaranteed. This project is of great significance to ensure the national energy security of Japan [7]. In addition to “Sakhalin-2” project jointly implemented by Russia and ROK, more than 93% of the section of “Power of Siberia” natural gas pipeline from Kovykinskeye Gas Field to Chayandinskoye Gas Field has been completed. Chayandinskoye Gas Field serves as the main resource reservoir of the natural gas pipeline. The pipeline is expected to be connected and completed by the end of 2022. Kovykinskeye Pipeline Natural Gas Project is also a key component of the oil and gas cooperation between Russia and ROK [8].

At present, an agreement has been reached on the development of China-Russia-Mongolia natural gas pipeline. 50 billion m$^3$ of natural gas could be transported to China through the pipeline. This agreement is of great significance for the energy and economic development of the three countries.

2.3. Clean Energy Technological Cooperation among Different Northeast Asian Countries

In the process of energy utilization, the application of energy conservation and emission reduction technologies and clean energy technologies is a key issue in the regional energy technology cooperation of Northeast Asia. Different Northeast Asian countries vary with energy reserve structures and are complementary to each other in the proficiency of energy development technology. China has started the study on carbon capture, utilization and storage (CCUS) technology since 2005. China’s first million-ton CCUS project was completed for intermediate delivery in January 2022, which could reduce carbon dioxide emissions by 1 million tons. This project is significant to develop China’s clean energy. Japan is competitive worldwide in terms of coal environment protection technology, such as coal utilization efficiency promotion technology, desulfurization and denitrification technology and coal conversion technology, thus bringing about a huge potential to the reduction of greenhouse gas emissions [9]. The application of clean energy technologies and technological cooperation between countries are of great significance to promote the clean energy development of Northeast Asia and improve climate environment.

3. Game Analysis on Clean Energy Cooperation in Northeast Asia

Cooperation environment and cooperation condition will decide whether any country takes cooperative actions in energy cooperation. Here the environment faced by all Northeast Asian countries and the selection of strategies during cooperation are analyzed using the evolutionary game model of energy cooperation.

3.1. Evolutionary Game Model of Energy Cooperation

The strategies of energy cooperation between countries are affected by economic interests, security interests and cooperation costs of both parties. If one country selects cooperative or non-cooperative strategies, its net benefits will be affected by the strategy of other countries. The payoff matrix of both parties for energy cooperative game is shown as Table 2.
Table 2. Payoff matrix of energy cooperative game.

<table>
<thead>
<tr>
<th>Country A in action</th>
<th>Action</th>
<th>No action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>$U_i(X,Y), U_j(X,Y)$</td>
<td>$U_j(X,Y) - C_i(X,Y), U_E(Y,X)$</td>
</tr>
<tr>
<td>No action</td>
<td>$U_i(X,Y), U_j(X,Y) - C_i(X,Y)$</td>
<td>$U_j(X,Y), U_E(Y,X)$</td>
</tr>
</tbody>
</table>

where

$$U_i(X,Y) = E_i(X,Y) + UE_i(X,Y) - C_i(X,Y) - \lambda_i E_j(X,Y)$$ (1)

which is the expected utility function of country $i$ ($i \neq j$) under the condition that both parties are cooperative in the evolutionary game model; $U_i(X,Y)$ is the expected utility function of the country $i$ in action under the non-cooperative state; $E_i(X,Y)$ is the residual benefits obtained by the country $i$ in action from cooperation; $UE_i(X,Y)$ refers to the benefits that can be obtained by the country $i$ in action when it is non-cooperative; $C_i(X,Y)$ indicates the cost of the country $i$ in action on seeking for cooperation; $\lambda_i$ is (in the opinion of the country $i$ in action) the coefficient of inhibition and influence on the country $i$ due to the residual benefits obtained by the country $j$ during cooperation, indicating the allocation of relative benefits for both parties in cooperation.

The strategic model adopted by one country while cooperating with another country on energy is subject to the urgency of cooperation between the countries. The urgency depends on the benefits (including absolute benefits and relative benefits) that can be obtained by the two countries from cooperation. According to the evolutionary game model and urgency of energy cooperation between two countries, the decision situation of a country is divided to the following four levels, as shown in Table 3.

<table>
<thead>
<tr>
<th>Urgency of one country</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urgency of the other country</td>
<td>Turbulent</td>
<td>Urgent</td>
</tr>
<tr>
<td>Low</td>
<td>Disturbing</td>
<td>Peaceful</td>
</tr>
</tbody>
</table>

In different situations, the strategies of energy cooperation between two countries are divided into the following types, as shown in Figure 1.

3.2. Selection of Strategic Behaviors of Northeast Asian Countries for Clean Energy Cooperation

The selection of strategic behaviors for Northeast Asian countries during regional clean energy cooperation is affected by domestic market factors, national security factors, international market factors and international relation factors. Russia and Mongolia are known as two major suppliers of traditional energy and importers of clean energy technology in the region. China is not only a big importing country of energy and energy technology but also an exporting country of energy investment. Japan and ROK are two importing countries of energy and exporting countries of energy investment and technology. These countries vary with national status and environmental pressure. Accordingly, they are faced with different cooperation conditions. The strategic
behaviors selected by the related countries are respectively analyzed followed.

3.2.1. Russia

Russia is a big traditional energy producer. It is only slightly influenced by energy security issues. It has a vast territory but a small population. Therefore, it will not suffer severe environmental problems. The Russian Government has started the development of clean energy except natural gas. However, it is not urgent for Russia to conduct clean energy cooperation with other Northeast Asian countries though these countries are suffering a greater tension from environment and energy security. In this process, Russia is a follower. A big gap exists in the intention of clean energy cooperation between Russia and other Northeast Asian countries. Other Northeast Asian countries, especially China, Japan and ROK, are eager to achieve clean energy cooperation with Russia, relieving the high dependability on the energy from Middle East. There is a huge demand for importing the natural gas of Russia. Besides, these countries hope to promote the in-depth development of energy cooperation based on enhanced clean energy cooperation.

The international environment faced by Russia has changed greatly since 2014. The relationship between Russia and Ukraine is being worsened. Under such circumstance, the United States and European Union impose sanctions on Russia. Russia cuts its natural gas supply to the European Union and needs to divert the surplus natural gas to the east, thus providing an opportunity for Northeast Asia to conduct regional energy cooperation. The relation between Russia and Ukraine got worse at the beginning of 2022. Then Japan and ROK imposed sanctions on Russia. With the tension of energy supply, Japan and ROK have not terminated the energy cooperation with Russia. Both of them returned to the peaceful state. The war between Russia and Ukraine has brought changes to the international environment. As a result, Russia gradually turns to the strategy of survivor in the process of energy cooperation with China. Both the countries tend to agree on the absolute benefit and relative benefit of national security in the cooperation. However, the cooperation on new energy is mainly achieved by the corresponding Russian and Chinese enterprises. Therefore, measures should be taken to facilitate and protect these
enterprises. China should formulate long-term strategies to deal with any change in Russia’s policies when the international environment gets better.

3.2.2. Mongolia

Mongolia is a coal exporting country in the region. In face of environmental pressure and power shortage, it is urgent for the country to join the clean energy cooperation of Northeast Asia. Moreover, the country’s coal export highly depends on China. It intends to strengthen the cooperation with Japan and ROK on clean energy to reduce the dependence on China’s markets. But its domestic market has a small scale. It is a trier when cooperating with other Northeast Asian countries on new energy. It does not feel urgent during cooperation. However, they have been aware of the potential benefits from cooperation. All parties should keep an eye on any change of the international environment and establish a communication mechanism and achieve cooperation at a proper time.

3.2.3. China, Japan and Republic of Korea

China, Japan and Republic of Korea (ROK) are three big energy consumption countries and carbon emission countries in the region. It is of great necessity to not only ensure the safety of traditional energy but also speed up the development of clean energy. Competitions among the three countries in the field of traditional energy have resulted in “Asian Premium”. A regional effective energy cooperation mechanism should be established to eliminate zero-sum game among the countries. In respect of clean energy technology transfer, a competitive relation exists among the three countries in third-party markets, such as Russia and Mongolia. In this sense, it is urgent for the three countries to cooperate with each other, showing a strong intention of cooperation. Political distrusts arising from historical factors, territorial issues and external interventions make the three countries focus on relative benefits. In order to achieve cooperation, the strategy of compromiser should be adopted. Based on sufficient negotiations, the country with greater absolute benefits should make a concession. A mode of cooperation appropriate and acceptable for each of the countries should be selected.

4. Path of Energy Cooperation in Northeast Asia

As reflected by the above analysis, the regional clean energy cooperation of Northeast Asia should be implemented in a progressive way.

4.1. Promote the Cooperation between Enterprises

Regional clean energy cooperation should be implemented by relevant enterprises. For this purpose, the government of different countries should facilitate the cooperation between enterprises. Most energy projects need a long time and a large amount of investment. It is recommended that these countries should provide relevant enterprises with financing support by mutually setting up financial institutions, realizing financial innovation and making full use of the Asian Infrastructure Investment Bank, NEA EXIM Banks Association and other multilateral financial institutions, thus providing a fund guarantee for these enterprises to implement specific projects. Interregional technological cooperation agreements should be signed to ensure and promote the transfer of new energy technology between enterprises.
4.2. Promote the Cooperation in Third-Party Markets

Russia’s Eastern Siberia and Far East and Mongolia contain excellent conditions for the exploitation of solar energy and wind energy [10]. It is proposed to make full use of China’s financial strength and technical advantages in UHV power transmission, hydropower generation and solar power generation, Japan’s electric energy, solar energy, carbon capture and carbon storage technologies and ROK’s wind power generation and biomass energy technologies to cooperate with third-party markets, such as Russia and Mongolia. Such cooperation will facilitate the production and transportation of clean energy in Northeast Asia, thus reducing the greenhouse gas emissions in this region [6].

4.3. Accelerate the Construction of Infrastructures

All Northeast Asian countries should firstly strengthen the construction of clean energy infrastructures for the region. For example, regarding power infrastructures, China, Russia and Mongolia are suggested to firstly start the construction of China-Russia-Mongolia Integrated Energy Network and UHV power transmission lines for the interconnection of power grids and the integration of power generation using fossil energy with power generation using renewable energy. As for the long-term goal, it plans to connect China-Russia-Mongolia Energy Network with the power grid of Japan, ROK and other East Asian countries through land or submarine UHV power transmission lines and finally develop a larger East Asian integrated energy network [10].

4.4. Strengthen Interregional Economic and Trade Cooperation

Most energy cooperation mechanisms of the European Union and North America are embedded in corresponding regional economic cooperation agreements. All Northeast Asian countries are accordingly suggested to conduct the regional economic cooperation with fewer interference factors to accelerate the establishment of Northeast Asia Free Trade Area. Then a regional energy cooperation mechanism should be set up on the basis of regional cooperation organizations, thus boosting the regional clean energy cooperation.

5. Conclusion

The regional clean energy cooperation of Northeast Asia is a necessary way to cope with climate change, which meets the urgent need for regional environmental governance and energy security. However, the Northeast Asian countries have different positions in energy productions and consumptions as well as different international relations in the region. Therefore, each country has taken different strategies for regional energy cooperation. In this case, each country in the region should promote the cooperation between enterprises, boost the cooperation in third-party markets, improve clean energy infrastructures and drive clean energy cooperation based on regional economic and trade cooperation to finally achieve the regional clean energy cooperation of Northeast Asia.
Acknowledgements

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