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Impacts of Carbon Emission Trading Markets on Energy Transformation: A Review of the Existing Literature

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Abstract

In the current era, carbon emission trading markets seem to be a booster when the global society vigorously advocates energy transformation. Different scholars mainly focus on analyzing the transmission mechanism of carbon emission trading markets on energy transition, the role of carbon emission trading markets on renewable energy, and the impact of carbon emission trading markets with other policies on energy mix. However, the conclusions on whether carbon emission trading markets can indeed contribute to energy transformation vary. Therefore, this article presents research papers on the impact of carbon emission trading markets on energy structure transformation in recent years through literature review and summarizes hot topics to facilitate future scholars to fill the research gap in this field.

Keywords: carbon emission trading market, energy transformation, renewable energy

1. Introduction

The transformation of energy structure has received widespread attention in the process of climate reform. According to the data released by the International Energy Agency (2017), energy intensive industries and manufacturing account for 42% of the global total carbon dioxide emissions, while Friedlingstein et al. (2010) and Huisingh et al. (2015) previously indicated that these industries are the main sources of pollution. Therefore, the transformation of energy structure can play a positive role in reducing carbon consumption. To study the influence of carbon emission trading markets in carbon reduction, it is crucial to prove the function of carbon emission trading markets in the transformation of energy structure.

Energy structure transformation refers to the structural transformation of the global energy system dominated by renewable energy (Edenhofer et al., 2011; Lu & Nemet, 2020). It is worth noting that although the definition of energy structure transformation is not easily controversial in the academic community, there are some differences in the measurement standards of energy transformation as an explanatory variable in empirical research. Some articles measure the proportion of coal consumption to energy consumption, while others quantify the proportion of the total output value of industries with primary energy consumption to the GDP of each province.

2. The Role of Carbon Emission Market in Energy Transition

2.1 The Impact of Carbon Quota Allocation Methods on Energy Transformation

According to the maturity of each country's carbon emission market and the heterogeneity of industries, the government will adopt different carbon quota allocation methods for trading. Therefore, each carbon market will have corresponding effect on the abatement of emissions and the degree of energy transition. Depending on the implementation stage, the carbon quota allocation methods can be free quota, auction, or a combination of the two.

There always exists the misconception that introducing a carbon emission market increases the production costs of carbon-intensive industry, which can lead to the closure of these enterprises to improve production technology and use clean energy (Lin & Jia, 2020). However, based on this misunderstanding, Zhao et al. (2022) tested whether the auction allocation method can promote the renewable energy power generation industry through the neo-trans -log production function model and MOLP method. The results showed that the auction allocation method cannot facilitate renewable energy power generation in the short term, and the impact is very weak. The reason is that the coal power industry is under greater pressure under auction allocation method, and the cost of paying for defaults may be lower than the cost of reducing carbon emissions. They suggest that China is currently not suitable for directly adopting a large-scale auction allocation method, but companies need to be prepared for the future transition to an auction allocation method.

Müller and Teixidó (2021) studied the impact of Poland's free quota method of its carbon emission market on its power generation industry. In the third stage of the European Union (EU) carbon emission market, the EU provides transitional policies for countries facing serious difficulties in energy mix, allowing them to continue using free quota policies. However, this result is that the Polish power generation industry have not reduced the use of lignite as the main energy source, nor did it accelerate the development of renewable energy, as these hidden incomes continue to be used in the input and output of lignite. In addition, they suggest that the auction allocation method should be gradually used to change the current situation.

2.2 Mediating Factors for Achieving Energy Transformation Through Carbon Emission Trading Markets

Based on the spatial spillover effect model and the mediating effect model, Zhang et al. (2022) discussed the transmission mechanism of China's carbon emission trading market to the development of renewable energy, which can be divided into three categories: fossil energy consumption; Energy intensity; Green technology innovation. Research has shown that all three can significantly serve as mediating factors in promoting the carbon emission trading market for renewable energy, with the shift in fossil energy consumption being the key factor, accounting for 73%; The other two together only account for 27%.

Although green technology innovation has a driving influence on energy transition, it is necessary to be wary of rebound effects. Carrying out green innovation in the power industry, improving energy efficiency will drive relative carbon emissions mitigation, and electricity prices will also relatively decrease. This result will stimulate consumption. The domino effect confirms that the growth of electricity demand further increases carbon emissions. Therefore, the difference between the previously offset carbon emissions and the latter increased carbon emissions captures the impact of the rebound effect.

Ai et al. (2020) divided green technology into two categories: independent innovation and imported innovative technologies. The study found that after considering the rebound effect, independent innovation failed to further energy-saving effects, while imported innovation technologies was the opposite. In response to this phenomenon, some scholars took Sweden (Brännlund et al., 2007) and the United States (Thomas et al., 2013) as study objects, and proposed to alleviate the rebound effect through carbon taxes, subsidies, pollution auction mechanisms, and other methods (Von Weizsäcker, 2014). However, there are currently no articles on whether the carbon emission trading market can also alleviate the rebound effect. Although both the carbon emission trading market and carbon taxes are market-oriented policies, the content and channels of their impacts are not similar. Therefore, it will be an innovative point of future research to be able to discuss whether the carbon emission trading market can help the transformation of energy structure under the background of the rebound effect.

2.3 The Relationship Between Carbon Prices and Energy Prices

Market changes are always ever-changing, and fluctuations in one market are highly likely to trigger linkage in another market. The implementation of carbon emission trading markets will invisibly increase the energy costs of carbon emissions, not only affecting the production costs of industrial producers, but also guiding consumers to make rational choices and stimulating the demand for low-carbon energy. Therefore, there is a two-way linkage relationship between the carbon market and the energy market (Caporin et al., 2021; Hammoudeh et al., 2014). This is also the "linkage effect" theory proposed by Hirschman (1958), where the impact of fossil energy prices on carbon prices can be divided into two paths: income effect and substitution effect. Due to the wide variety of energy markets, scholars selectively consider fossil and non-fossil energy markets when discussing them, and believe that the correlation between different energy markets and carbon markets may vary (Sousa et al., 2015).

However, most of the existing literature currently explores the relationship between the carbon market and fossil fuels, or the relationship between the carbon market and non-fossil fuels. In future research, exploring the mutual impact of the three can become a new entry point.

3. The Relationship Between Carbon Emission Trading Market and Renewable Energy

3.1 The Redistribution of Carbon Emission Trading Markets' Income for Renewable Energy

The initial investment in renewable energy requires significant funds and public support. A market-oriented carbon emission trading market alone cannot directly be conducive to the development of the renewable energy industry. The best solution is to redistribute the income from carbon quotas and subsidize the production and consumption structure of renewable energy. Lin and Jia (2020) used the general equilibrium theory model to simulate the separate effect of the carbon market on green energy in 2017-2030. The fitting results show that the separate carbon market has failed to advance the transformation of the energy structure. If the carbon quota income is redistributed to help the renewable energy industry and a small part is subsidized to low-income groups, the desired goal will be achieved.

3.2 Is the Carbon Emission Trading Market Compatible with Renewable Energy Policies

Some scholars have launched a heated discussion on the compatibility between the carbon market and renewable energy policies, and have come to varying conclusions. After sorting out the literature, it has been found that there are four main viewpoints: firstly, the carbon market cannot directly exert its effectiveness and needs to be combined with other policies to enhance the development of renewable energy (Gawel et al., 2014; Mo et al., 2016); Secondly, it advocates that the carbon market and renewable energy policies are incompatible; Thirdly, it can be concluded that renewable energy policies have a greater incentive effect on energy shift compared to carbon markets; The last belief is that the carbon market is sufficient to drive energy transition and achieve climate goals (Anke & Möst, 2021).

Scholars who support the first viewpoint suggest that the carbon market and green certificates should gradually be integrated (Polzin et al., 2015). In addition, there are views that support the parallel implementation of carbon market policies and tradable certificate policies. Regarding the shift between the first and second perspectives (Helm, 2002; Rogge & Hoffmann, 2010; Smith & Swierzbinski, 2007), Lindberg (2019) abandoned the previous argument that "renewable energy policies will disrupt the carbon market" and shifted to a compatible perspective between the two. Zaklan et al. (2021) supposed that the carbon market should change the total amount and ceiling of carbon quota, and provide a signal of scarcity of carbon quota in combination with some other policies such as phasing out oil subsidies, so as to force the covered industries to carry out energy conservation and emission abatement.

3.3 The Impact of Carbon Emission Trading Markets

on Renewable Energy Investment and Return Period

Although renewable energy is currently in an upward trend of development and has great potential, a continuous source of financial support is a key factor. Therefore, some scholars analyze the role of the carbon market from the perspectives of low-carbon energy investment and green foreign direct investment (GFDI). Vlachau and Pantelias (2020) used Greece as a research perspective and found that when Greece was swept and impacted by economic recession, carbon prices fluctuated sharply, resulting in a financial crisis that severely damaged long-term investments in renewable energy. As a result, the carbon market did not play a good role in achieving energy shift. It has been proven that the fluctuations in the international economy have led to an inverted U-shaped investment in renewable energy by developed countries from 2004 to 2018, peaking in 2011 and then beginning to decline (Frankfurt School, 2019). Mo et al. (2016) took wind energy as a specific perspective and set up three scenarios of no-carbon market, carbon market, and carbon market price stabilization mechanism. The study found that China's carbon market mechanism has a significant impact on wind energy investment, but it needs to be simultaneously considering the upper limit and lower limit of carbon price, when the carbon price is at a relatively high lower limit, wind energy investment can be more stimulated. However, the current carbon price in China is still not above the higher lower limit.

In summary, the fluctuation of carbon prices can indirectly affect investment in renewable energy. How to form a stable carbon price mechanism is a major issue that countries implementing carbon markets must face.

In addition, green foreign direct investment (GFDI) has also become one of the current hotspots. Wall et al. (2018) explored the impact of different regulatory policies, market-oriented policies, and public policies on GFDI. The results showed that the green energy subsidy policies (FIT) and fiscal policies (such as carbon taxes) on GFDI have the most obvious effects. Regarding national heterogeneity, OCED member countries are more suitable to use carbon tax policies to promote GFDI, while non-OCED countries are more suitable to use carbon markets to promote GFDI.

For the return period of renewable energy, Kim and Junghans (2022) believe that, without considering other factors, the return market of photovoltaic and geothermal energy investment in the construction industry is relatively long. However, through the carbon market and solar tax credit policy, the return period of heating, ventilation and air conditioning (HVAC) investment can be shortened, indirectly stimulating consumers to choose these two kinds of renewable energy sources.

3.4 Discussion on the Heterogeneity of the Carbon Market in the Power Generation Industry

In earlier years, Polzin et al. (2015) proposed that carbon trading systems exhibit a statistically significant positive effect on biomass and wind energy, while showing a negative effect on solar energy. The reason for the imbalance lies in the lack of maturity of solar technology compared to wind energy. Meng et al. (2018) simulated the development of the carbon market in Australia, and the conclusion is consistent with earlier years: the carbon market has different outcomes on different energy industries, with the clean energy power generation industry being more significant. Specifically, wind power plants can greatly benefit from carbon prices, while carbon mechanisms only have a marginal effect on photovoltaic and hydroelectric power plants.

In addition to considering the impact of the carbon market on the power generation industry, it is also necessary to consider the on-grid ratio (OGR). When renewable energy power stations are vigorously emerging, how they are transmitted to power companies, and the acceptance of power companies will all affect the final efficiency of use. As mentioned above, the carbon market itself has not directly driven the development of the green energy power generation industry, but needs to cooperate with various auxiliary measures, so the OGR is particularly important (Mo et al., 2016).

When exploring the relationship between the carbon market and the energy generation industry, it is also necessary to consider the relationship between carbon prices and electricity prices. Koch et al. (2013) argue that electricity prices have a positive impact on carbon prices, while Caporin et al. (2021) found in their study of the Italian carbon market that an increase in 1 euro carbon price is accompanied by an increase in 7 euro cents electricity prices. However, research has shown that there is no strong causal relationship between carbon prices and electricity prices. In addition, policymakers hope that the goal of high carbon prices leads to the reform of energy use, which may be affected by the low incidence rate of electricity prices. Therefore, the conclusion that the carbon market can largely transfer the cost of quotas to producers is questionable.

4. Conclusion

In recent years, empirical research has shown that the implementation of carbon emission trading market in each country has a different statistical impact on energy transition due to the maturity of the carbon market and the different industries covered. Based on existing literature, the linkage effect between carbon prices, energy prices, and electricity prices can become a hot topic in future research. However, with the gradual implementation of the carbon market, various countries will also make corresponding adjustments in covering industries and quota allocation methods. Therefore, the role of carbon markets and other policy combinations in energy shift may evolve over time and yield different results.

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