Framework Design and Mechanism Evaluation of Personal Carbon Emissions Trading

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ABSTRACT

The climate crisis is a severe environmental issue currently faced by all mankind. Carbon dioxide emissions caused by household energy consumption are playing an increasingly dominant role. Personal carbon trading is a market mechanism targeted at consumers for carbon emission reduction, aiming to promote carbon emission reduction in household energy consumption. It is a policy proposal that has received considerable attention in recent years. This paper reviews the development of personal carbon trading, explores the model and operational mechanism of personal carbon trading from differences in range, distribution, and pricing, and evaluates the mechanism from equity, efficiency, and effectiveness. It is concluded that personal carbon trading can internalize the externalities of consumers' personal carbon emissions and incentivize consumers to participate in carbon emission reduction through a price signal. Personal carbon trading is an organic innovation of a binding market economic instrument and voluntary policy tools, enabling every citizen to consciously participate in environmental policy practice. It is of great significance to achieving the "double carbon" goal and high-quality and sustainable economic development.

Keywords: *personal carbon trading; framework design; mechanism evaluation*

1. INTRODUCTION

In 2021, the Government Work Report by the State Council clearly stated that the "double carbon" goal should be achieved with high quality by optimizing the industrial and energy structures. Since the government announced the launch of the pilot carbon emission trading rights in 2011, China has established a relatively complete unified national carbon market trading system in the industrial sector and achieved remarkable results after years of exploration and practice. The cumulative carbon emission trading volume had been close to 200 million tons by 2021. However, from 2010 to 2019, the share of carbon emissions from household energy consumption increased by 69%, and in 2019, this data already accounted for 34% of total emissions. This share is even higher in developed countries, where carbon emissions from residential consumption have become the main source of carbon emissions in developed countries. Theoretically, when the carbon trading mechanism among upstream producers is fully effective, the emission reduction can influence consumers. In this case, the personal carbon trading mechanism need not be implemented. In reality, the carbon trading mechanism among upstream producers is not and cannot be fully effective, and its emission reduction effect is limited. To achieve the emission reduction target, it is still necessary to implement the personal carbon trading mechanism. Therefore, it is necessary to take proactive measures to handle the rapid growth of carbon emissions in the consumption sector. Otherwise, emission reduction achievements in other areas will likely be lost. Once people form the innate high emission mindset and behavior habits, the cost and difficulty of emission reduction will greatly increase in the future.

Compared with the industrial sector, China's current carbon reduction measures for the residents' consumption sector take a single form, mainly "soft constraints" for the spirit and morals. However, the gap from awareness to action is the key to achieving the goal of carbon neutrality. Therefore, the main issue to be addressed is how to guide, incentivize, and ensure residents participate and stimulate the potential emission reduction of the consumption sector. Personal carbon trading is considered an effective method of reducing emissions from household consumption by enforcing individual responsibility and accountability. The government can provide a total amount of emissions that are constantly tightened to achieve the emission reduction target. Based on China's

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national conditions and the studies of scholars at home and abroad, this paper reviews the development of personal carbon trading, discusses its trading model and operation mechanism, and evaluates the effectiveness of the personal carbon trading model to provide some references for China's path of achieving peak carbon neutrality.

2. LITERATURE REVIEW

The introduction of personal carbon emissions trading can be traced back to the concept of carbon allowances proposed by Fleming in the 1990s, which means emission reduction can be effectively promoted according to the given carbon allowance that constantly tightens. The main bases of the theory are the externality theory (Pigou,1920) and Coase's modern property rights theory (Coase,1960). The former emphasizes the negative impact of personal carbon emissions on the overall society in a market economy[1], while the latter believes that this negative externality results from the fact that the social cost outweighs the private cost[2]. It means the definition of environmental property rights enables the parties involved trade at low cost, so the externalities of environmental problems can be internalized to efficiently distribute environmental resources. Based on the two theories, Fan Jin (2012) established a theoretical framework for personal carbon trading in China and investigated its effects on individuals, social welfare, and consumers' choice[3].

According to Fleming (1997), though there is no empirical evidence to prove, personal carbon trading still positively affects reducing carbon emissions from households[4]. Based on Fleming's theory, Starkey et al. (2005) further discussed domestic carbon trading allowances regarding fairness, efficiency, and specific implementation details[5].

In 2006, Britain Ministers Simon Roberts and Joshua Thumim elaborated on the meaning of the Personal Carbon Trading Scheme as a collection of policies for the Department for Environment, Food, and Rural Affairs. It includes personal carbon allowances, personal carbon rations, and carbon credits. This simple and attractive concept extends carbon trading in the U.K. from companies to individuals, paves the way for other scholars' research, and becomes the basis for future studies on different types of personal carbon trading (Zhang Qingyu, 2013)[6].

In response to the U.S. government's proposal of an "upstream" approach to greenhouse gas emissions regulation, which means the upstream regulators reduce administrative costs due to fewer agents, Niemeier et al. (2008) proposed a household carbon trading system that consists of four main components: state-to-household allocations, household-to-household transactions, household-to-public utility companies credit transfers, and public utility companies to government credit transfers. It is demonstrated that a household carbon trading system is fairer than a carbon tax[7].

Fawcett (2010) studies the high costs of personal carbon trading worried by the government and public acceptance. Despite its high costs, it was found that it is at least as socially acceptable as alternative tax policies. Besides, personal carbon trading can benefit from individual and social changes driven by the non-economic aspects of the policy. Fawcett's study on the feasibility of personal carbon trading study will benefit future scholars in conducting their policy evaluation[8].

In 2014, Li Jian et al. proposed a personal carbon trading model and operational mechanism based on China's national conditions and a "carbon coin" trading model after analyzing the initial quotas of personal carbon trading[9]. Their research standardized the process and steps of personal carbon trading. Although it is only a conception, it provides a constructive reference for improving the trading system. After that, many scholars also proposed various feasible models and systems for personal carbon trading based on the summary of carbon trading at home and abroad (Chen Hongmin, 2014; Zhao Lixiang, 2017; Zhang Xu, 2019)[10-12].

Li Jun et al. (2016) studied the impact of personal carbon trading on personal energy choice by constructing a consumer energy choice model. The study found that increasing carbon prices can stimulate consumers to choose clean energy and analyzed the importance of initial carbon pricing based on the proposed downward-sloping supply curve[13]. Liu Zimin et al. (2022) further discussed the ameliorative effect of personal carbon trading on household energy poverty in the household energy field. The results also demonstrated the carbon price has a positive effect when it is above the critical value. But the heterogeneity that existed at the regional level was also explored[14].

In addition, the research on carbon emission reduction in transportation has also been a focus for many scholars. Li Weichi et al. (2016) took the public bicycle transportation system as the object and designed a method to check individual emission reductions of the public bicycle program. It filled the accounting gap in this field with a quantitative approach[15]. Guo Hongxu et al. (2019) and Zhang Ling (2021) conducted quantitative studies from the perspective of buses and shared bicycles used by residents[16-17].

A literature review shows that the research on personal carbon trading starts from environmental issues and extends to the evaluation of policy implementation and welfare analysis. The research compared it with the carbon tax, conducted a systematic analysis of the model and operation mechanism of personal carbon trading, and finally analyzed the impact of personal carbon trading on

different fields.

3. MECHANISM DESIGN

The design of personal carbon emission includes range, distribution, and pricing. Different definitions and choices of these three aspects constitute different personal carbon trading models.

3.1 Range

The discussion of the range of individual carbon trading includes the setting of the target for controlling the total amount of carbon emissions, the selection of pilot regions for carbon emissions, and the control of carbon emission projects. These three levels refine the scope gradually. The first aspect is whether the total amount of carbon emissions should cover the whole economy or only involve consumers: the former covers the carbon emissions generated by all economic behaviors in the whole region, while the latter only controls the carbon emissions on the consumption side. In the choice of control target, how to define the production side and the consumption side is a key issue, which cannot be differentiated only by the production supply chain or traditional economic logic. Only when the transaction cost and feasibility are considered is it possible in practice. Second, in the initial stage, personal carbon trading should select specific areas as pilot cities, so the range of trading is mainly among communities or households within the pilot cities. Based on the basic principles of "from local to parts and to the overall and from big cities to small cities," the pilot cities suitable for personal carbon trading are selected with reference to the feedback from the current pilot cities of carbon emission rights. Third, starting from the demand for money theory, consumers hold money for trading, prevention, and speculation, which reflects the source of carbon emissions. Carbon emissions based on the basic needs of life covered by the trading motives are the most important aspect to consider. In Fleming's personal carbon allowance scheme, only the residential household energy consumption is covered. While this choice reduces the complexity and operating costs of the system, it ignores the elasticity of carbon emission rights. Therefore, in addition to the living sector, the travel sector also needs to be taken into account. The data shows that transportation already generates 43% of carbon emissions. Carbon emissions from speculation can be understood as an incentive. For example, activities for public benefits that have a significant carbon reduction effect or can generate carbon sinks can be assigned a certain amount of carbon allowances. On the whole, personal carbon trading rights covering specific sectors may be better in terms of cost and feasibility. However, it is only by considering covering multiple areas that the intersection of personal carbon policy and other policies and personal carbon management and the uncertainty of carbon reduction can be integrated to better meet the national "dual carbon" goal.

3.2 Distribution

Distribution refers to the way and amount of initial carbon allowances that carbon emission subjects receive, which is the key to the construction of individual carbon trading. The ways of distribution include free distribution and purchase (including auction). The principle of regular free distribution of a certain amount of carbon allowances to individuals or households is generally accepted. Although the rationality of absolute equal distribution per person is still under debate, most of the existing studies on theoretical analysis, carbon pricing, and the impact of individual carbon trading follow the assumption of equal distribution per person. The main points in dispute for equal distribution per person include the following: First, whether children have carbon allowances equal to those of adults. The distribution is different under different concepts. For example, the TEQs programs do not give allowances to children, while PCAs do. Second, whether different regions should have equal carbon quotas among themselves. For example, Zheng Liqun believes that the distribution should be given priority to the interests of less developed regions and poor groups to meet the basic needs of regional development, with the goal of a minimal equity deflection index. Similarly, the possible high overall carbon emissions from heating in northern regions should be taken into account. Third, whether organizations and institutions should be distributed a certain number of allowances. Carbon allowances are all directly distributed to individuals and households, and market makers can only buy the remaining allowances from individuals to enter the market through re-purchase. At the beginning of the distribution, a certain percentage of carbon allowances will be auctioned directly to organizations through the auction of licenses along with a certain number of allowances. The government departments can use revenue obtained to make green investments or distributions again. It can be seen that different distribution methods have a great impact on the cost and feasibility of the scheme and have different incentive effects for individuals to participate in carbon trading. Based on the above discussion, this paper argues that the principle of efficiency and fairness in emission reduction should be followed, with the principle of "no net harm to each other." Based on meeting the basic needs of individuals living, the distribution of carbon allowances should consider factors such as family demographics, family wealth, geographic location, and income status. With the optimization of trading and the enhancement of awareness of emission reduction, the total distribution amount should present a gradually tightening trend. The cost can be reduced by making good use of organizations and institutions to distribute a portion of the initial allocation to public service providers, such as the power sector, water sector, and natural gas

companies. To maintain the liquidity of the personal carbon trading market, market makers can be involved by auctioning a portion of the allowances to them to meet the public's investment needs.

3.3 Pricing

Pricing requires consideration of costs and revenues, which is a difficulty for individual carbon trading design. Pricing is a game process under incomplete information, and the initial distribution of carbon emissions is the basis of consumers' game of pricing, while the Nash equilibrium point of the game is that the expected revenues of consumers are equal to the equilibrium price in the market when the transaction efficiency and quantity are the highest. Along with the decrease in transaction cost, the market activity will keep increasing and promote the initiative of personal trading. The most valuable study on the cost of personal carbon trading is the one conducted by DEFRA authorized Lane et al. in 2008, which concluded that the cost is much greater than the expense of introducing a general social trading system. Subsequent studies have demonstrated the high costs of personal carbon trading, including complex administrative and transaction costs, which are difficult to cover even by adding direct economic and environmental benefits. However, there are huge non-economic potential benefits of personal carbon trading; the popularity of personal carbon trading will cause a change in people's behavioral habits, which will lead to a low carbon society. According to the theory of consumer behavior, people will choose the point of maximizing their benefits within the established carbon allowance. It means that people will choose between the allowance they own and the current price in the market. When the market price is higher, people will consciously change their behaviors and reduce their carbon emissions. Both buyers and sellers can get greater benefits through trading. Eventually, personal carbon management reaches equilibrium, and low carbonization forms, bringing more long-term invisible benefits. Therefore, regarding personal carbon trading pricing, this paper argues that it is necessary to ensure its policy feasibility and social acceptability. In particular, China's carbon pricing can be based on international carbon trading pricing principles and be combined with the experience of carbon trading among Chinese enterprises and regions. The affordability of the public should also be taken into account. In the pilot phase, the focus should be to fully mobilize the enthusiasm of individuals and issue allowances to the public for free. Based on the initial pricing, the response of the market and the public should be combined with continuous dynamic optimization to make the market circulate to obtain the maximum benefit.

4. MECHANISM EVALUATION

The principles of equity, efficiency, and effectiveness (3E's) are the three main criteria for evaluating environmental policy instruments. Achieving a balance between them is fundamental to an effective mechanism. The implementation cost, technical feasibility, and public acceptance will also affect the design of individual carbon trading.

4.1 Equity

The discussion of the equity of personal carbon trading should start from the theory of externality, which refers to imposed non-compensable costs on other groups or benefits that do not need to be compensated, which are generated by production or consumption. Therefore, an important criterion for the fairness of personal carbon trading is whether the parties involved in the transaction can gain or lose accordingly and whether such gains or losses are evenly distributed among different groups. The existing literature generally agrees that personal carbon trading is a more effective mechanism than carbon taxes. On the one hand, personal carbon trading has a less regressive effect because the collection of the carbon tax may expand the taxation range. This makes the upstream enterprises with strong pass-through ability pass on the taxes to consumers, resulting in additional taxes on consumers. On the other hand, from the perspective of welfare economics, personal carbon trading will make the welfare of high-income earners suffer, and the welfare of low-income earners increase, which will make those high-polluting emitters bear higher costs to achieve social equity. According to the principle of equity, every adult is equally distributed with tradable carbon allowances every year. This principle originates from the tightening and convergence of the international carbon emission market. A number of scholars believe that personal carbon allowances can be used as a complementary currency to some extent. At the same time, any initial distribution method enables everyone to eventually receive equal allowances, but this convergence is modeled without considering the transaction costs. Therefore, given the high transaction costs that cannot be ignored, the equity can only be achieved by following the principle of "no net harm to each other," differentiating the design according to different communities, minimizing regressive effects, and designing a model that is more acceptable to consumers.

4.2 Efficiency

Efficiency is closely related to the pricing and is the most direct indicator for evaluating personal carbon trading. For example, in Lane et al.'s simulation of a complete personal carbon trading system in the U.K., the cost of establishing a downstream trading system is about 12 to 18 times higher than that of an upstream trading system, and the operating cost is about 18 to 32 times higher. Although there is a great deal of uncertainty in this approach built with analogical reasoning, there is no

doubt that a consumer-based carbon trading system faces a significant cost challenge. The revenue depends on the combined effect of trading volume and unit price, and the pricing strategy under multiple approaches was discussed earlier. It is true that an ideal equilibrium point exists in theory. But even in this case, the trading volume should achieve a certain percentage to make the revenue higher than the cost. From a comparison of upstream and downstream personal trading systems, although the upstream costs are lower, it has a poorer ability to influence personal behavior and emission effects, and more trading volume is needed to achieve more desirable benefits. In general, in the estimation of costs and the measurement of revenues, there are problems such as unclear assessment boundaries and simple assessment methods. Many preconditions and restrictions lead to high uncertainty. Even with the uncertainty, a basic conclusion can be drawn that there is no technical barrier to establishing a consumer-based personal carbon trading system, but its cost is much higher than other options. If the efficiency of the policy is taken into account, the benefits from emission reduction alone are far from enough to cover its cost. Therefore, the evaluation of PCT needs to consider the effects of other aspects to determine its optionality.

4.3 Effectiveness

Effectiveness, or efficacy, evaluates environmental policies from a more macro perspective. It refers to whether personal carbon trading has achieved the desired goals, which is mainly manifested from the following three aspects. The first one is the economic benefit, which is the direct benefit of personal carbon trading to individuals, enterprises, institutions, and departments. The parties involved in the transaction can all make profits through the transaction according to the changes in the market price. Meanwhile, those participants with good behavior have a larger profit margin. The second aspect is environmental benefits. Parties involved can maximize their benefits by continuous game and regulating their behavior in the trading process. The environment can be effectively improved under the ever-tightening total carbon emission target set by the nation. The third one is social benefits, which are the labor force absorbed and the benefit generated in the industrial chain related to personal carbon trading. At the same time, the popularity of personal carbon trading will cause a change in people's behavioral habits, thus achieving a low carbon society. In addition, more invisible social benefits include potential low carbon technology innovation, increased citizen awareness of equity, increased public awareness of the nation, and improved market effectiveness. Compared with the carbon tax and energy tax, personal carbon trading presents more benefits because it is essentially an incentive mechanism based on market value signals, which can fully mobilize the public's initiative to practice low carbon behavior and enhance the public's sense of participation and responsibility, thus expanding the range of carbon trading and improving the efficiency of trading. In addition, in terms of social acceptance, people can quickly understand the policy proposal of personal carbon trading, discuss its details deeply, and provide their own views compared with the carbon tax. With the advantages in equity and effectiveness, consumers are more inclined to accept the personal carbon trading mechanism, and the demographic variables significantly impact the degree of acceptance. This result is significant in the case of theoretical personal carbon trading and actual carbon taxes. Thus, PCTs have more potential opportunities in terms of effectiveness.

5. CONCLUSION

In conclusion, personal carbon trading is a complement or extension of carbon trading policies for upstream companies. Personal carbon property rights are defined through the construction of a consumer-based carbon market to internalize the externalities of consumers' private carbon emissions. The personal carbon trading market sends economic emission reduction signals to consumers through the price of emission rights to stimulate and encourage consumers to reduce energy consumption and adopt low carbon technologies to gradually adapt to low carbon consumption patterns. Unlike taxation, a compulsory administrative order, existing voluntary actions, and the existing "soft constraint" model of public participation, personal carbon trading is an organic innovation of market-based economic instruments and voluntary policy tools. It allows every citizen to consciously participate in environmental policies, and it is crucial to achieving the "double carbon" goal and the high quality and sustainable development of the economy. However, it is worth noting that the difficulties of personal carbon trading are the high cost and uncertainty of the effect. Therefore, the practical research on the personal carbon trading mechanism should be further strengthened in the future. In-depth studies are required to strengthen the basic theoretical construction of personal carbon trading, operation mechanism, methodology, incentive model, the game of participants, emission reduction, social benefits, supervision in trading, and the construction of implementation mechanism.

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