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The effects of allowance price on energy demand under a personal carbon trading scheme

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HIGHLIGHTS

- Personal carbon trading is an innovative policy instrument to reduce carbon emissions at the individual level.
- A CES utility function is adopted to examine the effect of carbon allowance price changes.
- An increase (decrease) in the elasticity of substitution results in an enhanced (reduced) effect of allowance price changes.

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ABSTRACT

Personal carbon trading (PCT) is a downstream cap-and-trade scheme which could be used to reduce carbon emissions from the household sector. To explore the effectiveness of this scheme, it is necessary to investigate how consumers respond to allowance price change. In this paper, a general utility optimization (GUO) model and a constant elasticity of substitution (CES) utility function are proposed to examine the price, substitution and income effects of carbon allowance price changes. It is shown that higher income consumers are more sensitive to the allowance price changes than lower income consumers. Moreover, the short-run adjustment in consumers' consumption of electricity in response to a change in allowance price would be lower than the long-run value. According to the sensitivity analysis, downward (upward) adjustments in the elasticity of substitution result in a positive (negative) effect on price effect. The findings in this study are used to draw policy implications. Suggestions for future research are also provided.

1. Introduction

Carbon emissions caused by the energy consumption of households have become a significant source of total emissions and have attracted widespread attention from scholars and government agencies [1,2]. For instance, according to Reinders et al. [3] the proportion of direct energy (electricity, coal, gasoline, etc.) consumption by the households accounts for the total energy demand in different EU countries varies from 34% to 64%. In China, about 30% of carbon emissions are generated by households' energy consumption [4]. Moreover, due to the increase in disposable income, population growth, mobility, urbanization, and growing penetration of energy intensive appliances in households, households' energy consumption and associated carbon emissions will continue to grow rapidly [5,2,6]. Thus, to avoid catastrophic climate change, changes in consumer behavior are generally considered to be an option for CO_2 reduction [3]. These changes are essential to build awareness of sustainable lifestyles and the synergies between policy, technology, and ethical imperatives. It is expected that sustainable lifestyles, as one of the carbon mitigation measures, would contribute to carbon reduction and mitigate climate change.

Personal carbon trading (PCT) has been generally regarded as a potentially powerful and innovative policy instrument to reduce carbon emissions at the individual and household level and promote low-carbon lifestyles. The concept of PCT was first proposed by Fleming in 1996 [7]. In recent years, at national government level, it has aroused great interest and considerable discussion in the UK where government aims to achieve a legally binding emissions reduction target of an 80% cut by 2050 relative to the 1990 level [8]. PCT is usually seen as a variety of the downstream "cap and trade" policies that allocate rights and responsibilities for carbon emissions from the household energy use. In a PCT scheme, each consumer would be allocated with an initial allocation of

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carbon allowances based on carbon reduction targets, which could be used alongside traditional money, to cover the consumer's emissions associated with the consumption of energy commodities, such as gas, coal, and electricity. Such allowances could also be traded between consumers. The over-emitters who emit more than their initial allowances have to buy extra allowances from the under-emitters who emit less than their allowances allocated. The demand and supply of allowances, which would be influenced by initial allowance allocation, energy emission rate, energy price and so on, will determine their price [9].

As a market-based approach to internalize environmental externalities at the level of personal emissions, PCT scheme provides a pricing mechanism for carbon emissions and a market for trading allowances. Specifically, allowance price enhances the cost of a high-carbon lifestyle and can pass through a more direct signal to reduce carbon emissions. The higher the allowance price, the more the consumers would be willing to shift from carbon intensive energies to less carbon intensive ones [10,11]. Therefore, the carbon allowance price plays a critical role to affect consumers' consumption decision making, especially the decision of energy consumption.

Considering the importance of the allowance price, it is essential to explore its effect on consumers' energy demand which reflects the effectiveness and efficiency of the PCT scheme to reduce carbon emission. In a PCT scheme, carbon allowances could be viewed as a form of complementary currency (CC) which could be used to solve some environmental problems that conventional currency cannot address directly [12]. Since allowances and energy can be treated as complementary goods, the allowances could be used either for supporting energy consumption or for being exchanged for money to generate a benefit [13]. When allowance price changes, the opportunity cost of selling allowances and the purchasing cost of energy consumption will change. How would consumers with different income respond to the allowance price changes? Would consumers' responses in the short-run be different from those in the long run? These questions are investigated for the first time in this paper. The empirical exercises are conducted by using a constant elasticity of substitution (CES) utility function. The paper thus fills the void in the literature.

The remainder of the paper is organized as follows. Section 2 provides a literature review. Section 3 introduces a theoretical model to obtain the formulae of the price effect, substitution effect and income effect under the PCT scheme. Section 4 evaluates the parameters of the model. Sections 5 and 6 present the results, discussion and sensitivity analysis. Finally Section 7 concludes the paper and points out the implication and limitations of the results.

2. Literature review

The potential for the introduction of PCT at individual or household level has attracted much attention in both academic research and policy making. For example, in 2010, the *Climate Policy* journal devoted a special issue to PCT scheme with ten articles. Most studies in the existing literature focused on scheme design, implementation, distributional effects, its comparison with other emission reduction instruments such as carbon tax (CT) and upstream trading scheme [8,14–17].

Under a PCT scheme, a key issue discussed by researchers is how the initial allowance allocation to consumers is carried out [16]. There are two basic choices for supplying initial allowance to individuals or households. The first choice is that allowances are allocated for free and the second one is that allowances would be auctioned. From the perspective of economic efficiency, it is often deemed to be more efficient if initial allowances are auctioned, rather than issued free of charge [18]. Many researchers however believed that the problems of political and social acceptability would be minimized through the way of free allocation of allowances, because it allows individuals or households to consume a certain amount of energy without bringing about any additional cost. Generally speaking, PCT is based on the egalitarian principle of equity [19], which is inspired by the international carbon reduction proposal of 'contraction and convergence', that is, everyone has an equal right to emit greenhouse gases [20]. Current studies on PCT were mainly based on the assumption of equal per capita or household allocation (usually free) as their analytical starting point. In this paper, we adopt the same assumption.

Some authors have compared PCT with the existing policy instruments in practice, such as carbon taxes and upstream trading schemes [21]. Weitzman [22] argues that taxes and tradable permits are theoretically equivalent in terms of efficiency and effectiveness. However, a carbon tax policy is a price-based environmental regulation which fixes the allowance price and lets the market determine the amount of carbon emissions emitted, while a PCT scheme is mainly a quantity-based instrument which fixes the quantity emitted and lets the allowance price be determined by the market. It is argued that, if there is uncertainty over the cost function, it is better to fix the price through a tax policy, and if there is uncertainty over the damage function, fixing the quantity through a trading system is more appropriate [23,24]. In the context of climate change, the damage function is uncertain due to the time lag between emissions and their effect on the environment, and potentially catastrophic impacts of missing abatement targets [16].

One of the merits of price based regulation, such as the carbon tax, is the simplicity and ease of implementation and administration [25]. A government can directly set the level of a tax, while it cannot set in advance the allowance price in a PCT scheme. The price signal of carbon taxes is certain, and the price response function of consumers associated with the amount of reductions is determined by the elasticity of energy demand. According to the price elasticity of energy demand,[1] carbon tax can be designed to obtain significant reductions in carbon emissions from the residential sector [25]. However, the tax rate is the same for all consumers. Therefore, this scheme is regressive because lower income households are paying proportionately more than higher income households [26]. In contrast, the PCT scheme which combines economic incentives and quantity control is believed to be progressive [27]. In a PCT scheme, everyone could obtain a certain amount of equal allocation of allowance free of charge, which represents the characteristic feature of equity [28]. Some have argued further that, since low-income consumers tend to emit less carbon than high-income ones, low-income consumers could obtain extra income by selling their unwanted carbon rights to those more wealthy in the market [18].

When comparing upstream trading scheme with downstream trading scheme, it is common to discuss the difference between them. Upstream trading schemes could be more transparent, simpler, cheaper, and quicker to implement in practice [29]. In an upstream trading scheme, the allowances are allocated to fuel suppliers and importers [30]. Nowadays, the world's biggest upstream emission trading scheme is European Union emission trading scheme (EU ETS), which covers emissions from energy-intensive industries [31]. Under this scheme, the cost of purchasing allowance will affects the cost of energy or some other goods supplied to consumers. Companies will seek to pass-through this costs to the consumers by building it into fuel price [30,31]. Moreover, many studies show that the effective pass-through rate of carbon

[1] Price elasticity values vary between −0.3 for the short-term and −0.7 for the long-term [27].