Researches on the Effect of Environmental Policy on Abatement Technology Adoption

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Abstract. To cope with global climate change, a growing number of countries have formulated carbon neutrality schedules. In this context, it is increasingly important for governments to design and implement the policy package to achieve this goal. This paper studies on the economic incentives of environmental policy on firms' investment in the adoption of new abatement technologies, providing policymakers with more understandings and facilitating the improvement in policy development. The main findings are as follows. First, the economic incentive of environmental policy on abatement technology adoption is ambiguous and it changes with different realistic conditions. Second, the behavior of firms' investment decisions for different types of abatement technologies under the same environmental policy is distinct. Third, the level of privatization has a positive incentive effect on the level of the abatement technology under taxes regulation. Finally, some key research questions for the future are provided.

1. Introduction

To cope with global climate change, a growing number of countries have formulated carbon neutrality schedules. In this context, it is increasingly important for governments to design and implement the policy package to achieve this goal. In fact, policy evaluation and choice has become an unavoidable issue that has attracted extensive attention from scholars. The economic incentives providing by an environmental policy for firms' investment in the adoption of new abatement technologies is an important evaluation criterion [1]. In general, market-based instruments such as emission trading schemes (ETS) are more likely to be preferred by policymakers than command-and-control instruments such as emission standards [2-5]. However, it should be noticed that this point does not hold in all cases. There is no doubt that different countries or regions implement different types of environmental policies. The findings vary depending on the focus of the study.

Furthermore, the investment behaviours of firms regarding different emissions abatement technologies under the same environmental policy are distinct [6-8]. Hence, the impact of environmental policies on low-carbon technology investment is still unresolved and the key findings are controversial. Moreover, it is necessary to consider the emission reduction heterogeneity of different low-carbon technologies when study this issue. Therefore, it is worthwhile to examine the economic incentives of environmental policy on firms' investment in the adoption of new abatement technologies, providing policymakers with more understandings and facilitating the improvement in policy development.

2. Researches on environmental policy choice

The economic incentives of environmental policy on the adoption of new abatement technologies have been extensively studied in the environmental economics literature. According to the differences in research focus, the research literature can be broadly classified into three main categories, see Table 1.

Table 1. Environmental policy choice

	The product market		The behavior of policymakers		Uncertainty
Important factor	Minimizing abatement costs	Maximizing profits	The myopic behavior	The forward-looking behavior	Technological uncertainties
Optimal policy	Emission taxes; ETS with allowance auction	ETS; Emission standards	Emission taxes	ETS with allowance auction	It depends on the policy stringency

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2.1 The product market

Initially, scholars usually do not consider the product market and studied the economic incentives of environmental policy on the adoption of new abatement technologies with minimizing the total of abatement costs [2, 3, 9-11]. The optimal problem can be described as follow.

$$\min_{e} \ ac(e)+cp(e), \tag{1}$$

in which e denotes the final emission level of the firm, $ac(e)$ is the abatement cost function and $cp(e)$ is the compliance cost function. For example, from an industry perspective, the effects of different abatement policies on the adoption and diffusion of new technologies are evaluated and performance standards were the least significant [10]. However, ETS with allowances banking are not necessarily the most economic incentive for firms to invest in technology adoption [11].

Subsequently, the product market is also included in the model framework with maximizing profits [4, 5, 12-15]. Then, the optimal problem can be described as follow.

$$\max_{q,e} \ p(q)\cdot q-c(q)-ac(q,e)-cp(q,e), \tag{2}$$

where q , e denotes the output level and the final emission level of the firm respectively, $p(q)$ is the inverse demand curve, $c(q)$ is the production cost function, $ac(q,e)$ is the abatement cost function and $cp(q,e)$ is the compliance cost function. For example, Compared to emissions taxes, ETS is more effective in triggering the adoption of clean technologies in coal power plants [13]. Considering the firm size, emission standards are more favorable for small firms to adopt new technologies [15].

2.2 The behaviour of policymakers

The expected behaviour of policymakers regarding the new technology is an important factor influencing technology adoption [16-18]. The economic incentives of environmental policy on the adoption of new abatement technologies may lead to completely opposite conclusions from the point of ex-ante regulation and ex-post regulation. Under ex-ante regulation, governments just take into account the current set of available abatement technologies and do not change the policy level to cope with the advanced abatement technologies in the future. On the contrary, the far-sighted government considers the set of advanced abatement technologies and sets the more stringent policy level under ex-post regulation.

Under ex-ante regulation, emission taxes provide the greatest economic incentive for firms to make the abatement technology investment decision, while emission taxes and ETS have the same incentive effect in the ex-post regulation [16]. Furthermore, the allowances allocation method has no effect on technology adoption [16]. However, under the ex-post regulation, ETS with allowance auctions are more economic incentive for firms to make the abatement technology investment decision than emission taxes when the strategic behaviour among firms is considered [17]. Moreover, the mixed emission reduction mechanism policies are better than the single mechanism [18].

2.3 Uncertainty

Generally, the uncertainties mainly include three different types including economic uncertainty, policy uncertainty and technological uncertainty. In general, the technological progress can be described as a Poisson process. The parameter δ follows a jump process, which reflecting the abatement efficiency of the technology. That is, $d\delta$ is equal to μ with probability λdt and the density function $f(\mu)$ is express as follow.

$$f(\mu)=\begin{cases}1/\bar{\mu}, & 0<\mu<\bar{\mu},\\ 0, & otherwise.\end{cases} \tag{3}$$

That is, the more advanced a new abatement technology is, the larger the parameter δ .

Most of the existing literature does not take into account the realistic context of technological uncertainties. If the arrive time of new technology is unknown, non-tradable quotas can encourage firms to adopt the energy-saving technology earlier than taxes under the low levels of environmental stringency, while the opposite conclusion holds for high levels of environmental stringency [19]. On this basis, ex-ante and ex-post regulation are included in the research framework, the economic incentives of taxes and tradable permits on the adoption of new abatement technologies are studied [20]. However, for the end-of-pipe abatement technology, emission standards can encourage firms to make investment decision earlier than taxes under the high levels of environmental stringency, while the opposite conclusion holds for low levels of environmental stringency [21].

3. Summary and Analysis

3.1 Summary

From the above review, several conclusions can be obtained as follows. First, in terms of research trends, the study on the economic incentives of environmental policy on technology adoption are getting closer to the actual situation and the models are relatively complex. Second, in terms of research results, the economic incentives of environmental policy on firms' investment in the adoption of new abatement technologies are ambiguous and it changes with different realistic conditions. Third, the behavior of firms' investment decisions for different types of abatement technologies under the same environmental policy is distinct.

Therefore, the effect of environmental policy on abatement technology adoption deserves quantitative analysis in depth. To provide a theoretical basis for precise abatement policy design, the work should define the research boundary, distinguish the types of abatement technologies, and construct corresponding mathematical models. The key research questions for the future are as follows. First, the majority of previous studies ignore the non-competitive market structure in high energy-intensive industries. Hence, it is worthwhile to study the effect of market power in the carbon market on policy choice. Second, the majority of the existing literature assumes that firms are risk neutral. Hence, it is worthwhile to study the effect of firms' risk preference on policy choice. Third, Most of the existing literature assumes that the firm maximizes its own profits and does not consider the property right of firm. However, with the development of mixed ownership reform, most of China's energy-intensive industries are composed of state-owned firms and private firms [22]. The state-owned firm usually maximizes social welfare while the private firm maximizes its own profits [23]. Hence, it is worthwhile to study the effect of firms' property rights on policy choice and a limited number of scholars focus on the issue. In a mixed economy, emission quotas regulations are selected by policymakers [24]. Emission standards will bring a greater social welfare than emission taxes under low levels of environmental stringency, while the opposite conclusion holds for high levels of environmental stringency [25].

3.2 Numerical analysis

This subsection brief shows the effect of firms' property rights on technology adoption under taxes regulation. The level of privatization parameter k denotes the property right of a firm. The higher the level of privatization of the public firm is, the larger the associated parameter, k . Considering an industry consisting of one representative public firm denoted by firm 0 and one representative private firm denoted by firm 1, each firm produces a homogeneous good. The product demand function is given by $p(Q)=10-q_0-q_1$, the production cost function is shown as $c(q_i)=q_i$, the technology adoption cost function is equal to $10\beta_i^2$ and the implemented policy stringency is measured by the tax rate (τ=2.5).

The strategic behaviors between firm 0 and firm 1 are described by the following two stage mechanism. In the investment stage, each firm makes technology adoption decision. Each firm chooses what type of advanced abatement technology to invest in, taking into account its own objective and its competitor's strategic behaviour. In the emission stage, each firm makes the output and emissions decisions to maximize its own object. The results are shown in Figures 1 and 2. First, it shows that the level of privatization has a positive incentive effect on the level of the abatement technology. That is, the higher the level of privatization, the more advanced the abatement technology in which the firm investment. Second, as the level of privatization increases, the emission levels between firm 1 and firm 2 gradually decreases.

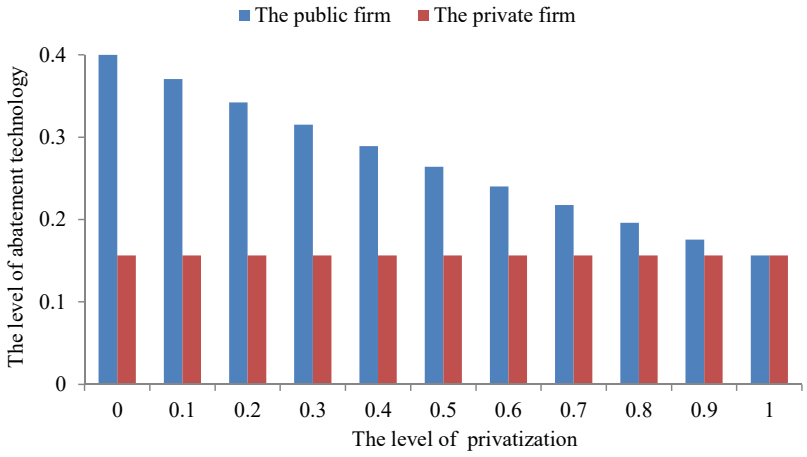

Figure 1. The level of privatization and the level of abatement technology

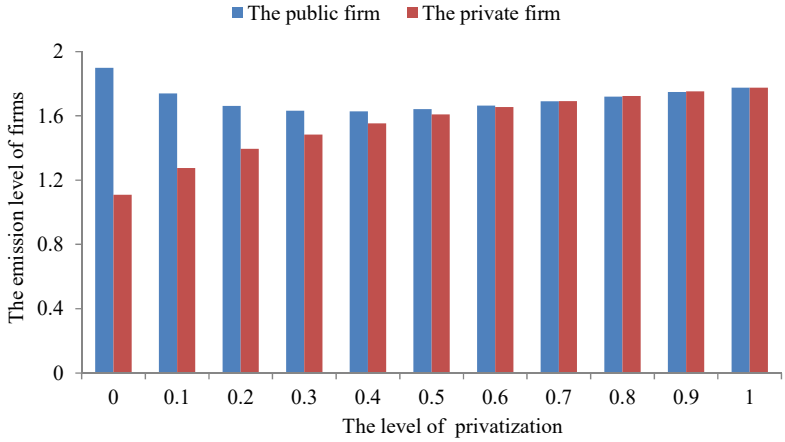

Figure 2. The level of privatization and the emission level

4. Conclusion

In the face of increasingly severe pressure on energy conservation and emission reduction, how to motivate firms to invest in new technologies, accelerate the diffusion of emission reduction technologies, and ensure the implementation of emission reduction policies is an addressed urgently issue. This is an issue that cannot be avoided when governments formulate the long-term energy and economic development strategic goals. Hence, identifying the impact of emission reduction policies on technology adoption and emission reduction behavior in different environments and providing a theoretical basis for precise policy design is the key to solving this issue.

This paper reviews on the economic incentives of environmental policy on firms' investment in the adoption of new abatement technologies, providing policymakers with more understandings and facilitating the improvement in policy development. The main findings are as follows. First, the economic incentive of environmental policy on abatement technology adoption is ambiguous and it changes with different realistic conditions. Second, the behavior of firms' investment decisions for different types of abatement technologies under the same environmental policy is distinct. Third, the level of privatization has a positive incentive effect on the level of the abatement technology under taxes regulation. Finally, to provide decision references for precise policy design and achieve the carbon neutrality goal, the research gap is pointed out and some key research questions for the future are developed. It is worthwhile to study the effect of some critical factors, such as the market structure, firms' risk preference and property rights, on policy choice.

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