The Effect of Consumers' Environmental Awareness on Business Operations Management

Bingxin Zeng(✉), Qian Zhang, Liyu Xia, Guangrui Tang, Jiaxu Chen, and Wenhao Zhu

State Grid Energy Research Institute Co., Ltd., Beijing, China
zengbingxin@sgeri.sgcc.com.cn

Abstract. The technology adoption decision has always been the core issue of business operation management. Consumers are increasingly concerned about the low-carbon attributes of products and the market demand is gradually affected by consumers' environmental awareness. Then firms' technology investment decision might be affected and its result is ambiguous. This paper examines the effect of consumers' environmental awareness on business operations management. This paper constructs a two-stage model to describe firms' decision-making and finds that consumer preference for low carbon will encourage firms to invest in a more advanced abatement technology. Moreover, for the same sensitivity factor of consumers to carbon reduction, a more stringent environmental policy induces a more advanced abatement technology adoption. Furthermore, the sensitivity factor of consumers to carbon reduction plays a greater role on technology choice in the high level of environmental stringency. Finally, some policy implications and key research directions for the future are provided.

Keywords: production operations management · consumers' environmental awareness · technology adoption

1 Introduction

The technology adoption decision has always been the core issue of business operation management. Nowadays, a growing number of countries have formulated carbon neutrality schedules. In fact, technological innovation is considered the primary solution to environmental problems [1, 2]. Hence, the issue of low-carbon operations management and emissions abatement technology adoption in firm is receiving increasing attention.

It is well known that the key point of the environmental policy design is the extent to which it provides economic incentives for the adoption of new abatement technology. The impact of environmental policy on the adoption and diffusion of new technologies has attracted extensive attention from scholars. However, most previous studies do not take into account consumers' environmental awareness. In recent years, consumers pay more attention to the environmental friendliness of products and are willingness to pay for low-carbon products [3–5]. Moreover, the market demand is also gradually affected by consumers' environmental awareness. Then, firms' technology investment decision

V. Gaikar et al. (Eds.): FMET 2022, AEBMR 227, pp. 786–792, 2023.
https://doi.org/10.2991/978-94-6463-054-1_85

might be affected and its result is ambiguous. On one hand, to enhance market competitiveness and capture more market share, firms are willing to invest in more advanced abatement technologies. On the other hand, the more advanced the emission reduction technology, the higher the investment cost. Thus firms need balance costs and benefits. Therefore, it is worthwhile to study on the effect of consumers' environmental awareness on abatement technology adoption, providing policymaker more understandings and facilitating the improvement in policy design.

2 Literature Review

The effects of environmental policy on abatement technology adoption have been extensively studied in the environmental economics literature. Initially, the product market is usually not taken into consideration and scholars assume that the firm's objective is to minimize the total of abatement costs [6–8]. 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 [7]. Subsequently, the product market is also included in the model framework with maximizing profits [9–13]. Compared to emissions taxes, ETS is more effective in triggering the adoption of clean technologies in coal power plants [11]. Considering the firm size, emission standards are more favourable for small firms to adopt new technologies [12].

In the meanwhile, the expected behaviour of policymakers regarding the new technology is also considered [14, 15]. Compared with the myopic regulation, the level of the environmental policy will be tighter under ex-post regulation. Under the ex-post regulation, ETS with allowance auctions are more incentive for firms to adopt new technologies than emission taxes [15]. Additionally, a small amount of literature focuses on the technological uncertainties environments [16, 17]. The effect of emission taxes and standards on the adoption of end-of-pipe abatement technology is investigated when the arrival time and degree of improvement of the new technology are uncertain [17]. Moreover, the mixed emission reduction mechanism policies are better than the single mechanism [18].

Furthermore, some scholars have study the effect of property rights on police choice [19–21]. Compared with emission taxes regulations, emission quotas regulations are selected by policymakers in a mixed economy [19]. Moreover, the superiority of the emission tax over the uniform emission quota depends on the parameters of the cost functions [20]. In the aspect of bringing about greater social welfare, the ranking of emission taxes and standards depends on the policy stringency [21].

However, the existing research about the effect of environmental policy on abatement technology adoption barely considers consumers' environmental awareness. The consumers' environmental awareness is more taken into account in the supply chain management literature. For example, the relationship between consumers' environmental awareness and competition intensity levels on the supply chain players is discussed [5]. The impact of consumers' environmental awareness on order quantities and channel coordination is examined [22]. In a one-manufacturer and one-retailer supply chain, the impacts of consumers' environmental awareness on environmental quality are studied [23].

From the above review, to fill the gap, this paper focuses on the effect of consumers' environmental awareness on business operations management abatement technology adoption.

3 The Model

3.1 Model Description

Considering a perfect monopoly market, the linear inverse demand function is given by

$$p = A - bq + ka \tag{1}$$

where q and a denote the output level and the abatement level of the firm, respectively. The positive parameter $k(0 < k < 1)$ is the sensitivity factor of consumers to carbon reduction. In the absence of environmental regulation, each unit of output generates a unit of emission. Hence, the final emission after abatement is expressed as $e = q - a$.

Under emissions taxes regulation, the regulator set a uniform tax τ to control the emission level of firm. The decision-making of the firm can be decried two-stage model. In stage 1, the firm need decide to choose which abatement technology to invest in. In stage 2, given the abatement technology level, the firm chooses its output and abatement level to maximize its profit. The two stages mechanism is introduced by backward.

In stage 2, the profit function of the firm is given by

$$\pi = (p - c)q - \tau(q - a) - \frac{a^2}{2m} \tag{2}$$

where c is the marginal production cost and the abatement cost function is expressed as $\frac{a^2}{2m}$. The positive parameter m denotes the abatement technology level. The more advanced the abatement technology, the larger positive parameter m.

According to the first order conditions (FOCs), we have the following equations:

$$q = \frac{A - c - (1 - km)p}{2b - k^2 m} \tag{3}$$

$$a = \frac{(A - c)km + (2b - k)mp}{2b - k^2 m} \tag{4}$$

By substituting Eqs. (3) and (4) for Eq. (2), the firm's profit function $\pi(m)$ can be obtained.

In stage 1, the objection function $ob(m)$ of the firm is given by

$$ob(m) = \pi(m) - \gamma \cdot m^2 \tag{5}$$

where γ is the positive investment cost coefficient.

According to the FOC, i.e., $\partial ob/\partial m = 0$, the nonlinear equation of the parameter m can be obtained. By solving a nonlinear equation in MATLAB with the parameter values given, the parameter m is not difficult obtained.

Then, the output level q and the abatement level a are solved, respectively.

Table 1. Parameters used in the numerical analysis

Parameters	Description	Values
A	The market demand	10
b	The market demand elasticity	1
k	The sensitivity factor of consumers	(0, 1)
c	The marginal production cost	1
γ	The investment cost coefficient	0.5
τ	The low level of environmental policy stringency	2
	The medium level of environmental policy stringency	5
	The high level of environmental policy stringency	8

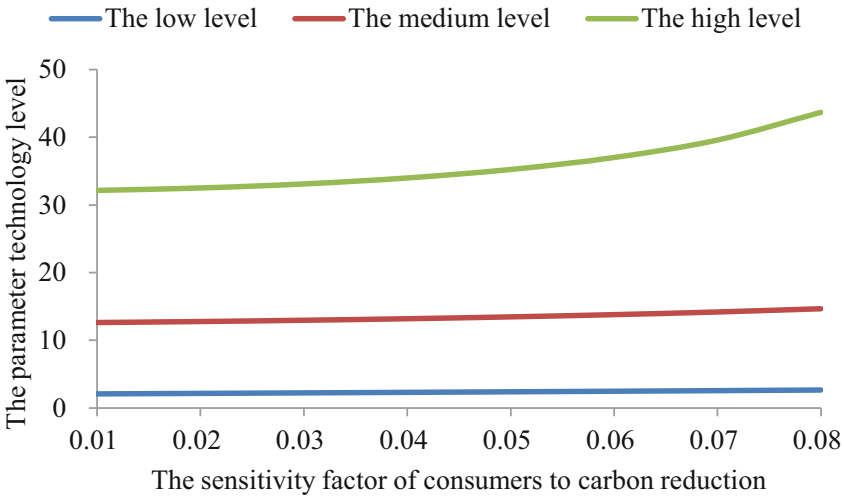

Fig. 1. Consumers' environmental awareness and technology adoption

3.2 Numerical Analysis

The linear inverse demand function is given by $p = 10-q+ka$. The marginal production cost $c = 1$ and the investment cost coefficient $\gamma = 0.5$. Considering the effect of levels of environmental policy stringency on the result, three policy level scenarios are discussed. The greater stringency of the environmental policies is measured by higher taxes. Hence, the low level of environmental policy stringency ($\tau = 2$), the medium level of environmental policy stringency ($\tau = 5$) and the high level of environmental policy stringency ($\tau = 8$) are provided.

Table 1 describes all the parameters used in the numerical analysis and the numerical results are shown in Fig. 1.

The following conclusions can be drawn. First, consumer preference for low carbon will encourage firms to invest in a more advanced abatement technology. This point

holds for three levels of environmental stringency. Second, for the same sensitivity factor of consumers to carbon reduction, a more stringent environmental policy induces a more advanced abatement technology adoption. Third, compared the low level of environmental stringency, the sensitivity factor of consumers to carbon reduction plays a greater role on technology choice in the high level of environmental stringency.

4 Conclusion

The abatement technology adoption decision has been the core issue of low-carbon business operation management, because a growing number of countries have formulated carbon neutrality schedules. Moreover, consumers are increasingly concerned about the low-carbon attributes of products and the market demand is gradually affected by consumers' environmental awareness. This paper examines the effect of consumers' environmental awareness on abatement technology adoption, providing policy makers with more understanding and insight on low-carbon operations management.

Through a theoretical analysis and numerical simulation, three main conclusions are drawn. First, consumer preference for low carbon will encourage firms to invest in a more advanced abatement technology. This point holds for three levels of environmental stringency. Second, for the same sensitivity factor of consumers to carbon reduction, a more stringent environmental policy induces a more advanced abatement technology adoption. Third, compared the low level of environmental stringency, the sensitivity factor of consumers to carbon reduction plays a greater role on technology choice in the high level of environmental stringency. Therefore, to accelerate the green and low-carbon transition and achieve the carbon neutrality goal, the policymaker need consider consumers' low-carbon preference in policy design.

Finally, in terms of mathematical tractability, there are several limitations in the model. First, the assumption of a perfect monopoly market might be rigorous and the oligopolistic market is more relevant for research. Second, the expected behavior of policymakers and technological uncertainties could be considered. These points are the main suggestions for future research.

Acknowledgement. The authors gratefully acknowledge financial support from the science and the technology project of State Grid Energy Research Institute (SGNY202112007). All remaining errors are the sole responsibility of the authors.

References

1. Weber T. A., Neuhoff K. (2010) Carbon markets and technological innovation. J. Environ. Econom. Management, 60(2), 115-132.
2. Ambec S., Coria J. (2013). Prices vs quantities with multiple pollutants. J. Environ. Econom. Management, 66(1), 123-140.
3. Laroche M., Bergeron J., Barbaro-Forleo G. (2001). Targeting consumers who are willing to pay more for environmentally friendly products. J. Consumer Mkt., 18 (6), 503–520.

4. Chitra K., (2007). In search of the green consumers: a perceptual study. J Serv Res., 7(1), 173-191.
5. Liu Z., Anderson T. D., Cruz J. M. (2012). Consumer environmental awareness and competition in two-stage supply chains. Eur. J Oper. Res., 218(3), 602-613.
6. Requate T. (1995) Incentives to adopt new technologies under different pollution-control policies. Int. Tax Public Finan., 2(2):295-317.
7. Jung C., Krutilla K., Boyd R. (1996) Incentives for advanced pollution abatement technology at the industry level: An evaluation of policy alternatives. J. Environ. Econom. Management, 30(1):95-111.
8. Phaneuf D. J., Requate T. (2002) Incentives for investment in advanced pollution abatement technology in emission permit markets with banking. Environ. Resour. Econ., 22(3):369-390.
9. Montero J. P. (2002) Permits, standards, and technology innovation. J. Environ. Econom. Management, 44(1):23–44.
10. Coria J. (2009) Taxes, permits, and the diffusion of a new technology. Resour. Energy Econ., 31(4):249-271.
11. Chen Y., Tseng C. L. (2011) Inducing clean technology in the electricity sector: tradable permits or carbon tax policies?. The Energy J., 32(3):169-174.
12. Endres A., Rundshagen B. (2013) Incentives to diffuse advanced abatement technology under the formation of international environmental agreements. Environ. Resour. Econ., 56(2):177-210.
13. Coria J., Kyriakopoulou E. (2018) Environmental policy, technology adoption and the size distribution of firms. Energy Econ., 72:470-485.
14. Requate T., Unold W. (2003) Environmental policy incentives to adopt advanced abatement technology: Will the true ranking please stand up?. Eur. Econ. Rev., 47(1):125-146.
15. D'Amato A., Dijkstra B. R. (2018) Adoption incentives and environmental policy timing under asymmetric information and strategic firm behaviour. Environ. Econ. Policy Studies, 20(1):125-155.
16. Van Soest D. P. (2005) The impact of environmental policy instruments on the timing of adoption of energy-saving technologies. Resour. Energy Econ., 27(3):235-247.
17. Zeng B. X., Zhu L., Yao X. (2020) Policy choice for end-of-pipe abatement technology adoption under technological uncertainty. Econ. Modell., 87:121-130.
18. Weber T. A., Neuhoff K. (2010) Carbon markets and technological innovation. J. Environ. Econom. Management. 60(2), 115-132.
19. T. Naito, H. Ogawa (2009) Direct versus indirect environmental regulation in a partially privatized mixed duopoly. Environ. Econ. Policy Stud., 10, 87-100.
20. Kato, K. (2011) Emission quota versus emission tax in a mixed duopoly. Environ. Econ. Policy Stud., 13(1), 43-63.
21. Zeng B. X., Dai G. Q., Liu J. (2021) Taxes versus standards in a mixed economy. CCGEES 2020, 228.
22. Zhang L. H., Wang B, J., You J. C. (2015) Consumer environmental awareness and channel coordination with two substitutable products. Eur. J Oper. Res., 241(1), 63-73.
23. Zhang L., Zhou H., Liu Y., Lu R. (2019) Optimal environmental quality and price with consumer environmental awareness and retailer's fairness concerns in supply chain. J. Clean. Prod., 213, 1063-1079.