THE OPTIMAL PRINCIPAL-AGENT MODEL FOR THE CO_2 ALLOWANCE ALLOCATION UNDER ASYMMETRIC INFORMATION

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Overview

Contract theory has been widely used in many field including finance, supply chain, taxation, government regulation and so on. This paper presents a study of CO_2 allowance allocation problems under asymmetric information, using contract theory as a regulatory tool for the government to evaluate the emission rate level of the firm, which the government as a principal will offer a menu of contract with allowance allocation rate ans a certain amount of emission reduction for the firm to control CO_2 emissions while the firm as an agent endowed with private information about its emission rate that the government cannot fully observe. An optimal principal-agent model for the allowance allocation problem is then developed with the purpose of maximizing the social welfare with the incentive compatibility and participation constraint. Furthermore, the equivalent form is given to solve the proposed model and a special case was provided, where the variation of allowance allocation rate has finite first-order derivatives. An application in electricity industry demonstrates that the allocated allowances and CO_2 emissions are low when asymmetric information is considered indicating that offering different contracts to different reported emission rate is beneficial to the environment whereas most allowances will be wasted when the private information is omitted. In addition, the proposed principal-agent model provides a useful illustration of how the allowance is allocated to the firm and how to define the contract combining allowance allocation rate with emission reduction in a bid to reduce environmental damage. Moreover, the sensitivity analysis shows that a higher carbon price leads to a lower allowance allocation rate and emission reductions under complete information but an opposite result for emission reduction under incomplete information. The changes of variation on allocation rate and the coefficient of emission abatement cost indicates the similar trend whether for allowance allocation rate or emission reductions. It is relevant to decision makers with the goal of maximizing social welfare and less environmental damage. This study not only point out an allowance allocation method for policy makers when the private information is taken into consideration, but may also provide a reference for allowance allocation and emission reduction when the relevant markets change.

The paper is organized as follows: In Section 2, the problem on allowance allocation is described and the principal-agent hybrid policy model is developed under different conditions. In section 3, the equivalent formulation of the model is presented; and the optimal allocation rate and emission reduction are obtained by means of applying the contract theory. In section 4, an empirical example is provided to analyze the proposed model and to analyze the results obtained in the previous sections. Concluding remarks are provided in the section 5.

Methods

A principle-agent model is considered between two key players: a profit maximizing-firm (the agent) and a social welfare-maximizing government (the principal) in this study. The incentive compatible constraint and participation constraint in the contract theory will be used to solve the optimal allowance allocation. A numerical study using representative data from the electricity industry is conducted to illustrate the analytical results.

Results

First, under incomplete information, some propositions can be obtained:

- The optimal allowance allocation rate depends on the actual emission rate of the firm. In other words, the lower the firm's actual emissions rate is, the higher allowance allcoation rate it can obtain.
- The allocated allowance is a quadratic function of the optimal output and the stationary point of the firm's allowance can also be obtained.

Second, when compare the two scenarios, we can also get some other results:

- The optimal allocated allowance rate and emission reductions decrease with the increase in emission rate. And they are higher under complete information than that under incomplete information. This may be due to, on the one hand, the high output under complete information and on the other hand, the contract combination of allowance allocation rate and emission reductions will lessen emission reductions.
- The actual CO_2 emissions shows a growth pattern as the emission rate increases. Moreover, when the emission rate is relatively small the firm's CO_2 emission are larger under incomplete information than that under complete information. By contrary, when the emission rate exceeds a certain level, the emissions under incomplete information become much lower than the emissions under complete information. This indicates an encouraging sign when the private information is considered.

- The environmental damage presents a decline trend with the increase of the allowance due to the growth of emission reduction as well as reduction of actual emissions. This indicates a necessity to take the private information into consideration and to provide different contracts for the firms according to their reported emission rate in order to stimulate emission reduction.

Third, from the sensitivity analysis, more results can obtained:

- There is no correlation between the allowance allocation rate and carbon price under incomplete information. And the allowance allocation rate becomes less with the increase of carbon price under complete information. However, the higher carbon price is, a smaller emission reduction is achieved when the emission rate is below a certain level under incomplete information.
- The effects of variation of allowance allocation rate on allocation rate and emission reductions show a similar trend. The higher the variation of allowance allcoation rate, the less allocation rate and emission reduction is.
- The change of emission abatement coefficient has nothing to do with the allowance allocation rate under incomplete information. The allowance allocation rate gradually decreased with the increase of this coefficient under complete information.

Conclusions

It is recognized that emission trading is cost-effective instrument to deal with environmental issues. Allowance allocation presents one of most critical issues during the policy design in emission trading. In the real world, the private information is not necessarily communicated between the government and the firms. These two parties have different objectives, i.e. the government allocates the carbon allowances to maximize the social welfare and to reduce environmental damage whereas the firm aims to maximize its profits without considering the emission damage. Such asymmetric information presents a significant challenge to the policy making on emission trading. In this research, a CO_2 allowance allocation method was developed by applying contract theory. The government makes decisions on allowance allocation rate and offers the contract on allowance allocation and emission reductions. Then the firm chooses the appropriate contract and decide its output.

The results show that offering different contract with different reported emission rate is beneficial to the environment whereas most allowances will be wasted if the private information is omitted. In addition, this research developed a principal-agent model to illustrate an effective approach to allocate the allowance to the firm and to develop the contract combining allowance allocation rate with emission reductions so that reduce environmental damage can be reduced. This research only considered the perfectly competitive market. Further research opportunities exist to examine the effects of other factors on the behaviors of individual firms in the proposed principal-agent model.

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