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Climate game analyses for CO_2 emission trading among various world organizations

Pei-Ing Wu [a,*], Chai Tzu Chen [b,1], Pei-Ching Cheng [a,2], Je-Liang Liou [c,3]

[a] Department of Agricultural Economics, National Taiwan University, No. 1 Section 4 Roosevelt Road, Taipei 106, Taiwan
[b] Agriculture Department, New Taipei City Government, 22F No. 161 Section 1 Zhongshan Road, Banqiao District, New Taipei City 22001, Taiwan
[c] The Center for Green Economy, Chung-Hua Institution for Economic Research, No. 75 Chang-Hsing Street, Taipei 106, Taiwan

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ABSTRACT

This paper simulates the saving in terms of the total abatement cost of CO_2 emission reductions for different trading games reflecting the potential cooperation among organizations including the European Union (EU), the Asia-Pacific Economic Cooperation (APEC) countries, the Union of South American Nations (USAN), and the Indian Ocean Rim Association for Regional Cooperation (IOR-ARC). A game approach is conducted to determine if the cooperation will come into existence among the organizations stated above. A similar idea is applied to the four largest emission countries, China, the United States, Russia, and India, as four individual players in the trading game.

Joining the market is the strictly dominant strategy for any organization from the results. The Nash equilibrium shows that, regardless of the organizations that have already existed in the market, joining the market is always the best policy for the remaining organizations which are currently not in the market. Similarly, India likes the organization to which it belongs, i.e. IOR-ARC, to trade with the EU and APEC, and the U.S. wants the organization to which it belongs, i.e., APEC, to cooperate with the organizations USAN and IOR-ARC. However, China and Russia prefer trading with other countries within their own organizations.

1. Introduction

The design and selection of policy instruments for increasing the incentive for each country to participate are normally the keys to the success of agreements such as that to reduce emissions of carbon dioxide (CO_2) internationally. Theoretically, the incentive can be based on a comparison of the costs and benefits of a specific policy instrument. The highest incentive will be the one that generates the highest net benefit for achieving the committed target. However, empirically computing the net benefit from the policy is normally difficult to achieve. As such, searching for the lowest cost, i.e., employing a cost-effectiveness approach to achieve the designed and committed target or generate the highest saving in terms of the total abatement cost (TAC) both with and without participating in the arrangement, becomes a pragmatic substitute.

According to the literature, there are three types of factors that affect the formation of incentive structures for the emission reduction commitment under an emission trading scheme.[4] The first relates to the number of countries joining the agreement (Eyckmans and Kverndokk, 2010). The second concerns the allocation of initial rights. The third has to do with the coalitions that the countries form. Different combinations of these factors affect the marginal abatement cost (MAC) for all the countries joining the commitment array (Berk and den Elzen, 2001; Fletcher, 2001; Haites and Yamin, 2000; Maradan and Vassiliev, 2005).

There are two issues regarding the number of countries joining in the agreement. One concerns the number of countries making up the emission reduction commitment and the other the number of countries joining in the emission trading market. Due to the cross-country nature and trans-boundary characteristics of CO_2 emissions, the consequences of cumulative CO_2 emissions are usually not borne by the countries that emit them. As a result, a free-rider problem exists. To fulfill the global

* Corresponding author. Tel.: +886 2 3366 2663; fax: +886 2 2363 5995.
E-mail addresses: piwu@ntu.edu.tw (P.-I. Wu), r98627001@ntu.edu.tw (C.T. Chen), r89627010@ntu.edu.tw (P.-C. Cheng), jlliou@cier.edu.tw (J.-L. Liou).
[1] Tel.: +886 933 711 998.
[2] Tel.: +886 968 757 963.
[3] Tel.: +886 958 499 058.

[4] In addition to these three factors, operating an emission trading scheme might involve transaction costs. The transaction costs across countries are normally handled through a platform. As compared with the abatement cost for emission reduction, the transaction costs from the emission trading market are relatively small. Accordingly, the transaction costs can thus be eliminated.

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emission reduction target, there is the idea that more countries should join in the commitment array (Buchner and Carraro, 2003; Liou and Wu, 2010; Ringius et al., 2002; Viguier, 2004).

Theoretically, the more countries that there are in the trading market, the more variations of MAC there will be. There is thus a high possibility for trading to come across (Chen and Zhang, 2005). In addition, under the assumptions of perfect competition and/or no transaction costs (or where the transaction costs are insignificant) the saving in the total abatement cost will be as large as the number of countries getting involved in the emission trading market from a global perspective (Wu et al., 2010). However, the benefit or welfare that each country or organization possesses differs as the highest saving in TAC in the world is reached.

As such, the design of an incentive mechanism for those countries or organizations that do not commit to any emission reduction is essential for a global target to be reached. The cooperation among organizations through a game where the emission reductions are determined has to be assessed. The literature in the past has focused on the issue involving the theory of the climate game to describe the willingness that a certain country or group of countries has in deciding to commit to a CO_2 emission reduction. A study conducted by Pronove (2002) indicates that there is already an existing emission trading market for CO_2, such as in the countries of the European Union (EU). In addition, efforts to engage in emission trading or other cooperation for development of green economy have consistently been made in countries such as Denmark, the U.K., Norway, Germany, France, Austria, and Japan (Barrett and Stavins, 2003; Carfì and Schilirò, 2012; Jacobsen, 1998; McKibbin and Wilcoxen, 2002). However, in a way that is similar to those studies conducted for the EU, trading for these countries also takes place within these countries (Eyckmans et al., 2002).

Moreover, past climate game analyses are either based on the chicken game or the prisoner's dilemma game and place emphasis on the theoretical discussion of damage occurring under the designated probabilities of various uncertain factors (Akimoto et al., 2000; Asheim et al., 2006; Carraro, 2003; Chen and Zhang, 2005; Okada, 2007; Pittel and Rübbelke, 2012; Svirezhev et al., 1999). That is, these studies are mainly purely theoretical simulation analyses. Furthermore, Wood (2011) uses a theoretical model to generalize various climate models and concludes that it is countries that are normally the decision makers in related research and the payoff is the total welfare of the country derived from the game. The results of the studies stated above and those of other studies such as Carraro and Moriconi (1997), Forgó et al. (2005), Haurie and Viguier (2003), and Scheffran and Pickl (2000) are arrived at only through numerical calibrations instead of actual estimations of emission reductions.

In addition to this, past studies usually assume that there is an existing market. Research interests are employed to analyze the impact for members (countries) that are already in the market or for those countries that are members of certain organizations, such as the EU, or are among the Annex B countries of the Kyoto Protocol (Bréchet et al., 2010; Forgó et al., 2005; Jaehn and Letmathe, 2010). A Cournot–Nash equilibrium is resolved for market suppliers of Russia and China under the emission rights demands of Annex B countries (Bernard et al., 2008). Studies are also conducted for individual countries which are either suppliers or demanders of emission rights to analyze the equilibrium price and/or equilibrium quantity (Godal and Holtsmark, 2011; Hopkin, 2004; Lee, 2011; Viguier, 2004; Von Der Goltz, 2009).

As a result, to enrich the development of the current literature the purpose of this paper is to simulate the saving in TAC for different emission trading games that reflect the potential cooperation among organizations. Since it is impossible for all countries to take part in the trading simultaneously at the current stage, it is assumed that the game takes place at the organizational level. The simulations are then accomplished for the existing organizations of the EU, the Asia-Pacific Economic Cooperation (APEC) nations, the Union of South American Nations (USAN), and the Indian Ocean Rim Association for Regional Cooperation (IOR-ARC). These four organizations are the players in the trading game. A game approach is then conducted to determine if the cooperation will come into existence among the organizations stated above. A similar idea applies to a few of the largest emission countries, i.e., China, the U.S., Russia, and India, which are treated as four individual players in the trading game.

2. Research method

Since a CO_2 emission reduction is a non-market good, in order to achieve the purpose stated above, a shadow price model incorporating the directional distance function that is used to infer the undesirable output (CO_2 emissions in this case) is an appropriate method (Lee et al., 2002; Liou and Wu, 2010; Marklund and Samakovlis, 2007; Wu et al., 2013). In addition, an initial allocation of rights corresponding to the context of the polluter pay principle for certain operational variables is necessary. The polluter pay is founded in duty-based notions of equity and it emphasizes the harmfulness of each nation's cumulative emissions to the environment in allocating emission rights (Berk and den Elzen, 2001; Finkbeiner and Neugebauer, 2013; Höhne et al., 2003). The desirable output is the real Gross Domestic Product (RGDP) and the undesirable output is the amount of CO_2 emissions.

On the other hand, the input variables are the annual energy consumption, capital stock, and labor of each country. These variables are used in the estimation of the directional distance function to compute the MAC for CO_2 emission reductions. All related variables are collected from the World Development Indicators prepared by the World Resources Institute and the related data banks from the United Nations' Statistics Division (World Resources Institute, 2011; World Bank, 2011). There are 102 countries covering the period 1993–2008 with 1632 observations in total. Among these, 49 countries belong to the different organizations stated above and the other 53 countries consist of the rest of the individual countries that have the potential to join the world trading market.

While the emission trading market is made up of different coalitions among countries, those countries that commit and those that do not commit, might take advantage of other countries through the game. This will indirectly induce the countries to commit themselves to a certain amount (or percentage) of emission reduction. Initial emission rights have to be allocated before the estimation of MAC is conducted. Various trading games are then analyzed thereafter.

2.1. Initial right allocation under the polluter pay principle

Under the polluter pay principle referred to by Liou and Wu (2010), it is concluded that the smaller the amount of emissions for a country, the larger the amount of emissions that will accumulate in a specific period. Countries with higher cumulative amounts of emissions will be assigned smaller amounts of emissions that they can emit. The allocation is calculated as in Eq. (1) shown below:

$$AE_k = TAE \times \frac{1-[\text{cumulative emission of country k/world total cumulative emissions}]}{\sum_{k=1}^{K} 1\text{-}[\text{cumulative emission of country k/world total cumulative emissions}]} \tag{1}$$

where TAE is the total allowable emission of the world and AE_k is the allowable emission for country k where there has already been a commitment to reduce emissions.

2.2. Marginal abatement cost under a coalition

The estimation of MAC under each coalition for multiple outputs is based upon the idea of the shadow-price model proposed by Färe et al. (1993) and Färe et al. (2006). It is assumed that $y = (y_1,\ldots\ldots,y_M) \in R^M_+$, $b = (b_1,\ldots\ldots,b_J) \in R^J_+$ and $x = (x_1,\ldots\ldots,x_N) \in R^N_+$ refer to the decision-making unit k (DMU) with desirable output GDP and undesirable output CO_2. x_n is a vector of inputs and y_m, $m = 1 \cdots\cdots M$, is vector of