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The energy price equivalence of carbon taxes and emissions trading—Theory and evidence

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HIGHLIGHTS

- The price equivalence of carbon taxes and emissions trading from theoretical and empirical models are developed.
- The theoretical findings show that the price effects of these two schemes depend on the market structures.
- Energy prices under a carbon tax is lower than an issions trading in an imperfectly competitive market.
- A case study from Taiwan gasoline market is applied here.

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ABSTRACT

The main purpose of this study is to estimate the energy price equivalence of carbon taxes and emissions trading in an energy market. To this end, both the carbon tax and emissions trading systems are designed in the theoretical model, while alternative market structures are taken into consideration. The theoretical findings show that the economic effects of these two schemes on energy prices depend on the market structures. Energy prices are equivalent between these two schemes given the same amount of greenhouse gas emissions (GHGE) reduction when the market structure is characterized by perfect competition. However, energy prices will be lower when a carbon tax is introduced than when emissions trading is implemented in an imperfectly competitive market, which implies that the price effects of a carbon tax and emissions trading depend on the energy market structure. Such a theoretical basis is applied to the market for gasoline in Taiwan. The empirical results indicate that the gasoline prices under a carbon tax are lower than under emissions trading. This implies that the structure of the energy market needs to be examined when a country seeks to reduce its GHGE through the implementation of either a carbon tax or emissions trading.

1. Introduction

While carbon taxes and emissions trading are treated as the major competing climate change policy tools used to reduce greenhouse gas emissions (GHGE) [1–3], there has recently been much debate on their economic effects. A carbon tax is treated as an environmental tax that is levied on production activities/services that pollute environmental goods. The prices of products/services are increased and the demand for them is reduced after the addition of the carbon tax. Such carbon taxes are sometimes referred to as "price-based" policy instruments [4]. On the other hand, emissions trading imposes a total amount of carbon emissions but allows emission permits to be traded at different prices. Emissions trading is considered to be a "quantity-based" policy tool.

The basic framework for emissions trading involves fixing a total emission level for all of players within a group with each player being able to buy or sell the right to an emission level at a particular price. In other words, the major function of the trading system is to reduce GHGE with lower abatement cost. Such a reduction through trading is more efficient. For instance, if the cost of reducing GHGE is lower in one location/sector than another location/sector, then the amount of the emissions reduction in a

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cheaper location/sector means that the right can be sold to the location/sector with a higher cost through this trading system in order to reach the reduction goal. Therefore, the social welfare in both locations/sectors will be increased.

There are some advantages and disadvantages of these two environmental tools. The biggest advantage of implementing emissions trading is to ensure that essential reductions in GHGE targets are met at the lowest possible cost. The other main advantage of this program is to provide the private sector with the flexibility required to reduce emissions while stimulating technological innovation and economic growth. Such a program has been implemented in many US states, in the EU, and in New Zealand and Australia.

The advantage of implementing a carbon tax is to encourage the use of alternative sources of energy by making them cost-competitive with cheaper fuels. For instance, the imposition of a carbon tax on a cheaper fuel such as coal could raise the cost of producing electricity as compared with other cleaner power production activities. The other advantage of a carbon tax is to create a more stable carbon price than in the case of emissions trading since emissions trading sets a definite limit on emissions and not a definite limit on the price of carbon.

Back to the empirical studies from literature reviews, we found that there are lots of studies related with the analysis of carbon tax on the reduction of greenhouse gas emission (GHGE). For instance, the effect of carbon tax on GHGE in a forest sector in Taiwan has been investigated by Chen et al. [5] and the empirical simulation results show that the significant reduction of carbon tax on wood product markets. Kahn and Franceschi [6] and Sumner et al. [7] have provided a very good review with possible policy consideration for this mitigation policy. On other hand, the effects of implementing a carbon tax on GHGE in a specific country have been examined by Callan et al. [8], Wang et al. [9], Fang et al. [10], Alton et al. [11], Vandyck and Regemorter [12], Liu and Lu [13]. Some of them have focused on developed countries such as Ireland and Belgium but some have paid attention on developing countries such as China and South Africa. Implementing a carbon tax in different countries may have different effects due to the alternative energy technology and marketing structures. This implies that such studies have not analyzed and compared with the effects of implementing a carbon by taking the marketing structure into the consideration.

On other hand, the effects of implementing emission trading on the reduction of GHGE have been examined by Stevens and Rose [14], Linares et al. [15], Linares et al. [16], Kara et al. [17], Karali et al. [18]. Stevens and Rose [14] have provided a nice theoretical framework when implementing this emission trading system. Linares et al. [15], Linares et al. [16], and Kara et al. [17] have applied such mitigation scheme on power sector in different European countries while Karali et al. [18] have simulated this scheme on iron and steel sector in the US.

Based on these literature reviews for carbon tax and emission trading, the effects of either carbon tax or emission trading on GHGE for different energy sectors in different countries have been investigated and analyzed clearly. However, the policy marker may like to select one of them as policy tool to mitigate GHGE since the cost of GHGE reduction needs to be minimized. Therefore, the economic outcomes including energy prices, gross domestic product (GDP), and welfare will be the criteria to compare when selecting these two policies [19–21]. For instance, countries or industrial sectors may select a lower energy price outcome when implementing a mitigation tool with the same GHGE reduction amount since the damage of lower energy price is much accepted. Therefore, the main contribution of this paper is to analyze and investigate the economic outcomes of these two policies in an energy market theoretically and empirically.

Although both carbon taxes and emissions trading are implemented under a market mechanism, the economic effects on the prices and welfare of goods and services between these two systems will be different. The actually situations of implementing carbon taxes and emissions trading in different countries have been introduced and analyzed by Sugino et al. [22], Pollitt et al. [23], Jotzo and Löschel [24], Crossland et al. [25], Liu and Lu [13], WorldBank [26]. For instance, UK has participated in EU Emission Trading Scheme (ETS) since 2005 while a carbon price floor (CPF) to tax on fossil fuels used for power generation with US$ 15.75 per ton of CO_2 emission was introduced in 2013. Japanese Voluntary Emission Trading Scheme (JVETS) was operated in 2005 to support the reduction of GHGE in Japan and a carbon tax with US$ 2 per ton of CO_2 emission for all fossil fuels was also implemented in 2012. Mexico has introduced carbon tax on fossil fuels with US$3.5 per ton of CO_2 emission in 2014, and subsequently announced an ETS for carbon emissions from energy sector. China prepares to launch a national ETS in 2016 to reduce carbon emissions and air pollutions. Such examples indicate that either a carbon tax or ETS is a practical policy tool which has been adopted by countries to reduce carbon emissions recently. Therefore, investigating the effects of such schemes on energy price has important policy implications for energy sector.

Limpaitoon et al. [27] have pointed out that different kinds of pollution emissions trading will result in different results in different market structures. When a country attempts to reduce its emissions of greenhouse gases in an energy market using these policy tools, the lower the energy price, the better the economy. So the major purpose of this paper is to develop a theoretical model to compare the economic effects of carbon taxes and emissions trading in an energy market by considering alternative market structures. After that, such a theoretical model will be applied to the gasoline market in Taiwan and tested empirically.

Therefore, the first contribution of this study is that we develop a theoretical model to compare the economic effects of carbon taxes and emissions trading in an energy market. The second contribution of this study is that we not only provide empirical evidence of Taiwan's gasoline market to support the theoretical model, but also suggest useful policy implications to Taiwan's gasoline market and other energy markets.

A conjectural variation (CV) represents each firm's (or player's) strategy with respect to other players' strategies on the quantity or price in a market. The CV method is comprehensively used in empirical analysis and could be applied to the estimation of the market structure in an imperfectly competitive market (see, for example, [28–30,27,31]). Therefore, such a CV approach is applied here to estimate the market structure of Taiwan's gasoline market. The structure of this paper is as follows. The second section builds up a theoretical model to compare the economic effects of a carbon tax and emissions trading in an energy market, while the third section establishes the empirical models. The empirical results are shown in the fourth section, and finally the fifth section presents the conclusion and policy implications.

2. Theoretical model

Suppose that there exist n firms that can produce gasoline accompanied by carbon dioxide emissions and that the inverse demand function in the gasoline market is $P = f(Q),\ Q = \sum_{i=1}^{n} q_i$, where q_i represents the quantity of gasoline of the ith firm. The following analysis will focus on a comparison of energy prices