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Carbon pricing and general equilibrium under Leontief production technology

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ABSTRACT

Comparing temperature and emissions data does not clearly show a relationship between the two variables. Going further, this study combines Leontief production technology with a computable general equilibrium model of global trade in order to quantitatively test the implications of mitigation policies for welfare and the environment. We compute optimal emissions taxes and show that administering carbon fees reduces environmental damages by nearly 50%. However, there is a tradeoff effect on production which calls for caution when implementing environmental policies. In general, environmental benefits and resources shifting due to carbon taxes lead to welfare gains.

1. Introduction

The apparent link between climate change and extreme weather events like rising temperatures, prolonged rainfalls, flooding, drought, etc., has led to a proliferation of policies aimed at boosting environmental standards. For instance, Wei et al. (2015) shows the existence of a 50% chance of increase in worldwide temperature by the year 2100 in comparison with the 20th century levels if sustainable emissions reduction measures driven by carbon taxes are not appropriately instituted. In Fig. 1, we show the trend in yearly average temperatures and CO_2 emissions from the period 1980 to 2014. Judging from this plot, it is not clear whether CO_2 emissions are influenced by temperature. In other words, available data from the period 1980 up to 2014 do not clearly suggest that the rate of CO_2 emissions is associated with temperature. Notwithstanding, it is still necessary to examine how mitigation policies would impact welfare and the environment.

The medium for greenhouse gas (GHG) abatement has stimulated much debate in the literature. There is already a general consensus that reducing GHG emissions is necessary for mitigating climate change. However, what is still not clear among researchers to date is the specific mechanism for abatement. Three popular mechanisms for abatement have emerged in the literature, namely: price-based, quantity-based, and command-and-control approaches (Wesseh and Lin, 2018). The command-and-control mechanism has been rated as inefficient and therefore not recommended. The main reason is that the government uses command-and-control as a way of utilizing force and using its administrative powers to limit GHG. On the other hand, the quantity-based approach guarantees a certain limit on emissions and makes provisions that support trading of emissions permits. As its major advantage, the quantity-based system is able to control the rate of reduction of emissions amidst uncertain carbon prices. The choice that participants have to buy or sell freely creates the possibilities of reaching their lowest cost which in turn lowers cost for the society in general. This means that whenever it becomes cheaper to limit emissions, stakeholders would sell excess permits. On the other hand, if the cost to limit emissions is higher, stakeholders would seek to buy permits and avoid reducing emissions. As a result, the total emissions would be the same as the total permits which means that emissions reduction would be undertaken if and only if the lowest cost is achieved. The third and perhaps the most popular mechanism for abatement in the literature is the price-based approach or simply carbon taxes. This approach to emissions reduction is a way of imposing fixed payments on every unit of CO_2 emissions. By attempting to control the

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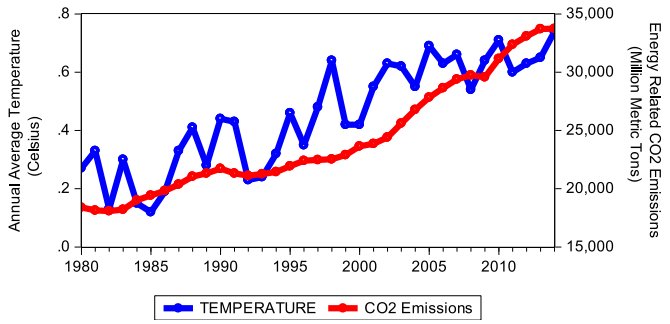

Fig. 1. Source: NASA/GISS and US energy information administration.

price on carbon directly, a carbon tax indirectly determines the rate of emissions reduction. Similar to the quantity-based system to emissions reduction, carbon taxes have proven to be cost-effective in that polluting agents would opt to limit emissions only in the case where the cost of reduction is lower than the carbon tax.

Emissions reduction approach based on the quantity mechanism has been favored because of political concerns. Notwithstanding, researchers for the most part, particularly those applying cost-benefit analyses, have all concluded that the price-based approach or carbon tax performs more efficiently.[1] Indeed, several studies seem to suggest that gains in welfare brought about as a result of executing an optimal carbon tax policy is by far greater than any welfare gains from implementing a quantity-based policy (Nordhaus, 2006).

Hence, a paper that attempts to review and provide insights on carbon taxes is critical for designing more pragmatic and efficient climate policies. In addition, such study would provide a useful avenue for testing the options value for the development of renewable energy technologies (Wesseh and Lin, 2016a). Certainly, one cannot really overemphasize the role of optimal carbon taxes. Instead, it is widely acknowledged that most of the applied carbon taxes are less than optimal. This is largely due to the difficulties in sourcing data and the complexities involved with measuring damages from climate change (Duan et al., 2014).

In view of the above, the purpose of this study is as follows: First, we attempt to review the relevant literature on carbon taxes and their impacts. Second, we compute optimal carbon taxes that could fully internalize environmental externalities. Finally, test the impacts of the computed taxes on production, welfare, and the environment. These investigations are conducted under the assumption of a Leontief production technology. In other words, we assume that no substitution is possible between inputs and emissions, that is, abatement occurs only by changing the technology.

The scientific contributions of this study add value to the literature as it does not only present findings relevant to important policy decisions of widespread interest but as well offer advances that may potentially influence the course of future research. First, it contributes to filling the literature gap in terms of providing further research into carbon taxes and their effects. Such a need arises because of uncertainties surrounding the inappropriateness of most carbon taxes as well as the mixed results inherent the 'carbon tax impact' literature. Second, as we have pointed out, most carbon taxes are less than optimal. For this reason, the present study reviews the literature and compute optimal carbon fees which could serve the purpose of fully capturing damages caused by environmental pollution. Finally, different from several studies in the literature that have tested either country-specific or region-specific scenarios, a global perspective is given in the present study on carbon taxes and their impacts. In particular, we aggregate 129 world regions into six aggregates namely: China, the United States; low-income countries, lower-middle income countries, upper-middle income countries and high-income countries. The income level grouping is consistent with the World Bank[2] list of countries.

To achieve the objectives in this study, we incorporate abatement technologies into the GTAP computable general equilibrium model of global trade. GTAP cuts across regions and is built to capture several interactions happening between and among policy variables. The main policy variables in GTAP are taxes, subsidies, and quotas.

The remainder of the paper is organized as follows: Section 2 provides a review of the relevant literature. Section 3 describes the data. Section 4 discusses the various methods employed in our research. Section 5 presents the results and discussions. Section 6 concludes.

2. Relevant literature

Because of the drive to control emissions, various measures have been orchestrated in several countries. These environmental tax policies or related measures have been implemented in Europe, North America, South America, Australia and Asia. In fact, a number of African countries have started to implement measures relating to carbon taxation. There are a number of studies on carbon taxes to date. Some of these studies have compared how carbon taxes perform in relations to other mechanisms for abatement while other studies have attempted to discuss past and future trend in carbon taxes. Still, several studies have looked exclusively at not just the environmental effects of carrying out a carbon tax policy but as well as the economic impacts of carbon taxes.

When it comes to welfare gains and reducing GHG emissions, several studies which have compared options for mitigation have concluded that levying a carbon tax is rather superior to other mitigation options. Weitzman (1974), one of the earliest, points to evidence that a carbon tax is more effective than a quantity-based approach. Notwithstanding, where a reverse inequality appears to exist, the cap-and-trade system appears to clearly dominate a carbon tax. Following similar line of research, Pizer (2002) simulated all two mechanisms, that is, a carbon tax and a quantity-based system. For the results obtained from the application of their stochastic computable general equilibrium (CGE) model, it was concluded that gains in welfare emanating from implementing an optimal carbon tax policy appeared to be approximately five times higher than the expected gains in welfare coming from the implementation of a quantity-based or cap-and-trade system. Different from these results, Dasgupta and Heal (1979) argue that, irrespective of whether a carbon tax is low or high, it does not offer a lot when it comes to limiting the concentration of nonrenewable energy or limiting the amount of GHG concentration. Following closely in these steps, Nordhaus (2006) matched the advantages against disadvantages of the implementation of a quantity-based system and a carbon tax mechanism. The author's major concern was to compare performances along various lines including the ease of implementation, the transparency with which each mechanism is implemented, the complexities of taxation and regulation as well as uncertainty inherent in the induced carbon taxes. Results of this study also suggested carbon fees as the mitigation mechanism most capable of performing in terms of efficiency and

[1] The literature has already produced a hybrid mechanism that combines both quantity-based and price-based approaches (Weitzman, 1974).

[2] See the following web page: https://www.gfmag.com/global-data/economic-data/pagfgt-countries-by-income-group.