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Modeling environmental policy with and without abatement substitution: A tradeoff between economics and environment?

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HIGHLIGHTS

- A set of optimal emissions taxes are computed and their implications are tested.
- Emissions taxes reduce environmental damages by nearly 50% in all regions.
- Emissions taxes lead to welfare gains in all regions except low-income countries.
- Production in rich countries is more adversely affected due to carbon taxes.
- There is a tradeoff between economics and environment due to carbon taxes.

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ABSTRACT

This study proposes a set of optimal emission taxes that could be used to fully internalize environmental externalities. Carbon fees are computed for low-income economies, lower-middle-income economies, upper-middle-income economies, high-income economies, China and the United States. Subsequently, the implementation of these emission taxes is evaluated under two different scenarios; one assuming abatement substitution and the other relaxing this assumption. Estimated damages and abatement from various sectors lie between 0.0003 to 0.021 and 0.001 to 0.012 lb per dollar output respectively. Optimal pollution taxes per dollar output range as high as 2.8% for heavy manufacturing in the high income countries, and as low as 0.01% in the service sectors of the low income countries. On the impacts of these taxes, the study produces evidence that, whether abatement substitution is present or not, production in low-income economies would be less adversely affected due to carbon taxes relative to high-income countries. In addition, the emissions taxes reduce environmental damages by nearly 50% in all regions. Worldwide welfare gains from internalizing negative externalities when no abatement substitution is present is about three times the welfare gains in the presence of abatement substitution. Although these results imply a sort of tradeoff between the economics of production and environment, improved environmental benefits due to carbon taxes seem to outweigh the deterioration in economic activities; and as such, welfare improves in general.

1. Introduction

A number of environmental policies have been instigated following the Kyoto Protocol and the UNFCCC [1,2]. One of such topics in the debate relates to the mechanism for GHG abatement. Even though the issue of mitigating climate change by means of reduction in GHG emissions has been generally accepted, controversy still hangs over the specific abatement mechanism. For instance, the literature has produced three popular mechanisms for abatement, namely: price-based, quantity-based and command-and-control mechanisms [3–7].

According to Nordhaus [4], the command-and-control mechanism is inefficient and therefore not recommended as the government uses this mechanism as a tool for applying force and utilizing administrative means to reduce GHG. On the other hand, the quantity-based mechanism, or cap-and-trade system, is a way of granting various stakeholders or participants a limitation on emission permits and allowing for the trading of such permits in the market [8–10]. The main advantage of the cap-and-control system,

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Nomenclature

Symbols	Description
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibrium
CO_2	Carbon dioxide
GHG	Greenhouse Gas
GTAP	Global Trade Analysis Project
UNFCCC	United Nations Framework Convention on Climate Change

as pointed out by Zhu and Wei [11], is the possibility of directly controlling reduction levels in the face of uncertain carbon prices. Because participants have the choice of freely buying and selling, it is possible for them to achieve the lowest possible cost, and hence, a lower cost for the broader society. This implies that participants would sell excess permits if it is cheaper for them to reduce emissions. On the contrary, participants would buy permits and avoid reductions where the cost of reductions is higher. The resulting effect is for total emissions to equal the amount of permits, thus, only reductions of the lowest cost will be undertaken. The third and perhaps most popular mechanism, the price-based mechanism or carbon tax as it is usually called, is one in which a fixed payment per unit CO2 emissions is made [12]. With a carbon tax, the level of emissions reduction is determined indirectly by means of directly controlling the carbon price. Like the cap-and-trade system, the carbon tax is also cost-effective since emitters would only choose to reduce emissions if the cost of doing so falls below the carbon tax.

Even though political concerns would favor the use of a quantity-based approach to abatement, a lot of researchers, especially those applying cost-benefit analyses, have documented carbon tax as more efficient.[1] Indeed, a couple of studies have shown that the welfare gains from implementing an optimal carbon tax is at least five times higher than expected gains from an optimal cap-and-trade policy [4,6,7]. Moreover, estimates by Sokolov et al. [13] show the possibility of a 50% rise in global temperature by 2100 compared with the 20th century levels if mitigation measures, driven by carbon taxes are not implemented. Therefore, a study of this nature which focuses specifically on carbon taxes is relevant for developing more realistic climate policies and for providing insights on the connections between energy prices and carbon mitigation solutions in terms of carbon capture and storage (see [14]. Moreover, such an analysis would serve as a valuable platform for evaluating the options value to renewable energy development [15–17] and for evaluating the effectiveness of renewable energy as a substitute for nonrenewable energy [18,19].

Indeed, the role of optimal carbon pricing cannot be overemphasized. However, because it is difficult to find a single database which consists of various carbon costs; and factoring in the fact that climate damages are difficult to measure, most carbon taxes are usually less than optimal [20–23]. This implies that further evidence on the modeling of economically appropriate carbon taxes and the impacts of their implementation is necessary and would bring more insights and clarity to the literature. In addition, the limitation of relevant data has compelled many researchers to rely on theoretical and simulated tax rates, which may or may not be realistic in terms of context conditions. As a result, this could point policy makers in the wrong direction. Furthermore, as we discuss in Section 2, the literature seems to produce mixed evidences. While some authors argue that the implementation of carbon taxes can provide economic and environmental gains, other studies argue otherwise. Giving the uncertainties surrounding the economic appropriateness of the kind of carbon taxes used in the vast majority of these studies, further insights into research of this kind becomes a necessity. Another feature of the present study that distinguishes it from previous work in the literature is the fact that we have modeled environmental policy while allowing for a more realistic abatement possibility. The study also allows for comparison with a scenario in which no abatement substitution is possible, thus, increasing the richness of the analysis.

Finally, unlike bulk of the literature which considers country- or region-specific scenarios,[2] this study aims at providing a more global perspective on environmental policy modeling. Since the willingness to pay for improvement in environmental quality and the level of income are correlated, our analysis breaks out the world's two largest economies, China and the United States; grouping all other world regions in accordance with the World Bank (2012)[3] list of countries, such as: low-income, lower-middle income, upper-middle income and high-income countries. Employing output and expenditure data from the GTAP database as well as abatement and emissions data from industries in the United States, optimal emissions fees are first computed for China and the United States, and then for the four different income categorizations (i.e., low-income, lower-middle-income, upper-middle-income and high-income). Subsequently, the economic and environmental impacts of implementing the constructed carbon fees are assessed.

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 explains the various methods. Section 5 presents the results and discussions. Section 6 concludes.

2. Relevant literature

In order to control emissions, carbon tax policies or related measures have been carried out in a number of countries especially European countries and Australia. North and South America, Asia and even African countries are beginning to show deep interest in instigating carbon pricing measures. There is a vast literature so far, ranging from studies which compare the performance of carbon taxes with other abatement mechanisms to studies which discuss the trends in carbon taxes and then to studies considering the implications of instigating carbon taxes.

As was reported earlier, studies on the comparison of various mitigation options have generally documented carbon tax as the superior and most efficient abatement mechanism in terms of welfare gains and reduction in the level of GHG emissions. The first of these studies, Weitzman [7], seminal work pointed to conclusions that, where the absolute value of the slope of the marginal benefit function is less than the slope of the marginal cost function, then a carbon tax is more efficient than a cap-and-trade system. However, in the case of a reverse inequality, the cap-and-trade system would seem to dominate a carbon tax. In the same vein, Pizer [6] simulated the two mechanisms. Simulation results from their stochastic CGE model suggested welfare gains from an optimal carbon tax to

[1] A hybrid mechanism combining both quantity-based and price-based mechanisms has also been proposed [6].

[2] A notable exception is Hertel [24].

[3] https://www.gfmag.com/global-data/economic-data/pagfgt-countries-by-income-group.