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Optimal emission taxes for full internalization of environmental externalities

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ABSTRACT

The present study proposes a set of optimal emissions fees that could be used to reduce the damages caused by industrial pollution. The approach we use allows for the setting of pollution taxes at their economically appropriate level. In particular, tax rates are computed for China, India and 19 Sub-Saharan African countries. All other world regions are grouped according to income level such as low-income, lower-middle-income, upper-middle-income and high-income economies. Our results show that constructed optimal pollution taxes range as high as 2.9% per 1 dollar of output for heavy manufacturing in the high income countries, and as low as 0.01% in the service sectors of the low income countries. These results show that a full internalization of the damages in each sector calls for raising the tax rates in some sectors and lowering them in others.

1. Introduction

A number of climate policies have been instigated following the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC). One of such topics in the debate relates to the mechanism for greenhouse gas (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 mechanism, quantity-based mechanism and command-and-control mechanism (Wei et al., 2014; Nordhaus, 2006; Pizer, 2002, 2001; Weitzman, 1974).

According to Nordhaus (2006), 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 (Barrieu and Fehr, 2014; Cong and Wei, 2010, 2012). The main advantage of the cap-and-control system, as pointed out by Zhu and Wei (2013), is the possibility of directly controlling reduction levels in the face of uncertain carbon price. 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 (Kanudia and Shukla, 1998). 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, the vast majority of researchers, especially those applying cost-benefit analyses, have

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documented that a carbon tax is 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 (Nordhaus, 2006; Pizer, 2002; Weitzman, 1974). Moreover, estimates by Sokolov et al. (2009) have demonstrated the existence of a 50% chance of rise in global temperature by 2100 compared with the 20th century levels if mitigation measures, driven by carbon taxes are not implemented. Hence, a study of this nature which focuses on optimizing the price of carbon to fully internalize environmental damages is relevant and vital for developing realistic and efficient climate policies. Moreover, such an analysis would provide a valuable platform for evaluating the options value to renewable energy development (Wesseh and Lin, 2016a, 2015; Lin and Wesseh, 2013a) as well as those on the substitution possibilities of renewable energy (e.g. Lin and Wesseh, 2013b; Wesseh et al., 2013; Wesseh and Lin, 2016b, c, d).

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, the vast majority of carbon taxes are usually less than optimal (Duan et al., 2014; Van der Zwaan et al., 2002; Manne et al., 1995; Whalley and Wigle, 1991). This means that further evidence on the modeling of economically appropriate carbon taxes and the impacts of their implementation is necessary; as this 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; and hence, could point policy makers in the wrong direction. Furthermore, bulk of the discussions on carbon pricing, as may been seen from the review in section 2, are mainly country- or region-specific and may not be sufficiently realistic for making generalizations across all countries and regions.[2]

For this reason, the present study aims at providing a more global perspective on carbon pricing. Giving that the willingness to pay for improvement in environmental quality and the level of income are correlated, this study breaks out China, India and 19 Sub-Saharan African countries; grouping other regions in accordance with the World Bank (2012)[3] list of countries, namely: low income countries, lower middle income countries, upper middle income countries and high income countries; and computing benchmark and optimal carbon fees for each income group. Such a comprehensive analysis is made possible by combining trade and policy data from the global trade analysis project (GTAP) database with abatement and emissions data from industries in the United States.

The originality and scientific contribution of this paper lies not only in the kind of data used but also in its geographical spread. In fact, this study is the first-of-its-kind approach to the computation of carbon taxes for a wide range or African countries. Indeed, this study adds 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.

The remainder of the paper is organized as follows: Section 2 provides a review of the relevant literature. Section 3 describes the data and approach used for computing optimal carbon fees. Section 4 presents the results and discussions. Section 5 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 (1974), 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 (2002) simulated the two mechanisms. Simulation results from their stochastic computable general equilibrium (CGE) model suggested welfare gains from an optimal carbon tax to be five times greater than expected gains from an optimal cap-and-trade system. Contrary to these findings, Dasgupta and Heal (1979) argue that, regardless of how high or low a carbon tax may be, its role in reducing the consumption of fossil fuels, and hence, reducing the level of CO2 emissions is marginal. Following similar line of research, Nordhaus (2006) compared the advantages and disadvantages of a carbon tax and the cap-and-trade mechanism. The main focus of the research was to evaluate the performance of the two mechanisms in terms of implementation, transparency, excess burden of regulation and taxation as well as uncertainty of the induced carbon fees. Findings from the study suggested carbon taxes as the mechanism likely to be more efficient and more effective. A more recent study by Zakeri et al. (2015) provides some form of support for Dasgupta and Heal (1979)'s argument. In particular, Zakeri et al. (2015) concludes that, on the overall, a quantity-based mechanism, albeit imperfect tends to result in better supply chain performance. Notwithstanding, the authors also report that a carbon tax may be more worthwhile.

A couple of studies have also directed attention to discussing the path in carbon taxes. The earliest of these studies was Sinclair (1992) who concludes that, in the steady-state, the carbon tax rate of ad valorem will continue to monotonically decline. On the contrary, Ulph and Ulph (1994) challenged the authenticity of Sinclair's conclusion arguing that, under some circumstances, carbon taxes may first rise and then fall or exhibit the so-called hump-shape. Hoel and Kverndokk (1996) also reached somehow similar conclusions as Ulph and Ulph (1994). According to Farzin and Tahvonen (1996), the optimal carbon tax may be monotonically increasing or follow a U-shaped pattern. Other studies suggesting conclusions as Farzin and Tahvonen (1996) include: Van der Zwaan et al. (2002) and Bosetti et al. (2011).

Few authors have attempted to throw light on the optimal rate of carbon fees while evaluating the distributional impacts of carbon taxes or by fully directing attention to estimating the optimal level of carbon taxes that completely internalize environmental externalities. For instance, Fazin (1996) evaluated the optimal pricing of environmental externalities and concluded that carbon tax, as an optimal abatement strategy, is particularly sensitive to changes in

[1] A hybrid mechanism combining both quantity-based and price-based mechanisms has also been proposed (Pizer, 2002).
[2] A notable exception is Hertel (1997).
[3] https://www.gfmag.com/global-data/economic-data/pagfgt-countries-by-income-group.