CARBON PRICING INSTRUMENTS: SECOND-BEST POLICIES?

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Overview

Decarbonizing the global electricity mix is an imperative to minimize carbon dioxide (CO_2) emissions and associated damage costs of global warming. This primarily implies shifting from fossil-fuel energy to renewables, on which the international community is focusing under different climate treaties. To support an efficient electricity mix in favor of renewables, the economic literature mostly advocates carbon pricing as potentially the first-best policy. Meanwhile, according to the International Energy Agency, there is currently a growing interest in wind and solar energy to increase renewables-based electricity (IEA (2021)). These depend on variable and uncontrollable conditions yielding in intermittent electricity which in fact calls for flexibility in the markets. On this basis, it is unclear if current carbon pricing instruments do also accommodate the intermittent effect from renewables.

Carbon pricing, as its name suggests, puts a price on each unit of carbon emissions to capture and tie damage costs related to fossil-fueled electricity to its source. It usually takes the form of a carbon tax or emissions trading scheme (ETS) whose purpose is to increase the variable production cost of fossil-fueled electricity and stimulate a shift towards renewable technologies. The economic theory envisions the socially optimal carbon pricing as the carbon tax or price of emissions permit that equalizes the marginal damage costs. In the presence of intermittent renewables which introduce variability in the electricity markets, it is appropriate to question if damage costs related to fossil-fueled electricity production can be fully internalized by a carbon price. In other words, this paper asks whether carbon pricing is a socially optimal (first-best) policy with intermittent renewables.

Methods

To investigate the above question, the paper proposes a theoretical framework with gradual decrease in fossil-fueled production and integration of renewable energy which is an important phase of the ongoing electricity transition. Electricity supply is therefore ensured by a mix of existing fossil-fired power plants and investment in renewables-based technologies. The fossil-fuel technologies cause carbon emissions but produce reliable or uninterrupted electricity (e.g., from coal and gas). In this phrased framework, it is appropriate to assume there is no capacity constraints for these technologies as in Twoney and Neuhoff (2010) and Rouillon (2015). In other words, existing total capacities are able to provide for electricity demand reliably. The renewable technologies, on the other hand, are emissions-free but yield in intermittent electricity. The variable conditions on which the renewables depend are referred as states of nature. I assume no electricity storage where the two types of technology coexist and supply electricity to match demand. Intermittency is captured through state-contingent competitive wholesale markets where state-contingent electricity are traded at state-contingent prices.

Electricity demand is first described by traditional consumers on flat-rate (fixed) tariff which is the widespread tariff. Flexibility in the electricity markets is modeled by smart consumers who, contrary to traditional ones, are on state-contingent tariffs allowing them to adapt their demand to changing wholesale market conditions. This follows from the contribution of Borenstein and Holland (2005) and Joskow and Tirole (2007) who suggest moving from time-invariant to varying tariffs to improve efficiency of markets in terms of capacity investment when demand is intermittent. However, in the present study, the source of intermittency is on the supply side due to the integration of renewables.

The regulating body, on its side, is concerned with implementing a socially optimal carbon pricing policy whilst taking account of the equilibrium conditions of the electricity markets. As a socially optimal policy, its purpose is two-fold. It must be able to internalize damages related to fossil-fueled electricity production. In addition, the policy must implement the electricity production plan and consumption allocation that ensure social welfare (well-being). In principle, a carbon pricing policy is an ex-ante regulation. It means that the policy must be fixed by the regulator in anticipation of future levels of production, consumption and damages. With the adoption of renewables inducing intermittency in the electricity markets, it can be expected that this anticipation exercise is rendered difficult. This in turn may challenge the task of the regulator in ensuring optimality of the policy.

A common situation that has been studied in the literature is that of electricity markets with traditional consumers on a flat-rate tariff. This tariff does not provide consumers with information on changing wholesale market conditions to which they do not ultimately adapt their consumption. Formally, it is said that consumption is constrained by the tariff. Ambec and Crampes (2019) and Abrell et al. (2019), for example, use a theoretically grounded model to examine such a setting. They find that the socially optimal mix with constraint consumption is implemented with a carbon (Pigouvian) tax that matches marginal damages. Nevertheless, these works consider the specific case where the marginal damage is constant and which correspond, for example, to local pollution damage (Ambec et al. (2016)). On the other hand, the present paper tries to relate more to environmental damages in the context of global warming. In fact, I consider a damage function which is increasing and convex, implying that damages are increasing at an increasing rate in emissions as proposed by Ambec et al. (2016) to differentiate between local pollution and environmental damages. This reflects the idea that incremental damages will become more and more severe for high levels of fossil-fuel production and thereby emissions.

Results

The proposed approach is very important for the policy literature related to global warming and decarbonization of electricity with renewables. I start by studying a common setting of an electricity market where there are traditional consumers with constraint consumption and the carbon tax as regulation. I refer to this as a reference case. Environmental damages are modeled using the proposed damage function. Here, I obtain a constraint second-best tax which is unable to internalize different levels of damages related to fossil-fueled electricity production.

In a second step, this paper attempts to find a pathway from the constraint second-best tax to one which is first-best. It fills the gap between setting a policy target and being able to implement same. Using the reference case, it primarily implies removing the constraint on consumption. I therefore introduce flexibility in the electricity market by substituting traditional consumers with smart consumers. State-contingent tariffs are observed to favor investment in intermittent renewables. Yet, the tax fixed by the regulator is unable to cover for environmental damages. There is only progress towards a second-best tax.

Finally, I analyze competitive electricity markets with smart consumers and an emissions trading scheme (ETS) instead of a carbon tax. It appears that studies on ETS in presence of intermittent renewables-based technologies are still in their infancy. The closest paper is that of Abrell et al. (2019) who posit that administering a carbon tax and ETS is equivalent in their framework. This study therefore aims at filling this gap in the literature. Also, the idea here is to introduce flexibility at the policy level through permits that are traded ex-post, i.e., when production and emissions occur. The permits markets are proposed to be state-contingent. Ultimately, I find that the ETS does not produce better results than the carbon tax from a policy perspective. In addition, I show that the two instruments are not equivalently implemented in this model. This is coherent with Weitzman (1974) who demonstrates that if taxes and permits schemes have equivalent results under certainty, they perform differently under conditions of uncertainty.

Conclusions

The key insight of this work is that in the context of global warming and electricity transition, carbon pricing instruments are not necessarily socially optimal policies. The integration of intermittent renewables is found to result in different levels of damages which are difficult to be internalized by a carbon tax or an emissions cap announced before the damages actually happen. The best that can be achieved is a second-best policy.

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