Carbon Pricing in Organized Wholesale Electricity Markets
Technical Conference
Docket No. AD20-14-000
September 30, 2020

Frank A. Wolak
Director, Program on Energy and Sustainable Development
Stanford University

1. Introduction

Thank you for the opportunity to speak on a topic that has taken up a significant part of my research, policy and outreach activity over the last decade. I first started working in this area in 2000, with a study of the impact of the South Coast Air Quality Management District's cap-and-trade market for NOx emissions on the performance of the California electricity market. From 2012 to 2014, I served on the Emissions Market Advisory Committee (EMAC) that advised the California Air Resources Board on the design and monitoring of the state's cap-and-trade market. In 2018, the three EMAC members performed a study of the performance of the market for its extension to 2030. I have also published several articles on this topic as well as number of opinion pieces and policy briefs that are listed at the end of my written remarks.

I would like to make three points. First, carbon pricing is the "least cost" way to reduce the carbon content of an electricity sector, and of a national or global economy. Second, it is impossible to measure the carbon content of electricity imported into a regional wholesale electricity market from a neighboring control area. This fact has important implications for policies aimed at limiting GHG emissions leakage. Third, in an uncertain economic environment there is a difference between a carbon tax and a cap-and-trade market. This fact is increasingly relevant to regions with significant intermittent wind and solar generation resources.

2. Reducing the Carbon Content of the Electricity Sector

A key point I make in all of the classes I teach is that "subsidizing green is a much more expensive way to reduce GHG emissions than taxing brown." If we subsidize green energy, more green energy will be produced. However, there is no guarantee this will lead to less greenhouse gas emissions. Because these subsidies reduce the price of green energy, and brown energy is a substitute for green energy, the demand for brown energy will fall, which leads to lower prices for brown energy. So even larger subsidies are required to spur more investment in green energy.

Subsidizing green energy requires a revenue source. Regardless of the source, the process of raising these revenues destroys economic value. Less of the product or service providing the subsidy is produced and consumed. The larger the subsidies paid, the greater the amount of economic value that must be destroyed to finance them.

What happens if we tax brown? It becomes more expensive to produce GHG emissions. The resulting higher price of goods and services that contain GHG emissions provides strong incentives to find the cheapest, least greenhouse-gas-emitting replacement.

A tax on brown also raises revenue that the government can use to reduce other distortionary taxes. Taxing brown has the potential to achieve what economists call the "double dividend:" simultaneously improving environmental quality by reducing greenhouse gas emissions and increasing employment and output because of lower payroll and income taxes enabled by the revenues raised by the carbon tax.

The above discussion is not just a theoretical possibility. There are hundreds of studies in the energy and environmental economic literature demonstrating this point. A 2008 study of the cost of rooftop solar systems found an implicit price of CO_2 in a kilowatt-hour (KWh) of energy from a rooftop solar system was between $300/ton and $600/ton depending on whether it replaced a KWh of natural gas or coal-fired energy.[1] The Obama administration cash-for-clunkers program was found to have an implicit CO_2 price of over $250/ton.[2] A highly publicized appliance replacement subsidy in Mexico found an implicit CO_2 price of over $500/ton.[3] A study of the US low carbon fuel standard found an implicit price of carbon of over $300/ton.[4] Finally, a study of state renewables portfolio standards found an implicit price of carbon that was more than three times the carbon price that would achieve the equivalent GHG emissions reductions.[5]

The case for carbon pricing is clear relative to policies that subsidize less GHG-emissions-intensive energy sources. In fact, many studies even find that these subsidy policies increase national or global GHG emissions.

3. Measuring the Carbon Content of Imported Electricity

Assembly Bill 32, which established California's cap-and-trade market that includes all GHGs from the generation of electricity delivered to and consumed in California, regardless of where the electricity is produced. This provision of AB 32 raised the difficult question of how to deal with an extreme form of GHG emissions leakage, which California parties call "reshuffling."[6]

Measuring the carbon content of electricity produced in California is straightforward. The GHG emissions of all in-state generation units are measured in real-time. By contrast, with electricity imports, only the flows of energy into the state can be measured, not what color the electrons are—green, brown, or other shades in between. Historically, the carbon content of an electricity import was measured based on the supply arrangement between the California party and a generation unit owner located outside the state. For example, a contract to import electricity between a coal-fired power plant in Arizona and a retailer in Southern California has the carbon content of this coal-fired power plant.

This approach to measuring the carbon content of electricity imports allows retailers in California to "reshuffle" whom they contract with in order to reduce the carbon content of their electricity imports with potentially no net change in the dispatch of generation units in Western

[1] Borenstein (2008).
[2] See Knittel (2009).
[3] Lucas, Fuchs, Gertler (2014).
[4] Holland, Hughes, and Knittel (2009).
[5] Johnson (2014).
[6] Bushnell, Peterman, and Wolfram (2008).

Interconnection. Under the current approach, imports from unspecified-out-of-state sources receive an administratively-determined default carbon content.

The state of California's attempts to deal with reshuffling have been a source of never-ending debate among stakeholders. The initial failure of policymakers to understand the implications of the impossibility of determining the carbon content of electricity imports was a major reason the start of California's cap-and-trade market was delayed by one year.

The only definitive conclusion from this debate is that there is no right answer, except to have the geographic footprint of the carbon market be at least as large as the geographic footprint of the wholesale electricity market. Reshuffling of electricity imports into California cannot be eliminated. The best available outcome only minimizes its impact on global carbon emissions.

4. Carbon Tax versus Cap-and-Trade Markets

A well-known result in economic theory is that every carbon tax has an equivalent carbon emissions cap that achieves the same equilibrium price for carbon allowances. However, an important assumption underlying this equivalence is a certain marginal cost of compliance and demand for carbon allowances. Uncertainty in either of these factors breaks this equivalence between a carbon tax and a cap-and-trade market.

A positive price of carbon reduces GHG emissions because it makes investments in technologies that produce electricity and GHG emissions more expensive than electricity produced from less carbon-intensive sources. Consequently, a stable and predictable price of carbon into the distant future will ensure as many of investments as possible in less carbon-intensive sources of energy because investors have a much better estimate of the future carbon costs they avoid by these investments than they would in a world with a volatile price of carbon.

In a recently published paper on California's cap-and-trade market, my co-authors and I demonstrate that before the start of the market, aggregate business-as-usual GHG emissions for the term of the carbon market are extremely uncertain. This uncertainty is go great that the equilibrium price of allowances is most likely to be at the price floor or price ceiling for the market, with only a small probability of an equilibrium price between the floor and ceiling.[7] We argue that this property is a feature of all cap-and-trade markets, which makes attaining the goal of a stable predictable price of carbon into the distant future extremely difficult to achieve with a cap and trade market of any finite duration.

With colleagues of mine at Stanford, we have implemented a number of economic experiments using our web-based Energy Market Game to compare the performance of a wholesale electricity market in an uncertain economic environment with a carbon tax, and the same electricity market with an "equivalent" cap-and-trade market.[8] For all three definitions of "equivalent" carbon taxes and cap-and-trade markets, wholesale electricity prices were significantly higher under the cap-and-trade market and electricity production was lower, without any lower carbon emissions. These results demonstrate an important advantage of carbon taxes versus a cap-and-trade market: the

[7] Borenstein, Bushnell, Wolak, and Zaragosa-Watkins (2019).
[8] Davis, Thurber, and Wolak (2020).

cost of carbon is a publicly observable input price. Under a cap-and-trade market, market participants can hold divergent views on the price of carbon because of different assessments of the resolution of the uncertainty about future compliance costs and allowance demand. Market participants with the most pessimistic views--they expect higher allowance prices--will tend to set higher prices in the wholesale electricity market.

There is an additional benefit of a carbon tax carbon as opposed to a cap-and-trade market if different states in the same electricity interconnection wish to pursue carbon reductions at different rates. Each state could set a different price for GHG emissions produced within their boundaries. This would eliminate the need to determine the carbon content of electricity imports, because GHG emissions are paid for where they are produced at a price set by the relevant state. Generation unit owners facing different carbon prices would be no different from generation owners facing different input fuel prices or labor costs. Suppliers would factor all of these costs into the offers they submit to the wholesale market.

5. Concluding Comments

To conclude, carbon pricing is the least cost path to reduce GHG emissions. Based on recent research, a carbon tax rather that a cap and trade market is likely to do this at a lower cost to consumers and less administrative burden in both the short and long term. The revenues generated from the carbon tax can be used to reduce distortionary taxes elsewhere in the economy. If we want to address the global climate challenge but do not want to burden current and future generations with unnecessary environmental and economic costs, then the choice is clear—tax brown and don't subsidize green.

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