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Does California's CO_2 price affect wholesale electricity prices in the Western U.S.A.?

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ABSTRACT

Using a sample of daily market data, we quantify the effect of California's CO_2 cap-and-trade program on the wholesale electricity prices of four interconnected market hubs in the Western U.S.A.: North of Path 15 (NP15) and South of Path 15 (SP15) in California, Mid-Columbia (Mid-C) in the Pacific Northwest, and Palo Verde (PV) in the Desert Southwest. A $1/metric ton increase in California's CO_2 price is estimated to have increased the electricity prices by $0.41/MWh ($p$-value < 0.0001) for NP15, $0.59/MWh ($p$-value < 0.0001) for SP15, $0.41/MWh ($p$-value $= 0.0056$) for Mid-C, and $0.15/MWh ($p$-value $= 0.0925$) for PV. These estimates reflect: (a) the NP15 and SP15 sellers' pricing behavior of fully including the CO_2 price in their intra-state transactions; (b) the Mid-C price's 100% pass-through of the CO_2 price in the Pacific Northwest's hydro export to California; and (c) the statutory obligation of paying the CO_2 emissions cost by California's buyers of the electricity imported from the Desert Southwest. The policy implication is that internalization of CO_2's externality in the Western U.S.A. requires a cap-and-trade program with a regional scope that encompasses all four hubs, thereby remedying the California program's limited geographic coverage which introduces distortions in neighboring markets.

1. Introduction

Growing concerns about climate change have led to transformations in the electricity industry in various parts of the world. These changes are partly driven by such policy instruments as the renewable portfolio standard (RPS) and cap and trade (C & T) programs that are designed to promote renewable energy development and reduce CO_2 emissions (Paul et al., 2015; Trieu et al., 2016). Implementing these programs helps achieve the international commitments of deep de-carbonization made at the 2015 "COP21" climate summit in Paris,[1] reinforced by the U.S.-China agreement ratified at the 2016 G20 summit held in Hangzhou, China.[2]

An RPS program mandates that a percentage target of electricity sales be met by qualifying renewable resources such as solar, wind or geothermal. For example, California has recently set a 50% target by 2030, extending the prior target of 33% by 2020. A load-serving-entity (LSE) such as a local distribution company (LDC) or an energy retailer may satisfy its RPS requirement by generating renewable energy or purchasing renewable energy credits (RECs) from renewable generators (del Río Gonzalez, 2007; Tsao et al., 2011; Delarue and Van den Bergh, 2016; Perez et al., 2016).

A C & T program allocates tradable allowances that give polluters the right to emit by grandfathering, auction or both (Palmer and Burtraw, 2005; Palmer and Paul, 2015; Accordino and Rajagopal, 2015; Schmalensee and Stavins, 2015). The polluters then meet the C & T program's compliance requirements by surrendering a sufficient quantity of allowances to cover their CO_2 emissions. Thus, the program aims to improve economic efficiency by pursuing the first-best pricing rule that the marginal social benefit should equal the marginal social cost of electricity consumption (Woo et al., 2008; Varian, 1992).

While incentive-compatible with a firm's profit-maximizing behavior (Laffont and Tirole, 1993), these market-based RPS and C & T programs impact generators differently. An RPS program subsidizes renewable energy development by granting developers tradable RECs that can serve as a compliance instrument pursuant to a statutory target. In contrast, a C & T program penalizes polluting resources by

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[1] 21st Conference of Parties for implementing the United Nations Framework on Climate Change (UNFCCC), http://www.cop21paris.org/about/cop21/.
[2] https://www.theguardian.com/environment/2016/sep/03/breakthrough-us-china-agree-ratify-paris-climate-change-deal.

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enforcing emissions payments, rendering them less cost-competitive than clean resources such as solar and wind (Novan, 2015; Van den Bergh and Delarue, 2015; Gavard, 2016).

Several CO_2 C & T programs have been implemented at the regional and international levels. A notable example is the European Union Emission Trading System (EU ETS) that began its operation in 2005, currently covering the European Union's 31 member countries for CO_2 emissions from the electricity, energy-intensive industrial, and aviation sectors.

In contrast to the EU ETS, the two CO_2 C & T programs in the U.S.A. have less comprehensive geographic coverage. Specifically, the Regional Greenhouse Gas Initiative that began in 2009 is a joint effort by nine northeastern states to regulate CO_2 emissions from the electricity industry (Burtraw et al., 2006; Hibbard et al., 2015).

Established under Assembly Bill (AB) 32 - the California Global Warming Solutions Act of 2006 and administered by the California Air Resources Board (ARB), California's C & T program commenced operation on 01/01/2013, encompassing ~85% of greenhouse gas (GHG) emissions by large emitting entities in the state across all economic sectors (Schmalensee and Stavins, 2015).[3] AB32 mandates statewide GHG emissions be reduced to the 1990 levels by 2020. In August 2016, California passed Senate Bill 32 to extend AB32, establishing a new mandate of 40% reductions below the 1990 levels by 2030.[4]

California is an important case study of CO_2 C & T because it is the most populous state in the U.S.A. and the sixth largest economy in the world.[5] It operates a C & T program within a large regional electricity market defined by the footprint of the Western Interconnection, a synchronous electric grid that covers parts of fourteen western states, two Canadian provinces, and one Mexican state. Thus, California presents a natural experiment for detecting a C & T program's effects on wholesale market prices at the in-state hubs subject to the requirement of CO_2 allowance surrender and those at the out-of-state hubs free from the same requirement.

There are recent simulation-based studies that assess the impact of the California C & T program on supply behavior, market prices and CO_2 emissions in the Western Interconnection (e.g., Chen et al., 2011; Limpaitoon et al., 2014; Bushnell et al., 2014; Thurber et al., 2015; Perez et al., 2016). Their foci include the equivalence of C & T differed by point-of-regulation (Chen et al., 2011), market power in C & T allowance market (Limpaitoon et al., 2014), market outcomes under the C & T program (Bushnell et al., 2014), interaction of RPS and C & T (Thurber etal, 2015), and efficiency of REC trading (Perez et al., 2016). To the best of our knowledge, however, there is no empirical analysis of market data to assess the California CO_2 C & T program's effect on the Western Interconnection's wholesale electricity prices. In comparison, the previous studies by Woo et al., (2014, 2016a, 2016b) do not include the CO_2 price as one of the fundamental drivers of California's electricity prices, nor did the prior analyses of the Pacific Northwest's electricity prices (Woo et al., 2013, 2015). These regression studies' exclusion of the CO_2 price reflects: (a) their foci of the effects of nuclear plant shutdown and renewable energy development on electricity prices and generation investment incentives; and (b) their samples' limited variations in the CO_2 price data, posing an empirical challenge in isolating the CO_2 price's effect on electricity prices.[6] Nevertheless, this exclusion is a research deficiency that the current paper aims to amend.

This paper estimates the effects of California's CO_2 price ($/metric ton) on the wholesale electricity prices ($/MWh) at four electricity hubs in the Western U.S.A., which are considered as major pricing points by the U.S. Energy Information Administration (EIA). Linked by the Western Interconnection's major transmission paths, these hubs shown in Fig. 1 are: North of Path 15 (NP15) in northern California, South of Path 15 (SP15) in southern California,[7] Mid-Columbia (Mid-C) in the Pacific Northwest, and Palo Verde (PV) in the Desert Southwest. Additional Western hubs include the California Oregon Border (COB), Mona in central Utah, Four Corners in northeastern Arizona and Mead in southern Nevada. These less actively traded hubs are excluded from our analysis because they are not considered by the EIA as major pricing points in the Western Interconnection. Moreover, the Mid-C price is highly correlated ($r > 0.9$) with the COB price, as is the PV price with the prices at Mona, Four Corners and Mead. These price correlations lend further support to our empirical focus on the Mid-C and PV hubs as the major pricing points outside of California.

This estimation is important and relevant to policy makers and market participants for several reasons. First, it shows whether the California hubs incorporate the CO_2 price, thereby encouraging the state's use of CO_2-free generation such as solar and wind to displace the in-state natural gas generation. Second, it shows whether the C & T program created a persistent markup of wholesale electricity prices, resulting in unanticipated income transfers from consumers to CO_2-emitting producers. Third, it reveals whether the California C & T program in the presence of inter-regional trading affects the wholesale electricity prices outside of California. Finally, it shows the financial impact on energy sellers within and outside of California, critical for the promotion of CO_2-free energy development.

Echoing our paper's real-world relevance is California's leading role in the fight against global warming.[8] The California C & T program's electricity price consequences serve to inform the market effects that may come to other states in the Western Interconnection (e.g., Oregon and Washington) and the countries that already have or are considering C & T of CO_2 (e.g., Australia, New Zealand, Japan, Korea, India, and China).

Following Woo et al., (1997, 2013, 2014, 2015, 2016a, 2016b), our estimation is a regression analysis of the four hubs' daily electricity prices for the 65-month sample period of 01/01/2011 through 05/31/2016. As California's CO_2 trading commenced on 01/01/2013, the period has 24 pre-trading months and 41 post-trading months, yielding a large sample of ~1400 daily observations for detecting the CO_2 price's effects on wholesale electricity prices.

Our paper makes two main contributions to the literature on the empirical relationship between the CO_2 price and wholesale electricity prices. First, it documents that an increase in the CO_2 price tends to increase the bilaterally negotiated day-ahead heavy-load-hour (HLH) price for a working weekday's 16-h period of 06:00–22:00. A $1/metric ton increase in the CO_2 price is estimated to have increased the electricity prices by $0.41/MWh ($p$-value < 0.0001) for NP15 and $0.59/MWh ($p$-value < 0.0001) for SP15. Hence, we infer that the NP15 and SP15 prices fully embody the CO_2 price because Section 2.2.2 shows that the 100% pass-through of a $1/metric ton increase in the CO_2 price is ~$0.37/MWh for a combined cycle gas turbine (CCGT) and ~$0.48/MWh for a gas turbine (CT).

[3] http://www.arb.ca.gov/cc/capandtrade/guidance/cap_trade_overview.pdf.

[4] http://www.latimes.com/politics/essential/la-pol-sac-essential-politics-updates-jerry-brown-california-climate-1472077480-htmlstory.html.

[5] http://www.sacbee.com/news/business/article83780667.html.

[6] In the case of California, the focus of Woo et al. (2014) is the market price effects of renewable energy and nuclear plant shutdown. Its sample period is April 2010 ., Wang, J., 2014. Electricity-market price an_2 price data after the California C & T commencement date of 01/01/2013. The focus of Woo et al. (2016a) is the merit order effect of renewable energy development and the price divergence in California's day-ahead and real-time markets. Its sample period is 12/12/2012 price divergence in California., Ho, $T._2$ price data exhibit limited variations, as reflected by the sample mean = 12.51, standard deviation = 2.16 and coefficient of variation = 0.17. Finally, the focus of Woo et al. (2016b) is the *ex post* payoffs of natural-gas-fired generation based on the real-time market data for the same sample period. In the case of the Pacific Northwest, the focus of Woo et al., (2013, 2015) is the merit order effect of renewable energy development, not the CO_2 price effect on the Mid-C price.

[7] "Path 15 connects the transmission grids between northern and southern California and plays an important role in maintaining regional electric system reliability and market efficiency" (http://www.datcllc.com/projects/path-15/).

[8] http://www.nytimes.com/2016/12/26/us/california-climate-change-jerry-brown-donald-trump.html?_r=0.