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Tax induced emissions? Estimating short-run emission impacts from carbon taxation under different market structures

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ABSTRACT

This article finds that the introduction of a carbon tax increased short-run carbon emissions in an imperfectly competitive wholesale electricity market. The unique feature of the Western Australian setting is that the same carbon tax was introduced and later repealed, but the market structure differed at each event. At the repeal event, the dominant firm had less incentive to exercise unilateral market power. Then, the opposite result is observed — emissions were lower with the tax. I show how the short-run impact of pollution taxation in imperfect markets depends on production technologies, market structure and the size of the tax.

1. Introduction

In the absence of a global agreement on carbon pollution policy, many jurisdictions are adopting stand-alone carbon pricing instruments to meet their long- and short-run emission targets.[1] One mechanism by which short-run carbon emission reductions can occur is a reallocation of production toward an existing stock of lower emitting plants. Such fuel switching has been observed during the recent USA shale gas boom, because lower natural gas prices improved the cost competitiveness of natural gas electricity generators relative to higher carbon polluting coal generators. However, as first documented in Levin (1985), a fall in emissions in response to cleaner technologies becoming relatively cheaper (for example, due to a pollution tax) is not guaranteed. There are conditions where pollution taxes in oligopolistic markets interact with firm market power to induce *more* pollution. The profit maximizing response of firms can result in equilibrium market shares adjusting such that firms with clean marginal units reduce their production and firms with dirty marginal units increase their production.

This article provides an empirical illustration of how industrial and technological conditions can interact such that a pollution tax can induce more pollution in the short-run. The empirical setting is the concentrated wholesale electricity market of Western Australia. The market was subjected to a AUD$23/t$CO_2$(USD$23.5)[2] carbon tax introduced on July 1, 2012. On January 1, 2014, the market was reorganized such that the dominant generator owner in the market was merged with the monopolist retailer. This reorganization of the market substantially changed the incentives of the dominant supplier. Because retail prices in Western Australia are a regulated price, the incentive for the generating arm of the vertically integrated firm to

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[1] Examples of localized carbon pricing policies include California, British Columbia, Québec, Alberta, Japan, Chile, Mexico, New Zealand and South Korea. Full list available in World Bank et al. (2017, pp. 27–28).

[2] The tax was indexed and rose to AUD$24.15 on July 1, 2013. The currency exchange rate on July 1, 2012 was AUD$1 to USD$1.02. Given the near parity, all further prices will be reported in Australian dollars.

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exercise unilateral market power to raise prices was diminished. On July 1, 2014 the carbon tax was repealed.

This change in market structure and sequence of events provides an ideal setting for analyzing the role of market structure on the effectiveness of carbon pricing in reducing emissions because the same carbon price was added and removed under two different market structures but in the same market. Measuring the effectiveness of carbon pricing under each market structure is possible given that over the sample window: there were no changes to production technologies; industry structure otherwise remained the same; the market is isolated and free of trade to other markets, and; end-user demand is not responsive to wholesale price.

I find that carbon emissions *increased* following the introduction of the carbon tax. One requirement for this unexpected response was that the carbon tax was set at a magnitude that mostly reduced – without eliminating – the cost advantage of high polluting coal generators over the cleaner natural gas generators. A second requirement was that the dominant firm possessed market power. Although these requirements are not sufficient for the result to occur, in this case they provided conditions whereby the carbon tax flattened the marginal costs and residual demand the dominant firm faced such that its new profit maximizing strategy was to increase its production. At a market level, this resulted in a reallocation away from competitor natural gas-fired generation to the dominant firm's coal-fired generation, increasing total market emissions by 1.6%, all else being equal. Despite the pollution increase, the increase in carbon damages was smaller than the gains in production efficiency resulting from lower cost coal generation replacing higher cost natural gas generation. At the removal of the carbon tax, the market structure had changed where the dominant firm internalized the profits of the regulated fixed price retailer. I show that as a consequence of the reorganization, the dominant firm had less incentive to raise wholesale prices, and that total market costs of production fell. Then, the tax removal resulted in a production reallocation toward higher emitting plants, with emissions estimated to be lower with a carbon tax by an average of 1.4%, all else being equal.

Together, I use the two events studied in this paper to demonstrate how the short-run pollution impacts from pollution taxation are sensitive to the industry structure and the technologies used to serve demand in a market. This could be of practical importance for concentrated industries that contain a mix of production technologies that are cheap-and-dirty and expensive-and-clean. For example, although a "small" tax may appear politically appealing for policy makers that want to act on reducing pollution but do not want to instigate a large transfer of wealth from coal to natural gas electricity generator owners, there is a risk that the policy will increase carbon emissions. This could be politically undesirable if such an industry effect is not swamped by reductions in other polluting industries to meet emission reduction targets, or if the expected long-run benefits from carbon taxation are difficult to communicate to the public.

The article proceeds by discussing the empirical setting and reviewing existing empirical results on short-run fuel switching in electricity markets from fuel price shocks. I then outline the theoretical ambiguity on the impact carbon taxation has on carbon emissions in imperfect markets. Then, the data, empirical strategy, and the empirical results for the impact the carbon tax had on emissions, market power and prices are presented. The final section explores the implications of the empirical results for policy makers.

2. Empirical setting: the Western Australian electricity market

The Western Australian Wholesale Electricity Market (WEM) features one dominant player – Synergy Energy – which owns and operates over 50% of the electricity generating capacity in a market that contains no interconnections to any other markets. The remoteness of the market and the stability in the power plant stock provides a clean setting for assessing the short-run impact of a carbon tax.[3]

Two related articles have investigated how lowering natural gas prices (relative to coal) have affected carbon emissions from electricity generation during the US shale gas boom. First, Cullen and Mansur (2017) use the price variation over the boom to infer the potential impact carbon taxation could have on reducing carbon emissions from production reallocation within the existing stock of generators. The authors raise the possibility that these reductions could be small, depending on the size of the tax, market structure and the prevailing coal and natural gas prices in the market. Second, Knittel et al. (2015) document that changes in the generating mix in restructured electricity markets were substantially less responsive to the shale gas boom than traditionally structured (state-owned or regulated monopoly) markets. Studying the WEM builds on these studies in two ways. First, the impact of an actual carbon tax can be studied. Second, the importance of market structure can be stressed given the timing of the events displayed in Fig. 1. At the introduction of the carbon tax in 2012, Synergy Energy (then named Verve Energy) only owned electricity generators. However, on January 1, 2014, Synergy's generating arm merged with the market's monopolist retailer to become a vertically integrated entity.[4] The incentives faced by Synergy were dramatically changed by acquiring the retailing arm, where it was regulated to charge a fixed price to its retail customers. Their strategic supply responses to the carbon tax therefore differed at the introduction and removal of the tax, and consequently the overall impact of the carbon tax differed for each event. These incentives will be described in Section 3 in a broader theoretical discussion.

An important feature of this setting is the impact the carbon tax had on the marginal costs of electricity generation in the WEM. In Fig. 2 (and Table B1) we see that the carbon tax diminished, without eliminating, the cost advantages of cheap-and-dirty plants relative to expensive-and-clean plants.[5] The four charts display engineering estimates of the short-run marginal cost curves and emission rates for Synergy and all other generators, with and without the $23/tCO_2$ carbon tax introduced in 2012. Each horizontal line joining the dots represents the capacity and marginal cost of a generator and the cumulative order is from the lowest to highest marginal cost. The major impact of the tax on Synergy's marginal costs is the flattening of the curve between 1000 and 1500 MW. This flattening still has the higher emitting coal power plants just cheaper than the lower emitting natural gas plants. As for the rest of the market, there was a large flattening of the marginal cost curve between 500 and 1000 MW of cumulative capacity, again with coal generators maintaining a cost advantage over the natural gas generators.

In perfectly competitive markets we should expect little impact on the pollution intensity of market production following the introduction of a tax that does not change the marginal cost ordering of plants. However, in imperfect markets, this is not the case. The flattening or steepening of marginal cost curves and residual demand curves of firms will impact the optimal production strategies of firms

[3] No new coal or natural gas generating capacity was added, and no existing capacity shut down, between the sample window of 2011–2015.

[4] Before the vertical integration, the generating arm was owned by Verve Energy. Throughout this article, references to Synergy are intended to refer to the dominant generating firm.

[5] Sources for marginal cost estimates are described in Table B1 and the data section. 201 MW of peaking, distillate fueled generators are omitted from the table and charts. They are high cost, high emissions plants used infrequently. The marginal cost estimates for some gas cogeneration units reflect the costs apportioned to the electricity production of the plant. These plants use also the heat or steam generated from combustion for other purposes. These marginal cost estimates are not formally used in the statistical analysis, and are left unadjusted for this descriptive portion of the analysis. For further details, see Sinclair Knight Merz MMA (2014).