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Carbon mitigation in the electric power sector under cap-and-trade and renewables policies

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HIGHLIGHTS

- CO_2 cap-and-trade interacts with policies targeting one specific sector under cap.
- Interaction creates emission displacement and/or impacts CO_2 price.
- The central contribution is the derivation of impact curves from the emission plane.
- The method is applied to a case study of Central-Western Europe.
- The analysis reveals a large impact of renewables on CO_2 displacement and/or price.

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ABSTRACT

In Europe, CO_2 emissions from the electric power sector and energy intensive industries are capped under a cap-and-trade system (i.e., the EU ETS). When other indirect measures are taken to impact emissions in a specific sector under the cap (such as a push for renewables in the electric power sector), this has implications on the overall allowance price, and on CO_2 emissions both from this specific sector and the other sectors under the cap. The central contribution of this paper is the derivation of impact curves, which describe these interactions, i.e., the impact on allowance price and the shift of emissions across sectors. From a set of detailed simulations of the electric power system operation, a so-called "emission plane" is obtained, from which impact curves can be derived. Focus is on interactions between CO_2 abatement through fuel switching and measures affecting the residual electricity demand (such as deployment of renewables) in the electric power sector, as well as on interactions with other sectors, both in a short-term framework. A case study for Central-Western Europe is presented. The analysis reveals a substantial impact of renewables on CO_2 emissions, and hence on emissions shifts across sectors and/or on the CO_2 price.

1. Introduction

Different countries and regions launched or intend to launch policy packages to limit the emission of greenhouse gases. The two main types of direct emission policies are an emission tax, i.e., a price instrument that imposes a fixed payment per emitted unit, and an emission cap, i.e., a quantity mechanism that imposes a maximum to the amount of emissions. An emission cap policy can be implemented as a cap-and-trade mechanism. In such a system, an aggregated emission cap is imposed to a group of emitters and a trade in emission allowances is organized between the emitters, resulting in a CO_2 price. This paper focuses on a cap-and-trade mechanism as emission policy instrument.

CO_2 emissions, however, are not only affected by a CO_2 price directly.[1] Other determinants can relate to energy market effects (such as fossil fuel prices), but can also often (directly) result from policies other than directly setting a CO_2 cap such as renewable energy policies (Johnson and Novacheck, 2015). Hence, under a cap-and-trade system, such other policies on their turn can have an impact on the CO_2 price and can create shifts of emissions between different sectors under the cap.

The EU ETS is currently the largest emission trading system in the world. Initiated in 2005, the EU ETS puts a cap on the CO_2 emissions of the European electric power sector, other heavy industry (e.g., steel, aluminum, cement, pulp and paper), and more

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[1] In the electric power sector, which is the focus of this paper, the most relevant greenhouse gas is CO_2. Hence, the scope of this paper is narrowed to CO_2 (no other greenhouse gases are considered).

recently aviation (flights within Europe). Within the EU ETS, the electric power sector is responsible for about half of the CO_2 emissions, while the other industries take up the other half (Ellerman et al., 2014). The EU ETS covers about 45% of total European greenhouse gas emissions. For every ton of CO_2 emitted, an allowance has to be surrendered. These allowances can be traded freely on the market, between companies, active in the different sectors under the cap. This way, CO_2 emissions are abated where it is cheapest and CO_2 emissions are displaced from sectors with cheap abatement possibilities towards sectors with more expensive abatement options. After a trial period running from 2005 to 2007, the second ETS trading period spanned the Kyoto commitment period (2008–2012). The third period currently runs from 2013 till 2020. Allocation of allowances was initially largely for free (till 2012). As from 2013, the major share of allowances is auctioned (at least in the electric power sector). For more background on the functioning of the EU ETS, we refer to Ellerman et al. (2010).

The ETS sectors face an absolute cap on CO_2 emissions, declining each year, to reach a 21% reduction in 2020 compared to 2005. The tightness of the cap determines the level of abatement required compared to business as usual (no cap), and hence sets the price of the allowances (marginal abatement cost). With an absolute cap, the demand for allowances is, however, also heavily influenced by external factors. A first example is the economic/financial crisis reigning in Europe from 2008 onwards, clearly having an impact on industrial activity and hence CO_2 emissions (Koch et al., 2014; Declercq et al., 2010). Second, also certain policy measures can affect the demand for allowances, e.g., imposing targets for renewable energy, this way pushing carbon free electricity into the system, again reducing the tightness of the cap. These two effects, together with a relatively high inflow of international credits (which can cover part of the emissions under the cap), have led to a surplus[2] of allowances, gradually built up since the second trading period. Allowances are furthermore bankable to subsequent trading periods. The surplus being built up in the second period was as such transferred to the third trading period, leading to a surplus of allowances of over 2000 $MtCO_2$ in 2014 (European Commission, 2014). Correspondingly, for several years the EUA price has been consistently low, between 4 and 8 EUR/tCO_2.

While CO_2 emissions are below the cap and hence meet the target set, a current concern in the policy debate is the resulting CO_2 price, which is too low to serve as a solid signal for low carbon investments deemed crucial for the transition to a low-carbon energy system on the longer term. In this regard, the European Commission (EC) has implemented a backloading measure in the third phase and a more structural reform through a market stability reserve as from 2019 (with the back-loaded allowances being put directly in this reserve). Despite these current issues, the EU ETS is still considered as Europe's main instrument to reduce carbon emissions.

Next to the EU ETS, especially renewables have played an important role in Europe's recent climate and energy policy. By 2020, 20% of Europe's final energy consumption is to come from renewables (European Commission, 2009). The 20% target is translated to binding individual member state targets. Member states are free to adopt appropriate support measures (such as feed-in tariffs or green certificates) to achieve their renewables target.

In this paper, the interaction between a cap-and-trade system for CO_2 emissions and other indirect CO_2 emission measures[3] is being assessed. Specific focus is on how measures in one specific sector under the cap, have an impact on overall allowance price and how these can create shifts in emissions between different sectors under the cap. Focus is on the European electric power sector. This sector is subject to the EU ETS on the one hand, and faces an imposed increasing share of renewable electricity generation (RES) on the other.

The central new development of this paper is the derivation of impact curves. These impact curves present a range of the potential impact of RES, on both an emission shift under the overall cap, and the ETS price (i.e., a set of equilibrium positions). A methodology is developed to derive such impact curves from an emission plane, depicting CO_2 emissions as a function of the residual demand (affected by RES) and the CO_2 price. This emission plane captures all the operational electricity generation system effects, by making use of detailed unit commitment modeling. By deriving the impact curve from such a plane, the developed method helps gaining a better understanding of the interaction effects. As such, from a detailed bottom-up perspective, the interactions between these two policy instruments are being assessed and quantified, taking a relatively short-term perspective.[4] The interaction (allowance price and shifts of emissions) between the electric power sector and the other sectors operating under the ETS cap is finally addressed.

In the next section, background and relevant literature are being discussed, together with the specific contribution of this paper. Then the overall methodology is described. Results are presented and discussed in the fourth section of this paper for the Central-Western European Region. The final section concludes and addresses the policy implications of our findings.

2. Background and literature review

Different policy instruments can be deployed to mitigate CO_2 emissions. These can range from a direct CO_2 emission price or emission performance standard, to measures related to fossil fuel taxation, energy efficiency measures, renewables deployment policies or R&D funding. From a wider economic perspective, arguments could be raised to call for multiple instrument deployment. Fischer and Preonas (2010) review in this sense the conditions that would make different policies necessary. Fischer and Newell (2008) present an analysis to come to an optimal overall policy to reduce emissions, which involves a portfolio of different instruments due to knowledge spillover. Beato and Delgado (2015) claim that the use of various instruments is justified under circumstances that undermine the effectiveness of carbon markets, such as market design flaws or innovation externalities. However, it is shown by Tuladhar et al. (2014) that under a mixed policy regime, a CO_2 price is an unsuitable indicator of economic costs of carbon mitigation.

Focusing on the electric power sector, the interaction between a direct CO_2 policy being implemented as tradable permit system with a fixed cap, and renewable energy polices, has been discussed in various contributions in the literature. An electricity generation investment model is typically set up and deployed to address

[2] Ellerman et al. (2015) point out that the term "surplus" should be used carefully. Part of the allowances being banked (i.e., saved up for being used later) can be banked intentionally, to minimize overall abatement costs over a longer time period, given the continuously decreasing cap. This explains at least part of the difference between the cap and actual emissions.

[3] In this paper, focus will be mainly on the push for renewables as indirect measure. However, as will also be briefly illustrated in Appendix A, the methodology is generally applicable to other measures, such as support for electric vehicles.

[4] A short-term perspective is taken, where the impact of a CO_2 price in the electric power sector is through operational fuel switching. In Appendix B of this paper, the methodology is expanded for a case where the impact of a CO_2 price on RES investment decisions is accounted for.