Quantifying the net cost of a carbon price floor in Germany

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ABSTRACT

The German energy and climate policy mix is failing to decarbonize electricity production until now, with only 6% overall CO₂ emissions reductions since 2005. Using empirical methods and hourly market data, we estimate the aggregate supply curve of the German power market and simulate the effect of a 20€/tCO₂ and 40€/tCO₂ carbon price floor on the German power market and on the renewable subsidy scheme. With the 40€/tCO₂ carbon price floor, median prices increase by 37€/MWh and average price peaks by 50€/MWh. At the wholesale level, the market’s annual volume increases by some €18 billion to €39 billion. At the retail level, however, the net cost to consumers is moderated due to costs savings from the renewable subsidy scheme worth some €4 billion, or roughly one-fifth. The same ratio applies to a price floor at 20€/tCO₂.

1. Introduction

Between 2005—the start of the EU emissions trading scheme (EU-ETS)—and 2015, yearly CO₂ emissions from the German power sector fell by 6% overall, with periods of increasing emissions (Agora, 2016). At this pace, decarbonization of the German power sector will be achieved in the middle of the 22nd century. Since the economic downturn of 2009, the EU-ETS has been structurally out of balance, with an ongoing surplus of nearly one year worth of allowances (Koch et al., 2014). More recently, the EU concluded that current reduction efforts are insufficient to reach the 2030 target of reducing emissions by 40% below 1990-levels and therefore introduced further measures known as backloading and market stability reserve (EEA, 2015; EU, 2015; Sandbag, 2013). However, Koch et al. (2016) show that prices actually fell on news from the backloading decision process, implying that announced measures are less stringent than expected.

In addition to climate effectiveness, the current German energy and climate policy mix seems to under-achieve on at least two other dimensions, namely energy affordability and system adequacy. In Germany, as in most European countries, renewable energy sources (RES) are promoted through a national feed-in-scheme, termed “EEG”, which compensates producers for the difference between market prices and their higher production costs. Although such schemes can be justified on various grounds, e.g. local or dynamic benefits (Lehmann and Gawel, 2013; Lecuyer and Quirion, 2013), the resulting policy overlap with the EU-ETS is often criticized for its inefficiency. Cludius et al. (2014) highlight the rising cost burden on households, as the EEG is financed through a levy on final electricity consumption.1

Moreover, the additional wind and solar generation fed into the system exert downward pressure on spot market prices. This lowers the economic viability of systematically important back-up generation (Würzburg et al., 2013; Traber and Kemfert, 2011; Hildmann et al., 2011), and undermines system adequacy in the long run.

The experience and developments outlined above cast doubt whether the current climate policy setup can provide sufficient incentives to reduce emissions from power supply to almost zero by 2050, as set out by the EU’s Roadmap (EU, 2012). It is well known that tax-like instruments are best suited to deal with the problem of climate

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1 At the beginning of 2016, the EEG-levy amounts to roughly three times the wholesale market price for electricity (Agora, 2016).
change (Newell and Pizer, 2003), and if not available, that hybrid instruments provide useful safety valves to guarantee against unreasonably high costs (Roberts and Spence, 1976: Burtraw et al., 2010).²

Ironically, the lesson learned from the EU-ETS led other jurisdictions to implement price floors and ceilings from the start (World Bank, 2015; Newell et al., 2013; Goulder, 2013), but has not yet been considered at the EU-level until recently. However, the United Kingdom (UK) introduced a carbon price floor in 2013, in the form of a complimentary tax on emissions if the EU-ETS price falls below a predetermined floor (UK Parliament, 2013), and France is considering a price floor starting at 30€/tCO₂.

The idea of discretionary price management mechanisms recently gained traction among large utilities and some member states in the form of a reserve price in the auctions for emissions allowances in the power sector. Reserve prices are an important feature of good auction design (Ausubel and Cramton, 2004): if the market clearing price of the auction falls below the price floor, the unsold allowances automatically restrict the supply of allowances and support the carbon price.³ A carbon price floor affects marginal costs of fossil-fired plants and thereby wholesale power prices. Depending on its stringency, fuel-switching occurs in the merit order (Delarue et al., 2008), implying significant emissions reductions. Moreover, with higher wholesale prices, the costs of promoting RES decreases.

We use a novel approach, proposed by He et al. (2013), to quantify the impacts of a carbon price floor on the German electricity market. We estimate the yearly supply curve of the German wholesale market using the 8760 hourly price-load observations. By controlling for fuel and carbon prices, we derive the aggregate heat rate curve of the market, a fundamental power market characteristic. This allows us to simulate the market outcome with a fabricated price vector, e.g. a market, a fundamental power market characteristic. This allows us to capture real world market imperfections, such as strategic bidding, and complex technical constraints leading, among other things, to hours with prices above marginal costs or in negative territory. Thanks to its empirical foundation, the model captures and replicates such extreme situations.

These market outcomes are rare, more complex to explain fundamentally and often pose a challenge for technically explicit bottom-up models.

The main limitation of our approach is the assumption of a static heat-rate curve and thus a fixed supply side. By abstracting from the possibility of fuel-switching in the short term and from plant replacements in the longer term, we neglect the cost-minimizing behavior on the supply side. This means our results should be interpreted as an upper ceiling of the probable effects of a carbon price floor.

2.1. Data

Daily primary energy, CO₂ and hourly spot market price data are taken from European Energy Exchange (EEX) or Gaspool (GPL). Hourly load, RES-infeed,⁴ net exports, unavailability due to planned and unplanned outages of power plants are taken from the transparency platforms of EEX, the European Network of Transmission System Operators for Electricity (ENTSO-E) or directly from the four TSOs operating in Germany.

Hourly vertical load data represents the flows from the highest level transmission grid to the lower grid levels. As virtually no RES plants are directly connected to the transmission grid (Bundesnetzagentur, 2015), vertical load represents the residual part of consumption that needs to be covered by conventional plants, after subtracting the generation of RES. By contrast, common supply represents the entire national consumption.

All time series are converted to an hourly resolution, generating 8760 hourly observations per year. Table 1 reports summary statistics and sources, Fig. 1 depicts the price series.

2.2. Modeling

HHHA propose several deterministic model specifications for the aggregate supply curve. We test all their specifications with our newer data. For shortness, we only present the two extreme cases, the simple exponential model and the fuel-adjusted heat rate model.

In terms of fundamentals, two parameters that affect the economics of power plants and thus the slope of the merit order curve are the CO₂ content of a given fuel input, ϕf, and the heat rate of a power plant type, λp, where (ϕf = lignite, coal, gas). The heat rate represents the amount of thermal primary energy required to generate one unit of electricity and is therefore the inverse of efficiency. The product of heat rate and CO₂ takes the form of a competitive bidding model (HHHA, 2013), where the price is a function of the carbon content of the fuel and the heat rate of the power plant type. This can be written as:

\[ p(t) = \min_{j \in J} (\phi_j \cdot \lambda_j(t)) \]

where \( J \) is the set of all power plant types, \( \phi_j \) is the heat rate for power plant type \( j \), and \( \lambda_j(t) \) is the heat rate at time \( t \) for power plant type \( j \).

2.2.1. Simple exponential model

The simple exponential model is given by:

\[ p(t) = \frac{1}{\lambda_j(t)} \cdot \phi_j \]

2.2.2. Fuel-adjusted heat rate model

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2.2.3. Hybrid model

The hybrid model combines the simple exponential model with the fuel-adjusted heat rate model. It is given by:

\[ p(t) = \min_{j \in J} (\phi_j \cdot \lambda_j(t)) \]

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2.2.4. Deterministic model specifications

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