DISTRICT HEATING SYSTEMS UNDER HIGH CARBON PRICES: THE ROLE OF THE PASS-THROUGH FROM EMISSION PRICES TO POWER PRICES

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Overview

With the signature of the Paris Agreement, the European Union (EU) committed itself to pursue climate policies to limit global warming to "well below 2°C" (United Nations Framework Convention on Climate Change, 2015), which implies the need for a drastic reduction in greenhouse gas (GHG) emissions. The EU's flagship instrument to reduce GHG emissions is the Emissions Trading System (ETS). However, the incentives for emission reduction provided by current low emission prices are considered insufficient to reach ambitious long-term GHG reduction goals.

Low emission prices have prompted discussion about political measures aimed at increasing the cost of carbon emissions. These costs affect district heating system operators (DHSO), often municipal utilities, that use a variety of (emission intense) heat generation technologies. On the one hand, higher emission prices raise the cost of (emission intense) heat generation. On the other hand, power generation in DHSO's co-generation plants may become more profitable if emission intensity of co-generation plants is low compared to the emission intensity of the price setting technologies in the power system. Thus, we examine whether DHSOs benefit from measures that increase emission prices in the short term.

In the following, we (i) develop a simplified analytical framework to analyse decisions of a district heating operator. Our analysis suggests, that the pass-through from emission prices to power prices is a key determinant of heat generation cost, dispatch of heat generators and DHSOs' total profit.

The literature on the pass-through from emission prices to power prices is dominated by econometric analysis of pass-through levels at actual historical emission prices (Sijm, Neuhoff, & Chen, 2006; Zachmann & von Hirschhausen, 2008; Hintermann, 2014; Fabra & Reguant, 2014). However, Hintermann (2014) points out that econometric analysis based on price or price spread regressions produces biased pass-through estimates, amongst others due to the merit order being correlated with input prices.

Consequently, we (ii) investigate the pass-through of emission prices to power prices with MEDEA, a bottom-up unit commitment model of the joint Austro-German market area. This allows us to take into account full (inter-temporal) optimization of the power system, instead of relying on hourly models of the merit order only.

Methods

We use the power system model MEDEA to investigate the effect of emission prices on power prices, i.e. to estimate the pass-through from emission prices to power prices. MEDEA is a clustered unit commitment model that builds on work by Palmintier (2014). Total system costs of meeting price inelastic (residual) electricity and heat demand are minimized through the hourly dispatch of installed thermal and hydro storage power plants, taking power generation from intermittent sources of renewable energy (wind and solar radiation) as given.

Within the common bidding area of Austria and Germany, 893 conventional power plants are included. Each conventional plants belongs to one of 29 power plant clusters, which are differentiated by fuel (uranium, lignite, hard coal, natural gas, mineral oil, biomass, water) and generation technologies (steam turbine, combustion turbine, combined cycle, etc.). Technical parameters of power plant operation are represented in detail. Start-up of a plant requires additional fuel. Once a plant has started up, its generation can be adjusted flexibly between the plant's rated capacity and its minimal generation. Shutting down a power plant implies additional costs (Morales-España, Latorre, & Ramos, 2013). Power plant efficiencies are estimated based on the plant's age and technology (Egerer, et al., 2014). Co-generation of heat and power is possible in CHP-plants, which can adjust power and heat generation flexibly within a given, three-dimensional feasible operating region. To provide additional operational flexibility for CHP-plants, heat demand can alternatively be met by heat-only natural gas boilers. In addition to thermal plants, electricity can also be generated by the 45 pumped hydro storage plants and seasonal hydro storage plants with a total capacity of 10.4 GW included in the model.

To reduce computation times, the model is solved iteratively for blocks of 1167 hours. To avoid last-round effects, the last 72 hours of each iteration are discarded. The solution for the 1095th hour is then used as starting values for the subsequent iteration. We also solve a linear (LP) and a mixed-integer linear (MIP) version of the model. The model is written in GAMS and solved by CPLEX (12.6.1.0). A detailed formal description of the model is provided in appendix A.

Results

Irrespective of the chosen modelling approach, we see the pass-through decline from around 1.1 at emission prices around 10 €/t CO2e to approximately 0.78 at emission prices near 55 €/t CO2e. This can be explained by (i) a "fuel switch" triggered by rising emissions prices, (ii) a changing pattern of co-generation outputs and (iii) an increase in the overall fuel efficiency.

Based on our stylized model of district heating system operation, we estimate the pass-through rate that is minimally required to achieve cost reductions for a less efficient combined heat and power (CHP) plant (electrical an thermal efficiency of 0.4) at 0.5. Total profit of the entire system (CHP and boilers) will increase if the pass-through exceeds 0.556 provided that the share of heat generated in boilers does not exceed 20% of the total emission intense heat generation.

Conclusions

We have shown that the emission price has a large effect on the power price through an almost complete pass-through of marginal cost to power prices at current emission price levels. Moreover, the rate of pass-through depends not only on the weak incentives for mark-up adjustment and the absence of relevant price rigidities (Fabra & Reguant, 2014), but also on the absolute level of the emission price.

Our estimated pass-through rates are substantially higher than the pass-through rates required to make owners of district heating systems with low emission intensity better off. Given the current power generation system in the common German and Austrian market area, increased emission prices will lead to power price increases that exceed cost increases and induce higher utilization of gas-fired CHP-plants. Consequently, DHSOs' profits rise, provided that a sufficient share of total fossil heat generation is sourced from co-generation units.

Thus, we conclude that district heating system owners that operate gas-fired assets should favour higher emission prices.

References

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