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The impact of the German response to the Fukushima earthquake☆

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ABSTRACT

The German response to the Fukushima nuclear power plant incident was possibly the most significant change of policy towards nuclear power outside Japan, leading to a sudden and very substantial shift in the underlying power generation structure in Germany, an enthusiastic leading proponent of renewable power. This provides a very useful experiment on the impact of a supply shock in the context of increasing relative generation by renewable compared to conventional fuel inputs into power production. Our quasi-experimental exploration of a modified demand-supply framework finds that despite the swift, unpredicted change in nuclear power, the main impact was a significant average increase in prices, surprisingly particularly at low residual load levels.

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1. Introduction

The German "Atomausstieg" decision to have a nuclear moratorium following the Fukushima nuclear disaster in Japan in March 2011 was sudden, unexpected, decisive and significant internationally (Joskow and Parsons, 2012). Immediate closure for testing in March 2011, confirmed by end-May 2011 as a permanent shutdown, of 6 of the 17 plants producing nuclear energy (as well as two that were offline at the time) was instituted. As a result, whereas in 2010 over 22% of its power was from nuclear sources, this decreased to less than 16% in 2012 (BDEW, 2014). Removing this amount of capacity from the system in such an unplanned manner would be infeasible in some other countries; for example in Britain it would likely cause complete collapse.[1] This did not happen in Germany, because it is relatively well-endowed with power plants, it is well-connected with other countries (it remains a significant net power exporter) and it has invested heavily in renewables. However, what did happen was a sudden switch to a less controllable system; essentially base-load generation was removed whilst, through a separate policy process, there was a significant increase in intermittent sources. We investigate the impact of the sudden change in nuclear policy in terms of effects on load and prices.

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[1] National grid scenarios do not encompass such a major drop in capacity.

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Reductions in the nuclear fleet can be expected to increase spot prices, since nuclear plants produce power at low marginal cost and therefore operate as baseload. Some observers would predict the largest rises would occur at peak times (Poyry, 2010). However our estimates show something that at first blush might seem surprising: the major price impacts are felt in the dead of night, as a result of necessary movements up the merit order curve (i.e. the supply side ordered from lowest to highest marginal cost generation unit representing the economic order in which plant is brought onstream as load increases) once a significant part of the nuclear fleet had been taken off-line. In part as a result of this, despite increasing electricity generation from renewables by over 1/3 between 2010 and 2012, Germany *increased* its CO_2 emissions from power plants by around 3.9% over these two years, whilst generating slightly less electricity in total in 2012 as a result of increased use of coal and lignite plants.[2] This means that the CO_2 emissions per unit of residual demand generated were 13% higher in 2012 than in 2010, going against the German policy of Energiegewende.[3] This provides a wider context to our analysis of price effects.

The data we have enable us to document in detail, over hours of the day and throughout levels of residual load, the impact of the decision on supply, spot prices and, to some extent, on generation mix.[4] Our approach to the topic utilises a detailed hourly dataset on prices and load over four years, using a broad supply-demand framework tailored to the German case. Specific features include detailed disaggregated temperatures across the country, information on all key import and export interconnections and a specially calibrated residual supply index so that market power effects due to tighter supply can be separated from the direct influence of the Atomausstieg. Econometrically, we are careful to set out our identification assumptions and instrumentation strategy. We explore a variety of approaches, using a range of techniques, on the supply side to check robustness and to identify the separate impacts at different times of day and generation levels.

To preview our results, we confirm that whilst there is no evidence equilibrium quantity was negatively impacted by the sudden decision, there is a clear significant impact on price - a movement up the supply curve, other things equal, resulting from the use of higher cost fuel sources.[5] We estimate an average price increase of around 8.7% and calibrate the net impact on German consumers at approximately 1.75 Bn € per year. Our estimates find the price increase to be partly driven by increased market power - scarcity price markups become more common - in addition to a general leftward shift in the merit order. Furthermore, the closure of the 6 GW nuclear capacity was partially absorbed by cross-border trade. Our results contribute to the ongoing analysis of whether electricity prices would have been lower with extended nuclear plants life spans (Nestle, 2012), as well as permitting some more general lessons to be drawn.

Fig. 1 charts the data we later investigate in some detail, simply taking mean prices and mean load into account. Comparing complete years before (average of 2009 and 2010) and after (2012) the Atomausstieg decision, we observe an average price increase in off-peak periods but the reverse impact on the early afternoon hours where significantly augmented solar power has its greatest impact. With regard to load we observe a decrease in the morning hours and an increase during the day. A figure illustrating these patterns split into summer and winter is available in Appendix A. For comparison we also report figures on prices and load for the British market since the market shares no direct interconnectors with the German market in Appendix A.

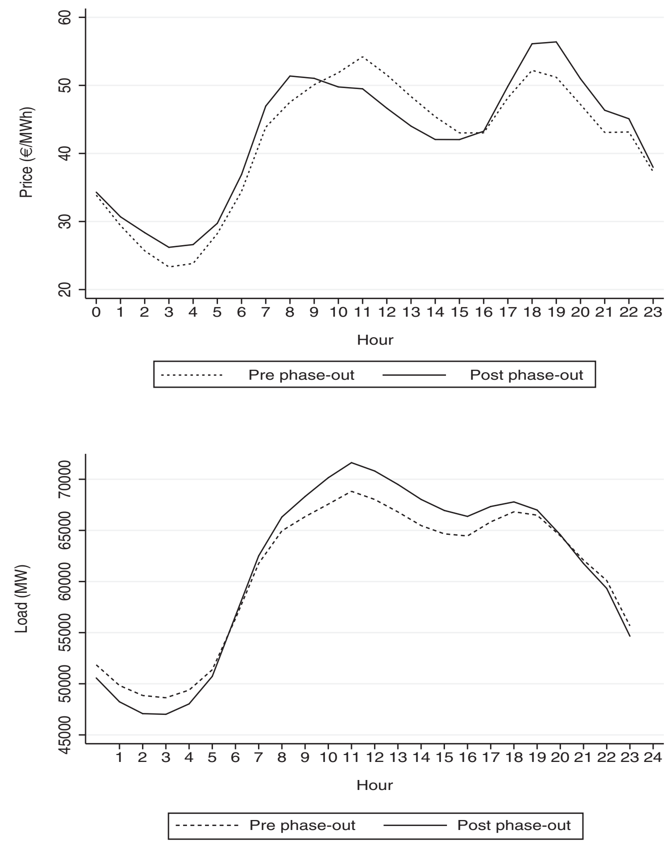

Fig. 1. Mean hourly spot price and load (average of 2009 and 2010) and after (2012) the Atomausstieg decision.

Many authors have looked at the impact of the German decision to date (e.g. Betzer et al., 2013; Ferstl et al., 2012; Thoenes, 2014) focussing on event studies in order to infer profitability impacts, not the arguably more important effects on consumers, although Thoenes (2014) investigates futures prices. A more relevant paper is Kunz and Weigt (2014), which surveys some early model-based predictions of the effects on prices, amongst other things, summarizing that prices will rise up to 10 €/MWh in the short term. This is surprisingly close to what we find. However, although the finding that the outage causes a price rise is unsurprising, we are able to show big price rises particularly in low demand periods whilst the impact on price is insignificant during peak load. To our knowledge, this is something that was not predicted.

The closest study to ours is a recent paper (Davis and Hausman, 2016), that also examines market reaction to an unanticipated nuclear outage through a before and after experiment. In their case it is the sudden unexpected closure of a nuclear power plant in California which had an impact on Californian generation capacity of similar relative magnitude to the German decision on German capacity. Davis and Hausman's main goal is to evaluate the consequence of the plant closure on generation mix, generation costs and emissions in the first 12 months after the closure. Given the observed natural gas generation, they aim to measure how much of

[2] Source: http://de.statista.com/statistik/daten/studie/38893/umfrage/co2-emissionen-durch-stromerzeugung-in-deutschland-seit-1990/.

[3] For further information on the carbon abating potential from nuclear see Davis and Wolfram (2012). Of course, not all of the 13% can be assigned to the nuclear outage; we should not neglect that lower coal prices lead to relatively more generation by coal as opposed to gas. On the issue of CO_2 emission sensitivity to alternative scenarios regarding fuel prices, see Knopf et al. (2014).

[4] Unlike some other countries such as Spain (Fabra and Reguant, 2014) in Germany, plant-level generation data are not available.

[5] If there had been selective disconnection or "brown-outs" then we would expect to see these in the empirical estimates for load through a reduction in expected load given exogenous parameter values. There is no hard evidence that they occurred; on this see later.

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