Integrated Electricity and Natural Gas Market Modeling – The Effects of Market Liberalization in Europe

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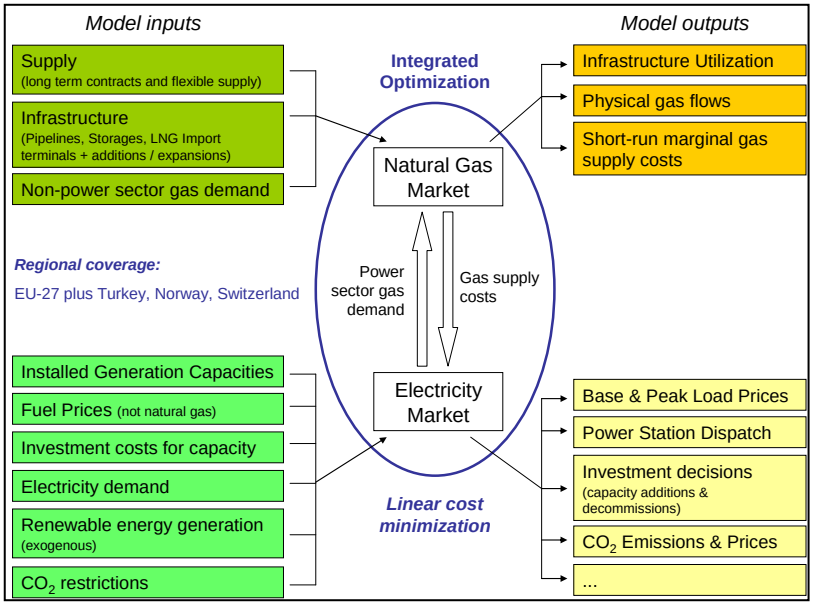
Overview

Most natural gas sales in the just recently liberalised continental European gas market are characterized by long-term contracts with prices indexed to the relevant gas substitutes, usually oil, hard coal or light fuel oil. Natural gas hubs for short-term trading only exist in some countries (e.g. The Netherlands (TTF), Belgium (Zeebrugge Hub)) and are not as liquid as the ones in the UK (NBP) or the United States (Henry Hub). Thus, consumers often obtain a more or less fixed gas volume for a somewhat fixed price from producers or importers - without the opportunity to buy additional natural gas or resell volumes at a commodity exchange. While this might reduce risks for long-term investment decisions, this form of price discrimination, i.e. two prices for two different consumers at the same time and location, may also lower allocative efficiency. Furthermore, these long-term contracts are considered uncompetitive by the European Commission and may cease to exist in this form in the near future.[1] Additionally, liquidity at the continental European gas trading points is constantly increasing. Thus, in the near future, short-term commodity prices at these trading points will become the major reference for consumers. Especially gas consumers with the highest short-term price elasticity, which might arguably be gas-fueled power stations, may thus take these market-based gas prices increasingly into account.

In this paper, we develop and apply a large-scale integrated European electricity and natural gas market model to investigate how changing gas market fundamentals impact electricity generation dispatch and investment decisions as well as natural gas and electricity prices in a realistic framework.

Methods

In order to assess, and get quantitative insights of, the interactions of natural gas and electricity markets in a competitive framework, we combine improved versions of the long-run electricity market model DIME and the natural gas infrastructure and dispatch model TIGER developed at the Institute of Energy Economics at the University of Cologne.[2] A simplified overview of the major in- and outputs of the combined model is depicted in the figure on the right. The applied model covers the European Union plus the large non-member states in Europe and allows analyses up to 2030 with results down to a two-hour granularity. It, thus, exceeds existing integrated energy market models with respect to the underlying data in both, temporal and regional coverage and resolution.[3] On the gas market side, upstream long-term contracts as well as flexible production is taken into account to satisfy an exogenously given non-power sector demand and the demand endogenously created by gas-fueled electricity generation. In order to get the natural gas to consumers and provide flexibility, the model can use the long-distance transmission infrastructure and gas storages, both included in a high level of detail with individual characteristics regarding



[1] We do not suggest that this applies to long-term or price indexed contracts in general. However, merely declaring the clause which prohibits the resale of contracted natural gas would imply that consumers have to take commodity exchange prices into account as selling (instead of consuming) the gas is always an option.

[2] Detailed descriptions of the original stand-alone models can be found in Bartels (2009) and Lochner and Bothe (2007). Alternatively, visit: http://www.ewi.uni-koeln.de/Models.167.0.html.

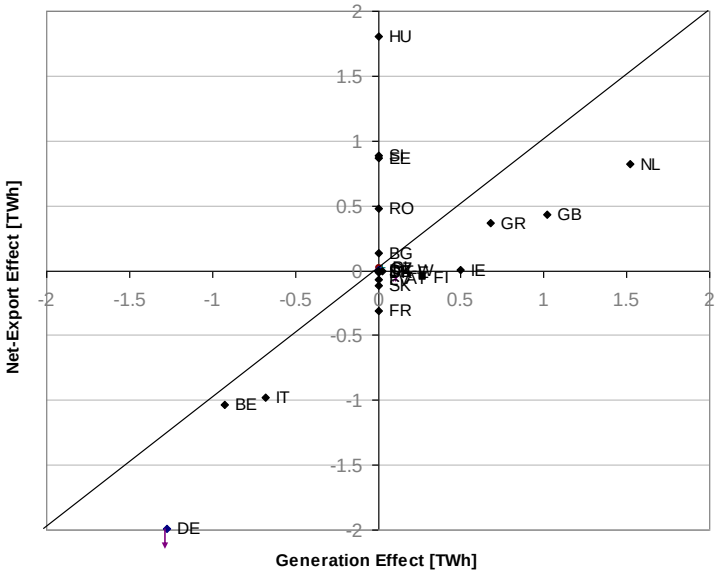
[3] See for example Mello and Ohish (2005), Bartels and Seeliger (2005) and Gil et al. (2003).

capacities, etc. In the electricity market, the exogenous demand has to be met in each country and at each point in time (two-hour period). Therefore, the model can cost-optimally dispatch the given 2008 power plant capacities (and use electricity interconnector capacities for cross-border exchange). Natural gas demand in the power sector has to be obtained via the gas market and, thus, enters the cost optimization in that market. Hence, short-run marginal cost in the natural gas market (which can be interpreted as prices in a competitive market) influence the fuel input price in the electricity dispatch. In the long-run simulation, these effects are also taken into account for endogenous investment (or decommissioning) decisions in all electricity generation capacities.

In order to assess the impact of natural gas market liberalisation on electricity dispatch and investment decisions, and therefore electricity and gas prices, we compare the described simulation with one where gas market prices are not market driven but solely depend on substitute-indexed long-term contracts.

Results

We find that taking into account volatile natural gas market prices influences investment and dispatch decision for natural gas power plants. Generally, it makes them relatively more competitive in natural gas off-peak periods. At the same time, electricity generation at natural gas and electricity demand peak times becomes more expensive. How this effects electricity and natural gas dispatch depends on the respective countries generation capacities and, thus, differs significantly across the EU. Apart from that temporal effect, an aerial impact of competitive natural gas prices is observed, too. Generally, this effect moves electricity generation from natural gas geographically closer to the sources of natural gas reducing natural gas transportation requirements. Instead, increasing cross-border electricity exchange in the same direction as the prevailing natural gas flows in Europe is observed. The short-run effect of this is depicted for the 2008 simulation in the diagram which illustrates gas-fired generation and exchange balance (net-export) effects in Terawatt hours when competitive gas prices are introduced (relative to a fixed gas-price scenario). Those countries close to natural gas deposits (e.g. the Great Britain, Netherlands, Eastern European countries) increase gas-fueled generation an improve their import-export balance (1st quadrant in diagram), while natural gas importing countries (e.g. Germany, Belgium) import more electricity and reduced gas-fired generation at the same time (and can thus be found in the 3rd quadrant of the figure).



Conclusions

The development of an integrated model for the European electricity and natural gas market proved a complex task – but a necessary one to understand observations in an increasingly liberalized energy market. The application of the integrated model demonstrates that the two markets experience strong interdependencies. Generally, it can be concluded that the theoretical presumption that each commodity's favourable characteristics will be employed most efficiently in an integrated market is confirmed by our analysis – the first to investigate this in a realistic framework with a large-scale energy market model of the EU.

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