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# European Gas Markets, Trading Hubs, and Price Formation: A Network Perspective

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The establishment of single market for energy is a long-standing European Union objective, initially outlined in 1957 by the Treaties of Rome, and iteratively developed through three European energy packages in 1998, 2003 and 2009. These directives aim to increase market access, transparency and consumer protection through the development of a single, harmonised European market for energy, including natural gas.

Owing to the regulatory innovations outlined above, a large body of literature studying the attainment of a single European gas market has been developed. Many studies have provided evidence of long-run convergence of European gas markets (Renou-Maissant, 2012; Growitsch *et al*., 2015; Neumann & Cullmann, 2012), with the Agency for the Cooperation of Energy Regulators (ACER) confirming this through their annual market monitoring reports. This paper aims to provide a different perspective on the European gas market integration issue through analysis of short-run interactions, dynamically identifying 'price leaders' and 'price followers' and extracting this information to draw inferences relating to the practical attainment of a single European market for gas.

We achieve this through applying network theory to analyse the interactions of gas prices at twelve European trading hubs. We construct dynamic networks, where the nodes correspond to the European trading hubs, and the edges weight the causality between the variations of the respective day ahead gas prices. The network model is capable of describing the changing influences between European gas prices, displaying the evolution of 'price leaders' and 'price followers' within the European gas market. Further to this, a network density term is specified, which computes the aggregate quantity of causal interactions recorded within the system at each point in time. This provides valuable information on short-term variations and abnormal changes in the connectivity of the European gas network.

We find a number of spikes in network density, suggesting short periods of improved connectivity of European gas markets, which are driven by exogenous factors such as unseasonal weather patterns, seismic activity and capacity reductions. Applying a Markov regime-switching model to network density, we find that abnormally positive or negative changes are equally distributed in magnitude and volume, indicating that short-run gas market integration is not substantially pronounced.

The model detects one physical and two non-physical barriers to a single, integrated European market for natural gas.

The physical barrier detected, a €1.67/MWh PEG-TRS premium over PEG-Nord, is attributed to a lack of available capacity on the Liason Nord-Sud pipeline. This finding is consistent with the earlier work of Heather and Petrovich (2017). It is anticipated that this distortion shall be suppressed due to the additions of the Val de Saone and Gascogne-Midi pipeline projects and merger of the two trading zones on 1st November 2018.

Given the absence of physical capacity constraints at PVB (Spain) and VTP Gaz System (Poland), non-physical factors appear to be the cause of low levels of integration of these hubs into the European network. Despite the systematic €1.09/MWh premium paid at PVB (Spain), the average pipeline utilisation at VIP Pirineos was 50.3% throughout the sample, indicating a non-physical barrier to trade. Heather and Petrovich (2017) attribute this to low availability of transmission capacity for day ahead participants who aren't engaged in term contracts. VTP Gaz System's (Poland) premium to Gaspool (Germany) stipulates that arbitrage forces should be in effect, however this study found limited evidence of arbitrage flows. Prior authors suggest that a low degree of internal market liberalisation is the primary reason for Poland's low integration into the European market. As VTP Gaz System (Poland) is the only hub denominated in an emerging market currency, market participants may impound more foreign exchange risk into pricing at VTP Gaz System (Poland).

Our results confirm that the short-term gas trade in Europe is developing, however each hub holds unique characteristics, providing different rates of development and integration. The low number of physical barriers to market integration detected implies that the Third Energy Package's focus on cross-border mechanisms has been broadly successful, alleviating pipeline capacity constraints throughout the European network. Conversely, the persistence of non-physical barriers to trade suggests that the development of specific national gas markets (VTP Gaz System, PVB) is yet to be achieved, tacitly inferring that improvements in technical arrangements are required.

The findings elucidate the time varying nature of European gas market dynamics, and the importance of continual monitoring of market evolution. We conclude that the model is a suitable tool for monitoring short-run market integration within European gas markets.

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