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Congestion management in electricity networks: Nodal, zonal and discriminatory pricing

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Storage possibilities are negligible in most electric power networks, so demand and supply must be instantly balanced. The consequence is that transmission constraints and the way they are managed often have a large influence on market prices. The European Union's regulation 1228/2003 (amended in 2006 and 2009) sets out guidelines for how congestion should be managed in Europe. System operators should coordinate their decisions and choose designs that are secure, efficient, transparent and market based. Regulatory authorities shall regularly evaluate the used congestion management methods, with respect to compliance with the principles and rules established in the regulation and guidelines. In this paper, we compare the efficiency of three market designs that are in operation in European electricity markets: nodal, zonal and discriminatory pricing.

In the nodal pricing design, every node of the network is a local market with a local uniform market price. This allows production in import-constrained nodes to sell at a higher price than production in export constrained nodes. This design is mainly used in US, but also in Russia and New Zealand. The zonal design, which dominates in Europe, has one market price in a large region, often a country or state. This drastically reduces the number of market prices and often it is a politically more acceptable design (as compared to nodal pricing). However, a problem with zonal pricing is that it becomes complicated to manage congestion within the zones. After the zones of the real-time market have been cleared the system operator often needs to order redispatches, where supply in import constrained nodes is increased and decreased in export constrained nodes, so that intra-zonal congestion can be relaxed. Producers are compensated for these redispatches without influencing the zonal market prices. We consider the market oriented redispatch, which is called countertrading, where

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redispatched production is paid as bid. This method is used in the real-time market of the Nordic countries (Nord Pool) and was used in the old Texas design. The third design, discriminatory pricing, is not very common. The real-time market in the UK is one of the few examples where all accepted offers from producers are paid as bid rather than a local market price. But since the UK has zonal pricing in the day-ahead market, it is not a pure pay-as-bid design.

We evaluate the three designs for a general electricity network (possibly meshed), where nodes are connected by capacity constrained transmission lines. There are many producers in our theoretical model, and demand is certain and inelastic. We find that the three designs, nodal, zonal with countertrading and discriminatory pricing, lead to the same socially efficient dispatch. In addition, payoffs are identical in the pay-as-bid and nodal pricing designs. However, in the design with zonal pricing and countertrading, there are additional payments from the system operator to producers in export-constrained nodes. Thus producers overinvest in these nodes. To avoid these inefficient investments, we recommend that a congestion management design should have a pure format, such as nodal or discriminatory pricing.

Another result from our analysis is that there is a significant amount of firms that make offers exactly at the marginal prices of the nodes in the zonal and pay-as-bid designs, which is not necessarily the case under nodal pricing. This supports the common view that that especially the pay-as-bid design, but also the zonal design, improve liquidity in the market compared to nodal pricing. On the other hand, the very elastic residual demand in both the zonal and discriminatory designs has the disadvantage that a slight miscalculation of a firm's offer can result in a big change of its dispatch. This increases the chances of getting inefficient dispatches, especially when demand or competitors' output is uncertain. The nodal pricing design is more robust to these uncertainties.

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