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# On the long run effects of market splitting: Why more price zones might decrease welfare

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## HIGHLIGHTS

- We analyze investment and production in energy only markets with market splitting.
- Market splitting can lead to decreased welfare even for reasonably chosen zones.
- We identify the reasons for the negative impact of introducing prices zones.

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## ABSTRACT

In liberalized electricity markets we observe different approaches to congestion management. While nodal pricing is implemented in Canada and some markets in the United States, European markets are split up into a limited number of price zones with uniform prices, in order to at least partially realize the benefits of regional price differentiation. Zonal boundaries often coincide with national borders, but some countries are also split into multiple zones. In this paper we shed light on possible negative welfare effects of market splitting that arise in a model where investment incentives in new generation capacity are taken into account if zones are misspecified. We show that standard approaches to configure price zones – on the basis of projected nodal price differences or congested transmission capacity – may fail to suggest reasonable zone specifications. Also an adjustment of Available Transfer Capacities (ATCs) between zones or a switch to flow-based market splitting does not ensure positive welfare effects. Our analysis suggests that a careful and detailed evaluation of the system is needed to ensure a reasonable zone configuration.



## 1. Introduction

In today's liberalized electricity markets, how to deal with network congestion is a major issue. Several authors argue that the most efficient congestion management is the implementation of nodal prices that precisely reflect the scarcities induced by the physical transmission network (see Hogan, 1992). Today, nodal prices have been introduced in the United States, Argentina, Chile, Ireland, New Zealand, Russia, and some other countries (see Holmberg and Lazarczyk, 2012). However, it is sometimes argued that a system of nodal prices could be perceived as too complex and politically and administratively difficult to handle. As a matter of fact in many countries and regions a system of price zones has been adopted, which reflects the scarcities induced by the physical transmission network in an approximative way (see Bjørndal and Jørnsten, 2008). Such a system is nowadays implemented in Australia, Denmark, Sweden, Italy or Norway, among others (see Holmberg and Lazarczyk, 2012).

The introduction of price zones is often considered to be an attractive compromise, mainly because of lower complexity of the resulting pricing scheme. Intuition indicates that the finer the split-up of the market is chosen, the closer market outcomes should be to the nodal pricing outcome. This perception has been confirmed in several scientific contributions (e.g., compare Bjørndal and Jørnsten, 2001 or Ehrenmann and Smeers, 2005). However, all those contributions focus on a short-run perspective, where investment incentives in generation facilities are not considered endogenous. In our study we consider the long-run

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perspective where firms also adjust capacities of their production facilities through investment. As we show, the introduction or refinement of price zones is not necessarily welfare increasing in this framework. Our results obtain both, for the standard consideration of fixed network capacities between zones in the form of available inter-zonal Available Transfer Capacities (ATCs) as well as for the so-called flow-based market splitting.[1] In our analysis we consider investment and production decisions on a network with potentially constrained transmission capacities. Existing and new production facilities, and consumers, are located at the nodes. Prior to spot market trade, firms have the possibility to invest in generation capacity at selected nodes. At the spot market, market clearing prices and quantities are determined. The spot market might be divided into price zones. If this is the case, prices may differ across zones if the ATCs are not sufficient to permit all economically desirable flows. Prices cannot differ across different nodes within a zone. Infeasible market outcomes are dealt with by the transmission system operator (TSO) post trade through redispatch. Upon redispatch, all physical constraints are taken into account by the TSO.

In this framework we compare welfare in an energy only market without price zones to welfare in several configurations with market splitting. We find that with endogenous investment decisions, market splitting can be welfare decreasing. The intuition is the following: If spot market trade does not account for transmission constraints, firms may have the incentive to overinvest because the spot market rules allow them to sell to consumers that physically cannot be supplied. The incentive to overinvest may be lower if there is a sufficient number of competitors in the market, since their potential supply (feasible or not) reduces the possible return on investment of a firm. If the market is divided into price zones in a way that separates those competitors from the firm under consideration, incentives to overinvest might increase if intra-zonal demand is high, but the newly built capacity cannot generate consumer surplus due to remaining intra-zonal transmission constraints. Then, the corresponding investment cost directly reduces welfare. We also show that in interconnected networks this effect can occur even in case there are *no* intra-zonal transmission constraints. The reason is that in networks with cyclic flows,[2] the scarce inter-zonal capacities negatively affect usable capacity also of lines within a zone. This implies that it is not necessarily an appropriate approach to split the network into zones with low inter-zonal, but high intra-zonal capacities.

We demonstrate our results using a three-node network, which is the minimal number of nodes where the effects can occur. It is obvious that all phenomena discussed are at least equally relevant in larger networks. Moreover, it is worth emphasizing that in order to demonstrate the detrimental effects of price zones, no strategic firms are needed – all effects are obtained already under the assumption of competitive firms.

From a policy perspective our findings do not suggest that the introduction of price zones is *in principle* undesirable in liberalized electricity markets. Our results rather point out that it cannot be taken for granted that an in principle reasonable split of the market along congested lines in the long-run indeed leads to welfare improvements. Those results are of substantial political relevance in the context of the current debate on the organization of congestion management regimes in Europe, since the introduction of market splitting is considered in different European countries such as Austria, Germany,[3] or Great Britain. In essence, our results emphasize the need of a detailed a priori analysis of price zone configurations that also accounts for long-run welfare effects. This is, however, beyond the scope of this paper and a topic for future research.

Our paper contributes to the literature on congestion management regimes in liberalized electricity markets. To name just a few examples, Ehrenmann and Smeers (2005), Pérez-Arriaga and Olmos (2005), Inderst and Wambach (2007), Neuhoff et al. (2011), or Oggioni and Smeers (2013) investigated the inefficiencies of zonal markets with redispatch as compared to the nodal pricing system in the short-run. As the effects of market splitting depend on adequate zone boundaries, this question has repeatedly been discussed in the literature. Amongst others, Stoft (1996, 1997) and recently Wawrzyniak et al. (2013) analyzed the two criteria of using congested network lines as inter-zone links and nodal price differences as optimal zone boundaries. Walton and Tabors (1996) suggested the use of statistical methods. In this context, Yang (2005) and Breuer et al. (2013) proposed new clustering approaches to detect efficient zonal decompositions. Bjørndal and Jørnsten (2001) investigated optimal zone configurations using small networks that illustrate the problem of optimal zone boundaries given the number of price zones. They showed that a finer node set partition (i.e., the introduction of additional price zones) may only increase welfare or leave welfare unchanged. Ehrenmann and Smeers (2005) found similar results analyzing a congested six-node network based on Chao and Peck (1998). The described studies mainly focused on short-run electricity markets ignoring the incentives for generation investment induced by market splitting.

This paper is organized as follows: Section 2 introduces our method and the basic three-node network. Section 3 analyzes specific cases in which the introduction of an additional price zone cannot have a negative effect on welfare and demonstrates in which cases negative welfare effects may be observed. We also discuss issues related to the determination of an optimal number of price zones and their respective boundaries. Additionally, we give an outlook to flow-based market splitting and the use of conservative ATCs in Section 4. Section 5 summarizes our findings and explores policy implications.

## 2. Model and three-node network

In this section we introduce a model that allows us to analyze the welfare effects of market splitting, accounting for generation and production decisions of private firms and physical power flow constraints. We introduce the model in Section 2.1 in an informal fashion. A detailed description is provided in Appendix A. In Section 2.2 we introduce a three-node example that we use to demonstrate the main effects we identify. We provide a basic intuition for the effects in Section 2.2, and elaborate in more details on the driving forces in Section 3.

### 2.1. The model

THE NETWORK. Consider an electricity network with nodes $n \in N$ and fixed transmission lines $l \in L$, where $N$ and $L$ are the sets of nodes and lines, respectively. Each transmission line is fully

[1] See, e.g., www.casc.eu.

[2] In the electricity market literature cyclic flows are sometimes referred to as "loop flows".

[3] In this context compare the final warning sent to Germany by the European Commission on June 18, 2015 to comply with the energy efficiency directive. Failure to do so would result in a formal infringement process by the EU. One of the central issues of this directive is the requirement to enhance grid and infrastructure efficiency (compare Article 15: Energy Transformation, Transmission and Distribution). The current system of a unified price zone, as it is currently implemented in Germany, is typically assumed to distort incentives, whereas a split-up into several price zones is assumed to enhance efficiency.