Energy Policy 107 (2017) 109–118

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

# Market efficiency assessment under dual pricing rule for the Turkish wholesale electricity market

Goksel Asan[a,*], Kamil Tasaltin[b,c]

[a] Istinye University, Department of Economics, Topkapı Kampüsü, Maltepe Mah., Edirne Çırpıcı Yolu, No. 9 Zeytinburnu, 34010 İstanbul, Turkey
[b] Deloitte LLP, Economic Consulting, Athene Place, 66 Shoe Lane, London EC4A 3BQ, UK
[c] Istanbul Bilgi University, Turkey

ARTICLE INFO

*Keywords:*
Electricity
Market structure
Market efficiency

ABSTRACT

This study analyses the price dynamics of day-ahead and real-time electricity prices following the implementation of dual-pricing legislation in Turkey, to understand the legislation's impact on arbitrage opportunities and market efficiency. The convergence of prices between the day-ahead forward and the real-time markets analysed in order to determine whether persistent price differences between the two markets exist. Arbitrage opportunities exist if there is a persistent difference between prices in the day-ahead forward and real-time market. Markets are considered to be efficient if it is not possible for market participants to earn an excess profit through exploitation of price differences. Furthermore, we examined how the ex-post risk premium changes over time using rolling estimations and find that after the implementation of dual pricing, the risk premium increased significantly for day and peak hours where the demand is relatively higher compared to night hours. As market participants have more experience regarding the dynamics of the market, the difference between real-time and day-ahead forward prices converges to zero since the dual-pricing regime enforce market participants to forecast accurately by punishing the forecast error.

## 1. Introduction

The Turkish electricity market has been through a process of liberalization over the last couple of decades. From 2006, the rules of the free market were introduced which allowed for the purchase and sale of electricity from a day-ahead market on an hourly basis. This provides market participants an opportunity to hedge their positions against the real-time price fluctuations by taking positions in the day-ahead forward market.

Having a liberal free market raises questions regarding the efficiency of the market structure as well as the relationship between electricity spot price and day-ahead forward prices. Markets are considered to be efficient if it is not possible to achieve a consistent excess return over time compared to the average market return. In an efficient market, participants are not able to earn an excess profit by exploiting price differences. It is important to note that traditional market efficiency measures assumes commodities are storable. However electricity is different to other common commodities due to its non-storable nature. If the trading commodity is storable, then a market player can purchase the good today, store it for a period of time and sell in the future – expecting to gain profit through price differences. However, electricity traded on present day is a different good compared to that tomorrow as storing the electricity is not economically viable. Bessembinder and Lemmon (2002) states that since electricity cannot be economically stored and the spot power prices are volatile, the standard no-arbitrage-based approaches are not applicable for modelling forward prices. No-arbitrage-based approaches assumes an arbitrageur to hold the asset until the contract expiration date while taking a position in the underlying asset.

However, in an electricity market arbitrage opportunity exists for the market participants if a persistent price difference exists between day-ahead forward prices and real-time prices.[1] In theory, strategies for market participants to gain excess revenue by exploiting the price differences should make the real-time and day-ahead market prices close to each other under the assumption of no transaction costs and risk-neutral market participants.

In this study, price convergence between the day-ahead and the real-time markets is analysed in order to determine whether persistent price differences between the two markets exist. The electricity wholesale market is considered to be efficient if there are no arbitrage

* Corresponding author.
*E-mail addresses:* gasan@istinye.edu.tr (G. Asan), ktasaltin@yahoo.com (K. Tasaltin).

[1] The available arbitrage opportunities have been summarized for both suppliers and generators in Section 2. Please also see Quan and Michaels (2001) and Jha and Wolak (2013) for further discussion on available arbitrage opportunities between day-ahead forward and real-time markets.

http://dx.doi.org/10.1016/j.enpol.2017.04.024
Received 4 October 2016; Received in revised form 7 March 2017; Accepted 9 April 2017

opportunities as a result of trading strategies between real-time and day-ahead markets. If there is no transaction cost the expected value of the difference between day-ahead (current forward price) and real-time prices (spot price) should be zero.

Through the liberalization process of Turkish electricity market, the hourly balancing and settlement system was set in place in December 2009 to allow market participants to buy and sell electricity in day-ahead and spot market on an hourly basis. On December 2011, the dual-pricing system rule for imbalances in electricity market was implemented in Turkey, (3 November 2011, legislation No: 28104). Implementation of dual pricing rule for imbalances changed the price dynamics of electricity. Under the dual pricing rule, electricity buyers and sellers in the real-time market are charged based on the price that is least favourable to the market participant. The difference between the actual consumption or generation and that which was purchased through the day-ahead market (simply imbalances) is charged based on the price that is least favourable to the market participant. In other words, buyers have to pay the greater of day-ahead or real-time prices, while sellers receive the lesser.

The main objective of the dual pricing rule is to discourage participants seeking arbitrage opportunities by making it unattractive for them to make false bids or offers since these could harm system security as well as enforcing market participants to bid their actual forecast using the available information at the time. False bids or offers could harm short-term system security, for example by implying greater capacity in the market than actually exists. This study finds that while dual pricing rule increases the short-term system security, it also creates a persistent difference between day-ahead and spot electricity prices (forward risk premium[2]) which implies a market inefficiency, since it limits market participants to exploit the arbitrage opportunities that exist.[3] However, in the long run the risk premium in the market reduces. Newly introduced wholesale power markets could result in the observed forward prices differing from the pricing structure that will be observed in a long-run equilibrium, reflecting the inexperience of market participants. The results show that, although there is an increase in risk premium after the implementation of dual-pricing, it decreases over time. This indicates that market efficiency increases as the market becomes more mature.

Due to the non-storable nature of electricity, it was decided not to use familiar no-arbitrage-based methods to examine the persistent price differences in Turkish electricity market in this paper. Instead, the price convergence between the day-ahead and the real-time market is analysed similar to Longstaff and Wang (2004), Borenstein et al. (2001) and Arciniegas et al. (2003) to understand the presence of persistent price differences in electricity forward prices.

There are various market efficiency assessment studies in the literature. Borenstein et al. (2001) examine the price convergence in the California wholesale electricity market from the deregulation of the market in April 1998 to November 2000. Their hypothesis is that profit-maximizing traders exploit price differences between the day-ahead market and the real-time market that converges the prices of the two markets. The study concludes that the prices in the day-ahead market and real-time market converge as the market become more mature. Extending Borenstein et al. (2001) study, Arciniegas et al. (2003) analyses the doubts about the benefits of energy deregulation due to California's energy crisis in 2000 by assessing the level of efficiency reached by the electricity markets in California, New York, and PJM and compares the degree of efficiency across markets (forward vs. real-time) and across time. In addition to comparing the efficiency levels of electricity markets, they also conclude that as markets become more mature over time, their efficiency levels go up.

Jha and Wolak (2013) evaluate the market efficiency of California's wholesale electricity market after the implementation of virtual bidding. In their study, they estimate the cost of trading in the market by using the day-ahead forward and real-time spot locational marginal prices and concluded that purely financial forward market trading can improve the operating efficiency of short-term commodity markets. Longstaff and Wang (2004) conduct an empirical analysis of hourly spot and day-ahead forward prices in the PJM electricity market and find that there are significant risk premia in electricity forward prices related to volatility of unexpected changes in demand, spot prices, and total revenues. De Vany and Wall (1999) analyse the market integration of 11 regional markets in the western United States during 1994–1996 by using cointegration analysis and test the peak and off-peak electricity spot prices for evidence of market integration. The results of their study show that western US wholesale power markets were efficient and stable.

To the best of our knowledge, the only study on the impact of dual pricing rule is that conducted Boogerta and Dupont (2005) which analyses the effect of dual-pricing implemented by Dutch regulator to prevent trading across day-ahead market and real-time markets in the Netherlands through studying the ex-post profitability of trading strategies. Their results show that under dual-pricing these strategies are rarely positive and implementing a profitable trading strategy between the day-ahead and imbalance markets is not possible under dual-pricing.

This paper contributes to the literature on electricity prices by examining the existence of forward premium (persistent price differences between day-ahead and real-time electricity prices) after the implementation of dual pricing rule in Turkey and concludes that although in the short-run the markets could be inefficient due to the change in pricing rules, the markets become efficient as the markets become more mature.

The sections of this paper are as follows. In the first section, we provide an overview of the Turkish electricity market and explain how dual pricing for imbalances effects the arbitrage opportunities (through an explanation of the strategies of buyer and sellers in Turkish electricity market). In the second part of this paper, the market efficiency framework is explained. The third part explains the data used in this analysis. The fourth section gives the empirical evidence on risk premium in the Turkish electricity market. In the final section of this paper, we provide the output of rolling estimation of risk premium in day-ahead and explain how market efficiency changes over time as the market becomes more mature.

## 2. Turkish electricity market overview

The Turkish electricity market has been on a liberalization process over the last couple of decades. Before 1984, the electricity market was controlled by the Turkish Electricity Authority (TEK), a vertically integrated state-owned enterprise. Since then, the sector has undergone significant restructuring via market liberalization. The monopoly power of Turkish Electricity Authority was first removed in 1984 by allowing for privately owned generation companies. Starting from 1994, the vertically integrated value chain of Turkish Electricity Authority has been separated into generation, transmission, distribution and sales activities. This has been undertaken to lay the foundation of privatization in the electricity sector and pave the way for the creation of a liberalized competitive market.

In 1994, Turkish Electricity Authority was split into two companies; Turkish Electricity Distribution Company (TEDAS) and Turkish Electricity Generation and Transmission Company (TEAS). This

[2] In this study, forward risk premium (or simply forward premium) defined as difference between day-ahead and spot electricity prices however the terms risk premium, forward premium, forward risk premium and market price of risk are not uniquely defined in the literature. Please see Weron and Zator (2014) for further discussions.

[3] Based on our best knowledge there are no other economic and/or political factors that have led to the increase in the premium after the implementation of the dual pricing apart from the launch of intra-day market. Since, intra-day market have started its operations as of 1st July 2015 after 3.5 years from implementation of dual-pricing rule, it is not relevant within the scope of this analysis.