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Problems of the Supply Industry in Wholesale Electricity Markets

Toptan Elektrik Piyasalarında Üretim Tarafı Sorunları

Mustafa Çağrı Peker [a, *] & Aysen Sivrikaya [b]

[a] Hacettepe University, Faculty of Economic and Administrative Sciences, Department of Economics, Beytepe Campus 06800, Ankara /Türkiye
ORCID: 0000-0001-7191-2646
[b] Prof. Dr., Hacettepe University, Faculty of Economic and Administrative Sciences, Department of Economics, Beytepe Campus 06800, Ankara /Türkiye
ORCID: 0000-0003-2199-3593

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ÖZ

Bu makalede, elektrik piyasası dönüşümünün ana itici gücü olmaları nedeniyle; üretim yetersizliği, kayıp para, piyasa gücü ve kesintili yenilenebilir enerji gibi toptan elektrik piyasalarında üretim tarafındaki sorunlar araştırılmıştır. Makalenin literatüre ana katkısı, bu sorunlara hem bireysel hem de bütünsel olarak odaklanmasıdır. Makalede sorunlar arasındaki nedensellik ilişkilerine odaklanılmıştır. Sorun odaklı bir bakış açısına dayalı olarak bu sorunlara olası çözümleri tartışılmıştır. Kesintili yenilenebilir enerji sorunu dışında, etkin olmayan yönetişim ve düzenleme üretim tarafındaki temel sorunların kaynaklarıdır. Yetersiz yönetişim ve yanlış düzenlemeler, verimsiz fiyatlandırma ve kesintili yenilenebilir kaynaklar, arz yetersizliği ve kayıp para gibi sorunları yaratmıştır. Rekabeti sürdürmek için devlet mülkiyetinin azaltılması, enerji piyasalarını tamamlayacak kapasite piyasalarının oluşturulması, piyasa odaklı yaklaşımın uygulanması, vadeli piyasaların oluşturulması, piyasanın izlenmesi ve iyi işleyen bir ağ tasarımı, üretim tarafının sorunlarını aşamalı olarak ortadan kaldırmanın başlıca yollarıdır.

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ABSTRACT

In this paper, we investigate the problems in the supply industry in wholesale electricity markets such as supply inadequacy, missing money, market power, and intermittent renewables since they are the main driver of the electricity market evolution. The main contribution of the paper is that it focuses on these problems both individually and holistically. We focus on the causality relationships among the problems. The paper discusses the possible solutions to these problems based on a problem-oriented perspective. Inefficient governance and regulation are the sources of the main problems in the supply industry except the problem of intermittent renewables. The problems of inefficient governance and regulation, inefficient pricing, and intermittent renewables create issues such as supply inadequacy and missing money. Reducing state ownership to sustain competition, establishing capacity markets to complement energy markets, implementing of market-oriented approach, setting up future markets, market monitoring, and a well-functioning network design are major pathways to phase out problems of supply industry.

1. Introduction

The electricity has been used in many fields such as heating, transportation, communication, and production along with lighting since its invention in the 19th century. The increasing dependence on electricity in modern life with technological development has required a well-functioning electricity market (Streimikiene et al., 2013). However, a well-functioning electricity market relies on addressing the problems encountered in the supply side of the electricity market, called the supply industry in the literature (Jamashb, 2002). In this study, we review the related literature to discuss the electricity supply industry problems and to reveal the systematic relationships among them.

The wholesale electricity markets in the world have evolved by addressing the problems since the 1980s. However, during its evolution, addressing one problem has created

* *Sorumlu yazar/Corresponding author*.
e-posta: *cagripeker2@gmail.com*

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new problems in the supply industry due to the multifactorial nature of the problems (Woo et al., 2006). For instance, the electricity markets have been deregulated in the USA (Borenstein and Bushnell, 2000; Chao and Wilson, 2001). Deregulation in the USA has created several problems in the supply industry such as efficiency problems and market power (Borenstein and Holland, 2003). On the other hand, several governments have launched several regulations in Europe (Newbery, 2002). However, these regulations have also brought about inefficiency let alone supply inadequacy and the problem of intermittent renewables (Danwitz, 2006; Pollitt, 2009). Similar to the wholesale electricity markets in the USA and Europe; the ones in Latin America, Asia, and several developing countries have also faced the problems of market power, lack of investment, and supply inadequacy (Jamashb, 2006; Kessides, 2007; Oseni and Pollitt, 2016). Therefore, even though the electricity markets in different regions have developed in different ways by overcoming the specific problems; several other supply industry problems still exist.

In this study, we have conducted a literature review on the supply problems of the supply industry. This review shows that the studies generally overview the electricity markets regardless of a specific emphasis on the problems. Moreover, they generally focus on one or two problems (Rudnick et al., 2005; Roques, 2008; Newbery, 2015; Aghaie, 2016). However, the problems are the main driver of the electricity market evolution. Thus, exploring the causes and the consequences of these problems is crucial to understanding this evolution. Besides, evaluating them separately might cause ignore the strong relationships among them (Green, 2003; Pittman, 2014).

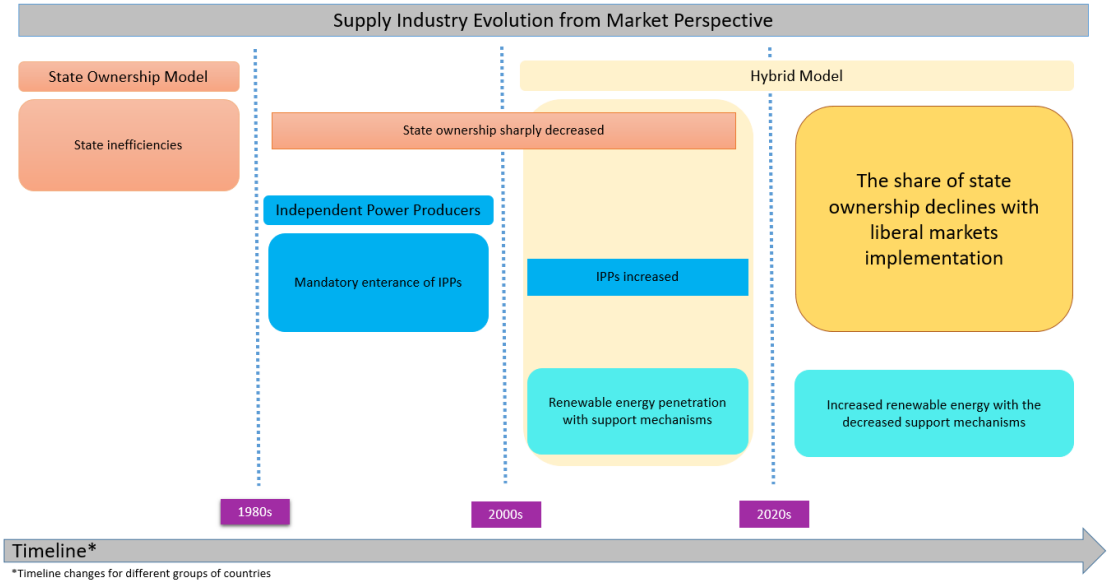
On this ground, different from the previous studies, this study focuses both individually and holistically on problems of the supply industry. The other novelty of this study is that we also review the causality relationships among the problems. Moreover, based on the problem-oriented perspective, this study discusses the possible solutions to these problems.

The remainder of the article is structured as follows: In Section 2, we present the evolution of the wholesale electricity markets and supply industry in electricity markets. In Section 3, we review the literature of the problems of wholesale electricity markets and supply industry by giving the causes, consequences, and the possible solutions of the problems. The last section concludes this study.

2. Evolution of Wholesale Electricity Markets

The electricity market has been undergoing transformation and development for many years. In this process, generation, transmission, distribution and retail divisions have been shaped. In this period, unbundling of the vertically integrated structure and privatization were used in order to liberalize the markets. The public-private transformation, the change of generation resources, and the development of the organized market have come to the fore over the years. The historical evolution of supply industry of electricity market is shown in Figure 1.

Figure 1: Supply Industry from Market Perspective



As seen in the Figure 1, evolution of supply industry determines the structure and working of electricity market. Until 1980s, state is the only owner in all segments of electricity market due to lack of private sector model. This vertical integrated structure caused low collection of bills, lack of new investment, cost-free price, poor governance, increased state budget deficits, and some exogenous poor macroeconomic factors (Danwitz, 2006; Williams and

Ghanadan, 2006; Elizondo et al., 2014). These problems brought up sector reforms to decrease the cost of consumers, to utilize the profit motivation of companies, and to provide competition for sustainable efficiency.

After the 1980s, states used a variety of liberalization and privatization strategies. The order of the privatization was determined via the primary needs of the electricity industry and states (Krishnaswamy and Stuggins, 2003; Bacon and Besant-Jones, 2001; Newbery and Pollitt, 1997; Wilson, 2005). Ease of financial accessibility, fragmented structure of generation, and importance of marginal costs in the electricity market highlighted the supply industry. Therefore, the process of privatization was started with the supply industry. In the beginning, independent power producers (IPPs) were introduced. Guarantee of purchase mechanisms, build operate and build operate transfer models were used to initially implement IPPs. The design tool of government with these models was the contracts of power purchase agreement. In power purchase agreements, generation investors capture the risk of fuel prices, cost of material, labor cost, and unexpected plant failures. These long-run power purchase agreements reduce the risk of investors by inter-party risk sharing via closures and including force majeure conditions. In the 2000s, the supply industry become more liberal. Renewable energy investments have become part of the electricity supply industry, which lead to a sharp decline in state generation share (Winkler, et al., 2016; Batalla-Bejerano and Trujillo-Baute, 2016). Renewable implementation has been done via auctions varying in risk allocations, bidding types, price changes, and transmission coordination. Recently, the renewable penetration continues with less support mechanisms and more aggressive renewable implementation policies.

Figure 2: Supply Industry Evolution from Resource Perspective

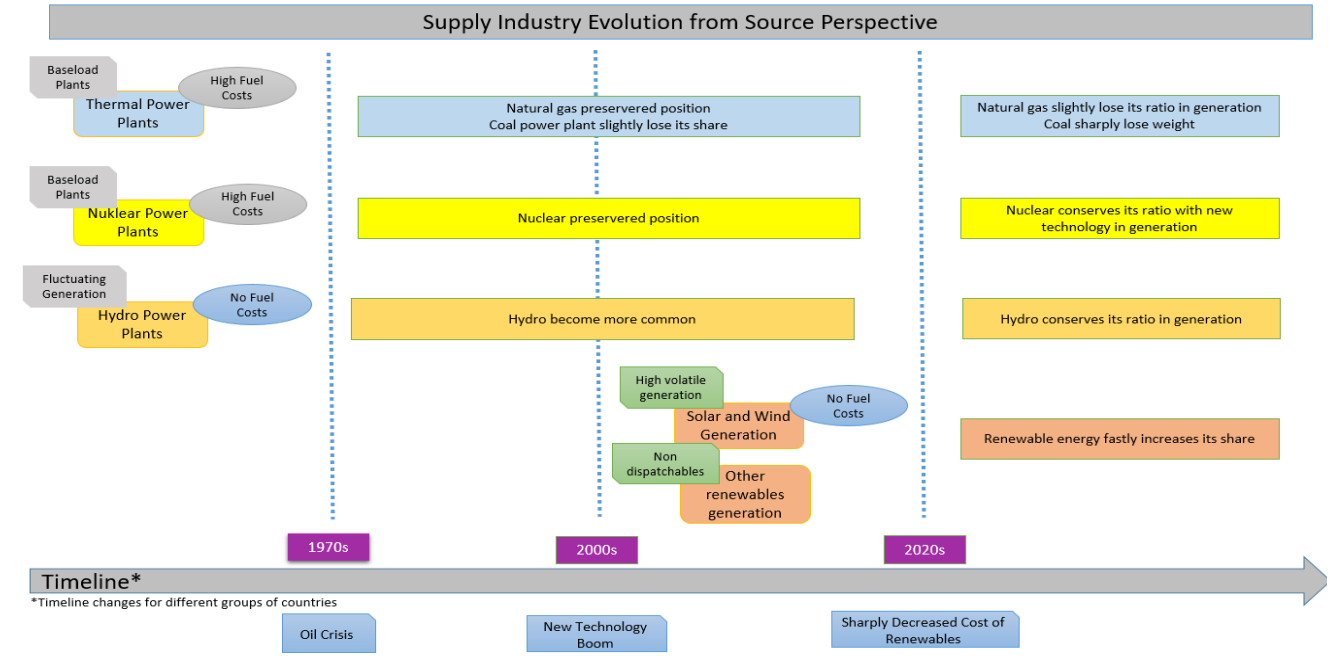
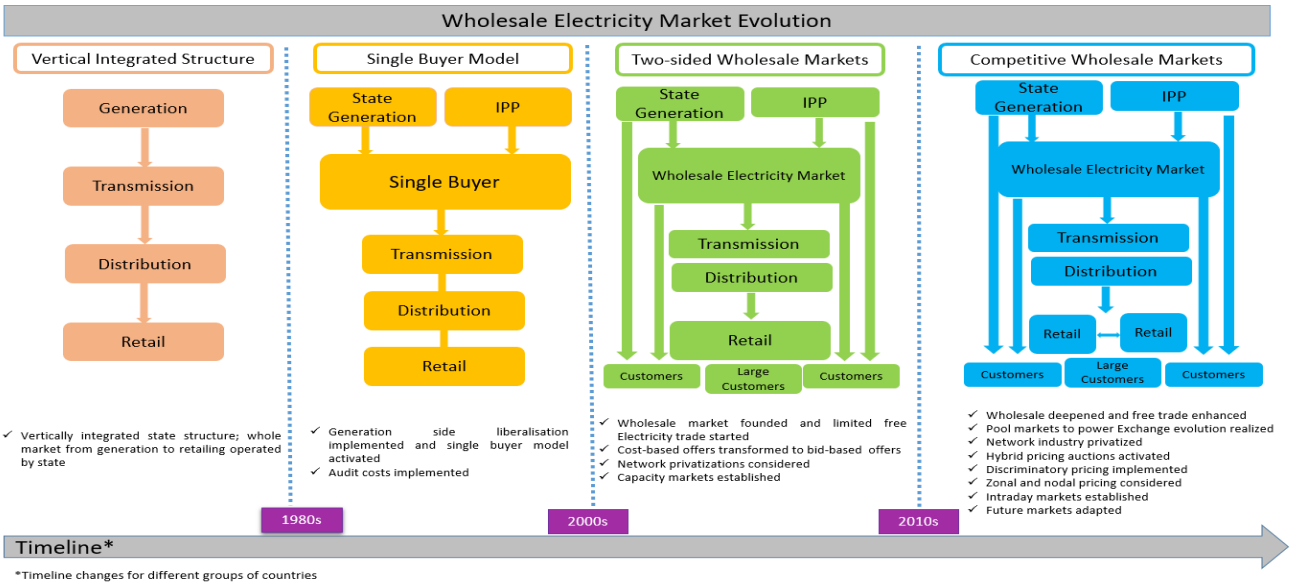


Figure 2 depicts the supply industry evolution with respect to resources. Resource composition of supply industry affects the marginal cost of electricity and price in the wholesale electricity markets. The share of high carbon thermal power plants that use coal and natural gas as input has declined in supply industry in the last years. New electricity generation investments have transformed from high carbon resources to zero carbon renewables for the last fifty years. Implementing renewable energy plants using solar and wind have gained momentum with decreasing its marginal costs and zero-carbon characteristics. However, renewable energy generation has instantaneously based on its resources' natural characteristics. This characteristic has caused fluctuations in the wholesale electricity prices. The replacement of baseload thermal power plants with intermittent renewables has created not only price fluctuations but also new network constraints in the wholesale electricity markets. Therefore, the renewable domination in wholesale electricity markets has not provided a stable electricity generation.

In addition to the transformation of supply industry according to the resources it uses, wholesale electricity market structure has also evolved. Figure 3 shows the emergence and evolution of the wholesale electricity market structure. Before 1980s; generation, transmission, distribution, and retail markets were operated by state. Some studies show this structure as the source of inefficiency as the states cross-subsidize between segments of the market (Roques, 2008a; Ibarra-Yunez, 2015; Wilson, 2005). Until 2000s, the market structure of supply industry started to become a single buyer model. State ownership was partly

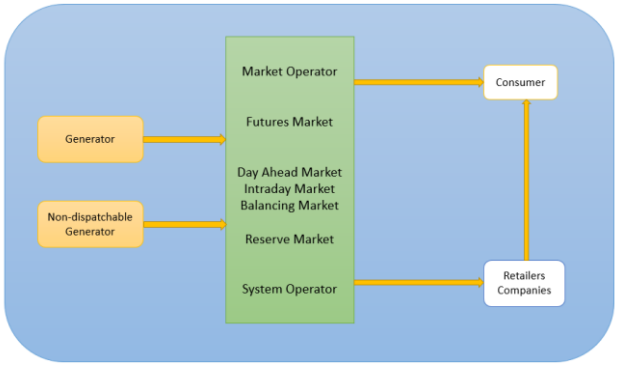
replaced by independent power producers (IPPs) while the only buyer was the state. State used audit cost model to determine the marginal cost of the electricity. Thus, the price of electricity was based on cost-based offers. The number of regions using independent power producers has increased. In 2000s, wholesale electricity markets' demand side is privatized. Free electricity trade was limited in wholesale electricity markets, and electricity prices was determined by bid-based offers.

Figure 3: Wholesale Electricity Market Evolution



The wholesale electricity markets were redesigned in 2010s. In this period, capacity markets were implemented complementary to energy-only markets and to support energy generation in peak demand periods. Reserve and balancing markets have been improved. They are runned by the system operator to make the physical and financial balancing in the electricity markets. Future markets have been started to be used to hedge the risks. Free trade has been enhanced by privatization of other segments of electricity market such as distribution and retail markets. In new structure, consumers buy electricity from private retailers or wholesale electricity markets. Power plants make long-term contracts and make offers in day ahead or intraday markets, which have also been established in last fifteen years. The frequency of offers in intraday market is higher than the day ahead market's.

Figure 4: Final Structure of the Wholesale Electricity Market



The final structure of the wholesale electricity market, was depicted in Figure 4. It consists of generators, consumers, retail companies, market and system operators, and several sub-markets such as futures, day ahead, intraday, balancing, and reserve markets. The progress emerges to a free-market structure to sustain electricity trade.

3. Supply Industry Problems, Their Interconnectedness and Solutions

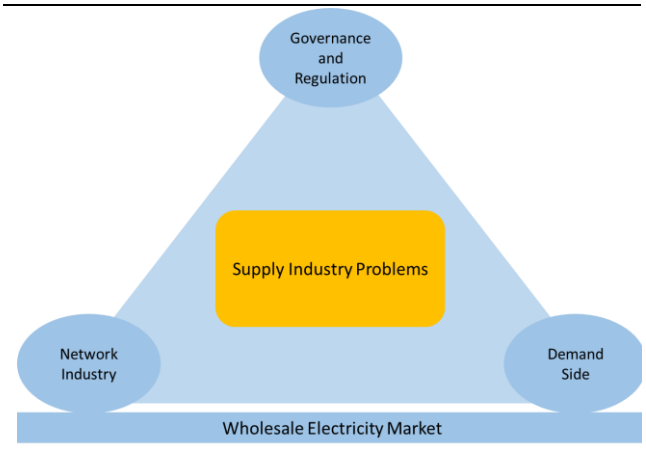
This section discusses the basic problems of the supply industry from the perspective of wholesale electricity markets. Problems in the supply industry emerge in various segments. They have direct and indirect causality relationships between each other and other segments of the electricity market. In the literature, electricity market problems are clustered by using many classifications. The most common one is the framework window classification (Sioshansi, 2008; Rudnick and Velasquez, 2018; Wolak, 2019). Main themes that determine the challenges and problems in industry which effects wholesale electricity market structure are legal framework, regulatory and institutional environment, market structure, and market rules.

The wholesale electricity market fundamentals are supply constraints, electricity grid (transmission and distribution included) congestion, and demand-side involvement. Electricity market segments excluding supply industry are defined as governance and regulation, network, and demand side. In a wide perspective, inefficient government and

regulatory issues are followed by the low financial viability and tariffs problems, which distort the short-run and long run equilibrium in the wholesale electricity markets. Regulation, governance, and pricing problems are classified as inefficient regulation and governance, pricing, and the volatility of the market. In addition, network industry problems are operational inefficiency, missing money at electricity network, transmission congestions. Moreover, demand-side problem is inactive involvement of demand. These problems influence the supply industry problems and functioning of wholesale electricity market. A large amount of literature provides theoretical explanations and empirical evidence of these problems, which are reviewed in this article.

The focus of the article is problems in the supply industry which are related to other segments of the wholesale electricity markets. Supply-side problems are clustered as supply inadequacy, missing money, market power, and renewable intermittency. We categorize the wholesale electricity problems into four main branches: governance, supply, network, and demand as shown in the Figure 5.

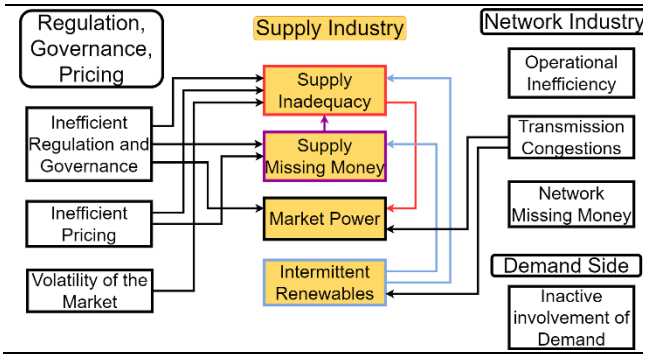
Figure 5: Supply Industry Problems in Wholesale Electricity Markets



On the one hand, governance problems are related to the market structure of electricity that results in inefficiencies such as inefficient and volatile pricing in the wholesale electricity markets. Moreover, network problems arise from the inefficient operations in the electricity grid, new grid investment problems, and the capacity problems of the electricity transmission. Another problem is low level of consumer involvement in demand side. To sum up, main problems excluding supply industry were listed as inefficient regulation and governance, inefficient pricing, volatility of the market, operational inefficiency, transmission congestions, missing money at network, and inactive involvement of demand. Problems in the supply industry stem from the lack of new generation investment, inappropriate government planning, monitoring inadequacy in the industry and the effect of technological evolutions. They are named supply inadequacy, missing money, market power, and intermittent renewables.

A brief summary of the relation between supply industry problems and other segments of the wholesale electricity market is shown in Figure 6. In the following sections, we explain the problems in the supply industry with their causes, consequences, and solutions in detail.

Figure 6: Summary of Causality Relations

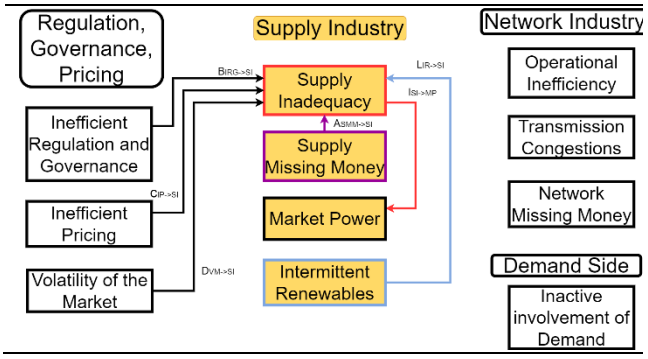


3.1. Supply Inadequacy

The supply industry consists of private and public generation companies that are located in the electricity grid. In the short run, the system operator aims to achieve supply-demand equilibrium for every time slot. Therefore, the supply industry's main goal is to continuously meet electricity demand. However, it is not always the case. The situation that electricity demand has not been provided by the supply industry is called supply inadequacy in the electricity market. Main supply inadequacies are lack of generation units, low level of generation capacity factors, and the shortages due to the fluctuations in renewables energy resources.

Most of the literature puts supply inadequacy at the beginning of the supply side problems of the wholesale electricity market. In the Figure 7, the causes (inflows) and consequences (outflows) of supply inadequacy problems are shown as a summary of the literature. Supply inadequacy comes from inefficient regulation and governance (BIRG->SI), inefficient pricing (CIP->SI), volatility of the market (DVM->SI), intermittent renewables (LIR->SI), supply missing money (ASMM->SI).

Figure 7: Problem Chart of Supply Inadequacy



Due to high initial investment costs and long payback time, generation plant investments are more difficult to be realized than other investments (Joskow, 2008; Ibarra-Yunez, 2015). Roques(2008a) focuses on generation capacity, reliability of supply design, and optimization of investments. In the supply industry, investors would prefer foreseeing the possible new production investments. However, false price signals and insufficient public incentive interventions create difficulties to do so (Wolak, 2003; Kessides, 2013). On the other hand, investment security problems are experienced in wholesale electricity markets where there is excessive public intervention (Ibarra-Yunez, 2015). High price volatility in electricity market might also result in an increase in producer (and consumer) losses both in the short term and in the long term. Due to all these problems, generation plant investments fall short to prevent supply inadequacy problem.

As shown in Figure 7, BIRG->SI; Borenstein(2002), Toba(2007), Sioshansi(2008), Gratwick and Eberhard(2008), Roques(2008b), Diaconu et al. (2009), Battle and Rodilla(2010), Malgas and Eberhard(2011), Ela et al. (2016), Grubb and Newbery(2018), Rudnick and Velasquez(2018) use descriptive statistics to explore the supply inadequacy problem and emphasize the importance of market design, market rules, and inefficiency. Many studies reveal that supply inadequacy problem mostly emerges from governance, market reform, state-ownership, and regulation issues (e.g., Woolf and Halpern, 2001; Newbery, 2002a; Bacon and Besant-Jones, 2001; Shuttleworth, 2002; Borenstein, 2002; Rudnick and Montero, 2002; Krishnaswamy and Stuggins, 2003; Williams and Ghanadan, 2006; Joskow, 2008; Diaconu et al., 2009; Malgas and Eberhard, 2011; Ibarra-Yunez, 2015). Studies investigate the US, the UK, Europe, Latin America, and developing countries for different time periods and highlight the importance of independent regulation and good governance; where Shuttleworth (2002), Krishnaswamy and Stuggins(2003) focus on tailored (country-specific approach) market reforms to solve supply inadequacy problem for Central Asia, Europe, Georgia, Sri Lanka, and Vietnam between 1990-2013 period. Furthermore, many studies find that state ownership in the supply industry is another reason that creates supply inadequacy problems (Newbery, 2002a; Borenstein, 2002; Rudnick and Montero, 2002; Wolak, 2003; Joskow, 2008; Kessides, 2013; Ibarra-Yunez, 2015). Many studies find that strong government intervention in wholesale electricity markets end up with supply inadequacy (Newbery, 2002; Shuttleworth, 2002; Rudnick and Montero, 2002; Gratwick and Eberhard, 2008; Malgas and Eberhard, 2011). Wolak (2003), Joskow (2008) study finance insufficiency at the state ownership domination in supply industry by analyzing US and Latin America countries such as Argentina, Brazil, and Chile for 1985-2005.

Furthermore, CIP->SI in the Figure 7 shows that inefficient pricing is one of the major contributors to the supply inadequacy problem. Low prices in the wholesale electricity markets harms the investment climate and hinder new investment in the supply industry (Bacon and Besant-Jones, 2001; Wolak, 2019; Krishnaswamy and Stuggins, 2003). This cause to supply inadequacy challenge in the market. Volatile prices also create uncertainty in the wholesale electricity markets (Roques, 2008a; James Bushnell et al., 2017). This situation creates varying returns in the market that damages new generation plant investments. Moreover, over-regulated prices and government interventions to market clearing price produces an unreliable wholesale electricity market. Due to this uncredible regulation climate and therefore a low level of investment, supply adequacy emerges (Wolak, 2003; Rudnick and Velasquez, 2018; Sioshansi, 2008).

The literature also suggests that volatility of the market hinders investment and causes supply inadequacy (DVM->SI) (Borenstein, 2002; Woo et al., 2006; Higgs and Worthington, 2008; Kalantzis and Milonas, 2013). Borenstein(2002) focuses on the California crisis to analyze its effects on the electricity market volatilities by using descriptive statistics in 2000 for the US. Higgs and Worthington (2008) apply the mean-reverting and regime-switching model by using Australian data between 1999-2004 and finds that electricity markets suffer from high prices. The study concludes that supply inadequacy emerges from volatility. Kalantzis and Milonas(2012) states that low maturity with high volatility support supply inadequacy by considering France and German wholesale electricity markets in 2009 with VECM and GARCH models.

These result in missing money and investment problems. As seen in Figure 7 ASMM->SI missing money problem brings out supply inadequacy. Inefficient pricing also triggers missing money and investment security problems, which are experienced in wholesale electricity markets where there is excessive public intervention. In the wholesale electricity market, the government intervenes in the market with price ceilings and state-owned plants' supply bids. Joskow(2008), Battle and Rodilla(2010), Newbery(2015), Grubb and Newbery(2018) state that missing money problems result in supply inadequacy via using descriptive statistics and focusing on the UK and US.

In recent years, renewable penetration in the supply industry has changed the paradigm in wholesale electricity markets. As shown in Figure 7, renewable intermittency provokes supply inadequacy (LIR->SI). De Sisternes et al. (2015), Batalla-Bejerano and Trujillo-Baute(2016), Winkler et al. (2016), Pollitt and Anaya(2016), Aghaie(2016), Wolak(2021) study the relationship between renewable energy and supply inadequacy and finds a direct causal relationship from intermittent renewables towards supply inadequacy for the last 10 years. Rudnick and Velasquez (2018) emphasize the negative effect of renewable resources on supply adequacy for developing countries.

The literature proposes capacity markets and independent power producers to overcome supply inadequacy problem. Capacity markets are founded to fight against instantaneous

demand peaks and generation shortages (Wolak, 2021). Capacity markets divide into groups according to the mechanism they apply to set capacity price and amount. In one group of capacity markets, the regulator sets a capacity price and lets the market determine the amount of capacity. In the other group of capacity markets, the regulator sets the amount of capacity that has to be available and lets the market determine its price (Roques, 2008a). Several studies discussed the implementing capacity markets mostly solves the supply inadequacy problem for US (2007, 1972-2016), UK (1996-2001), Spain (1996-2001), and Nordpool (1996-2001) (e.g., S. Littlechild, 2000; Toba, 2007; Rudnick and Velasquez, 2018).

Most of the literature, including (Borenstein, 2002) for US in period 1999-2001; Kessides (2013) for Pakistan in period 2004-2010; (Ibarra-Yunez, 2015) for Mexico; (Toba, 2007) for Phillipines in period 1990-2010 focus on independent power producers to solve supply inadequacy problems. Independent power producers attract private investment to develop the electricity supply industry. The transformation from state-dominated generation to more private dominated supply side solves the market power and pricing problems via supporting competition in the market.

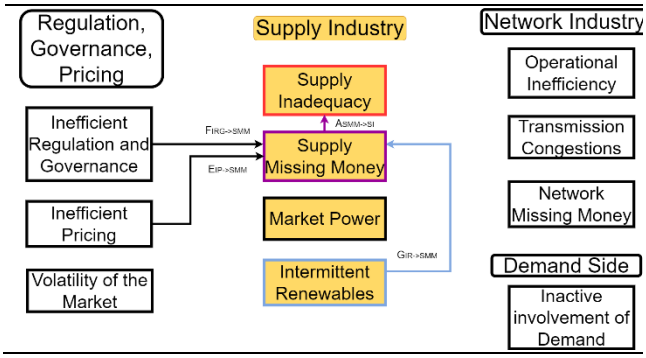
3.2. Missing Money at Supply

The supply industries in the electricity markets need to enhance their capacities to meet continuously increasing electricity demand. However, they have several features which suppress new investments. For instance, profit margins are low, and electricity prices are volatile, which makes new investments difficult. Missing money problem is the low return of investment money, which could not be matched with energy prices in the wholesale electricity market. Inefficient pricing and fluctuations in renewables increase the uncertainty in the electricity market, which bring out the missing money problem in the supply industry.

Therefore, the literature discusses missing money problem via classifying the supply industry of the wholesale electricity market. The Figure 8 shows the findings of the literature by showing causes (inflows) and consequences (outflows) of missing money problems. On the one hand, missing money problem stems from inefficient regulation and governance (FIRG->SMM), inefficient pricing (EIP->SMM), intermittent renewables (GIR->SMM). On the other hand, missing money problem results in supply inadequacy (ASMM->SI).

Inefficient regulation and governance cause supply missing money problems (FIRG->SMM). Regulatory and political issues are very important to determine the short-run equilibrium of the supply-demand and capacity requirements of the long-run system reliability (Newbery, 2015; Wolak, 2019). For instance, governmental interventions such as price ceilings (if price ceilings are set too low, below the Value of Lost Load, VoLL) might reveal missing money problems through a decrease in the return of investment (Pollitt, 2004). Ibarra-Yunez (2015) focuses on expected earnings as the indicator of this problem. The problem of missing money arises if the revenue is insufficient. (Joskow, 2011). Yet, there is a "missing market" problem if generation companies or their funders do not believe it to be adequate (Newbery, 1989). If ancillary services, such flexibility and black start capability, are not sufficiently compensated, problem of missing money can occur. (Pollitt, 2004).

Figure 8: Problem Chart of Missing Money



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Inefficient pricing is another cause of missing money problem (EIP->SMM). Even though Pollitt (2004) states that inefficiently low energy prices lead to missing money problem, Newbery (2015) considers it unlikely, even when there is an excess capacity. Rather, they might be above their competitive level. Inefficiently low energy prices yield supply inadequacy besides the missing money problem. To solve supply inadequacy problem, system operator might set energy prices above the marginal costs, at the level that at least covers generation units' fixed costs, while the installed capacity of the system is fully used. This is called scarcity pricing. However, scarcity pricing, in turn, cause the missing money problems. This is because the lack of demand-side response, short-term reliability management procedures, and inefficient ancillary services procurement often undermine scarcity pricing and distort long-term investment incentives (Roques, 2008b).

Newbery (2002b), Roques(2008a), Shuttleworth (2002), Littlechild (2000), emphasize that inefficient pricing provokes missing money at supply and network side (EIP->SMM). Europe (1991-2000), US (1999-2001), UK (1999-2001, 1996-2001), Latin America (1990-1999, 1985-2005), Nordpool (1996-2001) were analyzed with several methods such as descriptive statistics and non-linear optimization. These studies find that investments could sustain in efficient short-run and long run equilibriums.

Intermittent renewables induce supply missing money problems via distorting stable prices (GIR->SMM) (Newbery, 2015; Papalexopoulos et al., 2015; Hildmann et al., 2015; Winkler et al., 2016; Grubb and Newbery, 2018). Grubb and Newbery (2018) and Hildmann et al. (2015) focus on the generation volatility of renewable plants and their domination in the supply industry with descriptive statistics. In addition, Papalexopoulos et al. (2015) and Winkler et al. (2016) propose wholesale market models for Europe and US with intermittent renewables and they find evidence of the missing money problems for the case of intermittent renewables by employing the non-linear simulation models.

Several studies suggest capacity markets with well-designed energy only markets to solve missing money problems (Joskow, 2008; Newbery, 2015; Papalexopoulos et al., 2015; Newbery, 2016; Grubb and Newbery, 2018; Duan et al., 2018; Woo et al., 2019). Joskow (2008), Grubb and Newbery (2018) focus on the UK via descriptive statistics and simulation models for 2007-2017 and find that self-tailored capacity markets fully remove the missing money problem. In addition, Newbery (2015), Newbery (2016), McKenna et al. (2018), Woo et al. (2019) state the importance of implementation of capacity markets via analyzing Europe with descriptive statistics and nonlinear optimization for Europe. However, Neuhoff et al. (2013) points out that capacity auctions tend to over-procure capacity, which exacerbates the missing money problem.

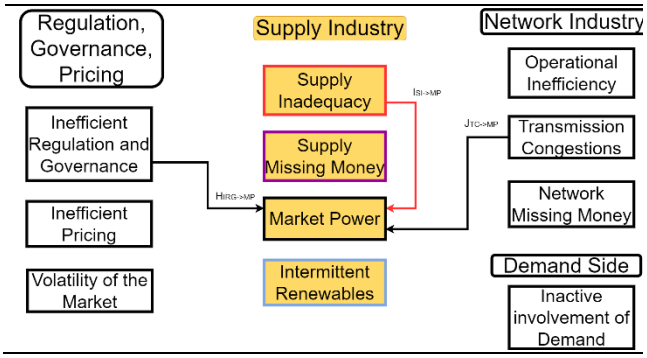
Along with capacity markets, the literature offers scarcity pricing and market-oriented designs as solutions to the missing money problems. Ela et al. (2016) states that scarcity pricing in energy-only markets might help revenue be sufficient, which addresses the missing money problems. Market-oriented wholesale electricity market designs might mitigate missing money problems in supply industries (Batlle and Rodilla, 2010; Joskow, 2008; Woo et al., 2019; Winkler et al., 2016). Market-oriented solutions mean less governmental interventions and a more deregulated structure. Therefore, the wholesale electricity market determines the equilibrium price and quantity itself. Battle and Rodilla (2010) and Joskow (2008) state that government intervention and over-regulated structures make the market inefficient; therefore, increasing the market-oriented rules create more sustainable and efficient wholesale electricity markets. Papalexopoulos et al. (2015), Simshauser (2019), Battle and Rodilla (2010), Grubb and Newbery (2018), Woo et al. (2019) use simulation models, central optimization for Europe, the UK, the USA and they find that profit and revenue optimizations in the market solve missing money problem.

3.3. Market Power

Market power is the main barrier to competition via creating inefficient prices. There are three types of market power; local, temporal, and pervasive. Firstly, local market power arises from insufficient transmission lines, in other words, transmission congestion. Secondly, temporal market power emerges from the lack of new investments and insufficient generation. Thirdly, if a generator continuously affects prices as a pivotal supplier, this generator is said to have pervasive market power. According to Wolak (2009), a supplier who exercises all unilateral market power that is available while abiding by the rules of the market is equivalent to a supplier who takes all legal steps to maximize the profits that it earns from participating in the wholesale market. The management of the firm also has a fiduciary duty to its shareholders to take all legal steps to maximize the profits that the firm earns from participating in the wholesale market.

As indicated, market power is one of the supply-side problems that is emphasized in the wholesale electricity market literature. The Figure 9 shows the causes (inflows) and consequences (outflows) of market power problems that the literature has provided so far. Market power emerges from inefficient regulation and governance (HIRG->MP), supply inadequacy (ISI->MP), transmission congestion (JTC->MP).

Figure 9: Problem Chart of Market Power



A fully deregulated market structure (full market opening) and deregulated structure brings out market power (HIRG->MP). It provokes high and inefficient prices due to the profit-maximizing target of the suppliers. Newbery(2002a) and Newbery (2002b) theoretically discuss the regulation effect on volatility via considering the California crisis. This volatility makes the market uncertain, hinders new investment, and causes some agents to go to crash. Borenstein et al. (2003), Woo et al. (2006), and Wolak (2014) discuss the policy transformation of the UK, US, and Europe and state that bad governance destroys the district wholesale electricity market with several mechanisms such

as auctions, bidding, and intervention. Market power occurs and binds market development.

Supply inadequacy with incompetent spot markets and inadequate long-term contract design causes market power (ISI->MP). Newbery (1998a) studies the UK with Cournot model, Wolak (2000) focuses on UK and US with descriptive statistics, Wilson (2005), Newbery (2002b), Newbery(2002a) analyze transmission, transaction costs, state ownership, market crisis for US, UK, Latin America, New Zealand and they find that market power mostly emerges from supply inadequacy. Generation concentration, regulation dynamics, and long-term contracts are the minor determiners of market power in addition to supply inadequacy (Newbery, 2002a; Evans and Green, 2003; Wolak, 2005; Sioshansi, 2008; Diaconu et al., 2009; Wolak, 2009; Bushnell et al., 2017; Wolak, 2014; Bushnell et al., 2004; Bushnell et al., 2002).

As indicated in Figure 9, transmission congestion is a common problem in the market that provokes market power (JTC->MP). Shuttleworth (2002), Newbery (2002a) Newbery(2002b), Wolak (2009), Ryan (2012), Bushnell and Saravia (2022) analyze the effect of transmission congestion with descriptive statistics and theoretical discussions and state that the inadequacy of network brings out uncompetitive structure in the wholesale electricity markets. For example, a generator that has a high network capacity to consumption points could easily create market power. In high-demand hours, network conditions might make limited network capacity generation units out of the bounds. Therefore, the system has to sustain its electricity from the power plant, which exercises market power.

A well-designed supply industry with sufficient generators, competition in the wholesale market and enough network solve the problem of market power (Newbery, 1998a; Chao and Wilson, 2001; Wolak, 2005; Diaconu et al., 2009; Ryan, 2012; Wolak, 2019). Wolak (2019) proposes five strategies for market designers, including dividing capacity owned by one firm among multiple independent suppliers, issuing fixed-price forward contracts to multiple suppliers to supply electricity to load-serving entities, involving final consumers as active participants in the wholesale market, ensuring the transmission network has adequate capacity to provide competition among suppliers, and regulating the wholesale market to incentivize all participants to meet their contractual obligations and follow market rules.

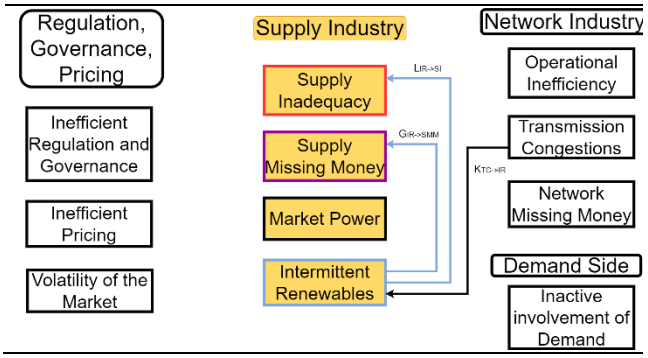
Future markets implementation and well-functioning market monitoring hinders market power potential (Wolak, 2000; Bushnell et al., 2017; Wolak, 2019). Bushnell et al. (2017) state that forward commitment contracts between retail and generation increase the competitive performance of the electricity markets. Adib and Hurlbu (2008) emphasize the independence of the regulatory authorities and monitoring of the electricity markets. Market monitoring consists of daily, long-term, and operation components. Bushnell et al. (2002) present the metrics of the electricity markets as the benchmark. Pivotal bidding analysis, oligopoly simulation, and Herfindahl Hirschman index are the basic methods to monitor market concentration and market power indicators. In addition, investigating market power abuses is another critical issue on the market design. System operators' actions such as short-term load forecast, ancillary services, and congestion management are continuously monitored. Market monitoring is a critical prerequisite to mitigate (Adib and Hurlbu, 2008; Wolak, 2009).

3.4. Intermittent Renewables

The main renewable energy sources are hydro, wind, biomass, geothermal and solar. They cannot be used to produce energy on a continuous basis like baseload power plants. Rather, the output of renewable power plants concentrates on certain hours. The concentration varies depending on the type of source. For instance, weather conditions such as rainfalls have a direct impact on generation capacity of the hydropower plant (Wolak, 2003). The problem of the discontinuous generation of renewable power plants is called intermittent renewables in the literature.

The problem of intermittent renewables are mostly classified as the supply industry of the wholesale electricity market by the literature. The Figure 10 shows the causes (inflows) and consequences (outflows) of intermittent renewables problems that the literature has provided so far. Intermittent renewable problem emerges from transmission congestions (KTC->IR) and intermittent renewables cause supply inadequacy (LIR->SI), supply missing money (GIR->SMM).

Figure 10: Problem Chart of Intermittent Renewables



First, the output of renewable power plants is volatile. Along with it, the purchase guarantees that the states provide as an incentive create a market distortion. In addition, renewable power plants require a big amount of investment for network, which also reduces the efficiency of renewable energy in the wholesale electricity market. Rudnick and Velasquez (2018) emphasize the generation volatility and high price effects of renewable generation plants. They also weaken the new investments of wind and solar generation plants. Wolak (2019) states that renewable generation plants' capacity factors are far below other baseload generation plants. Therefore, intermittent renewable

generation and capacity problems occur in the electricity market.

Inadequacy of the transmission grid (transmission congestion) that could not transmit low-cost generation to consumption locations leads to negative effects of intermittent renewables in the market (KTC->IR). Azuela et al. (2014), Politt and Anaya (2016), Keay et al. (2016), Grubb and Newbery (2018), Leslie et al. (2020) use descriptive statistics and demonstrate transmission congestion enhancing mechanisms on renewable energy implementation in wholesale electricity markets via considering pricing methods. Varying generation characteristics of renewables merge with transmission constraints and increase the harm of the system from supply-side problems.

Renewable implementation in well-organized wholesale electricity markets and balanced network design solves intermittent renewable problems for sustainability (Elizondo et al., 2014; Perez-Arriaga and Batlle, 2012; Batalla-Bejerano and Trujillo-Baute, 2016; Politt and Anaya, 2016; Keay et al., 2016; Grubb and Newbery, 2018; Leslie et al., 2020). Azuela et al. (2014) claim that local planning in the grid decreases the volatility effect of renewables. Therefore, regional pricing and planning are mandatory in the high renewable penetration system (Politt and Anaya, 2016). Regional planning directs supply and demand investments to the correct locations. For example, if a region's price is high, then supply-side investments will increase and demand-side investments will decrease in this region. Vice versa is also correct. In this situation, the market solves its pricing, supply, and demand problems by its dynamics.

On the other hand, according to Newbery (2015), letting wind and solar power plants generate electricity in the grid provides a flexibility that could make renewable generation to be continuous.

4. Conclusion

In this paper, we discussed the emergence, causality relationships, and solutions of the supply industry problems in the wholesale electricity markets by reviewing the related literature. First, we classified supply industry problems into four problems. One of them is missing money problem, which is the oldest problem of the electricity markets. It is defined as the insufficient investments in generations due to low returns in the long run. The second problem is supply inadequacy problem, which is considered as the main problem in the supply side. Supply inadequacy problem arises when electricity demand cannot be met by the supply industry. The third problem is market power, which stems from insufficient transmission lines, the lack of new investments, insufficient generations, and existence of pivotal supplier. The last problem is intermittency problem of renewable energy, which occurs because of discontinuous electricity production of renewable plants.

Then, we revealed the direction of causalities and transitions between major supply industry problems based on the literature review. By considering these relationships, this study focused on functioning of wholesale electricity market from supply industry perspective. Our findings indicate the complex relations between supply industry problems and wholesale electricity market. We found multidimensional causalities between problems that literature discussed.

Next, we presented the solutions of the each supply industry problem introduced by the literature. This study shows that the solutions are also linked to each other. In particular, multi-factorial solutions, such as market oriented design and effective regulations, increase the market efficiency in the wholesale electricity market. Moreover, less government intervention, more private ownership and more liberal markets are also offered in the literature to lead a sustainable and competitive market. The literature review also show that transparency, liquidity, predictability with future markets solve the most of the problems in the supply industry. Furthermore, as a new generation market oriented solution, capacity markets create more competitive pricing mechanism. Finally, efficient network design also hinder the supply industry problems.

The characterization of fundamental problems of the supply industry in wholesale electricity markets opens the door to more empirical work that would consider these problems as a part of an integrated market structure. Similar to the supply industry; network industry, governance, regulation, and demand side problems can be considered. This might unveil the intricate issues in the wholesale electricity markets that remained unexplored so far.

Kaynakça

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