View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Apollo

UNIVERSITY OF CAMBRIDGE
Faculty of Economics

Cambridge Working Papers in Economics

Cambridge Working Papers in Economics: 2043

WHAT EFFECT HAS THE 2015 POWER MARKET REFORM HAD ON POWER PRICES IN CHINA? EVIDENCE FROM GUANGDONG AND ZHEJIANG

Bai-Chen Xie | Jun Xu | Michael G. Pollitt

21 May 2020

This paper presents an analysis of the impact of the recent power market reform process in China – following the No.9 Document of March 2015 – on the industrial price of electricity. We do this by picking a typical power price for a medium sized industrial customer in two of China's leading reform provinces: Guangdong and Zhejiang. We find that power market reform, which is characterised by the introduction of wholesale electricity markets, has substantially reduced prices. Our detailed analysis shows that these price falls have come from a number of different sources: falls in the prices paid to generators, reductions in grid charges and falls in government taxes and additional charges. We show that the regulated price falls by 26.4% in Guangdong and by 26.9% in Zhejiang. The market price falls even further by 27.7% in Guangdong and 30.4% in Zhejiang. We conclude that while the impact of the power markets is significant, the associated changes to network charges and other government determined components of the price are more significant.

UNIVERSITY OF CAMBRIDGE | Energy Policy Research Group

What effect has the 2015 power market reform had on power prices in China? Evidence from Guangdong and Zhejiang

EPRG Working Paper 2010

Cambridge Working Paper in Economics 2043

Bai-Chen Xie

Jun Xu

Michael G. Pollitt

Abstract This paper presents an analysis of the impact of the recent power market reform process in China – following the No.9 Document of March 2015 - on the industrial price of electricity. We do this by picking a typical power price for a medium sized industrial customer in two of China's leading reform provinces: Guangdong and Zhejiang. We find that power market reform, which is characterised by the introduction of wholesale electricity markets, has substantially reduced prices. Our detailed analysis shows that these price falls have come from a number of different sources: falls in the prices paid to generators, reductions in grid charges and falls in government taxes and additional charges. We show that the regulated price falls by 26.4% in Guangdong and by 26.9% in Zhejiang. The market price falls even further by 27.7% in Guangdong and 30.4% in Zhejiang. We conclude that while the impact of the power markets is significant, the associated changes to network charges and other government determined components of the price are more significant.

Keywords Chinese power market reform, electricity prices, No.9 Document

JEL Classification L94

Contact xujun84@zufe.edu.cn
Publication May 2020
Financial Support EPRG; the National Natural Science foundation of China(71874121, 71603232); Major projects of the National Social Science Fund of China(17ZDA065, 18ZDA111) ; National Key R& D Programme of China (No. 2018YFC0704400); ESRC Impact Acceleration Award.

EPRG WORKING PAPER

What effect has the 2015 power market reform had on power prices in China? Evidence from Guangdong and Zhejiang

Bai-Chen Xie [a,b]

Jun Xu [a,c,]

Michael G. Pollitt [a, d]

[a] Energy Policy Research Group, University of Cambridge

[b] College of Management and Economics, Tianjin University

[c] China Institute of Regulation Research, Zhejiang University of Finance and Economics

[d] Judge Business School, University of Cambridge

March 2020

1. Introduction

The electricity price in China was strictly regulated before 2015, which reduced the price fluctuations for consumers and guaranteed a stable revenue for power suppliers (Chen et al., 2014). The strictly regulated price mechanism had been in effect since 1949 when the People's Republic of China was established. The electricity industry has long been regarded as very important for the industrial output more generally, leading to regulated final electricity prices for industry. Meanwhile a desire to protect residential electricity customers from high prices led to a lower regulated power price for households than for industrial and commercial customers. In China, both the prices paid by final consumers and the prices paid to individual generators were set by government prior to recent reforms. Whatever its shortcomings, this regulated price mechanism did successfully guide investment in power infrastructure to satisfy the increasing electricity demand which came along with China's fast economic growth (Lin et al., 2019).

However, the regulated price mechanism in China's power industry has attracted much criticism because of its inability to optimize the allocation of resources. An empirical study by Chan et al. (2017) covering the period 1991 to 2005 showed that the earlier restructuring of the electricity market had

brought nearly 15 percent savings in operating expenses and up to a 7.5 percent emissions reduction for the investigated power plants (National Energy Administration, 2016). However, by 2014 electricity prices in China for industrial customers were significantly higher than in the US, in part due to the inefficiency of the Chinese electricity system (see Pollitt et al. 2017). To address the negative consequences of the regulated price mechanism, the central government of China launched an unprecedented market reform of its power industry in March 2015, following the release of the so-called "No. 9 Document" (NDRC, 2015) to build a "complete, open, orderly and competitive" power market system. A series of supplementary documents have also been released aiming to facilitate the implementation of the reform. One of the core tasks of the reform is to deregulate the industrial electricity price (Liu et al., 2019).

This paper aims to investigate the impact of China's power market reform of 2015 on electric power prices. It does this by tracking monthly power prices for 35kV+ industrial consumers in Guangdong and in Zhejiang. These are two rich provinces in China, that traditionally suffer from quite high prices of electricity. They are also widely recognised as two provinces making substantial progress with power market reform. To better evaluate the effect of the reform, this paper examines the progress with power market reform beginning in 2012 detailing the emergence of bilateral electricity trading and progress with annual, monthly and spot markets following the No.9 Document of 2015. There is no reform in the first part of the study period while different kinds of policies were put forward in the latter part of the study period. The changing electricity price may indicate whether market reform has taken effect. Electricity prices would appear to have come down substantially since 2014, when they were very much higher than in the US. However, what we highlight is the extent to which the reform has been about the introduction of competitive market prices vs reductions in regulated prices/charges. We aim to show the sources of price reductions and the impact of the reform on prices paid to generators and on the transmission and distribution charges received by the grid companies.

The literature on the effect of the new round of power market in China is rather limited, and much of it focused on the *potential* effect of reform or possible reforms rather than on the measurement of *actual*

reform impact. Xia et al. (2013) designed mechanism for direct electricity trading between generators and large customers without a spot market. Several papers describe the status of electricity trading in China, identify the problems and give policy recommendation for further reform (Ma et al.,2017; Hu et al.,2017; Yan et al.,2017a; Shi, 2018; Gu, 2019; Wang et al.,2019). China Electricity Council (2020) reported that trade volume of China's power market reached 2177.14 TWh in 2019, accounting for 30.1% of total electricity consumption. Of which, intra-provincial trade volume was 2028.6 TWh and inter-provincial trade volume reached 148.52 TWh, accounting 93.2% and 6.8% of total trade volume. Yan et al. (2017b) simulated that GDP would increase by 0.613%, household income increase 0.037%, CPI decrease 0.031% and consumer welfare increase 8.771 billion CNY national wide using a CGE model, under the assumption of abolishing generation regulation and liberalizing customer choice. When it comes to individual provinces, Mo et al. (2017) find electricity bill only accounts on average 2.3% of total operation cost of manufacture industries in Guangdong. Thus, they argue that reducing the electricity price by six cents (CNY), or 10%, which is proposed by a policy document from provincial government will not have significant impact on manufacturers. He (2017) lists the potential price reduction sources from the market process in Zhejiang and give some further policy recommendations. To the best of our knowledge, there is no rigorous analysis of price effects of market reform which seeks to identify the overall price change following reform and decompose it into its regulatory and market elements. This is what this paper seeks to provide.

In section 2 we continue by discussing the background to the market reforms in Guangdong and in Zhejiang. In section 3 we track the evolution of regulated prices in Guangdong and Zhejiang for both customers and generators. In section 4 we examine the evolution of market prices in Guangdong and Zhejiang for both customers and generators. Section 5 looks at the overall price impacts in Guangdong and Zhejiang, including the extent to which the gap between US and Chinese electricity prices has narrowed. Section 6 offers a conclusion.

2. Background to power market reform in Guangdong and Zhejiang

2.1 Discussion of reform progress since 2012 (with timeline)

The direct electricity trading between generators and customers in China dates back to March 2005 when a power plant named Longhua thermal power plant sold 0.39 GWh electricity to Jilin Graphite Company in Jilin Province[1]. At that time, local government needed to obtain consent from a central government agency to organize electricity direct trade. In 2013 under the guideline for the streamlining administrative procedures from the new cabinet[2], the newly formed National Energy Administration (NEA) issued a notice which gave the green light to provincial governments to organize the electricity sector according to their needs[3]. Following this provincial governments actively engaged in organizing trading. Guangdong and Zhejiang are two of the leading provinces in this space.

The history of power transactions in Guangdong can be traced back to as early as 2005 when the Economic and Information Commission of Guangdong province and the Southern Energy and Power Regulatory Bureau put forward a pilot project for the small-scale direct power trading in Taishan in 2005. The project was first officially launched in 2006, allowing the Taishan Power Plant to directly trade with six local enterprises, and the annual direct electricity trading volume was about 0.20 TWh[4].

The current Guangdong power market began in 2013 when China Southern Grid company (CSG) started the pilot work on direct bilateral transactions across the whole province. From September to December in 2013, a total of 112 large-scale industrial enterprises and thermal power generation companies participated in direct bilateral transactions with an annual contract volume of about 2.24 TWh of electricity traded. In addition, Guangdong launched its quarterly auction trading for 2014 in December 2013, which achieved a traded volume of about 0.5 TWh. Generally, it has set varied thresholds for different industrial sectors, and the standards vary between the Pearl River Delta and other regions even

1 See National Electricity Regulatory Commission (2007)
2 See State Council of People's Republic of China (2013).
3 See National Energy Administration (2013).
4 http://www.chyxx.com/industry/201906/748180.html

for the same industry. Along with the development of the power market, the thresholds have decreased to include more customers in the market.

Zhejiang began its direct electricity trading at the end of 2014, even before the No.9 document was unveiled. Only coal and natural gas generators could participate in trading with customers with a connection voltage above 110kV. In addition, customers should be in sectors which are encouraged by central and provincial government. Their energy consumption per unit of product should be among the lowest in their industry. Firms who pollute heavily or fall behind the production technological frontier are excluded. Since it is the first time for market participants to engage in direct trade, this takes the form of bilateral trading. Each participant can freely find his potential trading partner and reach a bilateral contract with each other regarding price and volume[5]. Thus, the transaction price is not uniform and depends on the terms of the contracts. 12 generators and 32 electricity customers signed contract for 3.92TWh covering 13 months starting from December 2014 to December 2015.

Table 1 presents some milestones and progress metrics in the development of the Guangdong and Zhejiang electricity power markets.

[5] See Zhejiang Provincial Economic and Information Commission (2014).

Table 1: Timeline of Electricity power markets in Guangdong and Zhejiang

	Milestones		**Progress**	
Time	**Guangdong**	**Zhejiang**	**Guangdong**	**Zhejiang**
From Sept. to Dec. of 2013	A total of 112 large-scale industrial enterprises and power generation companies participated in the direct bilateral transaction.		An annual contract volume of about 2.24 TWh of electricity traded.	
Dec. 2013	Quarterly auction trade for 2014.		Traded volume was about 0.5 TWh.	
Jul, 2014	Monthly auction first began.		The power traded jumped to 15.5TWh in 2014.	
Dec, 2014		12 generators and 32 customers 110KV and above participated in the direct bilateral transaction.		A total annual contract covering from Dec 2014 to Dec 2015 with volume of about 3.92 TWh of electricity traded.
Mar,2015	The document of *Several Opinions of the CPC Central Committee and the State Council on Further Deepening the Reform of the Electric Power System* issued (No.9).			
Mar,2015	First online auction.		The market-oriented trading volume expanded to 22.7 TWh in 2015[6].	
Nov. 2015	National Development and Reform Commission (NDRC) issued the list of pilot provinces for special reform of power retail business.		Guangdong was approved to become the pilot province for special reform of power retail business.	
Dec, 2015		19 generators and 354 35KV and above customers		The trading volume rises to 15.1 TWh covering whole year of 2016.

[6] http://www.360doc.com/content/17/0501/14/34546942_650048035.shtml

		participate in the online auction.		
Mar,2016	Retail companies began to take part in the power market transaction.			
May, 2016		Zhejiang power exchange centre was established.		
June, 2016	Guangdong power exchange Centre was established.	Generators out of Zhejiang and connected to Zhejiang through HV interconnector join the trade. The number of customers increased to 55537.	The trading volume expanded to 43.9 TWh in 2016[7].	The trading volume jumped to 60.9 TWh covering next half year of 2016.
Oct, 2016		Zhejiang was approved by National Development and Reform Commission as pilot province for retail reform[8].		
Mar,2017	Guangdong power exchange centre was registered.			
Nov, 2017	The trading centre has introduced a new business model of annual auction contract.		The trading volume has increased to 115.7 TWh in 2017[9].	
Dec, 2017	The market mechanism of frequency modulation for auxiliary service proposed.		Simulation test for the mechanism.	
Aug, 2018	Guangdong was listed as one of the pilot province of power spot market.	Zhejiang was listed as one of the pilot provinces for the power spot market.		

[7] http://www.360doc.com/content/17/0501/14/34546942_650048035.shtml

[8] See National Development and Reform Commission (2016)

[9] 2017 年广东电力市场报告。The annual report of Guangdong Power market in 2017.

May,2019	The first test for spot market.	
June, 2019		The first test for spot market.
Sept, 2019	The spot market is run for a long period of time.	
Oct, 2019		Retail companies began to take part in the power market transaction

As can be seen from Figure 1, both of the volume of direct power transactions and other types of trading have increased rapidly in recent years in Guangdong[10]. Along with the introduction of the retail companies, the number of customers involved in the power market has also increased rapidly, from 112 in December of 2013 to 10519 in June of 2019, as indicated in Table 2. In 2014, the quarterly auction changed to a monthly auction in Guangdong electricity market, and annual bilateral contracts were put into practice. The third kind of trading form – an annual auction contract - first appeared in Guangdong in 2018. Figure 2 also shows that the structure of the traded power has also evolved, with annual bilateral contracts becoming the most popular form of trading.

Figure 3**Error! Reference source not found.Error! Reference source not found.** shows the power traded on the market and its share in the power consumption of industrial and commercial sectors in Guangdong in recent years[11]. From 2013 to 2019, the provincial power consumption has increased 5.59% annually. The power traded volume increased sharply, with its share in the power consumption of industrial and commercial sectors increasing from 0.68% to 35.56% over the period. Meanwhile, its share in the total power consumption has also increased to 29.20% in 2019.

Zhejiang has experienced a similar growth pattern to Guangdong which can be seen from Figure 1[12]. The only difference is that Zhejiang only organizes annual trades and not monthly trading. The number customers in Zhejiang involved in power trading surpasses Guangdong in 2016 and is nearly five times of that in Guangdong. The reason is Zhejiang decided to include a larger number of smaller electricity

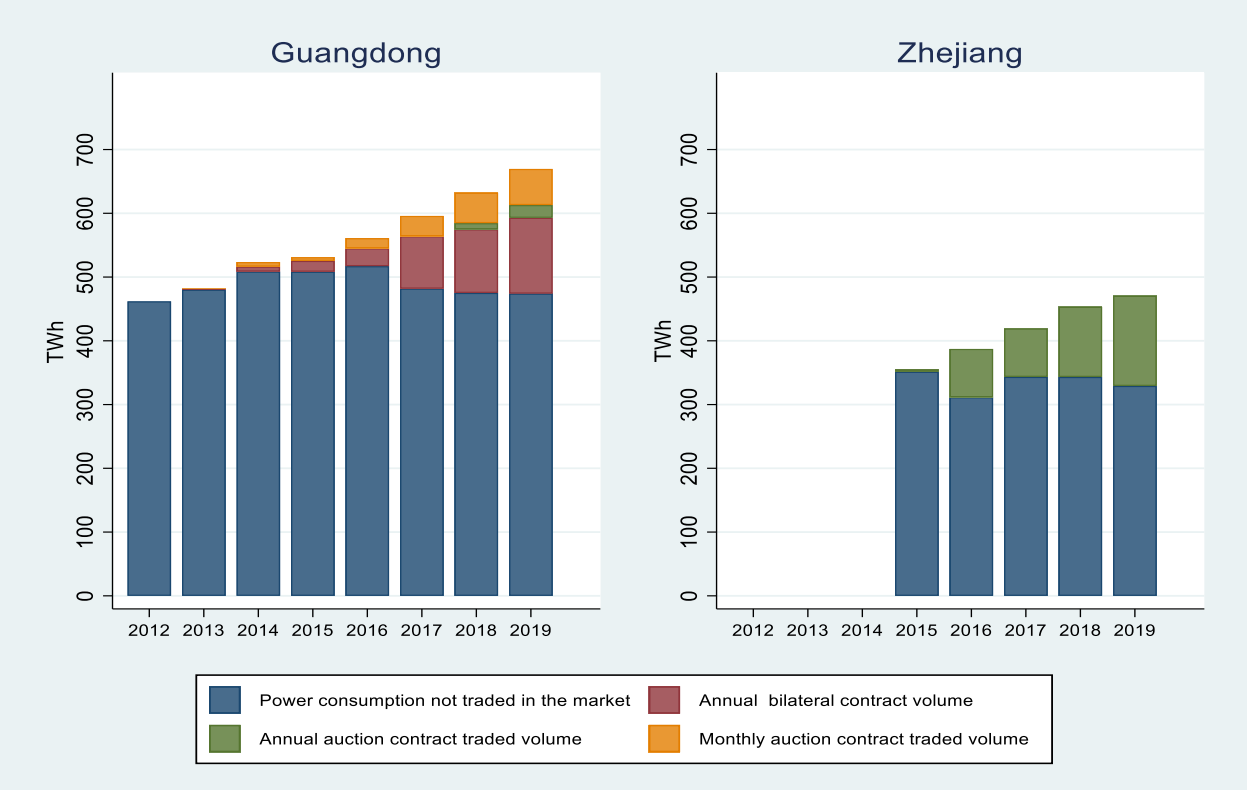
[10] https://www.ceicdata.com/zh-hans/china/electricity-consumption/cn-electricity-consumption-guangdong. China Energy Statistical Yearbook 2013-2019, and the Annual Report of Guangdong Power Market, http://shoudian.bjx.com.cn/html/20191129/1024758.shtml

[11] https://www.ceicdata.com/zh-hans/china/electricity-consumption/cn-electricity-consumption-guangdong. China Energy Statistical Yearbook 2013-2019.

[12] Source: The auction trade volume is obtained from website from Zhejiang Provincial Economic and Information Commission (before 2017) and Zhejiang Provincial Energy Bureau (after 2017) http://fzggw.zj.gov.cn. After 2017, the Electricity Section under Zhejiang Provincial Economic and Information Commission which oversees administration of electricity trade was merged into the Zhejiang Provincial Energy Bureau. The regulated volume is derived by subtracting traded volume from total consumption. The total consumption before 2017 is obtained from China Electric Power Yearbook. Total consumption of 2018 and 2019 is retrieved from http://shoudian.bjx.com.cn/html/20190108/954923.shtml and https://mp.weixin.qq.com/s/ajDUZwSBVStxQVg7bRRIYw.

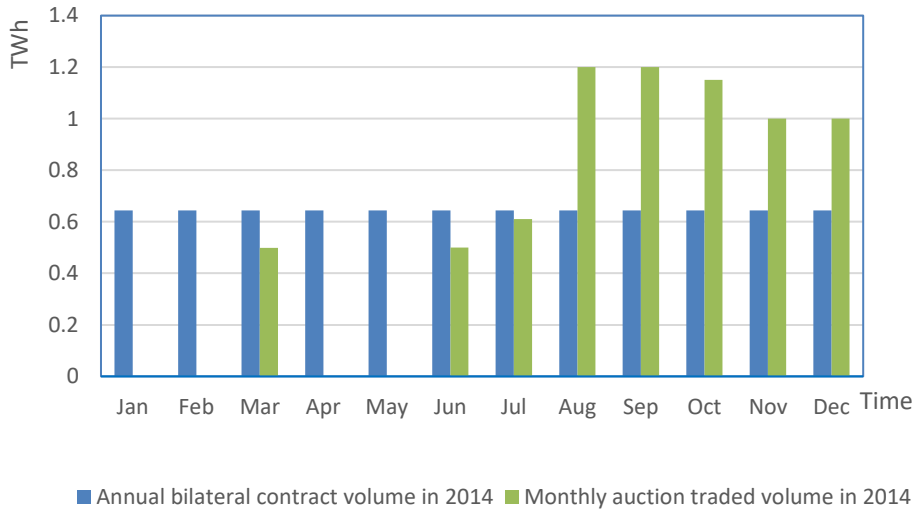
consumers whose annual consumption was only above 1GWh in the middle of 2016. Figure 3 shows the share of power trade volume in total industrial and commercial power consumption has increased from 1.33% to 36.17% over an even shorter period[13]. Meanwhile, its share in total power consumption has also increased to 30.53% in 2019.

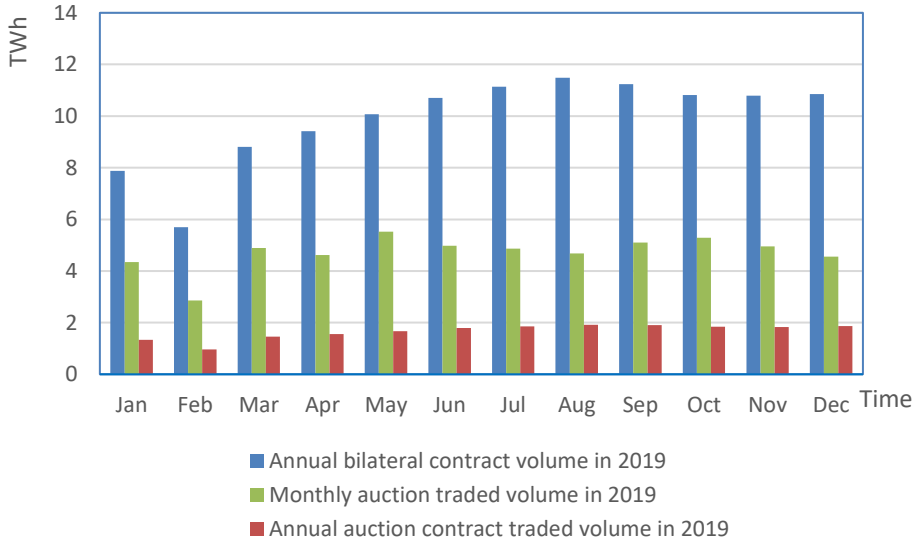
Figure 1 The power market trading volumes in Guangdong and Zhejiang from 2012 to 2019



[13] Source: Annual auction traded volume is the same as Figure 1. The industrial and commercial consumption is derived from Zhejiang Statistical Yearbook 2014- 2019 by summing up secondary and tertiary sector consumption from total consumption. 2019 data is derived by applying the average ratio of industrial and commercial consumption to the forecast total consumption.

Figure 2: The monthly power market trading volumes in Guangdong in 2014 and 2019[14][15]





[14] Before 2014, it was quarterly auction rather than monthly auction in Guangdong power market. Data source, 广东电力市场风云 2013-2017：转轨与突围。Changes and history of Guangdong power market 2013-2017: mechanism transfer and breakouts.

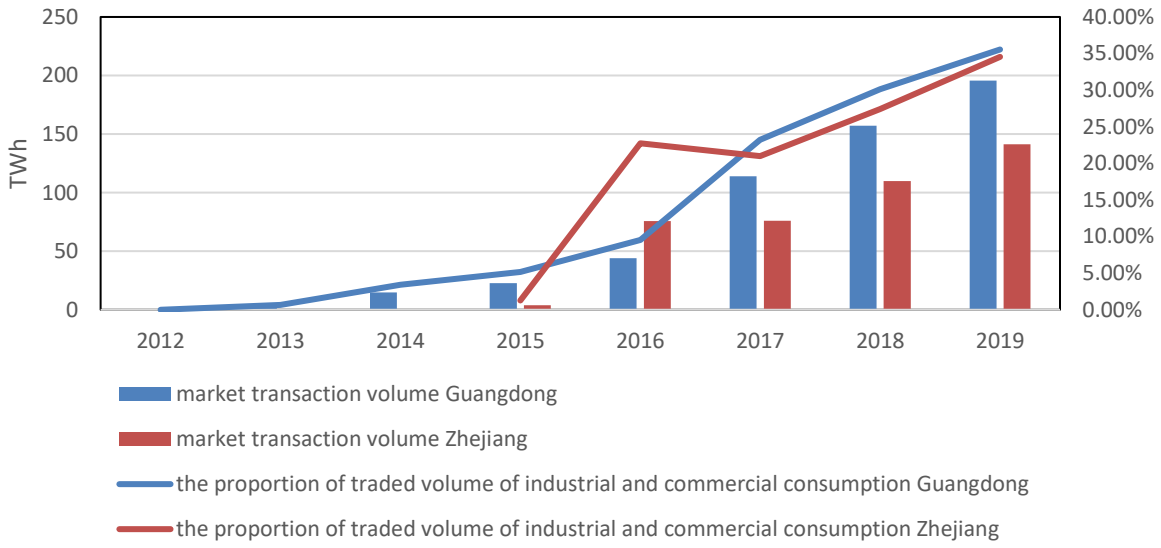
[15] 广东电力市场 2019 年年度报告, http://shoudian.bjx.com.cn/html/20191129/1024758.shtml

Table 2: The number of customers in Guangdong and Zhejiang power market

Time	2013	2014	2015	2016	2017	2018	2019
Customer numbers in Guangdong	112				5785	9266	10519[16]
Customer numbers in Zhejiang			32	55891	58089	48822	53039

Source: the Zhejiang data is the same as **Error! Reference source not found.**.

Figure 3 The proportion of traded power in industrial and commercial sectors in Guangdong and Zhejiang



It is important to point out that impressive though the rise in traded power is, the strict restrictions on market participation in China, means that far less power is traded in the market than is the case in a typical market economy. In the organised electricity markets of the US, such as in Texas, 100% of industrial and commercial power is traded via the market. It is also interesting to note that the rapid

[16] The number is until June of 2019. All the numbers come from Annual Report of Guangdong Power Market.

growth in power consumption over this period has meant that the non-market volumes have only declined slightly.

3. Benchmark electricity prices in Guangdong and Zhejiang

This section discusses what has happened to regulated prices, for both customers and generators in the two provinces.

3.1 Regulated retail benchmark electricity price

The regulated retail benchmark electricity price depends on the connection voltage of customers. The connection voltage ranges from 110kV to below 1kV for industrial and commercial customers. We take 35kV industrial and commercial customer as an example to conduct the following analysis[17]. According to the statistics of State Grid Company of China (SGCC), this type of customer accounts for 10% of the total power consumption while its price has changed much more than that of customer for 110kV or above. To some extent, the 35kV industrial and commercial customers are affected by the power market reform more than other kinds of customers. The commercial power price was always higher than that of industrial customers before 2015[18], but things changed when the government issued a document which combined the power price for industrial and commercial customers at the end of 2014[19].

From 2012 to 2019, the regulated power price for commercial customers has decreased eleven times in Guangdong.[20] This happened once in 2013 and twice in 2015, 2016, 2017, 2018 and 2019[21]. As a result,

[17] Even among the 35kV industrial and commercial customers, there are two subgroups: one pays a two part tariff and the other pays a single rate. The two part tariff consists of a consumption invariant monthly connection charge and a use of system charge which depends on monthly consumption. A single rate customer only needs to pay a use of system charge. Their connection charge is thus dispersed over their monthly consumption charges. So the single rate customer pays a higher use of system rate than their two part tariff counterparts. In this paper we focus on the single rate charge for ease of comparison over time.

[18] http://finance.eastmoney.com/news/1350,20141230462660163.html

[19] See National Development and Reform Commission (2013a).

[20] Prices vary across cities in Guangdong. We take the Guangzhou price (the price of the largest city in Guangdong) as a representative reference price.

[21] For the power price of 2012: http://www.chinaacc.com/new/63_74_201112/06ya1682375590.shtml
For the adjustment of September, 2013: https://wenku.baidu.com/view/37e120d604a1b0717fd5dd33.html;

the benchmark price for commercial customers (industrial customers) has decreased from 0.9758 (0.8858) CNY/ kWh to 0.6513 CNY/ kWh in Guangdong, as Figure 4 shows. The benchmark price for commercial customers and industrial customers has decreased from 0.8780 CNY/ kWh and 0.6750 CNY/ kWh to 0.6413 CNY/ kWh and 0.6344 CNY/ kWh respectively in Zhejiang (Figure 4)[22]. It is easy to see that the frequency of the price adjustment has accelerated in recent years, resulting in a large overall reduction.

Compared with the frequent changes in the regulated power price for the industrial and commercial sectors, there have been few changes in household electricity prices. Guangdong has a policy of block prices for residential customers since July 2012[23], and the first block price was kept as the same as that before the policy was put in place. For the customers that consumed power more than first block volume cap, they need to pay a higher price. There are no price changes for the first block over the studied period except the decrease of tax and add-on tariffs in Guangdong, just as Figure 5 shows. Through introducing price blocks, the average price for residential customers should be higher than the baseline price after introducing the reform of block price [24]. Combining with the decrease of the price for 35kV+ general industrial and commercial customers, the price gap between industrial and commercial customers and

For the adjustment January, 2015: http://finance.eastmoney.com/news/1350,20141230462660163.html
For the adjustment of May, 2015:
http://www.yangjiang.gov.cn/zxfw/bmfw/bmcx/zfgjj/201505/t20150504_124051.shtml
For the adjustment of January, 2016:
http://dgdp.dg.gov.cn/attachment/cmsfile/dgdp/dian/201601/daofile/59593doc279312.pdf
For the adjustment of June, 2016: http://www.qingcheng.gov.cn/info/9000128061
For the adjustment of January, April and July 2017: http://shoudian.bjx.com.cn/news/20170721/838589.shtml
For the adjustment of May, 2018: http://drc.gd.gov.cn/ywtz/content/post_833768.html
For the adjustment of July 2018: http://drc.gd.gov.cn/ywtz/content/post_833914.html
For the adjustment of April, 2019: http://drc.gd.gov.cn/ywtz/content/post_2281612.html
For the adjustment of July 2019: http://drc.gd.gov.cn/ywtz/content/post_2498633.html

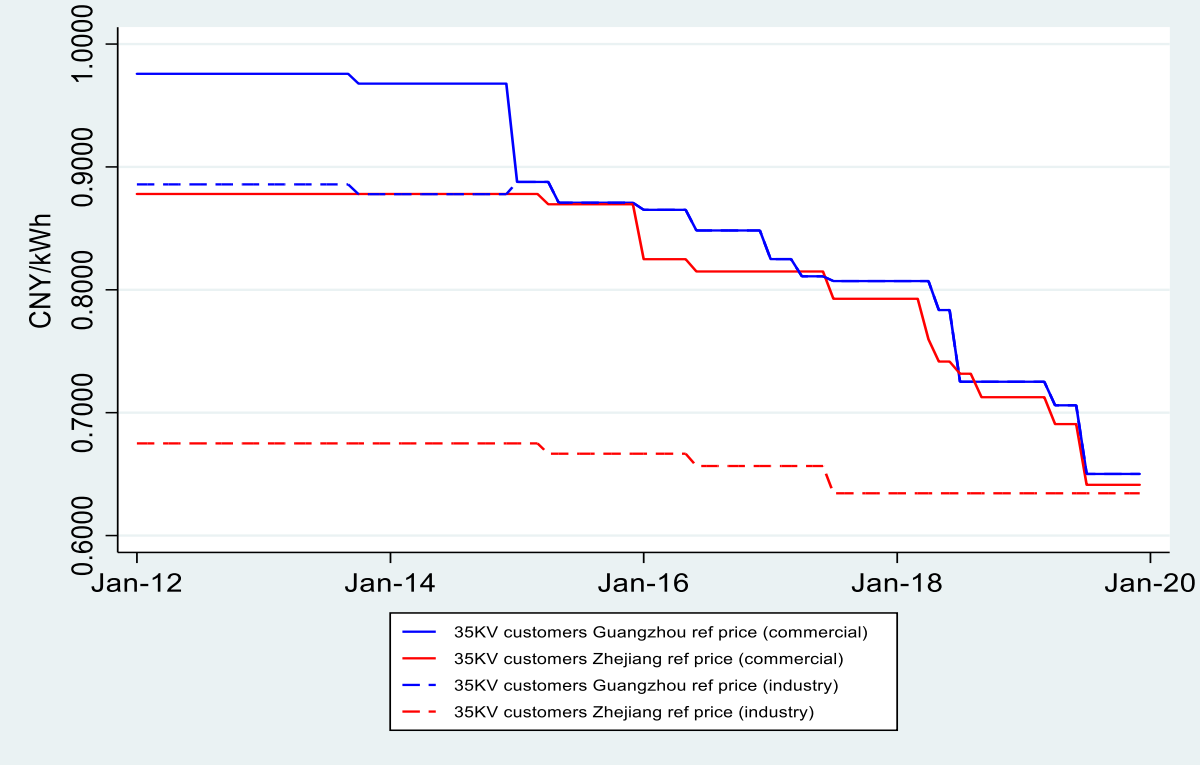
[22] Source: Notice documents published by Zhejiang Provincial Price Bureau and later Zhejiang Provincial Development and Reform Commission since the former agency was merged into the latter in 2018.

23 National Development and Reform Commission had issued a guideline about increasing block pricing which it has implemented nationwide in 2011. There are three blocks in the guideline. The consumption volume of the first block covers 80% of monthly average residential consumption with unchanged price, the second block covering up to 95% of monthly consumption (80%-95% of monthly consumption) with an increased price of no more than 0.05 CNY/kWh and the third block covering the residual monthly consumption with increased price no less than 0.3 CNY/KWh. See National Development and Reform Commission (2011a). For academic research on increasing pricing blocks of China, see (Lin et al., 2012)

24 For the price before July of 2012： https://wenku.baidu.com/view/76e8784afe4733687e21aaf8.html
For the adjustment of 2012: https://wenku.baidu.com/view/1d46e6ec172ded630b1cb68c.html
For the adjustment in July of 2017: https://www.sohu.com/a/161903543_500666
For the adjustment of 2018: https://95598.guangzhou.csg.cn/help/wzcx.do

the first block of household customers has decreased from 0.28CNY/kWh to 0.05CNY/kWh. With the second and third block price considered, the average household electricity price has surpassed that of the industrial and commercial customers from 2017[25]. Zhejiang is different from Guangdong in that it is the first pilot province to implement increasing block prices in 2004[26]. Although the tax and tariffs also decreased in Zhejiang, the final household price never changed. The price gap between industrial and commercial customers and the first block price of household customers also dropped from 0.34CNY/kWh to 0.1033CNY/kWh. But the average household price is still lower than that of industrial and commercial customers in Zhejiang.

Figure 4 Monthly retail price series for regulated electricity price of 35kV+ general industrial and commercial customer with VAT included from 2012 to 2019 in Guangdong and Zhejiang



25 Details can be seen in Supervision Report on the National Power Price in 2017 issued by the National Energy Administration.

26 See National Development and Reform Commission (2004a).

Figure 5: Monthly retail price series for the first block of household electricity customers with VAT included from 2012 to 2019 (Guangdong and Zhejiang benchmark)

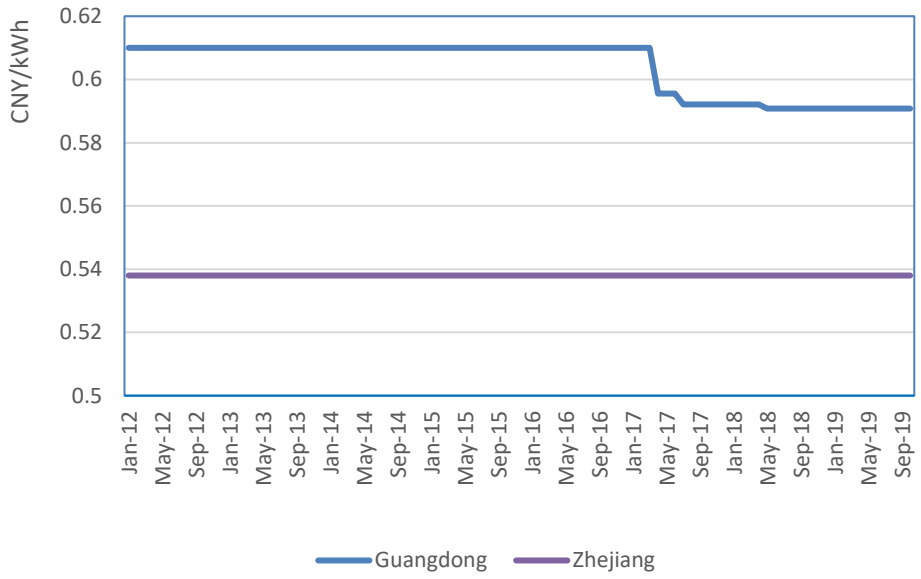


Table 3: Details of increasing block pricing for household customers from July 1st, 2012

	Blocks for ladder price	**Power consumption (kWh per customer)**	**Price(**CNY/kWh)
Guangdong	First Block	0-260(Summer month, May-October) 0-200(Winter month, November-April)	0.5921
	Second Block	260-600(Summer month, May-October) 201-400(Winter month, November-April)	0.6421
	Third Block	>601(Summer month, May-October) >401(Winter month, November-April)	0.8921
Zhejiang	First Block	0-230(each month)[27]	0.538
	Second Block	231-400(each month)	0.588
	Third Block	>400(each month)	0.838

27 See Zhejiang Provincial Price Bureau (2012).The increasing block price of Zhejiang only accounts for annual electricity consumption. This monthly consumption is derived by dividing annual consumption by 12.

Figure 6: Power block and prices for household customers in Guangdong

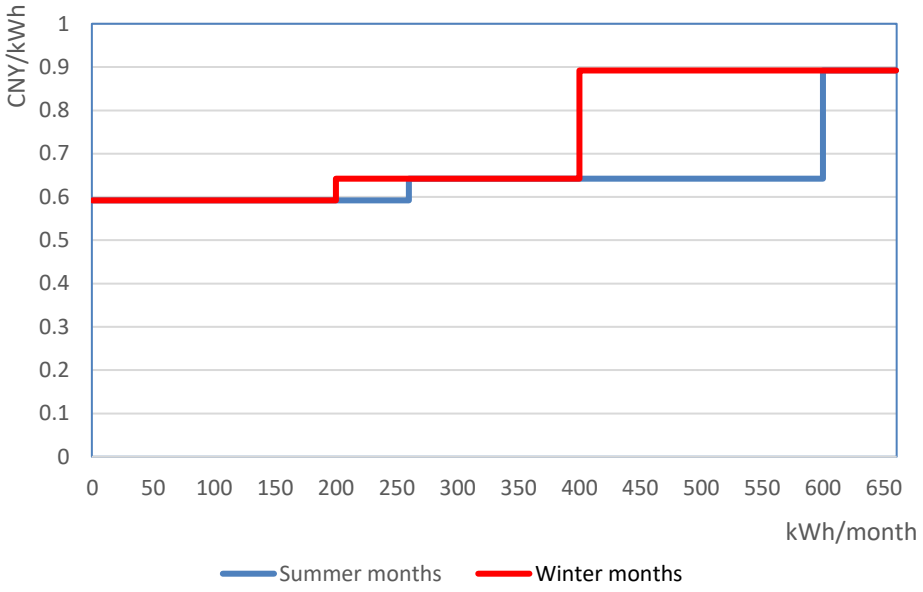
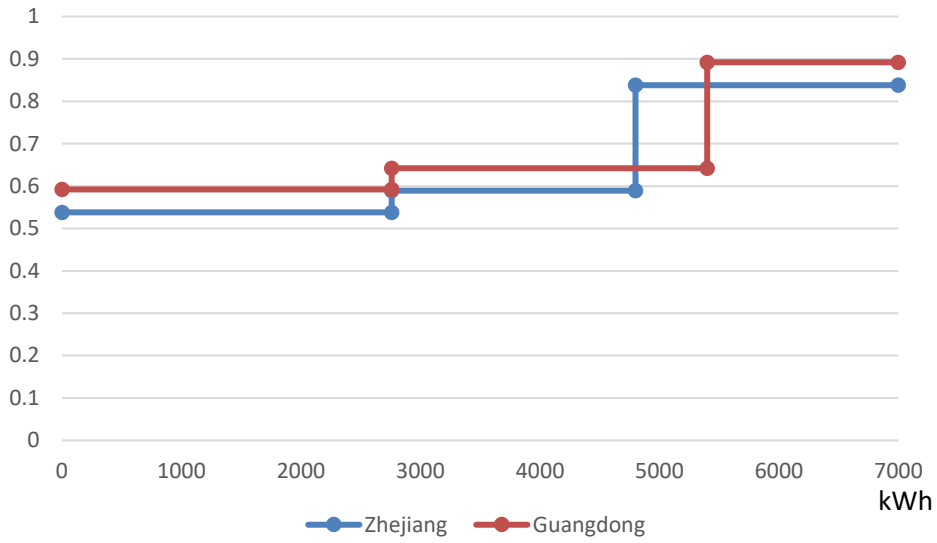


Table 4: Details of increasing block pricing for Guangdong household customers from July 1st, 2012

	Blocks for ladder price	**Power consumption (Per customer)**	**Price(**CNY/KWh)
Guangdong	First Block	0-2760[28]	0.5921
	Second Block	2761-6000	0.6421
	Third Block	>6000	0.8921
Zhejiang	First Block	0-2760	0.538
	Second Block	2761-4800	0.588
	Third Block	>4800	0.838

28 The increasing block price of Guangdong have different seasonal blocks in the summer and winter months. The annual consumption is derived by combining all the season months.

Figure 7: Annual power block and prices for household customer in Guangdong and Zhejiang in 2019



3.2 Regulated generation price

Before the 2015 electricity reform, all the generation prices from different fuel sources were regulated by the National and provincial Development and Reform Commissions. The method of price control had experienced significant regime change. Before 2004, the generation price was subject to a cost of service regulation regime. Different power plants or even different generation units were paid various generation prices. After 2004, China introduced yardstick competition regulation for coal-fired power plants [29]. Each province has separate uniform benchmark generation prices for all the coal-fired generators. These benchmark coal generation prices determine generation costs for the whole electricity system since coal is the major fuel source of China's generation. The same benchmark price control regime was implemented for hydro generators from 2004, abolished in 2009 and reintroduced in 2014. Nuclear generators were not subject to benchmark price control until 2013, with their price not exceeding that of coal-fired generators. Wind and solar benchmark generation pricing started at 2009. The only exception is gas-fired power. Since the cost of natural gas is high in China, only coastal rich province can afford such

[29] See National Development and Reform Commission (2004b).

relatively clean energy. Different provinces may have different price controls for natural gas-fired power plants.

Figure 8 show the benchmark prices of different generation forms in Guangdong and Zhejiang[30]. As the power mix of these two provinces are both dominated by coal-fired power, we will use the benchmark price for coal-fired power plants in the later discussion. The coal electricity price linkage mechanism is the main driving force for coal-fired power price changes. A similar situation happens for gas-fired power plants. The wind and solar power price changes are mainly driven by the subsidy changes. The price of hydropower and nuclear power are set by the government. As the prices vary among big hydropower

[30] For the coal generation price before October of 2013: https://wenku.baidu.com/view/6059e40e763231126edb1198.html
For the adjustment of coal generation price in October of 2013: http://www.cpnn.com.cn/cpnn_zt/2013_djxt/
For the adjustment of coal generation price in September of 2014: https://wenku.baidu.com/view/b5cbc1a3d5bbfd0a79567368.html?from=search
For the adjustment of coal generation price in December of 2015: http://futures.hexun.com/2015-04-20/175115097.html
For the adjustment of coal generation price in January of 2017: https://wenku.baidu.com/view/a5d0d84a814d2b160b4e767f5acfa1c7ab00825f.html
For the adjustment of coal generation price in July of 2017: https://www.sohu.com/a/202517251_99908549
For the gas generation price before October of 2017: http://news.bjx.com.cn/html/20171011/854386.shtml
For the adjustment of gas generation price in October of 2017: http://news.bjx.com.cn/html/20171011/854386.shtml
For the adjustment of gas generation price in July of 2018: https://www.in-en.com/article/html/energy-2273004.shtml
For the hydro generation price before April of 2013: http://drc.gd.gov.cn/gfxwj5633/content/post_864519.html
For the adjustment of hydro generation price in April of 2013: http://drc.gd.gov.cn/gfxwj5633/content/post_864845.html
For the wind generation price before January of 2016: https://wenku.baidu.com/view/041756697e21af45b307a857.html
For the adjustment of wind generation price in January of 2016: https://wenku.baidu.com/view/3d1db0dffad6195f302ba6aa.html
For the adjustment of wind generation price in January of 2018: https://wenku.baidu.com/view/87251ece6037ee06eff9aef8941ea76e58fa4a63.html
For the solar generation price before January of 2016: http://www.nea.gov.cn/2011-08/01/c_131097437.htm
For the adjustment of solar generation price in January of 2016: https://news.solarbe.com/201512/28/94357.html
For the adjustment of solar generation price in January of 2017: https://wenku.baidu.com/view/8124523d2379168884868762caaedd3382c4b573.html
For the adjustment of solar generation price in January of 2018: http://www.chinapower.com.cn/focus/20171222/100863.html
For the adjustment of solar generation price in January of 2019: http://www.gov.cn/xinwen/2019-04/30/content_5387917.htm
For the adjustment of nuclear generation price in April of 2019: http://finance.eastmoney.com/a/201904011085250853.html

plants, we use the price for small hydropower plants and representative nuclear power units to mirror their changes[31].

The pattern of the evolution of generation prices in Zhejiang is almost the same as in Guangdong since only the National Development and Reform Commission is mandated to initiate a new round of price changes[32]. Provincial Development and Reform Commissions can only follow the initiative of National Development and Reform Commission to change the regulated benchmark generation price according to local conditions. This is most significant for solar and wind power. Both Guangdong and Zhejiang are in the same pricing zone[33], for which they have the same generation price. The coal generation price in Zhejiang is slightly lower than that of Guangdong due to the shorter transportation distance. The only difference between Guangdong and Zhejiang is that Zhejiang has implemented two parts tariffs instead of a single rate tariff for gas generators since 2015[34]. Besides payment for electricity generated, they also receive capacity payments. The surge in the gas generation price in September of 2018 is mainly caused by the higher natural gas price.

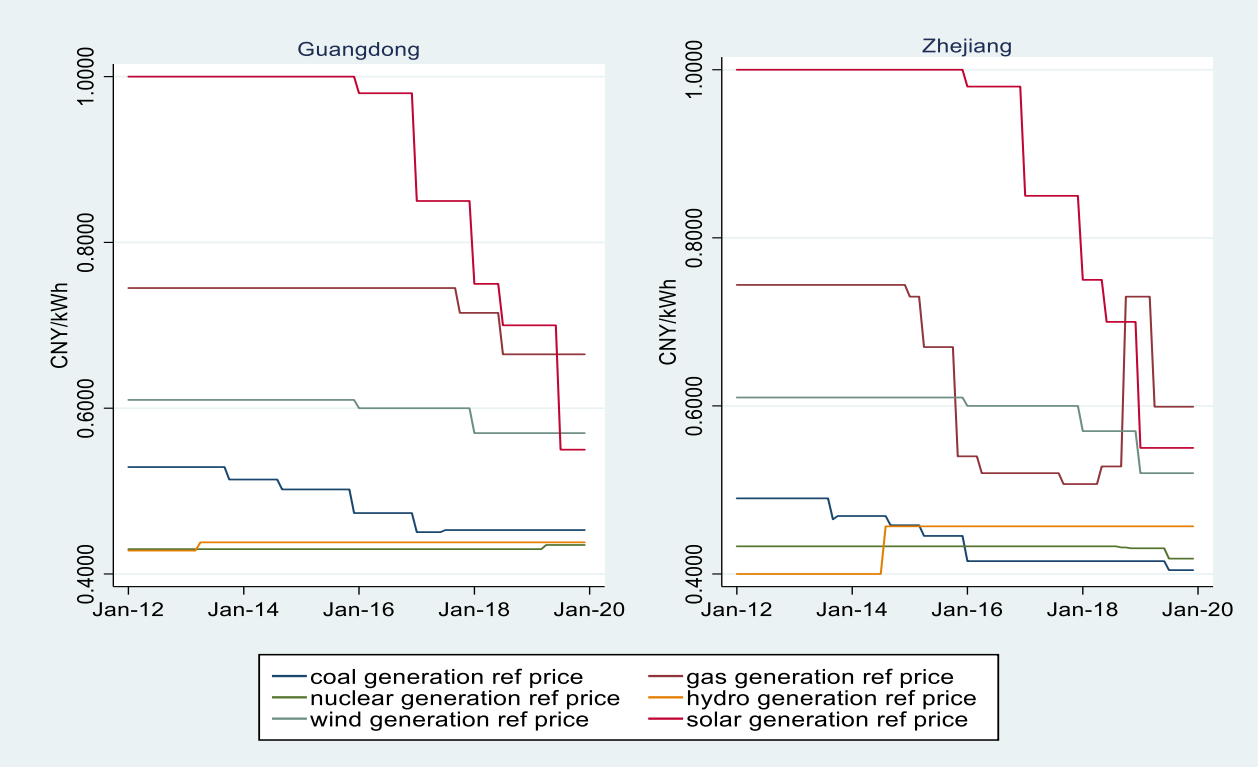
[31] For the adjustment in 2019. http://drc.gd.gov.cn/ywtz/content/post_2526212.html. We use Dayawan #2 unit to represent the price of nuclear power.

[32] For coal generation pollution abatement, China subsidizes the generation price once generation units have been installed abatement device and actual emissions reach the national mandatory standard. 0.015 CNY/kWh is paid to generators only if they have desulfurized emissions. 0.008 CNY/kWh is paid for denitrifying and 0.002 CNY/kWh for dust removal. 0.01 CNY/kWh is paid for ultra-low emission whose emissions are the same as natural gas emission. Installing the emission abatement device is profitable under such a subsidy regime. Almost all the generators reach that emission standard, so the generation price includes this subsidy. See Liu et al. (2018).
The hydro generation price is not uniform. Each hydroelectric station has its own regulated generation price according to the time of commissioning. The average generation price is calculated and displayed here. See Zhejiang Provincial Price Bureau (2011) and Zhejiang Provincial Price Bureau (2014).
There are 11 nuclear generation units in Zhejiang. Some of them inject power into the east China regional grid to supply Shanghai. The information about how much power they supply Zhejiang is unavailable. We just make the assumption that they all supply Zhejiang. Besides that, before 2013, different generation units have different generation prices. After 2013, all the newly commissioned generation units are paid a benchmark price of 0.43 CNY/kWh (see National Development and Reform Commission (2013b)). The average generation price of all units is calculated and displayed here. In the study period, two new AP1000 nuclear generation units are commissioned with different generation prices at the end of 2018. And the regulated generation price is reduced for all nuclear generation units in June 2019. So the moving average generation price is calculated to capture the price change.
The wind and solar generation price are set according to commissioning date. The later their commissioning, the generation price is lower to encompass technological progress. The commissioning date of each generation site is not available. So the latest benchmark price is displayed here.

[33] See National Development and Reform Commission (2009), National Development and Reform Commission (2011b).

[34] See Zhejiang Provincial Price Bureau (2015).

Figure 8 Monthly regulated generation prices with VAT included for coal, gas, hydro, wind, solar and nuclear from 2012 to 2019 (Guangdong and Zhejiang)



In the study period, the power mix of Guangdong has changed greatly. Although it is easy to get the information about the total imported power into Guangdong - mainly hydropower from Yunnan, Guizhou and Hubei Province - we do not know the detailed prices and amounts. In the following analysis, we use the power mix generated locally to study the cost changes associated with the power supply (see Figure 9). The generation mix of Zhejiang is almost the same as Guangdong in that most electricity is generated from thermal, nuclear and hydro. Zhejiang also imports electricity from Anhui, Fujian, Sichuan, Ningxia and Xinjiang through several high voltage interconnectors. The price and volume of imported electricity is set by central government or via agreement between provincial governments. This information has not been published. So, the following analysis for both provinces is based on in-province generation. The monthly generation volume is derived from the CEI industry database as noted in footnote 30.

Combining this generation volume, the weighted regulated generation price can be calculated as follows:

$$p_g^r = \frac{\sum_i p_{ig}^r \times q_i^r}{\sum_i q_i^r}$$

where p_i^r denotes regulated generation price of fuel source i, and q_i^r denotes the regulated generation volume of fuel source *i in a specific province*.

Figure 9 Power generation mix in Guangdong and Zhejiang from 2012 to 2019

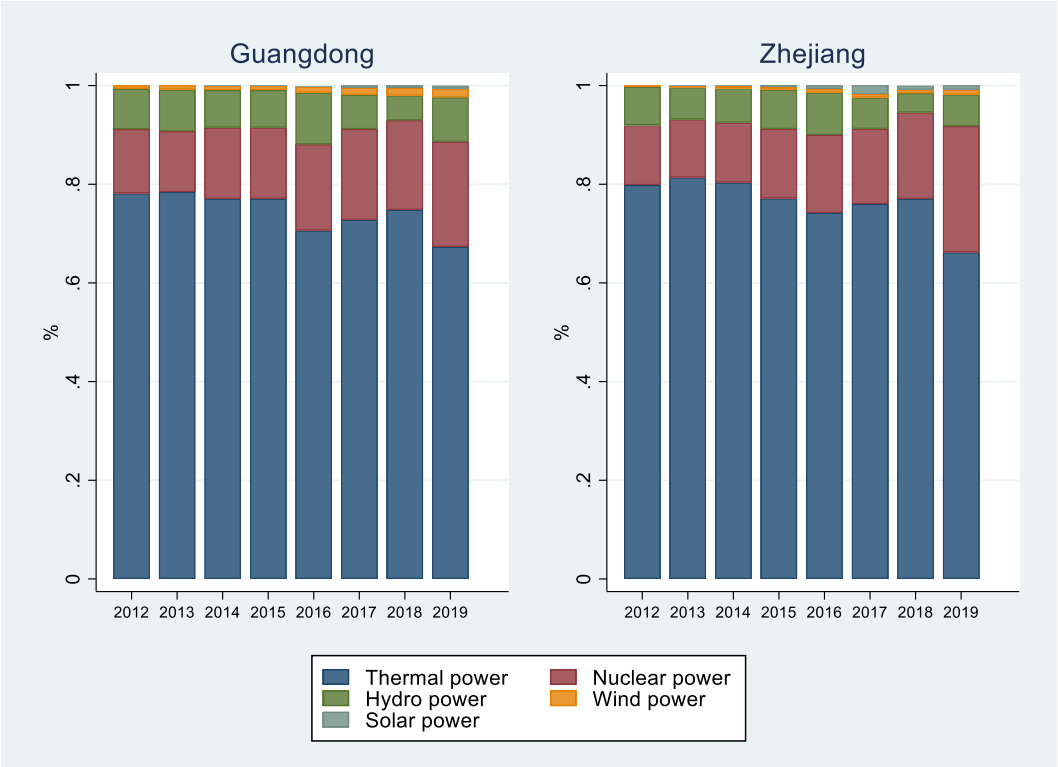
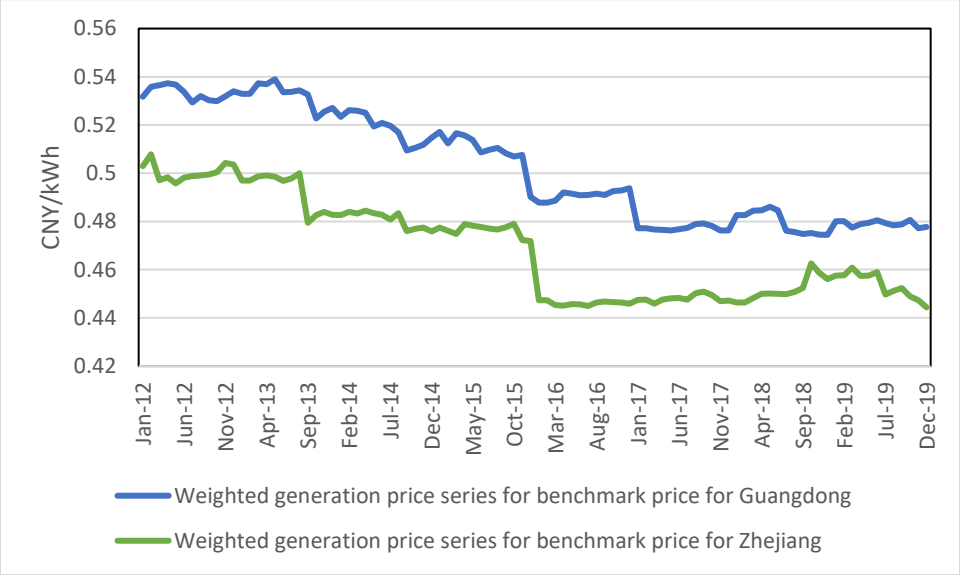


Figure **10** plots the weighted regulated generation price for the benchmark prices in Guangdong and Zhejiang.[35]. In general, the generation price follows a decreasing trend before 2017, but it fluctuates after 2018 because of the shares of gas-fired power, wind power and solar power increase significantly. In Guangdong the share of high cost generation also increased in 2019, but the weighted generation price did not rise because the regulated prices of these forms decreased. The spike in the weighted generation price of Zhejiang starting from late 2018, is the result of an increased share of nuclear generation and the increased price of gas generation.

Figure 10 The regulated price of weighted generation mix in Guangdong and Zhejiang



3.3 Additions and Value Added Tax

As for the customer price side, there are several kinds of additions added to the base regulated retail price for 35kV+ industrial and commercial customers, which change according to the local policy in Guangdong and Zhejiang. They include the fund for the Construction of Major National Water Conservancy Projects[36] which was the previously known as the Big and Medium Hydro power Construction fund, the

[35] The data comes from CEINT, https://www.cei.gov.cn/. We can only get the detailed data for coal-fired power and gas-fired power after 2017 while the data for gas fired power is always combined with that of coal-fired power before 2016. We assume the proportion of gas fired power is constant before 2016 when plotting the figure.

[36] Its Chinese name "国家重大水利工程建设基金" which was previously named "大中型水库建设基金"and"三峡工程建设基金".

Reservoir Resettlement fund for large and medium hydropower plants[37] and Surcharges for renewable energy development[38].

The additions have changed over the study period. The Reservoir Resettlement fund for large and medium hydropower plant was merged with the trans-provincial Large and medium-sized reservoir fund, the Three Gorges Reservoir fund, and the Central Reservoir Resettlement support fund from February 1, 2016 in Guangdong. Guangdong abolished the Small Reservoir Immigration fund in 2016 and Zhejiang did it in 2019[39].

From April 1, 2017, the Urban public utility surcharges[40] have been cancelled (see Notice of the Ministry of Finance on cancelling and adjusting relevant policies of some government funds)[41]; the surcharge fund for the Construction of Major National hydropower Projects and the Reservoir Resettlement fund for large and medium-sized have been reduced by 25% since July 1, 2017, and further reduced by 25% from July 1, 2018[42]. The tariff Surcharges for renewable energy changed more often than other kinds of additions. It has increased from 0.008 CNY/kWh to 0.019 CNY/kWh[43]. A lot of the adjustments happened in 2017[44].

The value added tax (VAT) is another important kind of addition that has been added to the retail price. In China VAT is charged to the firms directly. The benchmark generation price and regulated retail price issued by the development and reform commission have already included the VAT. The rate of Value Added Tax (VAT) has also changed over the study period. VAT rate reduced from 17% to 16% in May

[37] Its Chinese name is"大中型水库移民后期扶持基金",which was combined by"大中型水库移民后期扶持资金、跨省际大中型水库库区基金和三峡水库库区基金".

[38] Its Chinese name "可再生能源电价附加".

[39] See Zhejiang Provincial Department of Finance (2019).

[40] Its Chinese name "城市公用建设费附加".

[41] See Ministry of Finance (2017).

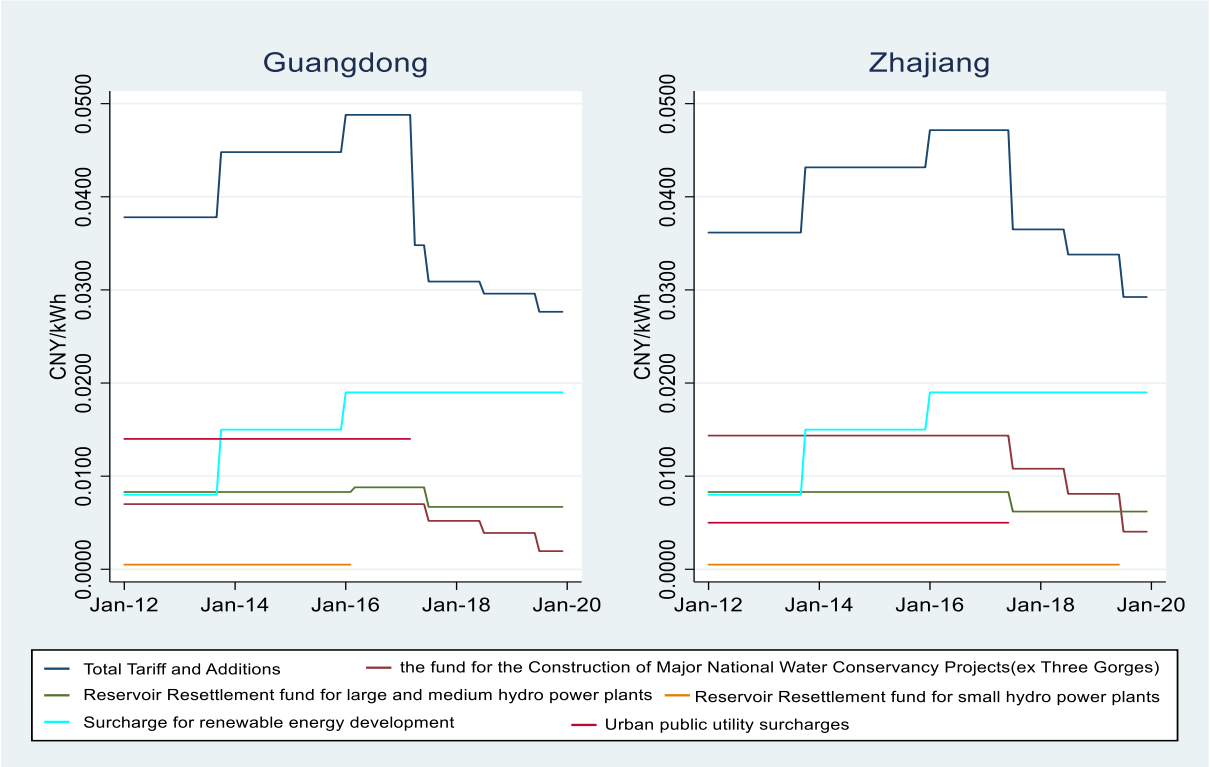
[42] It should be noted that the central government advised a further decrease in the regulated price of industrial and commercial customers as the fund for the Construction of Major National hydropower Projects had been further decreased by 50%.

[43] Renewable energy tariff surcharge changes in 2012. http://news.bjx.com.cn/html/20111231/334153.shtml
For the adjustment in 2013: http://mp.ofweek.com/solar/a745613622856;
Renewable energy tariff surcharge changes in 2016. http://guangfu.bjx.com.cn/news/20160115/701619.shtml

[44] For the adjustment in 2017: http://shoudian.bjx.com.cn/news/20170721/838589.shtml
The changes in 2016 can be found: http://shupeidian.bjx.com.cn/news/20181105/939344.shtml

2018[45] and further reduced to 13% in April 2019[46]. VAT applies to the retail electricity price net of additions.

Figure 11 Monthly additions to base regulated retail price for 35kV+ customer in Guangdong and Zhejiang[47][48]



45 财政部 税务总局《关于调整增值税税率的通知》(财税〔2018〕32 号)
http://www.chinatax.gov.cn/n810341/n810755/c3377945/content.html
46 财政部 税务总局 海关总署 《关于深化增值税改革有关政策的公告》(2019 年第 3 号)
http://www.chinatax.gov.cn/n810341/n810755/c4160283/content.html
47 For addition adjustment in Guangdong:
For the price before October of 2013:
https://wenku.baidu.com/view/da3ac15430b765ce0508763231126edb6f1a7609.html
For the adjustment in October of 2013: https://wenku.baidu.com/view/37e120d604a1b0717fd5dd33.html
For the adjustment in January of 2016: https://wenku.baidu.com/view/a08e7b40e53a580217fcfe50.html
For the adjustment in July of 2017: http://fgw.gz.gov.cn/zmhd/jfcx/content/post_2337123.html
For the adjustment in July of 2018: https://www.shigoog.com/news/201809/zjzhe1202.html
48 For addition adjustment in Zhejiang:
For the price before October of 2013: https://wenku.baidu.com/view/64f026dea58da0116c1749e6.html
For the adjustment in October of 2013: http://hzjd.zjzwfw.gov.cn/art/2014/5/26/art_10509_20585.html
For the adjustment in June of 2016: http://www.sohu.com/a/86935489_131990
For the adjustment in June of 2017: http://www.sx.gov.cn/art/2017/7/27/art_1463255_17179254.html
For the adjustment in September of 2018: http://xxgk.longwan.gov.cn/art/2018/9/5/art_1452483_20924580.html
For the adjustment in July of 2019: http://www.zhuji.gov.cn/art/2019/7/2/art_1370382_35241296.html

In order to derive VAT from the regulated retail price, additions are subtracted from the retail price and VAT rate is applied to the remaining amount. VAT changes are attributed to two sources: a change of the VAT rate and changes in the VAT base. The first one is calculated by keeping the VAT base fixed and changing the VAT rate while the second one is calculated by holding the VAT rate fixed and changing the VAT base. Figure 12 and Figure 13 illustrate the decomposition. The overall VAT reduction effect is significant: in Guangdong the amount of VAT included in the regulated retail price drops from 0.1232 CNY/kWh to 0.0716 CNY/kWh. In Zhejiang the amount of VAT correspondingly drops from 0.1223 CNY/kWh to 0.0704 CNY/kWh. The VAT base change has taken place over a longer period, but the VAT rate change is also significant.

Figure 12: The sources of VAT changes in Guangdong

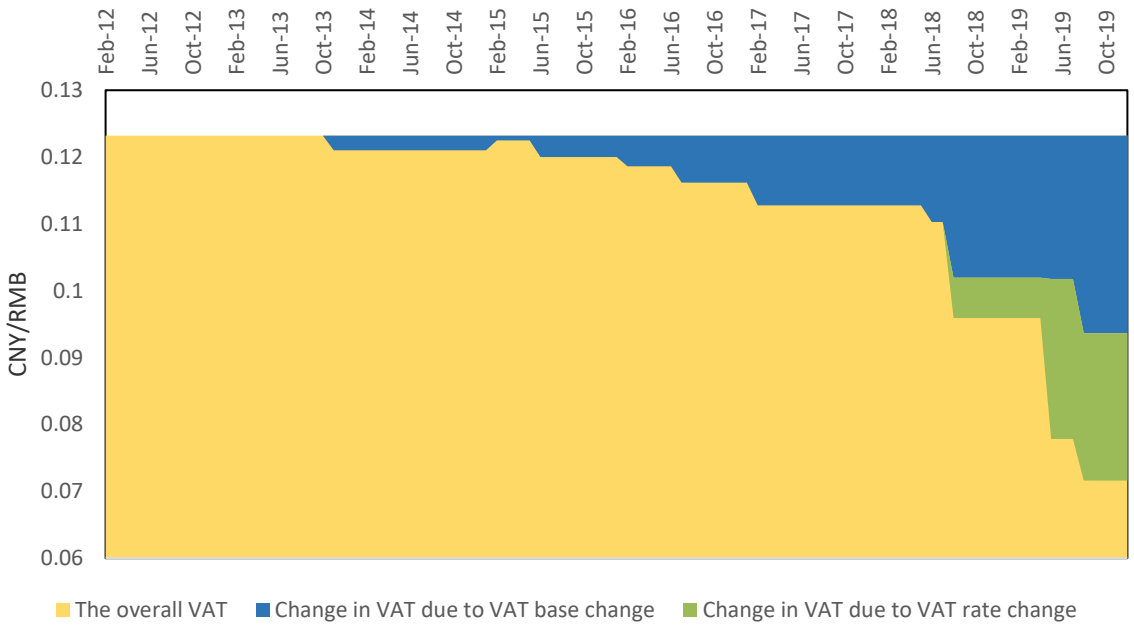
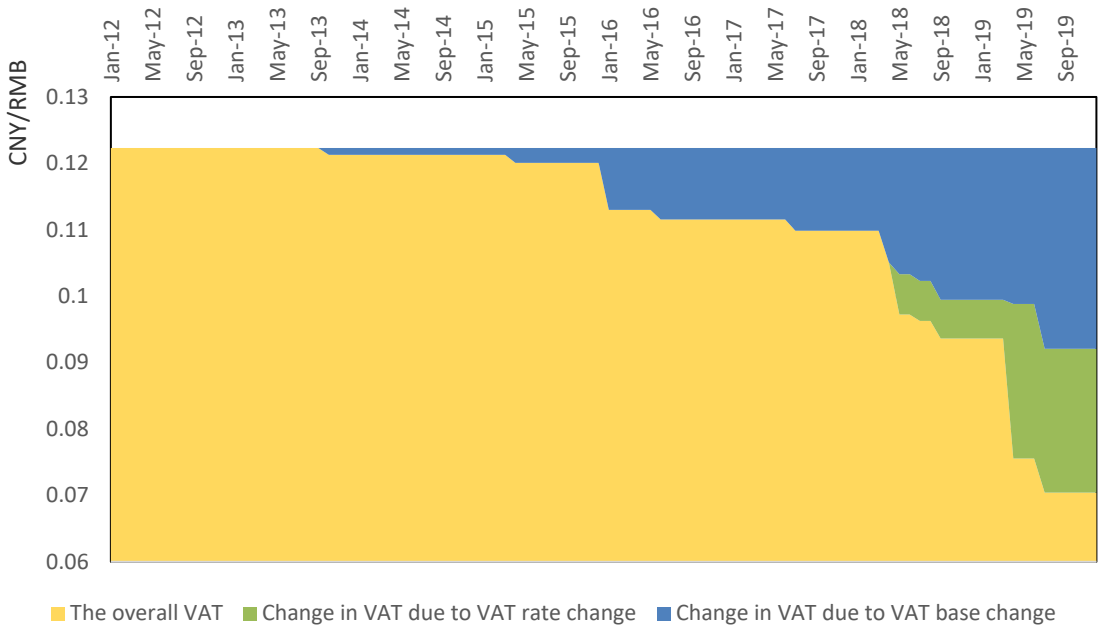


Figure 13: The sources of VAT changes in Zhejiang



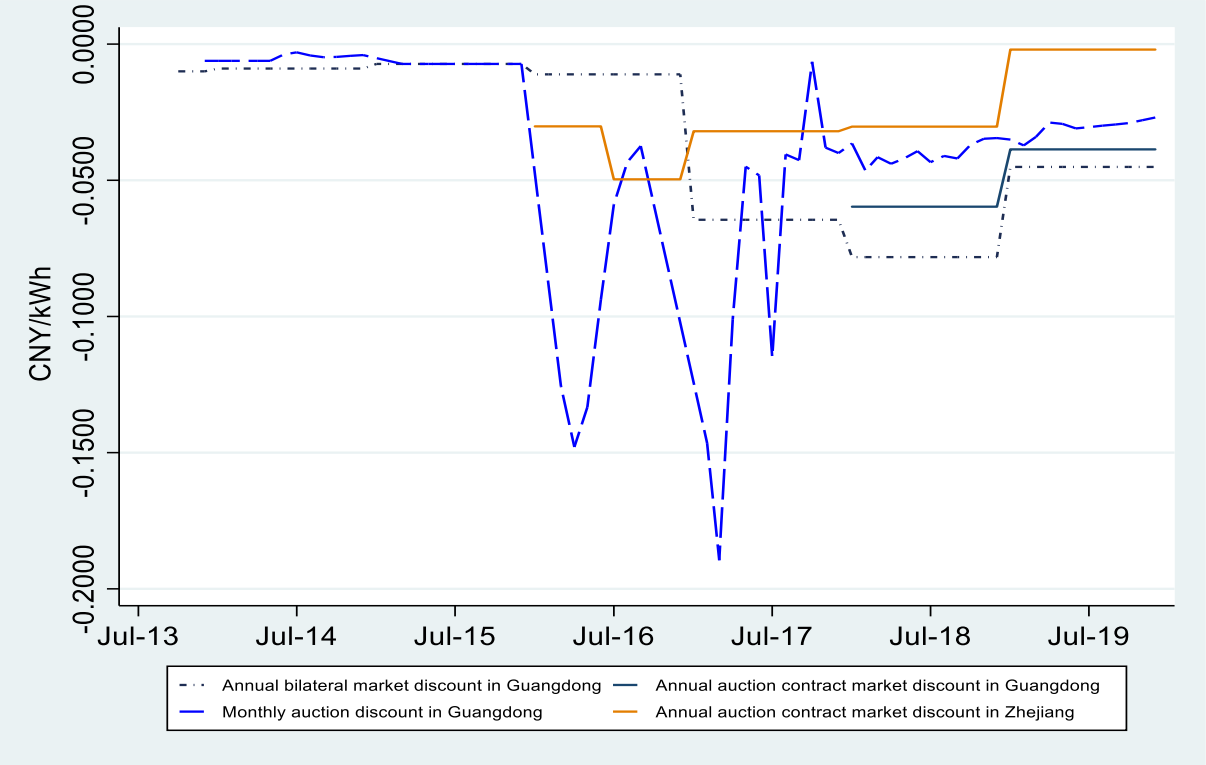
4. The Evolution of market prices in Guangdong and Zhejiang

So far, we have focussed on the evolution of the benchmark regulated prices for generators and customers. Now we examine impact of market prices over the period from 2012 to 2019. These are explicitly expressed as discounts to the regulated prices.

Figure 14 shows the discounts per kWh of the power transaction in Guangdong since 2012. It should be noted that a value of zero means there no transactions happened and hence there was no discount. The first annual bilateral transaction and monthly auction happened in 2013 while the first annual auction did not appear until 2018. In its early period, not all kinds of transactions happened every month. The discounts were very small in their early stages, and then they increased in 2016. The monthly auction discount differs significantly with the annual bilateral discount in 2016 and 2017 when the price of coal changed a lot. In 2018 and 2019, with the increase of the trading volume and the stable coal price, the discount of different kinds of market transactions has converged. The discount of annual bilateral trades

is the biggest, followed by the annual auction, as they were all longer term transactions and happened in January and do not reflect potentially tighter monthly supply and demand. However, the monthly bilateral auction is always the smallest discount after July 2017, as it is a short-term contract and the retail companies may have less choice over that timeframe. Another reason for the shrinking of the discount was that generators faced rising fuel costs and the decreasing benchmark regulated power price.

Figure 14 Monthly and Annual discounts per kWh since 2012 in Guangdong and Zhejiang for generators



There is significant difference in the way prices are formed between Zhejiang and Guangdong. In Guangdong generators bid (offer) a discount while their Zhejiang counterpart bid (offer) an absolute price. As a result, a gas generator can compete with their coal peer in Guangdong while gas generators can never undercut coal peers because of their significantly higher fuel costs in Zhejiang. For the purposes of comparison, the discount in Zhejiang is calculated from the absolute generation price and regulated

generation price, as depicted in Figure 14[49]. The discount drops sharply as trading proceeds year by year. However, the market price keeps stable. What needs to be mentioned is that a half year trade happened in the middle of 2016 with a market price (0.3551 CNY/KWh) significantly lower than that (0.4346 CNY/KWh) at the beginning of 2016 covering the whole year. After the trading at the beginning of 2016, the regulated price reduced from 0.4453 CNY/KWh to 0.4152 CNY/KWh. According to the market rule, the market price should reduce by the same amount as the regulated price. So, the comparable start of year market price is 0.3851 CNY/KWh. This and later half year price 0.3551 CNY/KWh are weighted by the traded volumes to get the weighted market price for later half year. The same thing happened in 2019. According to the trading arrangement published by Zhejiang Energy Bureau, customers from four sectors (coal, iron and steel, nonferrous metals and construction materials) joined separate trading from other ordinary eligible customers. Ordinary trading happens with price of 0.3851 CNY/KWh. The trade for four sectors happens in October for previous ten months with price of 0.3902 CNY/KWh. In the final two months in 2019 consumption is traded on bilateral basis. The transactional information of last two months is not published. A projection based on previous ten months is made for these two months with the assumption of same monthly consumption. The weighted average price is also calculated using a similar method to that for 2016[50].

The monthly and annual discounts are different for the generators and their industrial customers because the retail companies, which exist in Guangdong, will get a proportion of the discount to pay for their services. We assume that the generator discount is split 80:20 between customers and retailers, which seems reasonable based on discussions with market participants.

[49] Electricity trading in Zhejiang began at 2015. But that trade is on bilateral basis as mentioned in section 1. The transaction price of bilateral trade is not published. So, market price and discount are not included in this paper.

[50] Zhejiang allowed 110kV customers to trade in 2015. The threshold lowered to 35kV customers at the beginning of 2016 and further down to annual electricity consumption above 1GWh. Aggregate traded volume which accounts for customers of all connection voltages is published, but how much of it comes from 35kV customers is unknown. For simplicity, assumption is made that aggregate trade volume stands for 35kV customers.

In calculating the final price in Guangdong that a typical industrial customer pays we need to take two things into account: the weighted generation price discount, weighted by the percentage of generation that is in the market, and the fact that only 80% of the discount will accrue to the customer. Thus there are three lines in Figure 15 , the green one shows the average price for all the customers[51]. The blue one is the regulated power price for the 35kV+ industrial customers. The orange line is the average power price what the industrial and commercial customers paid for the power traded in the market. It can be seen that the gap between the green line and orange line enlarged at first, and then converged because of the discount changes for the power transactions. The discount becomes smaller with the increase of the trading volume and the decrease of the regulated power price. The gap between the orange and green lines enlarged before 2016 and then kept stable because the discount shrinks but the proportion of traded power increases.

Because electricity retailers only enter market in the last two months in 2019 in Zhejiang. Customers enjoy all the savings from market trades. The colour legend in Figure 16 is the same as Figure 15. The market retail price drops by the same amount as the regulated price since the contracted market prices need to reduce by the same amount when the regulated price drops.

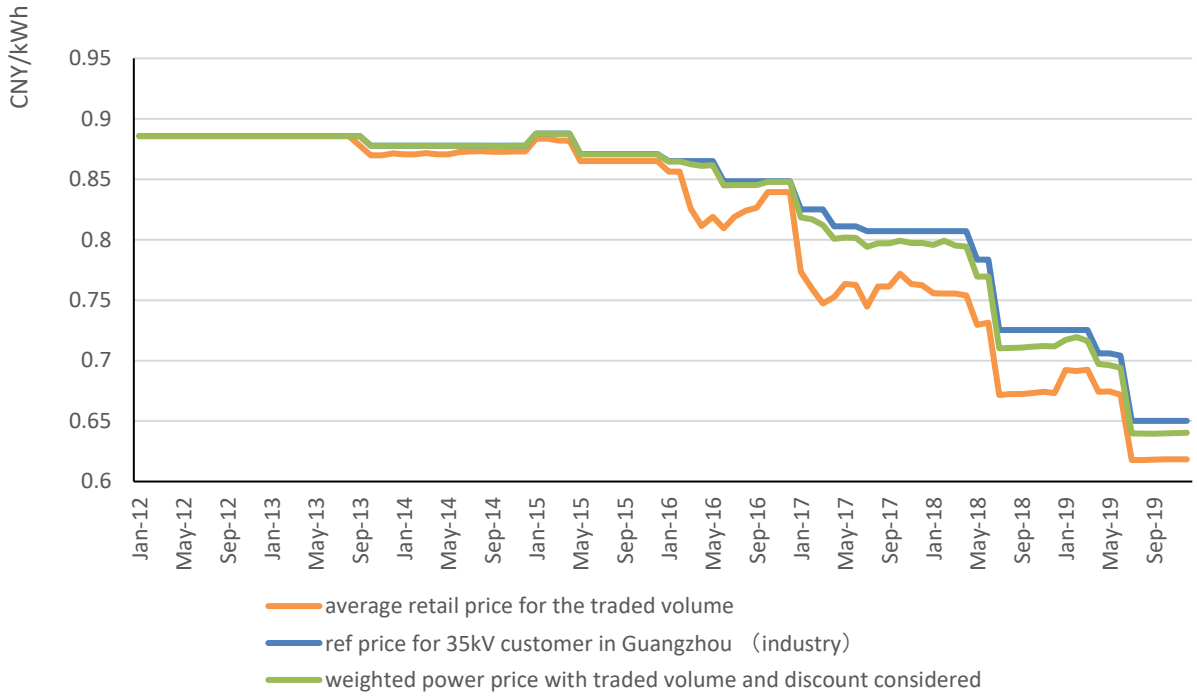
There are several reasons that have allowed generator prices to fall. First, although the price of fuels changed slightly in the past years, the cost of thermal power has decreased because of technology improvement in generation. Second, the shares of nuclear power and imported (extra-provincial) power have increased, whose cost is relatively low compared with the thermal power locally generated. Third, the prices of wind power and solar power decreased dramatically because of technological progress. Fourth, national line losses have decreased from 6.72% in 2012 to 5.90% in 2018. Fifth, the competition among generation corporations has forced the companies to decrease their prices to maintain market share. The net revenue of generation companies has decreased significantly.

[51] The weighted power price is calculated by assuming all the customers including households and farms share the same power price due to here is no detailed monthly information about the power consumption of industrial and commercial industry. This may overestimate the weighted industrial and commercial power price.

Both Guangdong and Zhejiang are two of spot market pilot provinces approved by the National Development and Reform Commission.They began spot market trial runs in June of 2019. The reduced earnings of generators in these two provinces pose huge risks for them. Since Yudean and Zheneng control almost half of installed capacity in Guangdong and Zhejiang respectively, they will be inevitably pivotal in most periods. The scope for the exercise of market power is large, especially as the capability of the regulatory agencies is currently rather limited. Generators may manipulate the spot price to a high level to partly compensate for their previous losses. The only way to proceed is to transform the current direct trade contracts into mostly forward contracts with relatively little exposure to the spot market. That is a practical way to curb market power problem. Virtual power plants created out of the assets of the incumbent generators could also be used if horizontal divestiture is currently not possible. A source of further price reduction may come from the shift to full economic dispatch stimulated by the spot market.

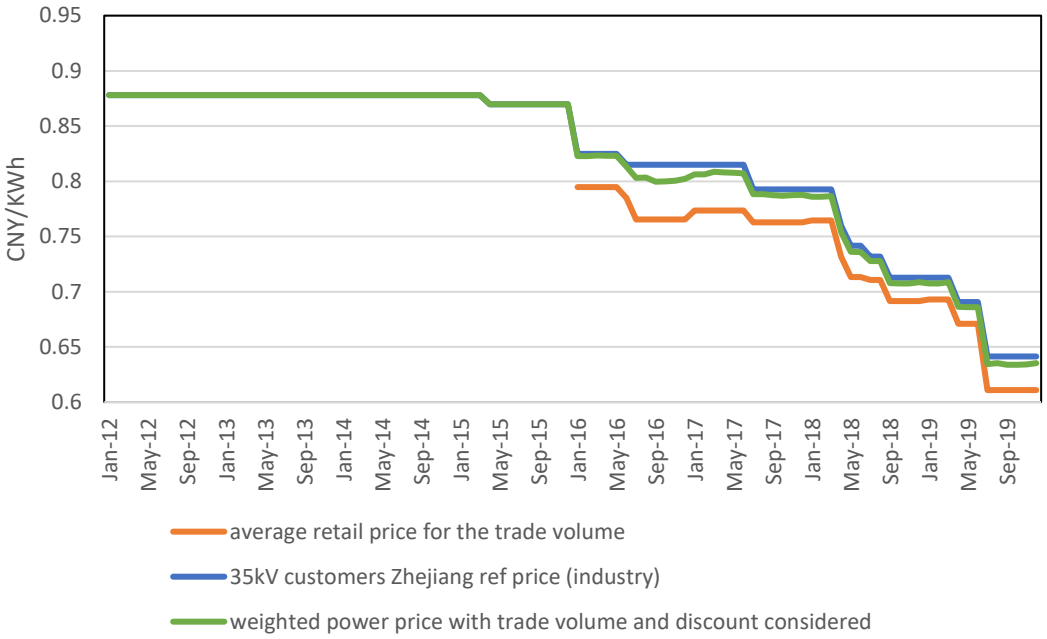
Figure 17 shows the main business operating revenue and profit rate of the Yudean and Zheneng electric power companies, which are the biggest electric power generation groups in Guangdong and Zhejiang respectively. At the beginning of the power market reform, they earn as high as 15% of their revenue as profit, but the proportion has decreased to less than 5% in 2019, along with the decrease of the reference price for the generation sector. The profit margin of generation groups is the same as or even less than in many other industries. To some extent, the price is nearly equal to the marginal cost. It is safe to say that generators are under significant pressure to cut costs.

Figure 15: Prices per kWh for 35kV industrial customers in Guangdong since 2012[52]



[52] There is no detailed discount information about the traded volume published for 2015. We get the monthly market prices by assuming the annual bilateral contract market discount is the same in each month and weight the monthly auction discount to get average monthly market discounts.

Figure 16: Prices per kWh for different kinds of transactions for 35kV customers since 2012 in Zhejiang[53][54]



Both Guangdong and Zhejiang are two of spot market pilot provinces approved by the National Development and Reform Commission[55].They began spot market trial runs in June of 2019. The reduced earnings of generators in these two provinces pose huge risks for them. Since Yudean and Zheneng control almost half of installed capacity in Guangdong and Zhejiang respectively, they will be inevitably pivotal in most periods. The scope for the exercise of market power is large, especially as the capability of the regulatory agencies is currently rather limited. Generators may manipulate the spot price to a high level to partly compensate for their previous losses. The only way to proceed is to transform the current direct

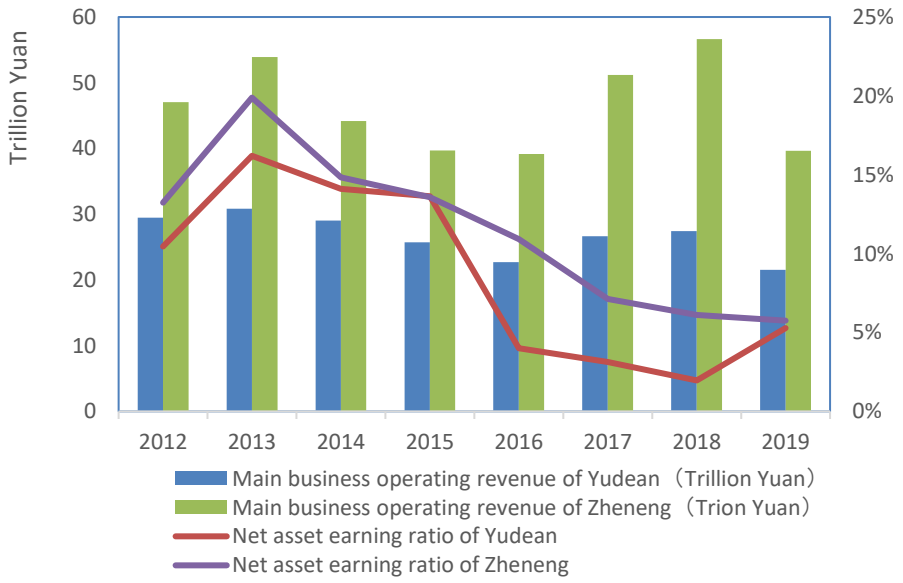
[53] Since there is only annual electricity trading over most of the time, the annual trade volume is divided evenly into 12 months in that year.

[54] The regulated retail price is derived from notice documents published by Zhejiang Provincial Price Bureau and later Zhejiang Provincial Development and Reform Commission. The market retail price is calculated by adding up market generation price, network charge and additions. Before 2017 there is no separated network charge. The grid company can only charge the difference between the regulated retail price and the generation prices it faces. So, the network charge in 2016 is calculated this way. Since 2017, a formal price control is imposed on grid companies and network charges are published for period of 2017-2019. The market retail price in that period is calculated based on this. See National Development and Reform Commission (2017).

[55] See National Development and Reform Commission (2017).

trade contracts into mostly forward contracts with relatively little exposure to the spot market. That is a practical way to curb market power problem[56]. Virtual power plants created out of the assets of the incumbent generators could also be used if horizontal divestiture is currently not possible. A source of further price reduction may come from the shift to full economic dispatch stimulated by the spot market.[57]

Figure 17: Main Business indicators of Yuedean and Zheneng generation groups from 2012 to 2019[58]



5. The impact of power market reform on final prices in Guangdong and Zhejiang

5.1 Explaining declining power prices

[56] See Newbery(1998) and Green (1999).

[57] See Chen, et al. (2020).

[58] The data for 2019 only includes the first three quarters.

In this section we show what has happened to final prices for those in the market and the extent that this is due to the introduction of the market or changes in the regulated prices.

The discussion below considers both the power in the market and the power transacted at the benchmark price. With an increasing share of the power traded in the market, the customers can get more benefits than before.

We should also discuss the breakdown of the fall in price into reduction in taxes (VAT), generator price reductions and falls in the residual grid (T+D) price. For the case of China, it might be that falling electricity prices are explained by falling coal prices. However, this is not the case.

Figure 18 shows the changes of the coal price of Qinghuangdao market, which is the largest coal market in China. The price discount in the power market is more closely related to the coal price in short term. But in a long term, although the coal price fluctuates significantly, the price did not change much in 2019 compared to 2012 (or indeed the beginning of reform in 2015). That is to say, the fuel price does not play a critical role in driving the power price down over the whole period.

To examine what might have caused prices to decline, we decompose the price change into four components: generation price, network charge, VAT and additional charges. Following market reform, the total electricity consumption can be divided into two parts: the regulated part and the market part. According to this partition, the total weighted retail price for customer to pay can be formulated as the following:

$$\bar{p}_r^T = \frac{p_r^R q^R + p_r^M q^M}{q^R + q^M}$$

where p_r^R stands for regulated retail price and q^R stands for total regulated consumption, p_r^M stands for market retail price and q^M stands for market traded volume. Since each retail price is itself composed of four components: generation price, network charge, VAT and additional charges. The regulated retail price can be expanded to:

$$p_r^R = \frac{\sum_i p_{gi}^R q_i^R}{(1+t)q^R} + \frac{p_n^R}{(1+t)} + v^R + a$$

Figure 18: Monthly coal price series for Qinhuangdao (We use the price of Qinghuangdao for reference)[59]

Regulated generation price for fuel source i is denoted as p_{gi}^R with related regulated generation volume denoted as q_i^R. By ignoring electricity import and export, total regulated consumption equals sum of various regulated generation volume $q^R = \sum_i q_i^R$. p_n^R denotes network charge for regulated part. v^R and t denotes VAT for regulated part and VAT rate respectively. a denotes additional charges. Since only regulated generation and retail price is published in government files, the regulated network charge and VAT for the regulated part need to be derived as following:

$$p_n^R = \frac{(p_r^R - a)q^R - \sum_i p_{gi}^R q_i^R}{(1+t)q^R}$$

$$v^R = \frac{(p_r^R - a)t}{1+t}$$

The market retail price can also be expanded to:

[59] Data Source: http://www.hibor.com.cn/ (Qinhuangdao Thermal Coal: >4500K)

$$p_r^M = \frac{p_g^M}{1+t} + \frac{p_n^M}{1+t} + \frac{(p_g^M + p_n^M)t}{1+t} + a$$

Since market generation price is uniform among different fuel sources its expression is much simpler than regulated generation price. Combining above equations, total decomposition of price change can be expressed in two way as following.

$$\bar{p}_r^T = \left[\frac{\sum_i p_{gi}^R q_i^R}{(1+t)q^R} + \frac{(p_r^R - a)q^R - \sum_i p_{gi}^R q_i^R}{(1+t)q^R} + \frac{(p_r^R - a)t}{1+t} + a\right]\frac{q^R}{q^R + q^M}$$
$$+ \left[\frac{p_g^M}{1+t} + \frac{p_n^M}{1+t} + \frac{(p_g^M + p_n^M)t}{1+t} + a\right]\frac{q^M}{q^R + q^M}$$

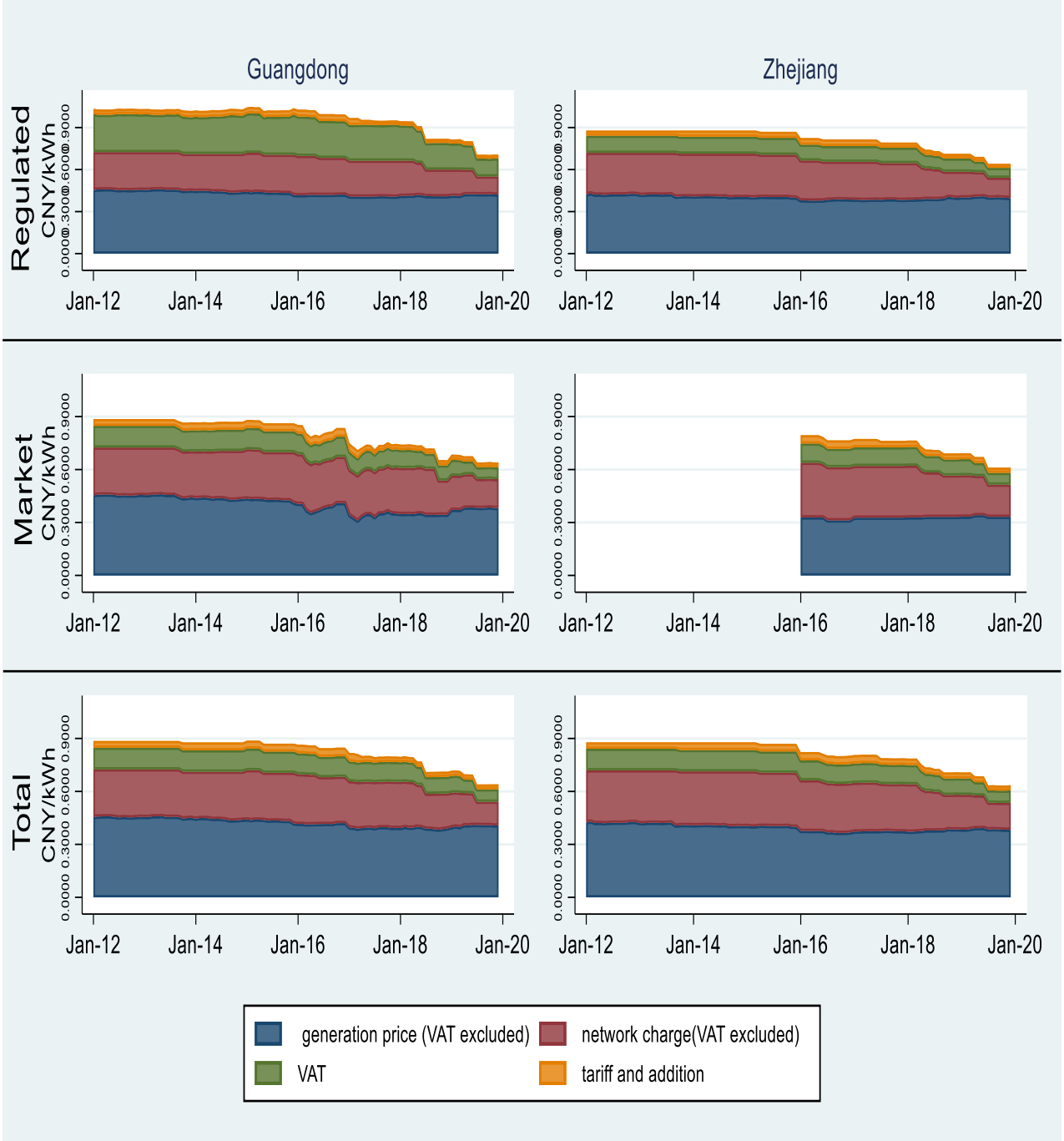
In this equation, the expression in the first bracket is the regulated retail price consisting of the four components. The expression in the second bracket is market retail price. They are weighted by regulated volume and market volume.

$$\bar{p}_r^T = \left[\frac{\sum_i p_{gi}^R q_i^R}{(1+t)q^R}\frac{q^R}{q^R + q^M} + \frac{p_g^M}{1+t}\frac{q^M}{q^R + q^M}\right] + \left[\frac{(p_r^R - a)q^r - \sum_i p_{gi}^R q_i^R}{(1+t)q^R}\frac{q^R}{q^R + q^M} + \frac{p_n^M}{1+t}\frac{q^M}{q^R + q^M}\right]$$
$$+ \left[\frac{(p_r^R - a)t}{1+t}\frac{q^R}{q^R + q^M} + \frac{(p_g^M + p_n^M)t}{1+t}\frac{q^M}{q^R + q^M}\right] + a$$

In this equation, the expression in the first bracket is the weighted generation price. The second is weighted network charge. The third one is the weighted VAT. Using these formula and the numbers discussed in earlier sections we can now show the sources of changes in the regulated, market and overall prices in Figure 19 that follow[60].

[60] In this section, we have to say that the weighted retail price for industrial and commercial customers in Guangdong and Zhejiang have been overestimated as we use the gap between total power consumption and the traded volume to stand for the regulated part of the 35kV industrial and commercial customers because of data availability.

Figure 19 The decomposition of the retail price for all the 35kV industrial customers in Guangdong and Zhejiang



5.2 The impact of power market reform vs regulatory reform

Figure 20 and Figure 21 show the decomposition of what is a substantial price reduction for customers in both provinces. The striking thing about the table and the figure is just how much of the reduction in price is due to a reduction in regulated network charges (60%), with additional substantial contributions from VAT and other charges. Generator price reductions are significant, especially when in the market, but they are only a minority of the price fall. When considering the size of the market discount as a percentage of the total price reduction, this is only significant for market participants, but becomes very small in terms of the average consumer.

Take January 2012 as the base case, we label a superscript to all the price related to it. Figure 22 presents the composition of the retail price changes.

For the regulated price change of generation mix:

$$\Delta p_g^t = \bar{p}_g^{Tt} - \bar{p}_g^{TB},$$

whereΔp_g^t stands for the price changes caused by the generation mix, $\bar{p}_g^{Tt}$ is the weighted price of the regulated generation mix at period t, and $\bar{p}_g^{TB}$is the weighted price of the base period January of 2012. Similarly, we can get the VAT changes and network cost changes, which are all based on the regulated power. As the tariff and additions are the same for the traded power and the regulated power, we can get the changes in this by subtracting the base tariff and additions in the base period.

With the introduction of the power market reform, the price of the generation power mix, network cost and VAT change to some extent, but they can all be attributed to the benefits of power marker reform. Take p_r^{wt} as the reweighted price of the final retail power for the regulated and traded power in the market at period t. And then,

$$p_r^{wt} = (1-\alpha)p_r^{Rt} + \alpha p_r^{mt},$$

$$\Delta p_n^{wt} = p_r^{wt} - p_r^{Rt},$$

where α is the proportion of the traded power in the market compared with the total generation. In this way, we attribute all the retail price changes Δp_n^{wt} of the demand side to the introduction of the market-oriented reform.

Figure 20 and Figure 21 depicts source of price change for 35kV industrial customers in Guangdong and Zhejiang. Both have experienced the same trend in overall price reductions. But the main source of the price change varies somewhat.

Figure 20: Sources of price changes for 35KV industrial customers in Guangdong from 2012 to 2019.

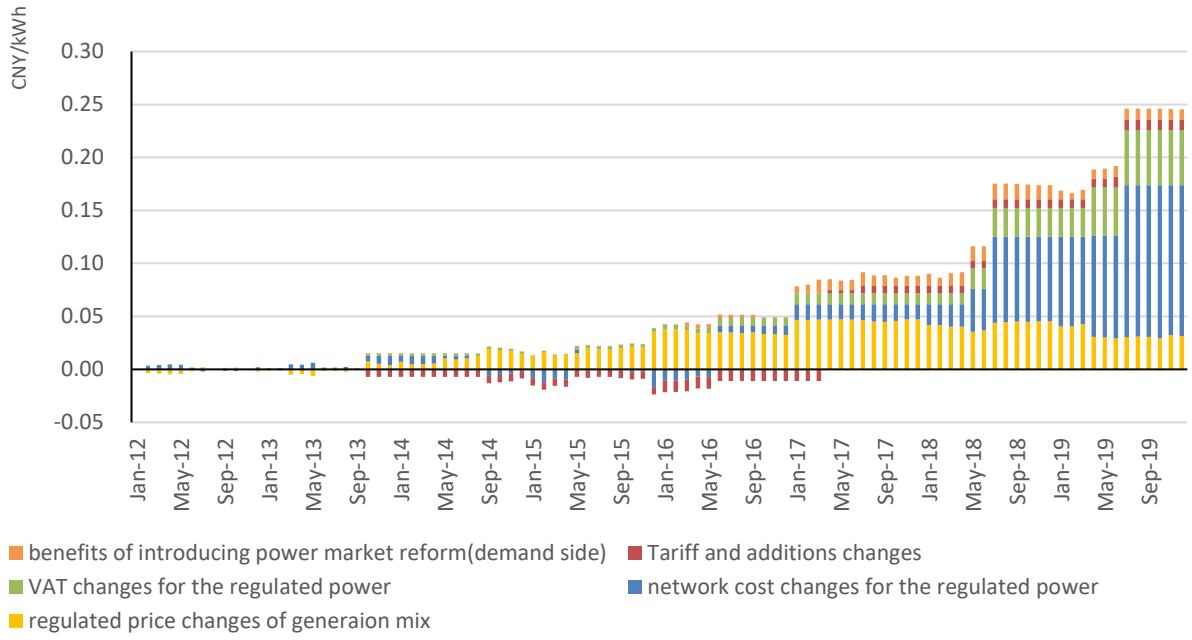


Figure 22 illustrates the sources of price reductions in Guangdong and Zhejiang. This result is calculated simply by subtracting the price in the end month by the beginning month for each component respectively. The contribution pattern is almost the same for two provinces. The network reduction is the major contributor to the total price reduction for both regulated and market customers, though generation cost reduction is more significant for market customers.

Figure 21: Sources of price changes for 35KV industrial customers in Zhejiang from 2012 to 2019.

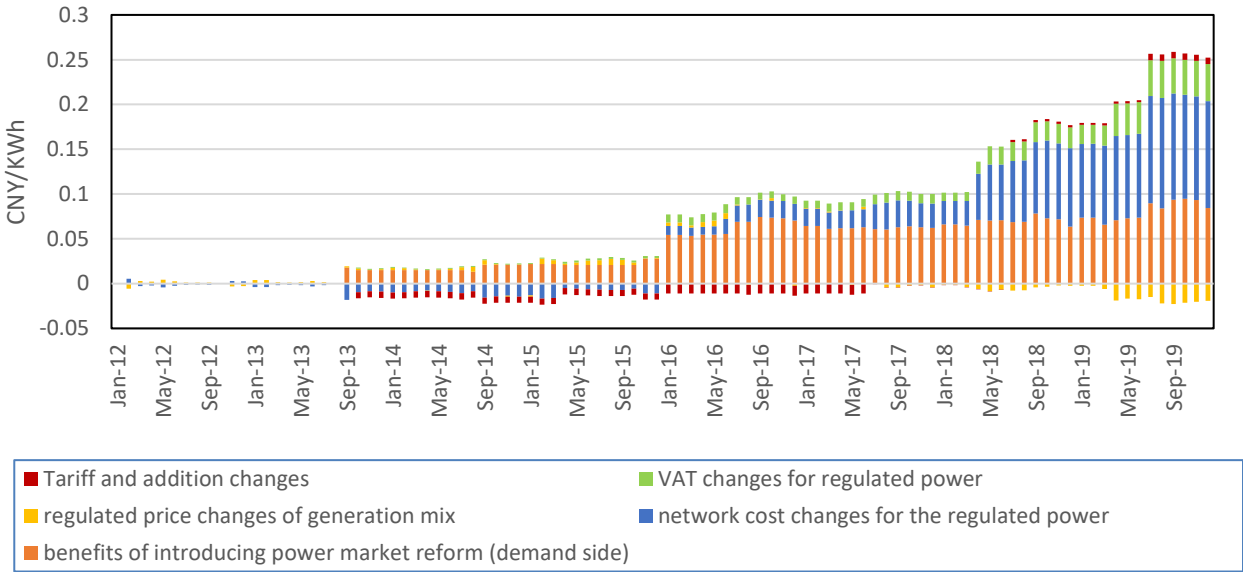
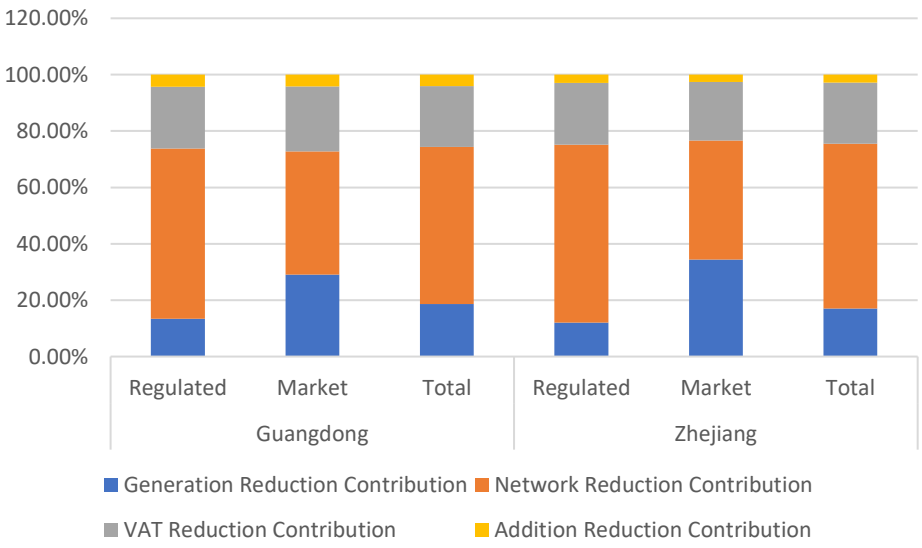


Figure 22 The contributions to price reduction over the period 2012-2019 in Guangdong and Zhejiang for market, regulated and average 35kV customers



The significant reduction of network cost can be attributed to two aspects. The first is the formal price control for network charge. Before the market-oriented reform of 2015, the grid companies earn

benefits from the gap between generation and retail prices. Under the market-oriented reform, Since 2016, price control is imposed on grid company. The grid company can only increase network revenues on the basis of electricity transmitted, which may reduce their revenue compared to the previous mechanism. The second part comes from the National Development and Reform Commission's effort to finish the task to reduce electricity bills by 10% for small and medium industrial and commercial customers who are not in the market from 2018 to 2019. This task is proposed by the Premier Li's government annual work plan to National People's Congress. The specific measure includes the cost saving from the price control imposed on inter-provincial and inter-regional interconnectors which transmit renewable energy from western China to eastern China. The government temporarily reduce the intra-province T&D charge by reducing the proportion of network investment included in Regulatory Asset Values from 75% to 70%[61], and by lowering the average depreciation rate of the grid company by 0.5 percent.[62]

5.3 Have Chinese power prices converged with the US, following the 2015 reform?

Chinese industrial power prices have fallen substantially since 2014. Meanwhile industrial electricity prices in the US have fluctuated but remained largely constant (see Figure 23). We compare prices for 35kV general industrial sector in Guangdong and Zhejiang with the price for industrial sector in the US, Texas and Florida[63]. We choose Texas and Florida, because Texas is one of the most competitive markets in the US, while Florida has a largely vertically integrated – unreformed - power system.

Fiscal policy is different between America and China. In America, there is no VAT or sale tax in the final price paid by electricity customers, while VAT is included in both customer and generator prices in China. Thus we assume that to make prices comparable between the US and China VAT should be removed from the Chinese prices.

[61] The proportion of new investment included into Regulatory Asset Value is set to no more than 75%. As the Department of Pricing of National Development and Reform Commission does not have the authority to grant consent of investment plan to grid company, it is a counter measure to curb the excess investment of grid company. See National Development and Reform Commission (2016) .

[62] See National Development and Reform Commission (2018a), National Development and Reform Commission (2018b), National Development and Reform Commission (2019).

[63] The data for Texas and Florida comes from survey FORM EIA-861 of Energy Information of Administration (EIA).

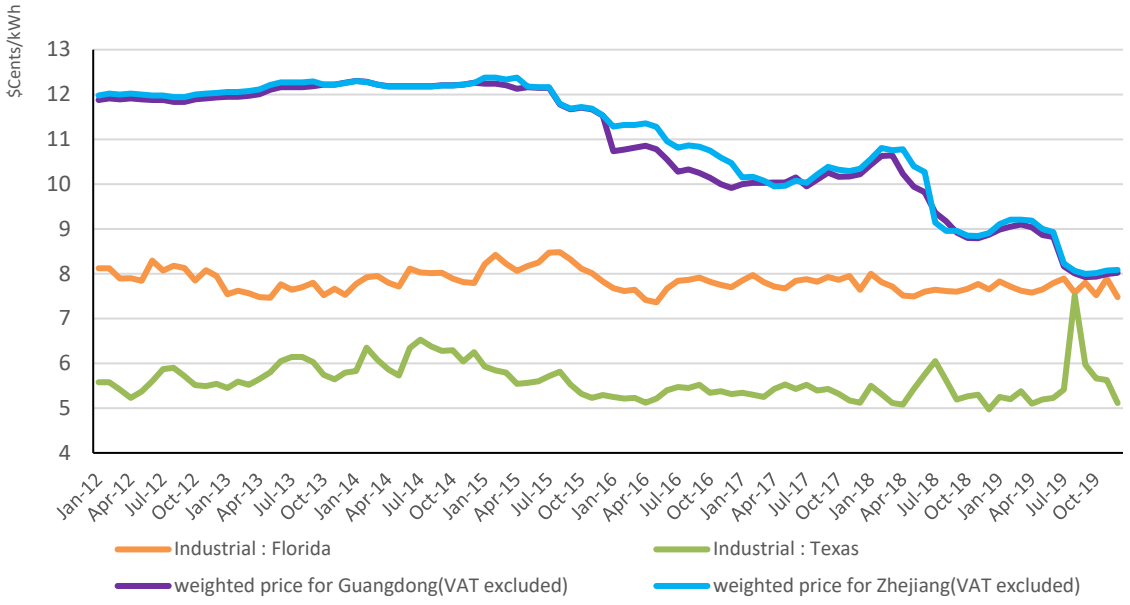
Furthermore, we can see that the electricity price of the two nations converge in the summer of 2019 when the power demand increased significantly in Texas due to hot weather. The smallest gap happened in July of 2019, the monthly final average price for industrial sectors in Texas was around 7.5 $cents/kWh when the average electricity price traded in the market in Guangdong and Zhejiang was about 8.0$cents/kWh[64] for the general 35KV industrial customers. According to the price supervision report of the National Energy Administration[65], the average price of industrial and commercial customers began to be lower than that of the average price of households from 2017. Given that in the US (and other OECD countries) household power prices are always higher than industrial power prices, this can be seen as another signal for the success of the power market reform in China.

Compared to the trend of electricity prices in Texas and Florida, the electricity price in Guangdong and Zhejiang has obviously fallen over the study period. In 2012, the price in Guangdong is 2.1 times as high as that of Texas, or 1.5 times as high as that of Florida, but in 2019, the price of Guangdong is 1.4 times of that of Texas, or 1.1 times that of Florida. Zhejiang shows a similar level of convergence. The retail prices of Guangdong and Zhejiang are fundamentally determined by the benchmark prices set by the government as only a fraction of power was traded in the power market. This is consistent with the previous result that most of the price changes are driven by the regulatory government rather than the power market. We should note the prices fluctuate in the US across the year in a way they do not in Guangdong and Zhejiang, this suggests that there is some way to go before power prices in China reflect the underlying power supply and demand situation.

The industrial electricity price in Europe is higher than that in the USA as fuel prices are higher (Pollitt, 2019). A similar situation is observed in China. Along with the decrease of the electricity price, there is less room to reduce the retail price than before in China as the sharp decrease of regulated electricity price has led to many generation enterprises to shut down.

[64] We have considered the influence of exchange rate.
[65] See National Energy Administration (2018)

Figure 23: The Monthly final average retail price of electricity in Texas and Florida and the 35kV general industrial customers in Guangdong and Zhejiang[66]



6. Conclusions

This paper presents an analysis of the impact of the 2015 power market reform process in China on the industrial price of electricity. We do this by picking a typical power market price for a medium sized industrial customer in two of China's leading reform provinces: Guangdong and Zhejiang.

We find that power market reform has substantially reduced prices. The regulated price falls by 26.4% in Guangdong and by 26.9% in Zhejiang. The market price falls even further by 27.7% in Guangdong and 30.4% in Zhejiang. These are falls in the nominal price of electricity.

These price reductions are very large compared to the US, and China has substantially reduced the gap between its industrial electricity prices and those of the US. There has also been an impressive rebalancing of electricity prices from industrial to residential consumers. For the first time the average

[66] Data Source: https://www.eia.gov/electricity/data/browser/

household price in the two provinces we look at is above that for our benchmarked industrial customers.

We examined the proximate causes of these large changes in the industrial price. The price falls have come from a number of different sources: falls in the prices paid to generators, reductions in grid charges and falls in government taxes and additional charges.

While this has been billed as a 'market' reform, it is clearly better characterised as a 'regulatory' reform as the market discounts offered by generators in the power markets have only constituted a small share of the total price reductions experienced by the industrial customers we looked at.

Overall, the Chinese power market reform highlights two important lessons worth emphasising more widely. First, getting power prices down for final consumers depends significantly on controlling network charges and additional government policy costs. Second, that one of the substantial benefits of markets is not that market prices are much lower than regulated prices, but that market reforms are a vehicle for improving regulation and shaking up previously poorly regulated industries.

References

[1] Chan, H.R., Fell, H., Lange I, Li, S. 2017., Efficiency and environmental impacts of electric ity restructuring on coal-fired power plants. Journal of Environmental Economics and Ma nagement, 81:1-18.

[2] Chen, H., Chyong, C. K., Mi, Z., Wei, Y. 2020., Reforming the operation mechanism of Chi nese electricity system: benefits, challenges and possible solutions. The Energy Journal, 4 1(2), 219-246.

[3] Chen, Q., Kang, C., Ming, H., Wang, Z., Xia, Q., Xu, G., 2014. Assessing the low-carbon eff ects of inter-regional energy delivery in China's electricity sector. Renewable and Sustain able Energy Reviews, 32,671-83.

[4] Green, R. J., 1999. The Electricity Contract Market in England and Wales. The Journal of Industrial Economics, 47(1), 107-124.

[5] Gu, F., 2019. "2018年全国电力市场交易情况分析". Analysis of China Power Market Trade Status in 2018. China Power Enterprise Management, 16,43-47(In Chinese).

[6] He, H., 2017. "浙江省降低企业用电成本政策效果分析及对策". Analysis of Policy Effects of Reducing Power Consumption Cost in Zhejiang. Energy Conversation,9, 7-9(In Chinese).

[7] Hu, W., Gu, Y., Xu, L., Li, Z., 2017. "2016年电力交易情况分析". 2016 Annual Report on Power Trading. China Electric Power, 50(04), 35-38(In Chinese).
[8] Lin, B., Jiang, Z., 2012. Designation and influence of household increasing block electricity tariffs in China. Energy Policy, 42, 164-173.
[9] Lin, J., Kahrl, F., Yuan, J., Chen, Q., Liu, X., 2019. Economic and carbon emission impacts of electricity market transition in China: A case study of Guangdong Province. Applied Energy, 238, 1093-1107.
[10] Liu, H., Zhang, Z., Chen, Z.-M., Dou, D., 2019. The impact of China's electricity price deregulation on coal and power industries: Two-stage game modeling. Energy Policy, 134, 110957.
[11] Liu, L., Ni, W., 2018. "我国环保电价政策体系及监管方式探索". A Probe of Environment Friendly Price System and Its Supervision Method. China Price Supervision and Antimonopoly, (10), 56-60(In Chinese).
[12] Ma, L., Huang, L., Xue, S., Fan, M., Zhang, X., 2017. "中国新一轮电力市场改革试点有序运行关键问题". Key Issues for Orderly Operation of China's New Electricity Market Reform Pilot. China Electric, (4), 17-22(In Chinese).
[13] Mo, J., Fan, X., Ran, W., Yang, X., Zhang, L., Liu, L., Shao, L., 2017. "关于降低制造业电费成本问题的研究——以广东省为例". Investigation and research on electricity cost of Manufacturing Industry in Guangdong Province. Price Theory and Practise, 10, 88-91(In Chinese).
[14] National Energy Administration, 2016. Chinese power generators face tougher times as deregulation sparks competition https://www.scmp.com/business/companies/article/2045769/chinese-power-generators-face-tougher-times-deregulation-sparks.
[15] Newbery, D. M., 1998. Competition, Contracts, and Entry in the Electricity Spot Market. The RAND Journal of Economics, 29(4), 726-749.
[16] Pollitt, M., Yang, C.-H., Chen, H. 2017. Reforming the Chinese electricity supply sector: lessons from international experience. EPRG working paper.
[17] Pollitt, M.G.,2019. The European Single Market in Electricity: An Economic Assessment. Review of Industrial Organization, 55,63-87.
[18] Shi, L., 2018. "我国电力市场运营现状、挑战及发展思路". Present, Challenge and Development Path for China Power Market. China Power Enterprise Management, (13), 49-53(In Chinese).
[19] Wang, P., Cao, Y., 2019. "2018年电力市场化改革的回顾与展望". Retrospect and Outlook for Power Market Reform in 2018. China Power Enterprise Management, (13), 54-57(In Chinese).
[20] Xia, Q., Bai, Y., Zhong, H., Chen, Q., 2013., "中国推广大用户直购电交易的制度设计与建议". Institutional Design and Suggestions for Promotion of Direct Electricity Purchase by Large Consumers in China. Automation of Electric Power Systems, 37(20), 1-7(In Chinese).
[21] Yan, Y., Li, G., Li, G., Zhou, M., Pang, B., Li, Z., 2017a. "新一轮电改形势下电力直接交易组织情况分析". Analysis of Power Direct Trade Organization Under New Round of Electricity Reform. China Electric Power, 50(07), 33-37(In Chinese).

[22] Yan, Q., Lei, K., Yi, J., 2017b. "基于CGE模型的中国电力市场改革政策模拟分析". Policy Simulation of China Power Market Reform Based on CGE Model. Economic Research Guide, (23), 12-16(In Chinese).

Government Publications

[1] China Electricity Council. (2020). "2019年12月全国电力市场交易信息". China Power Market Trade Information in December 2010. Retrieved from http://www.cec.org.cn/guihuayutongji/dianligaige/2020-01-21/197071.html. (In Chinese).

[2] State Council of People's Republic of China. (2013). "国务院批转发展改革委关于2013年深化经济体制改革重点工作意见的通知". Retrieved from http://www.gov.cn/zhengce/zhengceku/2013-05/23/content_1226.htm. (In Chinese).

[3] National Development and Reform Commission. (2004a). "国家发展改革委关于调整浙江省居民生活电价的通知". Retrieved from http://www.escn.com.cn/news/show-776016.html. (In Chinese).

[4] National Development and Reform Commission. (2004b). "关于进一步疏导电价矛盾规范电价管理的通知". Retrieved from http://www.nea.gov.cn/2011-08/16/c_131052531.htm. (In Chinese).

[5] National Development and Reform Commission. (2009). "国家发展改革委关于完善风力发电上网电价政策的通知". Retrieved from http://fzgg.tj.gov.cn/zwgk/zcfg/wnwj/jgwj/201306/t20130628_29470.shtml. (In Chinese).

[6] National Development and Reform Commission. (2011a). "国家发展改革委印发关于居民生活用电试行阶梯电价的指导意见的通知". Retrieved from http://www.nea.gov.cn/2014-05/21/c_133349832.htm. (In Chinese).

[7] National Development and Reform Commission. (2011b). "国家发展改革委关于完善太阳能光伏发电上网电价政策的通知". Retrieved from http://www.gov.cn/zwgk/2011-08/01/content_1917358.htm. (In Chinese).

[8] National Development and Reform Commission. (2013a). "国家发展改革委关于调整销售电价分类结构有关问题的通知". Retrieved from http://www.nea.gov.cn/2014-06/06/c_133388608.htm. (In Chinese).

[9] National Development and Reform Commission. (2013b). "国家发展改革委关于完善核电上网电价机制有关问题的通知". Retrieved from https://www.ndrc.gov.cn/xxgk/zcfb/tz/201307/t20130708_963918.html. (In Chinese).

[10] National Development and Reform Commission. (2016). "国家发展改革委办公厅 国家能源局综合司关于同意浙江省开展售电侧改革试点的复函". Retrieved from http://www.gov.cn/xinwen/2016-10/13/content_5118439.htm. (In Chinese).

[11] National Development and Reform Commission, 2016. "国家发展改革委关于印发《省级电网输配电价定价办法（试行）》的通知". Retrieved from http://www.gov.cn/xinwen/2017-01/04/content_5156506.htm. (In Chinese).

[12] National Development and Reform Commission. (2017). "国家发展改革委关于核定河南等12个省级电网2017-2019年输配电价的通知". Retrieved from https://www.ndrc.gov.cn/xxgk/zcfb/tz/201905/t20190529_962999.html. (In Chinese).
[13] National Development and Reform Commission, 2018a. "国家发展改革委关于降低一般工商业电价有关事项的通知". Retrieved from http://www.gov.cn/xinwen/2018-04/19/content_5283935.htm. (In Chinese).
[14] National Development and Reform Commission, 2018b. "国家发展改革委关于核定部分跨省跨区专项工程输电价格有关问题的通知". Retrieved from http://www.gov.cn/xinwen/2018-09/06/content_5319801.htm. (In Chinese).
[15] National Development and Reform Commission, 2019. "国家发展改革委关于降低一般工商业电价的通知". Retrieved from https://www.ndrc.gov.cn/xxgk/zcfb/tz/201905/t20190515_962447.html. (In Chinese).
[16] National Electricity Regulatory Commission. (2007). "电力监管年度报告（2006）". Electricity Regulatory Annual Report 2006. Retrieved from(In Chinese).
[17] National Energy Administration. (2013). "国家能源局综合司关于当前开展电力用户与发电企业直接交易有关事项的通知". Retrieved from http://zfxxgk.nea.gov.cn/auto92/201308/t20130808_1689.htm. (In Chinese).
[18] National Energy Administration. (2016) Chinese power generators face tougher times as deregulation sparks competition https://www.scmp.com/business/companies/article/2045769/chinese-power-generators-face-tougher-times-deregulation-sparks2016.
[19] National Energy Administration. (2018). "2018年度全国电力价格监管情况通报". Retrieved from http://www.nea.gov.cn/138530255_15729388881531n.pdf. (In Chinese).
[20] Ministry of Finance. (2017). "关于取消、调整部分政府性基金有关政策的通知". Retrieved from http://szs.mof.gov.cn/mlqd_8464/2013yljfcs/201706/t20170616_2624660.html. (In Chinese).
[21] Zhejiang Provincial Price Bureau. (2011). "浙江省物价局关于调整非省统调公用水力发电机组最高上网电价等事项的通知". Retrieved from http://www.zjpi.gov.cn/WebSite/XinXiCk?xxid=b3f0a07edeb64535930a6f3c3fc6c33b. (In Chinese).
[22] Zhejiang Provincial Price Bureau. (2012). "浙江省物价局关于完善居民生活用电阶梯电价政策有关事项的通知". Retrieved from http://jx.zjzwfw.gov.cn/art/2014/5/30/art_24517_23985.html. (In Chinese).
[23] Zhejiang Provincial Price Bureau. (2014). "浙江省物价局关于完善小水电上网电价政策有关事项的通知". Retrieved from http://www.zjpi.gov.cn/WebSite/XinXiCk?xxid=854871996e46409ca497e227d37be51b. (In Chinese).
[24] Zhejiang Provincial Price Bureau. (2015). "浙江省物价局关于我省天然气发电机组试行两部制电价的通知". Retrieved from http://www.zhejiang.gov.cn/art/2015/6/25/art_13007_240170.html. (In Chinese).
[25] Zhejiang Provincial Economic and Information Commission. (2014). "关于印发《浙江省电力用户与发电企业直接交易试点实施方案（试行）》的通知". Retrieved from http://www.zj.gov.cn/art/2014/11/6/art_13013_185700.html. (In Chinese).

[26] Zhejiang Provincial Department of Finance. (2019). "浙江省财政厅关于停征小型水库移民扶助基金的通知". Retrieved from http://czt.zj.gov.cn/art/2019/9/9/art_1164181_40979032.html. (In Chinese).