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Michael G.
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Measuring the Impact of Electricity Market Reform in a Chinese Context

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Abstract
This paper draws on international experience to examine how the ongoing power sector reform (PSR) in China since 2015 should be measured and assessed. We proceed by reviewing some relevant international reform experience and then applying this to the Chinese context. Thus we focus on some of the extensive previous literature which has documented reforms in cross-country and in single country studies. We pay particular attention to the European Union (EU) single electricity market, which is the largest integrated electricity market in the world. We also look at a social cost benefit analyses of UK electricity market reforms and how these might applied in a given Chinese province. We go on to examine the actual price impact evidence from two leading provinces – Guangdong and Zhejiang – on the overall price effect and on exactly how those price effects have been achieved. We then offer some insights from the extensive regulatory reporting by leading regulators on market performance that is relevant to PSR in China based on excellent annual reporting from the UK, Australia and the US.

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Section 1: Introduction

This paper seeks to discuss how the impact of electricity market reform should be measured in the context of the 2015 Power Sector Reform (PSR) in China which is the subject of this special issue.

A central idea in this paper is that the measurement of the impact of power market reform is not straightforward and therefore needs to focus on variables that are relevant and important for public policy. Better monitoring and data reporting by regulators can focus attention on the key variables and highlight problems that need to be addressed both ahead of and in real time.

We draw on extensive experience from around the world that would seem to be relevant to China. We proceed by first reviewing some relevant international reform experience and then applying this to the Chinese context. Our examples are necessarily selective but intended to be informative for a Chinese (and other reforming jurisdictions) audience.

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[1] The author wishes to thank the British Embassy in Beijing and the UK Prosperity Fund for their ongoing support for his work on China's electricity reforms. General lessons on Chinese power market reform from international experience are contained in Pollitt (2020) and Pollitt, Yang and Chen (2017, 2018) and Pollitt and Dale (2018). Financial support from the 'Efficiency Analysis and Policy Recommendation of Jiangsu Power Market Design and Operation' project (FPP207) from the UK Prosperity Fund is acknowledged, as are comments from colleagues on this project. Jun Xu also provided excellent comments on the paper. I am very grateful for the comments of two anonymous referees. All errors are his own.

We focus on some of the extensive previous literature which has documented reforms in cross-country and in single country studies. We pay particular attention to the European Union (EU) single electricity market, which is the largest integrated electricity market in the world, and covers (until the end of 2020) 518 million people[2]. This market provides a model for a Chinese electricity market built out of provincial and regional (multi-provincial) markets. We also look at social cost benefit analyses of UK electricity market reforms. These reforms started early (from 1990) and provide well documented experiences of both how to measure reform impacts and how big the impacts might be. Chinese power market reform has been running for more than 6 years (since at least March 2015, with some trialing before then) and it has had a substantial impact on the price of industrial electricity (which we show below). We look at the evidence from two leading provinces – Guangdong and Zhejiang - on the price effect and on exactly how those price effects have been achieved. We go on to offer some insights from the extensive regulatory reporting by leading regulators on market performance that is relevant to the 2015 PSR in China. We show that UK, Australian and US federal regulators and individual US market monitoring of reformed electricity markets provide excellent examples of annual reporting on market performance that are worthy of study.

We will begin section 2 by laying out some principles for measuring market reform impact and review some of the previous literature. Section 3 will discuss measurement of the reform in the EU single electricity market. Section 4 draws on the specific experience of the UK. Section 5 will look at initial measurement of the price impact of electricity reforms in Guangdong and Zhejiang. Section 6 will discuss the annual monitoring of reform and some examples of measurements that shed light on how well reform is going. Section 7 concludes.

Section 2: Some principles for measuring market reform impact

Pollitt (2012), in a review of the impact of global energy market liberalisation, discusses various studies which measure the impact of energy liberalisation. He identifies four (reasonably) robust types of studies in the literature. **Performance metric regressions** examine the impact of privatisation/liberalisation variables on panel data of performance (e.g. Steiner, 2001). **Statistical tests of before and after performance** conduct a t-test for significant differences in performance metrics before and after privatisation (following D'Souza and Megginson, 1999). **Social cost benefit analyses** of reform (following Jones et al., 1990) look at reform as an investment which has costs and benefits. **Macro studies** of reform attempt to find impacts using general equilibrium models of the economy. These studies track the impact of lower prices and costs in significant reformed industries on GDP (e.g. Chisari et al., 1999). Jamasb et al. (2017), in their recent review of studies of electricity reforms in developing countries, conclude that social cost benefit analyses of reform are less common than they might be given the importance of the topic, and that more of these sorts of studies are required.

Measuring electricity reform presents a particular challenge for these types of studies. This is because compared with, say, measuring the impact of the domestic privatisation of oil and upstream gas, electricity 'reform' is a package of measures which makes it difficult to

[2] Population of EU-27 + UK + Norway.

get a clean measure of the impact of reform per se. Thus electricity reforms often involve multiple changes – such as privatisation, structural reform, the introduction of wholesale markets and changes to the nature of regulation – in markets which are largely domestic and specific to the jurisdiction at hand. This simultaneity of reforms makes assessing the 'reform' impact difficult. It might be for instance that the introduction of a wholesale market was not a significant element in improving electricity system performance, but if it happened at the same time as other elements of reform which did have a positive impact (such as incentive regulation of networks), it might be hard to identify that this was the case. Data on a number of jurisdictions might aid the econometric identification of the contributions of various reform elements (f.Steiner, 2001).

The evidence on electricity reform from performance metric regressions seems to be that for European Union (EU) countries there is evidence of modest productivity improvements (e.g. Steiner (2001), Hattori and Tsutsui (2004), Fiorio et al. (2007)). However the impact on prices of the different reform elements is ambiguous: prices do not significantly change. Pollitt (2009), after examining the econometric studies from developing countries concludes that, in general: privatisation improves efficiency with independent regulation; privatisation/regulation have no significant effect on prices; private investment is stimulated by independent regulation.

Jamasb et al. (2004) highlight the positive experiences of the UK, Chile, Argentina, Peru, Philippines, Brazil and Colombia with electricity reform, based on individual country studies. Some of the studies they review make use of formal social cost benefit analysis, which we outline in the next section.

Table 1 summarises social cost benefit analysis of electricity reform studies. These particular studies focus on the privatisation event, but often - as in the case of the UK which we discuss in the next section – involved other reform elements happening at the same time. These studies show both the size of the gain in relation to the existing size of the companies involved and who, within society (consumers, producers or the government), got them. As can be seen in Table 1, the gains are positive but modest (around 5% lower revenue/costs) and in general they are not fully received by consumers but instead go substantially to investors (who are often foreign for smaller developing countries) and to the government.

Table 1: Results for Social Cost Benefit Analyses of Electricity Reforms

Authors	*Reform and Company/Date/Country Studied*	*Measured NPV of reform (central estimate)*	*Key distributional impacts identified*
Galal et al. (1994)	Privatisation of CHILGENER – generation and transmission /1981-1986/Chile	Permanent gain in welfare of 2.1% of 1986 sales	2/3 of aggregate gains go to foreign share holders.
Galal et al. (1994)	Privatisation of ENERSIS – distribution /1986/Chile	Permanent gain in welfare of 5% of 1986 sales	Paying consumers gain an amount almost equal to the aggregate impact
Newbery and Pollitt (1997)	Privatisation and breakup of CEGB - Generation and Transmission monopoly/1990/UK	Permanent gain of 6% of 1995 turnover	Consumers lose initially and overall, CO2 and SO2 benefits significant
Domah and Pollitt (2001)	Privatisation of 12 Regional Electricity Distribution Companies/1990/UK	Permanent gain of 9% of 1995 turnover	Consumers lose initially
Toba (2002)	Privatisation of distribution company – Meralco/1986/Philippines	Permanent gain of 6.5% of 1999 sales	Most of net gain is reduction in CO2 and NOX, consumers do gain by more than 50% of aggregate gain
Mota (2003)	Privatisation of distribution companies/1995-2000/Brazil	One off gain equal to 2.5% of GDP	Producers gain around 2/3 of aggregate benefit
Toba (2007)	Introduction of Power Purchase Agreements with Independent Power Producers by incumbent generator, NPC/1990-93/Philippines	One off gain of around 13% of GDP	Economy wide benefit due to earlier ending of power crisis
Anaya (2010)	Privatisation of 2 Distribution and Retailing Companies/1994/Peru	Permanent gain of 27% of costs when earlier connection included	Existing consumers lose, new consumers gain earlier connection

Source: Pollitt (2012, p.133).

The US has not experienced privatisation but has had a set of power sector reforms, often involving restructuring of existing monopoly companies to create competitive wholesale electricity markets. The US studies we report, all use performance metric regressions.

Fabrizio et al. (2007) use time series econometrics of US power plants to show that reform is associated with up to a 5% reduction in plant level non-fuel generation costs. Joskow (2006) used time series econometrics to find that competitive wholesale and retail markets reduced prices (relative to their absence) by 5-10% for residential customers and 5% for industrial customers. Barmack et al. (2007) look at the wholesale power market in New England and find a net gain of 2% of costs. Kwoka and Pollitt (2010) show that unbundling appears to raise electricity distribution costs, relative to not unbundling. Triebs et al. (2010) show losses on distribution unbundling are more than offset by gains on generation costs. Again the evidence is that the massive reorganisation of the US electricity sector has resulted in only modest overall gains.

There have been some studies of China's recent power market reforms. Chen et al. (2020) suggest that a move to market based economic dispatch could reduce power could reduce coal consumption in the Chinese power sector by 5.8%. Lin et al. (2019) find that wholesale electricity prices in Guangdong could fall by 9-27% as a result of market based pricing, while Abhyankar et al. (2020) found that even larger wholesale price reductions of up to 35% if the entire China Southern Grid area, including Guangdong, were integrated in a market based system.

The key thing to say about these studies is that these are not based on actual pre- and post-reform data. They are simulations of the potential for improved performance based on the existing system costs, by simply moving towards more efficient allocation of existing generation capacity. These studies do not therefore fit into any of the categories which we have discussed above. However they do indicate a large potential for reform impact, which is larger than an equivalent study for the US or the EU would have concluded prior to their wholesale market reforms[3], partly because these systems already used least-cost power plant dispatch algorithms even within large monopoly electricity utilities.

One study that does look at actual data on Chinese power market reform is Zheng et al. (2021).[4] They look at on-grid generation prices and average retail electricity prices for 2003-2018 for a number of Chinese provinces to conduct a performance metric regression analysis. They introduce a reform dummy in 2015 to find a statistically significant impact. This amounted to a 2-5% reduction in average retail electricity prices due to PSR and a fall of thermal on-grid generation prices of 12%. They also find that coal use per unit of output has fallen and that quality of service (measured by reliability and supply interruptions) has worsened following reform. This analysis only looks at the first 3 years of reform and is not based on a well-developed counterfactual of reform (as discussed below). Clearly further investigation of this result, especially in the light of the results of the simulation studies and the evidence presented in section 5 of much larger absolute price reductions in specific electricity prices since 2015, is warranted.

Lessons for China

The international evidence on the impact of power market reform, even where it involves structural reform, ownership change and the introduction of power markets happening all at once should be expected to have modest impacts if a proper control/counterfactual is undertaken.

This is for two reasons. First, the assets involved in the electricity sector change only slowly and hence much of the gain comes from saving short term operating costs (i.e. labour). This can only be achieved with significant reorganisation (including redundancy) costs. Second, reduced prices, per se, are not a pure net gain from reform. Lower prices may simply reflect a redistribution from shareholders and the government (who get lower VAT and profits tax) to consumers. In China the government is the primary shareholder in the electricity

[3] See, for example, Copenhagen Economics (2005) discussed below.

[4] Other studies do discuss Chinese power market reform and its impacts, but their analytical basis is limited. For instance, Liu et al. (2019) discuss electricity reforms in Yunnan province reporting falls in the price and reductions in the cost of the local grid company.

industry, so price reductions for customers may come at the expense of reduced government revenue, rather than solely reflect production efficiency improvements.

The literature does highlight a number of elements which increase the benefits of electricity reform relevant to China. These are: incentive based network regulation which reduces costs; regulation which promotes quality of service and network extension as part of the reform process; the deferral of expensive investments; and wholesale markets which improve the efficiency of generators competing to be dispatched. It also highlights elements of reform which raise costs. These are: expensive unbundling which raises separation costs and the costs of creating markets and new market players. Thus to the extent that PSR creates expensive new structures such as power markets and suppliers which are then financed by electricity consumers, these are costs which need to be set against benefits. All of these elements are illustrated in our discussion of the evidence from the UK in section 4.

Section 3: Measuring reform impact in the EU Single electricity market

The EU single electricity market covers the 27 countries of the EU, plus Norway and, until the end of 2020, the UK. Following the day-ahead market coupling of power exchanges across Europe around 86% of electrical energy in the EU is part of what can be a single price zone in the absence of transmission constraints (see Pollitt, 2019). The single market is being extended to intra-day trading (around 50% flows across country borders in the correct direction from low to high price areas) and balancing energy (around 19% flows across country borders in the correct direction) (see Pollitt, 2019).

The single market has been years in the making and has been created and promoted in four major sets of EU legislation (in 1996, 2003, 2009 and 2019 – so called 'energy packages', consisting of new 'Directives'). These reforms have included: unbundling of competitive and monopoly elements of the industry; open access to power networks; competition in wholesale and retail electricity markets; and the opening up of cross-border trade in electricity. This legislation has been masterminded by the European Commission (see Pollitt, 2019), who have sought to 'complete the single market in energy'. The Commission's own analysis of the impact of this major set of reforms – to 2020 - consists of (only) two reports: a 2005 report from Copenhagen Economics based on general equilibrium (GE) modelling using 1990-03 data; and a 2013 report from Booz et al. based on back of the envelope estimates of reform impacts.

The 2005 report (Copenhagen Economics, 2005) estimates market opening at the national level, estimating the impact of this on electricity sector performance, and then its wider impact in a GE model of whole economy. It estimates a long-run impact on electricity productivity of 7-8% and possibly higher price reductions.

The 2013 report (Booz et al., 2013), roughly, estimates savings from electricity trading at 50 Euros per MWh, attributes a quarter of this to market coupling and suggests current benefits are around 2/3 of this, or 2.5bn Euros per year, with 1.5bn still to be realised. The report emphasises the further gains from completing the day-ahead market coupling and extending it to intra-day, balancing, reserve capacity and financial transmission rights.

The rather poor job done by the European Commission in looking at the impact of its own reform suggests a number of elements that can be measured when looking at such a large and wide ranging reform over a number of national jurisdictions. We suggest 7 areas where progress with the EU's reform can be measured and what the measures might suggest.

1. Pro-competitive structural change

It is important to measure the extent to which structural change has occurred within national markets. The OECD product market regulation (PMR) indicators measure structural change in a number of regulated industries.[5] The overall PMR indicator for electricity shows improvement in electricity. Between 2008 and 2013, the PMR fell from 2.4 to 2.1 (out of 6, best = 0) for EU against 2.6 to 2.4 for OECD as a whole. This overall indicator was driven by a significant increase in competition in generation and retail markets. The PMR weights questions on entry regulation, public ownership, vertical integration, retail price regulation and other questions.[6]

2. Quality of sector regulation

Green et al. (2009) discuss how to measure the form and process of electricity sector regulation across the EU. They show that this has improved. For instance, on *form*, regulatory institutions with significant powers have been created and these often operate independently of central government. On *process*, regulators may be conducting sophisticated benchmarking exercises to compare the performance of regulated companies. However, as they discuss, it is difficult to measure if the *outcomes* of regulation have improved without a detailed analysis of a particular regulatory ruling.

3. Prices, costs, rate of return on capital and fuel poverty

It is important to measure the price, cost and rate of return impacts of reform. We want reform to reduce prices and costs while maintaining a fair rate of return for companies in the sector. We also have a particular concern for poorer consumers, as even if prices have to rise in some circumstances to cover costs and a fair rate of return, we don't want the poorest consumers to be too adversely affected. Roughly we are talking about the impact of reform on consumer and producer surplus and how it is distributed between consumers and the companies involved.

There is limited evidence of reduced household electricity prices in EU (da Silva et al., 2017), but better evidence on wholesale price convergence between countries (e.g. Menezes and Houllier, 2016). Mergers between utility companies across Europe has created merger gains at the same time as falling returns, especially following the 2003 directive (e.g. Tulloch et al., 2018). There is little evidence of increased fuel poverty (roughly, the percentage of households spending more than 10% of income on energy), though this remains a serious problem in some countries where energy bills can be high.

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[5] See https://www.oecd.org/economy/reform/indicators-of-product-market-regulation/

[6] See the Sector PMR schemata at https://www.oecd.org/economy/reform/indicators-of-product-market-regulation/

4. Quality of service

There has been a general reduction in customer minutes lost for final customers across EU in the years following reform (see CEER, 2016). There is also some evidence of improved transmission system reliability (looking at average transmission interruption time). There were some early issues with increased wide area trading leading to cross-border blackouts (e.g. in 2003 and 2006), largely as a result of a lack of real-time communication between transmission system operators (TSOs). However, there have now been significant efforts to improve inter TSO coordination with creation of regional security coordinators (e.g. CORESO which covers 7 countries and 279m people).

5. Environmental impact

The single market in electricity has seen a big increase in renewable electricity due to heavy investment. This has led to a big reduction in CO2 per MWh (-36%, 1990-2014) and larger reductions in SO2, NOX and dust emissions from power plants. There is even evidence that more extensive national electricity reform is correlated with reduced environmental impacts from the electricity sector and higher renewables penetration (e.g. Vona and Nicolli, 2014). This is consistent with the view that in the EU markets have favoured gas generation over coal generation and that the efficiency gains from liberalisation have been partly spent on increased renewables support.

6. Impact on innovation

1999-2021 is a long time over which to assess impact. Small short run static effects of the single market may be outweighed by long run dynamic effects. One channel for this might be via reduced research and development (R+D) expenditure. R+D in electricity by utilities declined sharply following reform, as did patenting by electricity companies. There is weak evidence of inverted U relationship in reform impact on patenting across OECD (Marino et al., 2017). However the impact of declines in electricity utility R+D on total economy energy R+D (and patenting) is unclear. So it is difficult to say what the long-run innovative impact of reform has been in the case of the EU.

7. Overall assessments of impact

The evidence for the overall impact of the EU single market reform is surprisingly thin. As we have seen the EU itself makes use of simulations of reform impacts (e.g. what would be the market power reduction impact on prices). Performance regressions on panel data (e.g. Polemis and Stengos, 2017) tend to have questionable approaches to distinguishing different reform element effects, especially in the presence of cost increasing renewables roll out which has been happening alongside pro-competitive market reforms and incentive regulation of networks. Thus the panel data econometrics shows evidence of limited productivity improvement but ambiguous price effects, though the overall modest gains have been disputed recently. Public dissatisfaction continues with reform, as does regulated final household pricing for around half of EU countries.

Lessons for China
Our review of the measurement of EU single market reform suggests a number of reform measurements which can be made in a Chinese context. Mainland China consists of 23 provinces, 5 autonomous region and 4 municipalities directly under central government, many of which are comparable to or larger than – in electrical terms – large single electricity market countries (Germany, France, Spain, Italy and the UK). The process of market electricity market integration across Europe has been impressive, especially considering the initial lack of both political and electrical integration. China has the potential for at least as extensive electricity market integration than Europe, as it is a single centralised state.

It is important to measure the extent of structural change across Chinese provinces in order to benchmark how competitive the market structure of each provincial market is. The OECD PMR indicator for electricity would be a good place to start with this. The OECD PMR indicators includes figures for China in 2008 and 2013, showing that China's PMR indicator for electricity dropped from 5.815 to 4.5 between 2008 and 2013. It would be interesting to do this for a number of Chinese provinces through the reform period since 2013.

China can benefit from benchmarking the quality of its regulatory institutions with respect of form, process and outcomes. These include the National Energy Administration(NEA), National Development and Reform Commission (NDRC) and their provincial offices. They remain important in promoting successful reform. We discuss the scope for improved regulatory monitoring of reforms in section 6.

As we highlight below, it is very difficult to get consistent information on prices, costs, rates of return and percentages of consumers likely to have difficulties in paying their electricity bills in China. This is something which should be monitored at the provincial level.

Quality of service at both the distribution and transmission level should be consistently monitored and incentivised at the provincial level. A major achievement of European reforms has been the application of incentive regulation to measures of quality. The Council of European Energy Regulators (CEER) and ACER (the Agency for the Cooperation of Energy Regulators) have both improved the monitoring and reporting of quality of service across Europe.

The environmental impact of reform is increasingly important. In China, how power market reform promotes efficient dispatch of plants and interacts with the pricing of carbon and other externalities will become more, not less, significant over time.

A lot of R+D is undertaken within existing electric utilities. This is clearly not sustainable as part of a competitive industry subject to incentive regulation of networks. Mechanisms need to be found to continue to promote electricity R+D which involve moving existing in-house research out of existing electricity companies. In some countries this has been done successfully by holding innovation competitions whereby network companies can compete for regulatory concessions to increase charges to fund R+D projects (up to a maximum percentage of extra revenue).[7]

A careful analysis of individual provinces overall reform impacts should be undertaken. An appropriate method for doing this is a social cost benefit analysis. We now discuss how this can be done, drawing on example analyses from the UK.

Section 4: Measuring reform impact in the UK

In this section we describe the social cost benefit analysis (SCBA) methodology applied to measuring reform impact. SCBA is great way of measuring reform impact for a single jurisdiction when the reform has been in progress for a number of years. It has been successfully applied by the World Bank for a number of industries that were liberalised and privatised (following the methodology in Jones, Tandon and Vogelsang, 1990). It has been systematically applied to UK electricity reforms in a series of papers (Newbery and Pollitt, 1997; Pollitt, 1997; Pollitt, 1999; and Domah and Pollitt, 2001).

The analysis aims to assess whether the overall welfare impact measured in terms of social surplus has a positive net present value (NPV). The total welfare can include quality and environmental impacts. The NPV can then be split between who receives it in society, namely consumers, producers and the government. Consumers might receive it in the form of higher prices or better air quality; producers in the form of higher profit and the government as fiscal transfers (from dividends/profits and/or asset sales). Weightings on each of these groups can be altered as thought desirable: one might for instance weight government net welfare receipts at 1, consumers at slightly less than 1 (because electricity consumers are slightly richer than the population as a whole) and private producers at significantly less than 1 (especially if they are foreign).

The crucial part of the analysis is to compare the actual and predicted future performance of the reformed industry with an appropriate counterfactual prediction of what might have happened in the absence of reform. The counterfactual might for instance be based on price and cost trends prior to reform. A reform which delivers a sharp fall in cost against a small annual trend fall in costs prior to reform might be expected to be NPV positive, as long as the costs of reform itself were small or its effects on non-monetary variables (such as air emissions) were non negative.

The basic formula for measuring the change in welfare as a result of a reform is a variant of the one used by Jones et al. (1990):

$\Delta W = V_{withref} - V_{withoutref}$

W= social welfare
$V_{withref}$ = social value with reform

[7] See for example the Network Innovation Competition in the UK. https://www.ofgem.gov.uk/network-regulation-riio-model/current-network-price-controls-riio-1/network-innovation/electricity-network-innovation-competition

$V_{withoutref}$ = social value without reform

Reform socially worthwhile if $\Delta W>0$.

When a reform is based on the performance of companies, the key source of social value change is a reduction in underlying costs. This can be computed as the difference between costs with and without reform, less the actual reform restructuring costs (which might take the form of redundancy payments or consultancy fees):

$\Delta W = C_{withoutref} - C_{withref} - RC$

$C_{withoutref}$ = costs without reform
$C_{withref}$ = costs with reform
RC = restructuring costs

Total welfare change is then allocated between different groups (customers, producers and government).

$\Delta W = \Delta Cust + \Delta Prod + \Delta Gov$

Cust = customer welfare
Prod = producer welfare
Gov = government welfare

As an example of a social cost benefit analysis of an electricity reform which involved the creation of a wholesale market, Newbery and Pollitt (1997) examined the restructuring and privatization of the Central Electricity Generating Board (CEGB). This was the monopoly generation and transmission company in England and Wales up until 31 March 1990. It was then restructured into competing generation companies and a transmission company. Power was sold by the generating companies in a wholesale power pool (from 1 April 1990). These companies were (mostly) subsequently privatized from December 1990.

The key data at the heart of the SCBA of this reform was to construct the turnover (revenue), cost and profit of the CEGB and its successor companies through the reform. This involved adding up the successor companies turnover, costs and profits to 'recreate the CEGB' and measuring what had happened to aggregate output (measured in TWh) over this period (because all the financial values need to be indexed to the output level). The same can be done for a typical Chinese province. Table 2 shows the information required to calculate the costs with reform over the period from 2012 (shaded cells are the data to be collected).

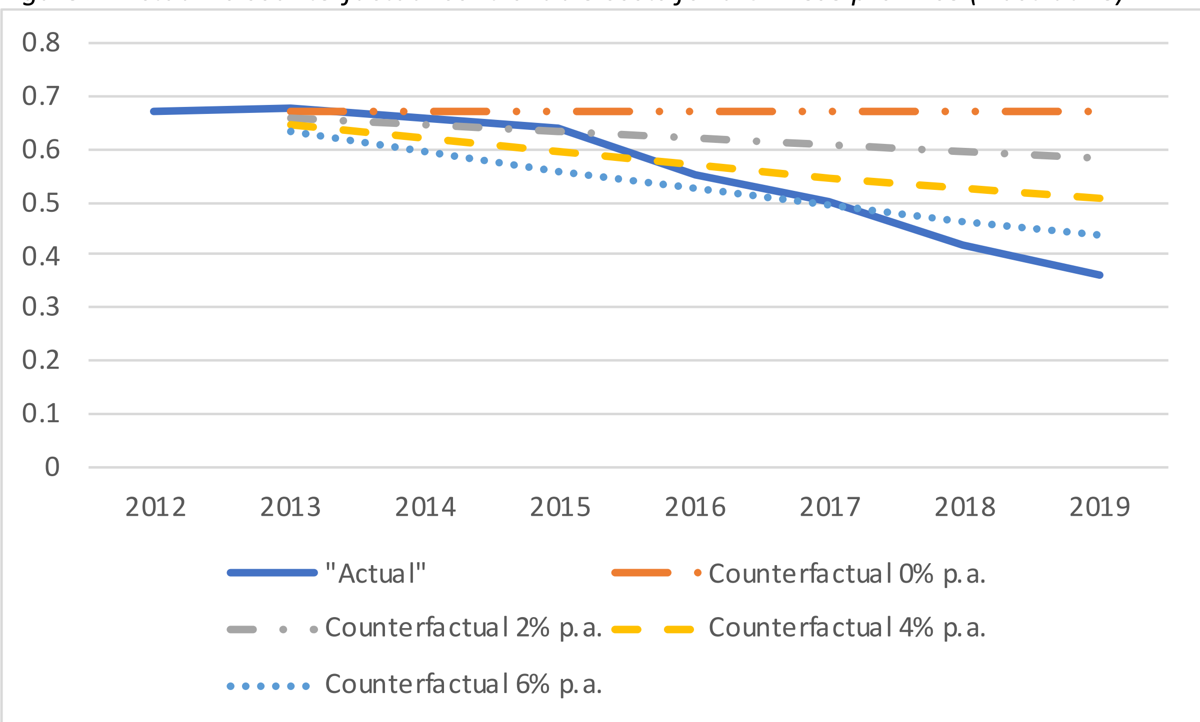
Table 2: The Accounts of provincial electricity sector through reform

	Pre-reform	Pre-reform	Pre-reform	Reform	Post-reform	Post-reform	Post-reform	Post-reform
CNY Billion current	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Gross Turnover								
Less intercompany transactions								
Turnover from sales								
of which								
Fossil fuel cost								
Nuclear fuel								
Depreciation								
Staff costs								
Materials and services								
Gross Profit								
Sales TWh								
Generation TWh								
Employees								

Based on Table 1, Newbery and Pollitt, 97, p.282.

Now the actual evolution of costs needs to be compared against a counterfactual of what costs might have been in the absence of reform. An example of this is shown in Figure 1, where we focus on real controllable unit costs (i.e. we further adjust for inflation). Here we base this on some illustrative data. By controllable costs we have excluded all costs which are not under the control of the companies, such as those driven by the price of fuel or government property taxes on companies. Here reform occurs in 2015 and we can see costs fall sharply. Now this actual performance can be compared to a counterfactual which shows that costs fell by, say 2%, 4% or 6%, p.a.

Figure 1: Actual vs counterfactual controllable costs for a Chinese province (illustrative)



Based on Figure 2, Domah and Pollitt, 2001, p.121.

Newbery and Pollitt (1997) distinguish between a couple of basic counterfactuals (which they label as pro-privatisation and pro-CEGB), one of which is more favourable to the reform showing a positive impact ('pro-privatisation' in this case), one of which assumes the CEGB would have performed relatively well if it had continued ('pro-CEGB'). These assumptions included costs about future fuel price and investment effects (see Newbery and Pollitt, 1997, p.287), some of which were reported individually in the final results (such as the value of cancelling the UK's next nuclear power plant at the time).

We illustrate the overall net present value benefits in Table 3 below. The pure cost effect (as per Table 2 and Figure 1) refers to the cost savings. This was the biggest effect in Newbery and Pollitt (1997). Other effects can be significant, such as the fuel cost saving effect of switching from more expensive coal to other fuels, lower environmental externalities and actual restructuring costs (R+P costs). We label two potential counterfactuals as pro-reform and pro-no reform.

Table 3 shows these for the two counterfactual scenarios and two discount rates (one closer to a social discount rate – 6%, the other closer to a private sector discount rate – 10%). Shaded cells are where the numbers need to be calculated.

Table 3: Net Benefits of power sector reform in a Chinese Province

	Net Benefits of Reform					
	Discounted to 2012		*Counterfactual Scenario:*			
	CNY Billions		*Pro-reform*		*Pro-no reform*	
	Discount Rate		*6%*	*10%*	*6%*	*10%*
1	Fuel savings excl. externalities					
	Externality savings					
2	SO2 @ CNY per tonne					
3	CO2 @ CNY per tonne					
4	Total externality benefits	2+3				
5	Reform costs					
6	Cost savings					
	Total net benefits					
7	excluding externalities	1+5+6				
8	including externalities	1+5+6+4				

Based on Table IV, Newbery and Pollitt, 97, p.291.

Table 4, then splits the overall gains from Table 3 between government, consumers and producers for our two counterfactual scenarios. Here we have to make assumptions about future consumer prices (in addition to assumptions about cost convergence which are in the overall analysis in Table 3). As the reader can see the analysis could assume faster or slower price convergence. In the Chinese case, prices have fallen substantially as a result of the 2015 reform (as we show in section 5) and we need to make an assumption about how fast the prices would have converged to their modelled level in the absence of reform. The table shows whether the overall social welfare is positive if non-equal social weights are used. In Newbery and Pollitt (1997) substantial benefits went to the companies (producers). If producer benefits are weighted less than one this can drive a positive benefit in Table 3 to a negative overall effect on social welfare. Shaded cells are for the numbers that need to be calculated.

Table 4: Distribution of Net Benefits of Reform for a Chinese province

Distribution of Net Benefits of Reform		*Counterfactual Scenario:*			
Discounted to 2012	*Social Weights*	*Pro-reform*		*Pro-no reform*	
CNY Billions		*6%*	*10%*	*6%*	*10%*
Total net benefits excl. externalities					
Case 1 prices converge by 2025					
Consumers	0.975				
Government via tax revenue	1				
Companies	0.5				
Social Welfare					
Case 1 prices converge by 2030					
Consumers	0.975				
Government via tax revenue	1				
Companies	0.5				
Social Welfare					

Based on Table V, Newbery and Pollitt, 97, p.295.

Domah and Pollitt (2001, p.130) compared four separate reforms in the UK electricity system, showing that while the overall NPV gains were generally positive, there were significant differences in who received them. The nature of the reforms were different to the CEGB and to each other. The Northern Ireland Electricity (NIE) reform involved the break-up and privatization of an integrated monopoly over generation, transmission, distribution and retailing, with the creation of separate generation, and network/retail companies. The Scottish Electricity Supply Industry (SESI) reform saw two integrated generation, transmission, distribution and retailing monopolies remain largely intact following privatization. This seems to lead a costly reform, with little positive overall impact. The regional electricity companies (RECs) reform in England and Wales saw regional distribution and retailing companies privatized intact, but subjected to strict incentive regulation and with retailing gradually opened up to competition.

Lessons for China

The UK's electricity system in 1990 was very similar to a typical Chinese province at the start of 2015 in terms of its reliance on coal fired generation, state ownership and lack of market arrangements (see Pollitt, 2020). Since then its electricity system has been transformed by waves of electricity market reform, making it an important global laboratory for the study of power sector reform. Social cost benefit analysis of reform is a powerful tool for showing the overall effects of reform. It only requires data from the reformed power market being examined. Thus each Chinese province can undertake a separate social cost benefit analysis of the impact of its reform so far.

Note that these analyses only require a small number of years of post-reform actual data and some reasonable projection on what would happen into in the future (such as no further gains will be achieved, or convergence back to the counterfactual within 5, 10 or 15 years).

The data requirements are a reasonable estimate of revenue, cost and profits at the provincial level from electricity sales. In addition data on estimated electricity taxes and CO2 and SO2 emissions are needed to estimate the impact on the government and on externalities.

In China's case electricity demand is growing rapidly and unit prices would likely fall any way under a counterfactual, as system fixed network costs are spread over more units. This would be the most interesting part of the construction of the counterfactual and something which is discussed in Pollitt and Smith (2002) for the GB railway reform, where demand grew rapidly after reform leading to an expected lowering of unit costs in the counterfactual, where demand growth was assumed to be independent of reform.

Accounting information on costs, profits and revenue may be difficult to obtain at the provincial level. If so, revenue could be estimated from prices and unit sales. Profits could be estimated based on national rates of return for the grid and generation companies and provincial level assets. Government tax receipts can be estimated from VAT rates (and estimated sales) and by considering their likely profits/dividend shares from grid and generation companies. CO2 and SO2 emissions are available at the provincial level. There may be an impact of the reform on net imports of electricity, which may mean an externality impact related to the effects on air pollution in other provinces.

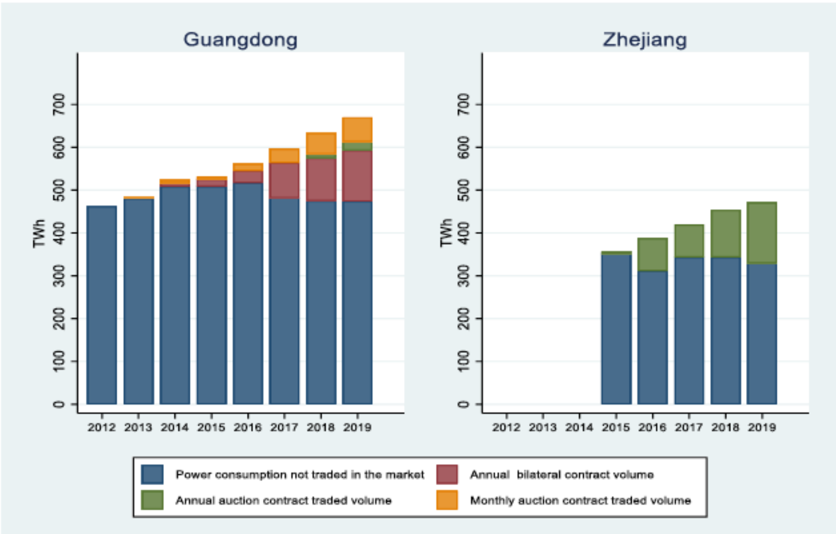
Section 5: The impact of electricity reforms in Guangdong and Zhejiang

Power sector reform in China has been about reducing initially high industrial electricity prices. While it might be difficult to get the accounting information required to do a full social cost benefit analysis in the way it has been done for the UK in the previous section, it is more straightforward to focus on the price effect and what has happened to power prices that final consumers have paid in individual provinces and to break down the sources of any price reduction. In this section we discuss how this can be done and what the results show for two selected provinces – Guangdong and Zhejiang - drawing on the work of Xie et al. (2020).

Xie et al. (2020) select one benchmark price (for 35kV one part tariff customers). They examine the evolution of the price from January 2012 to December 2019. They also look at the price for regulated and market customers. Then they examine the sources of the price changes in terms the component parts of the price. Thus price changes might be made up of changes in regulated generation prices, additional charges (e.g. for renewable support policies), VAT, the wholesale market prices (i.e. the impact of the power market) and the regulated network charge (as a residual). Their analysis attempts to weight each of these changes appropriately (e.g. VAT changes impact the overall consumer price differently depending on the size of the base price) and to weight the role of market in overall price changes given that the share of generation in the market changes over time. Individual price changes are published, albeit in multiple sources, over time. Thus focusing on price means that data is available.

Figure 2 shows the share of total sales that are in the market in the two provinces. Note that only a fraction of power is traded in the market and that with the rapid growth of demand, the amount of non-traded power is roughly constant.

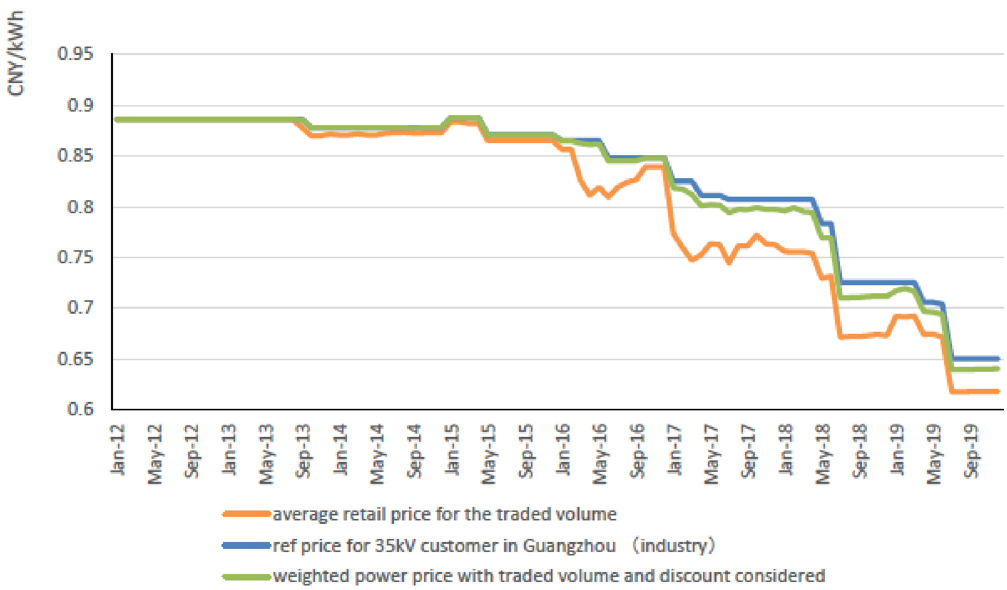
Figure 2: Size the market in Guangdong and Zhejiang



Source: Xie, Xu and Pollitt, 2020, p.9

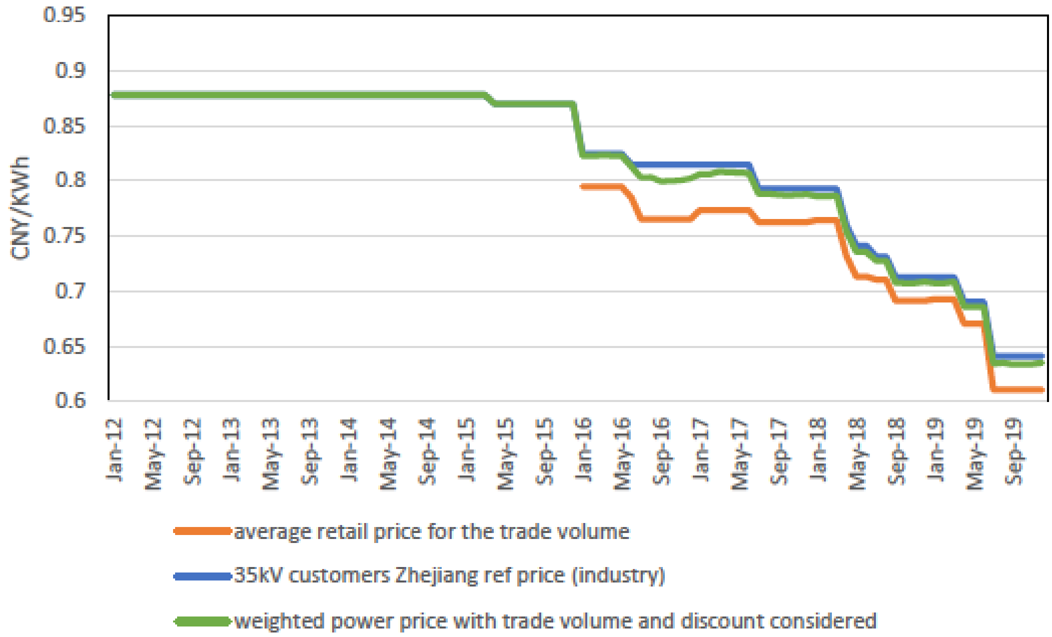
Figures 3 and 4 show that prices have fall spectacularly in nominal terms since 2012 in both of the provinces that are looked at. The real price fall, adjusting for inflation, would be even more impressive.

Figure 3: Price per kWh for benchmark 35kV+ industrial customer in Guangdong



Source: Xie, Xu and Pollitt, 2020, p.30.

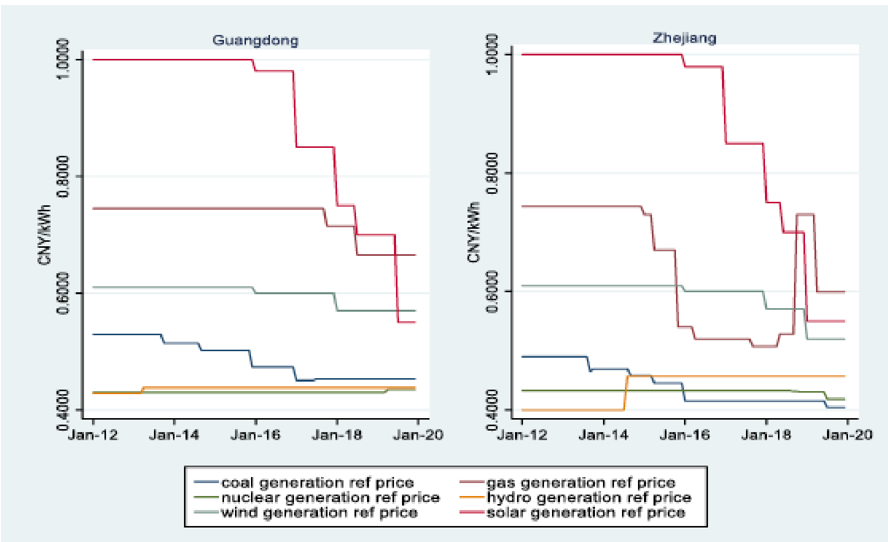
Figure 4: Price per kWh for benchmark 35kV+ industrial customer in Zhejiang



Source: Xie, Xu and Pollitt, 2020, p.33.

The Xie et al. (2020) analysis then looks at why the prices have fallen by examining the component parts of the price fall. Figure 5 shows a big decline in the regulated prices paid to generators.

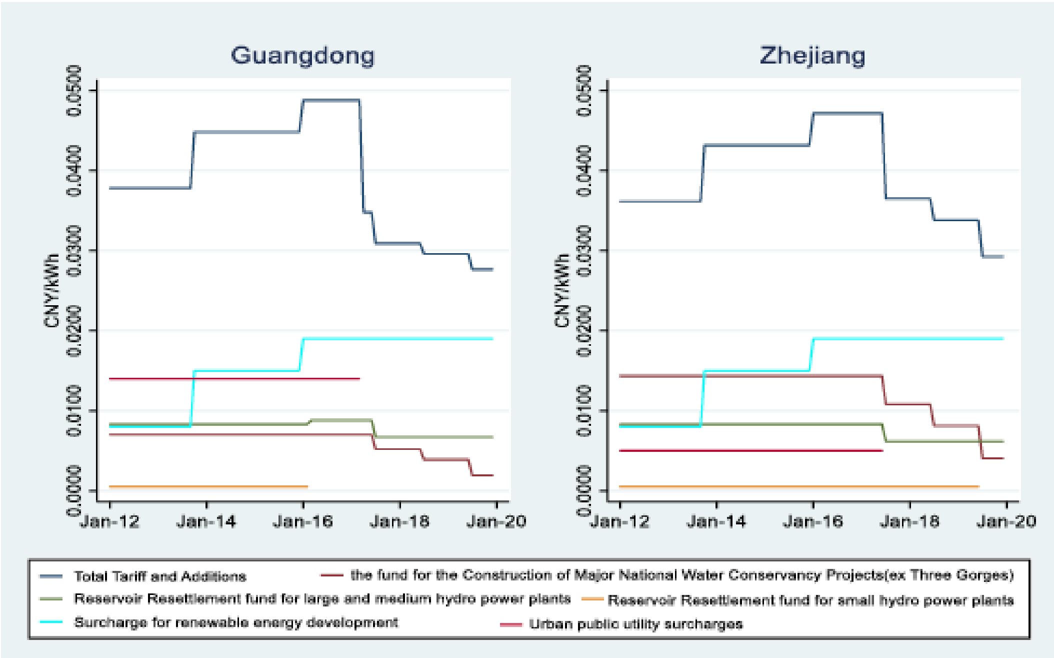
Figure 5: Monthly regulated generation prices with VAT included for different technologies in Guangdong and Zhejiang



Source: Xie, Xu and Pollitt, 2020, p.19.

Figure 6 shows that the additional charges which consumers paid within the price have also fallen.

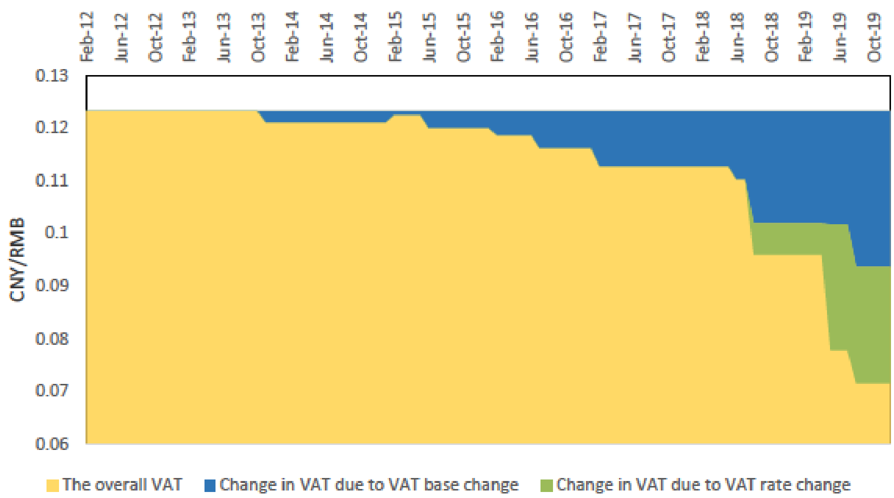
Figure 6: Monthly additions to base regulated retail price for 35kV+ customers in Guangdong and Zhejiang



Source: Xie, Xu and Pollitt, 2020, p.23.

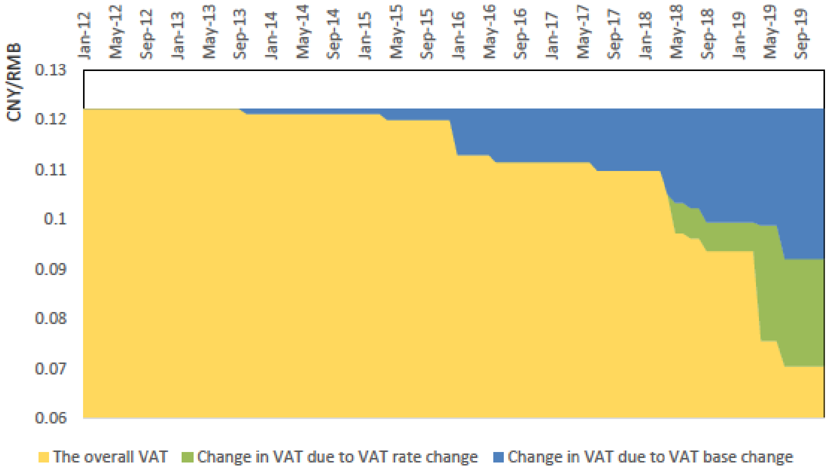
There have been major falls in the unit price contribution of VAT shown in figures 7 and 8. This is because both the VAT rate and the base price on which VAT is calculated have fallen over the period.

Figure 7: The sources of electricity VAT changes in Guangdong for 35kV+ customers per kWh



Source: Xie, Xu and Pollitt, 2020, p.26.

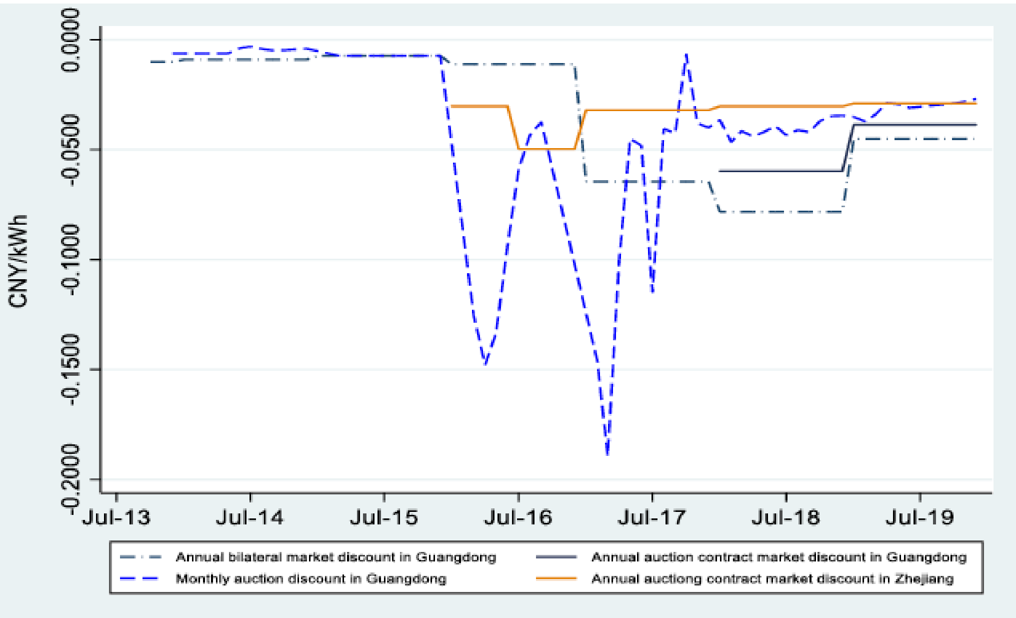
Figure 8: The sources of electricity VAT changes in Zhejiang for 35kV+ customers per kWh



Source: Xie, Xu and Pollitt, 2020, p.26.

Finally, figure 9 shows that the power markets have delivered a positive price reduction for final consumers, though this is less than the other elements we have looked at so far.

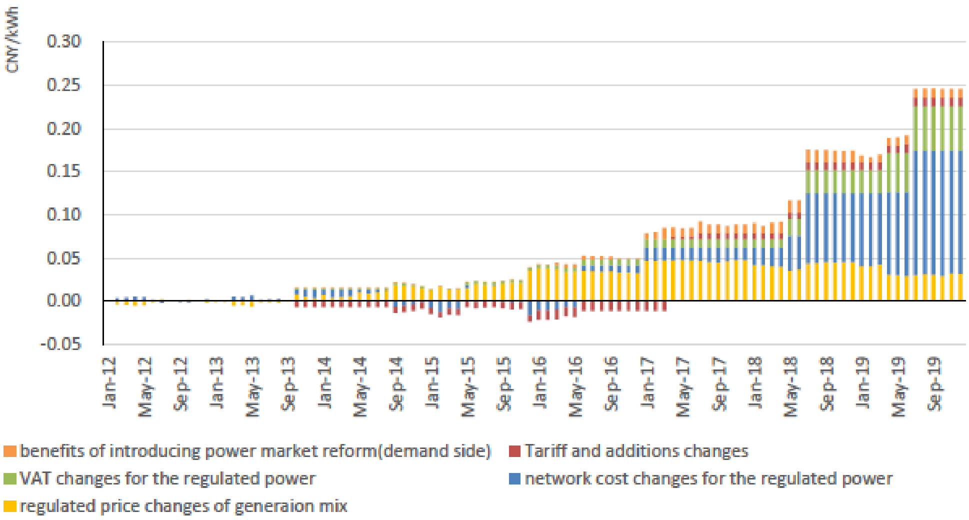
Figure 9: Monthly and annual wholesale market discounts per kWh in Guangdong and Zhejiang for generators



Source: Xie, Xu and Pollitt, 2020, p.28.

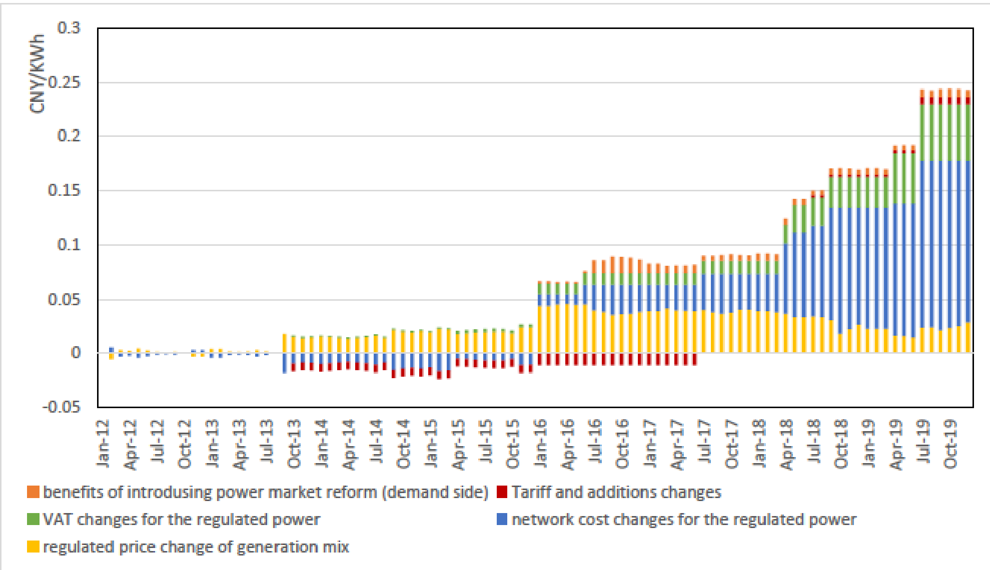
Figures 10 and 11 breakdown the overall price fall. They show that the network charge reduction (the residual) is the biggest contributor to the price fall, followed by falls in VAT, regulated generation price and additional charges. The power market makes a positive but small overall contribution.

Figure 10: Sources of price changes for 35kV+ industrial customers in Guangdong



Source: Xie, Xu and Pollitt, 2020, p.39.

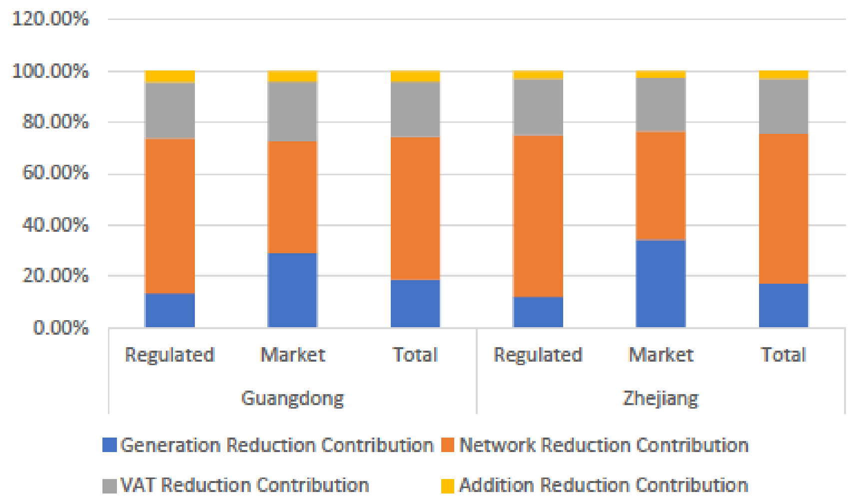
Figure 11: Sources of price changes for 35kV+ industrial customers in Zhejiang



Source: Xie et al., 2020, p.40

Figure 12 shows percentage contributions to price reductions from generation costs, network costs, VAT and additional charges, for the regulated price and for the market price (where generation charges are additionally reduced by the market).

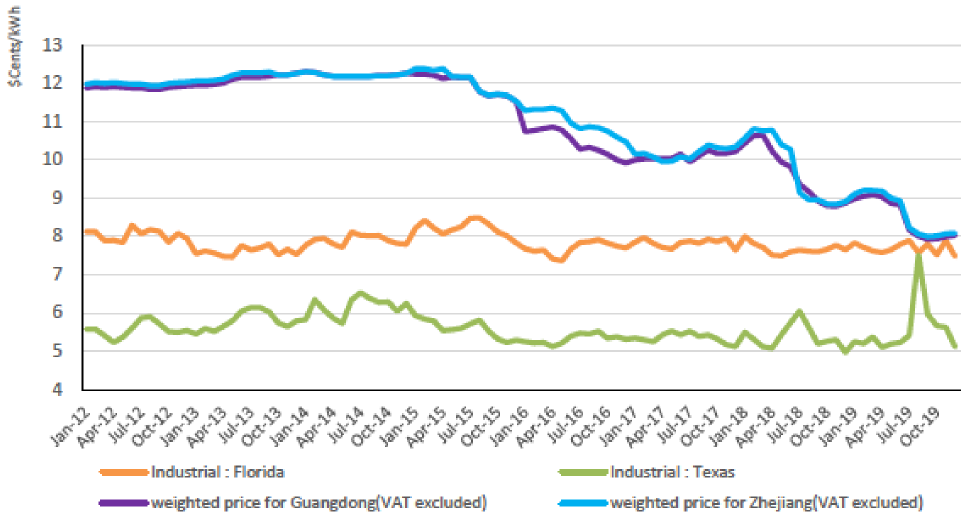
Figure 12: The contributions to price reduction over the period 2012-2019 in Guangdong and Zhejiang for market, regulated and average 35kV customers



Source: Xie et al., 2020, p.41

In terms of the high level objective of the PSR to reduce the industrial price of electricity. This has been significantly achieved with an impressive convergence towards US prices, as seen in Figure 13.

Figure 13: The monthly final average industrial price of electricity in Texas and Florida compared to the 35kV+ industrial customer prices in Guangdong and Zhejiang



Source: Xie, Xu and Pollitt, 2020, p.44.

Overall, Xie et al. (2020) find that the regulated price (relative to Jan 2012) for their benchmark customer falls substantially: by 26.6% in Guangdong and in 27.0% Zhejiang. The market price falls further (relative to Jan 2012): by 30.2% in Guangdong and 30.4% in Zhejiang. The weighted price (consisting of the weighted market and regulated price) falls 27.7% in both provinces.

This sort of analysis shows, very clearly, one important aspect of the reform: the extent to which prices have fallen. It also suggests that market reform in China is not just about the direct impact of the wholesale power market but about associated changes to regulation, particularly of network charges (which was what was driving the benefits of the restructuring of the regional electricity companies in England and Wales in the previous section). Doing this for each reforming province would seem to be essential.

Thinking about sections 4 and 5 together, it would be important to try and separate out how much of the price fall observed in section 5 is due to PSR related policies and how much would have formed part of a reasonable counterfactual. Such a counterfactual would look at the effect of continuing unit sales growth on unit network costs and any impacts from fuel price changes (or indeed changes in the generation mix) on electricity generation costs. It would also remove VAT changes as being due to PSR, as this is a tax policy, and should not be part of a social cost benefit analysis. It might also analyse the extent to which benefits for consumers have come at the expense of producers accepting lower rates of return.

Thus, for China and its provinces the overall societal benefit of PSR and its distribution between customers, the government and producers remains to be assessed by a proper SCBA.

Section 6: Observations on market monitoring from around the World

A key part of measuring the impact of power sector reform is the regular monitoring of market performance by either the regulator or the system operator.

There are some excellent examples of annual reports that do this well. These include the State of the Energy Market Report from Ofgem, State of the Energy Market Report from the Australian Energy Regulator (AER), State of the Markets Report from the US Federal Energy Regulatory Commission (FERC), and the independent State of the Market Report for PJM (in two volumes for 2020: Vol.1, 84 pages and Vol.2, 672 pages).

We over a few highlights of useful indicators from this reports.

Ofgem (2019) has data on the profitability of generators and suppliers (profit margin by generator/supplier)[8], price trends (price per kWh for different customer categories)[9] and an international comparison of ancillary services costs (Germany vs UK uplift charge per MWh)[10]. These variously highlight the need to monitor the reasonableness of company profitability, the actual trend in prices and the benchmarking of hard to interpret prices against other jurisdictions.

AER (2020) includes generation investment monitoring (MW entry and exit by technology)[11], comparison of market concentration (average HHI per 5 mins)[12] and the presence of pivotal electricity generators (percentage of time 1, 2 and 3 generators were pivotal)[13]. This

[8] Ofgem (2019, p.78).
[9] Ofgem (2019, p.63).
[10] Ofgem (2019, p.79).
[11] AER (2020, p.30).
[12] AER (2020, p.109).
[13] AER (2020, p.109).

highlights a particular concern in the Australian National Electricity Market (NEM) about the strategic closure of certain generator plants which then created capacity scarcity driving up prices.

FERC (2020) has a price heat map (with wholesale electricity prices per MWh)[14] and price monitoring (price per MWh per regional transmission organization (RTO) area)[15]. This short report from FERC nicely illustrates the value of visually comparing regional market outcomes across the US.

Monitoring Analytics (2021a,b) is a comprehensive report on PJM which includes an annual market assessment of each of the markets which comprise PJM (energy, capacity, reserve markets, frequency regulation and financial transmission rights)[16] and annual prices (per MWh for each market)[17]. This report, by the appointed independent market monitor for PJM, is particularly impressive because it includes an independent assessment of PJM's individual markets. Individual markets are assessed as being competitive, partially competitive or not competitive and their market design is assessed as being effective, mixed or flawed. Within each market a competitive assessment is made of aggregate market structure, local market structure, participant behaviour and market performance. This independently produced report is the benchmark for market monitoring globally.

Lessons for China

Regular market reporting and assessment is limited for most Chinese markets. While individual power exchanges do produce useful monthly market reports, these are not accessible to non-market participants, which all of the reports discussed above are. It is also very difficult to construct a price series for individual customer types by province. Xie et al., 2020, demonstrate what a large amount of work this is for just two provinces and one benchmark customer price.

The State Electricity Regulatory Commission (SERC) produced an Electricity Regulatory Annual Report from 2006 to 2011[18]. It also published the Statute on Formulation and Publication of Electricity Regulatory Annual Report in 2007[19]. This drew on leading reform countries' experience and was deemed as a powerful regulatory policy tool (Tan et al., 2016). However the SERC has now ceased to exist and this form of annual reporting has stopped. Its successor, the National Energy Administration (NEA) publishes special reports on different topics. One of the most significant reports is the electricity price regulatory report series covering 2013-2018[20]. These reports publish detailed provincial data on average generation prices of different fuel sources, transmission losses, network charges, retail prices and additions. This serves as a starting point for measuring the price impact of reform.

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[14] FERC (2020, p.6).
[15] FERC (2020, p.8).
[16] Monitoring Analytics (2021a, p.7, 8, 9, 10).
[17] Monitoring Analytics (2021a, p.17).
[18] 电力监管年度报告 http://www.gov.cn/gzdt/2012-06/27/content_2171508.htm
[19] 电力监管报告编制发布规定 http://www.gov.cn/gongbao/content/2008/content_892227.htm
[20] http://zfxxgk.nea.gov.cn/index.htm. Search keywords *Regulatory Report* in the search box on that webpage.

The NEA and individual power exchanges should consider producing an annual State of the Market Report (building on the SERC experience). The provincial system operator should pay attention to the sort of reporting seen by PJM, which concentrates on the performance of markets related to its own system. The NEA should look at the regulatory reports and produce higher level commentary on overall competitiveness and final price impacts (drawing on the experience of Ofgem, AER and FERC).

Improving the quality of market monitoring in China requires attention to both the training and resourcing of the regulatory agencies (which include the NEA and the National Development and Reform Commission, NDRC), especially relative to well-resourced electricity companies. A distinctive characteristic of regulatory agencies with superior quality reporting and transparency is that they are well resourced, with a sufficiently large number of employees with the appropriate qualifications (see Pollitt and Stern, 2011, for a discussion).

A key aspect of improved reporting in China would be to highlight the negative consequences of anti-competitive mergers within the electricity sector. Where such mergers involve state owned companies (such as those directly owned by the State-owned Assets Supervision and Administration Commission (SASAC)) regulatory monitoring would discourage mergers on narrowly fiscal grounds (to improve the government balance sheet) and encourage appropriate asset reorganization or market mitigation measures. Transparent market monitoring by regulatory agencies helps reduce internal policy conflicts within government where industrial policy competes (often unsuccessfully) with competition policy.

Section 7: Concluding thoughts

This paper has sought to discuss how progress with power sector reform (PSR) ought to be reported and measured at the individual provincial level.

There are many examples of good practice in this area, from around the world, which provide useful templates for China to follow.

We began by looking at how reform impacts have been evaluated previously. One important conclusion is that in market economies individual electricity market reform elements can be expected to have a small net effect and hence that it is important to measure these carefully. We, then discussed the sorts of measures by which the EU single electricity market – comparable to the Chinese national electricity market in scope - has been evaluated. Next we detailed how a social cost benefit analysis of reform can be conducted, drawing on case studies from the UK.

We then showed how the effects of PSR on industrial electricity prices has been measured for Guangdong and Zhejiang. The effects of the 2015 PSR look substantial and much larger than the impacts in market economies, indicating that there are multiple elements to Chinese power sector reform, the most significant of which appears to be the reduction of regulated generation prices and network charges, within a largely state owned industry.

However, more detailed analysis is required to establish the extent to which this large price fall is due to the natural effect of the increasing scale of the Chinese electricity sector or the reduction of government revenues from the power sector. Even if the actual overall PSR effect in China is large, as suggested by simulation studies, it is important to separate out the impact of individual reform elements, such as the introduction of wholesale power markets.

We discussed how detailed price measurements can be combined with elements of the social cost benefit analysis (SCBA) approach to develop better measures of actual reform impact. We then suggested how provincial and national level annual reporting on the state of electricity markets might be improved, drawing on examples of best practice from around the world. Proper reporting can ensure sustained benefits from PSR and appropriate regulatory learning from a process that is constantly evolving in the light of new information.

China’s PSR is a massive and worthy undertaking with global consequences. It deserves careful attention to its measurement.

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