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Pricing decisions and market power in the uk electricity market: A VECM approach☆

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ABSTRACT

This paper examines the influence of market power in the formation of retail and wholesale electricity prices in the UK over 1998–2012 on the basis of Vector Error Correction model (VECM). Market power is measured as the influence of the market share of the Big Six in a dynamic demand and supply VECM. The findings indicate that market power of the Big Six in the wholesale industry has a significant and large positive influence on the wholesale mark-up in the short-run. The long-run estimates support the arguments about 'revenue rebalancing' resulting from vertical integration. That is, low market power (and hence low revenues) in the wholesale industry leads to higher prices (hence higher revenues) in the retail industry. These findings are in contrast to the CMA's finding that no market power is exercised in the wholesale industry. Retail electricity prices are affected directly by both the wholesale and retail market concentration ratios in the long-run rather than indirectly through the wholesale mark-up. Overall, the findings in this paper provide support for the view that the UK electricity market exhibits significant anti-competitive conduct in both the retail and wholesale segments.

1. Introduction

The UK electricity market has gone through substantial changes since the late 1980s involving privatisation, changes in the wholesale market from the Pool to the NETA, introduction of retail competition and deregulation of prices for end users (Waddams-Price, 2005). While wholesale prices declined in the earlier years partly because of falling gas prices (Newbery and Pollitt, 1997), these gains could not be maintained in the long term. High prices in wholesale markets under the Pool led to the adoption of a bilateral contract system with the introduction of the NETA in 2001. However, this reform failed to deliver the low and stable prices that would be expected from a competitive market (Woo et al., 2003).

In more recent years there have been concerns about retail price increases, which instigated a probe in 2008 by Ofgem leading to a set of recommendations (Ofgem, 2013a). Despite these, the reported revenues, costs and profits of the large energy companies (British Gas, EDF Energy, E.ON UK, NPower, Scottish Power and SSE – collectively referred to as "The Big Six" continued to rise. Ofgem (2013b) showed that the earnings before interest and tax in the domestic supply market increased by 74.7% from 2011 to 2012. On the other hand, the wholesale electricity cost for the average household customer only saw a 2.3% increase in the same period (Ofgem, 2013c), suggesting that retail prices increased with a significantly greater pace than wholesale prices. The Big Six justified this on the grounds of rising in input (fuel) costs and investment requirements.

In March 2014 Ofgem referred the energy markets to the Competition and Market Authority (CMA). This investigation identified a number of areas in the supply of retail electricity and gas where the real problems lie. Firstly, the lack of switching or what is termed as 'weak customer engagement' is highlighted as the most significant shortcoming, giving the Big 6 a position to have unilateral market power. Secondly, the reforms introduced by Ofgem after 2011 are claimed to have weakened the competition in the sector. Thirdly, limited use of smart meters and lack of a settlement system based on more frequent readings, are considered to have adverse effects on competition in the sector. Finally, the existing financial reporting systems in the energy sector as a whole are found to be non-transparent, constraining decision making by regulators and policy-makers. The possibility of tacit coordination amongst suppliers is ruled out on the basis of lack of evidence. The profitability in the wholesale energy markets is not found to be a problem (CMA, 2016). A critical assessment of these findings from a policy perspective can be found in Amountzias et al. (2017).

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Consumer inertia is indeed an issue that emerges in several studies on retail electricity markets. For example, Giulietti et al. (2005) argue that an important source of market power acquisition in the retail industry relates to the significance of consumers' decisions regarding switching suppliers. Lack of switching enhances the incumbent firms' market power, and this is reflected in their prices. Among the studies that acknowledge and support this view are Defeuilley (2009), Waddams-Price (2004) or Waddams Price and Wilson (2007).

Market structure is another major issue that has been explored by a multitude of researchers. Writing before any NETA effects could be observed, Macatangay (2001) offers a number of ways in which providers could abuse the framework and acquire greater marker power. The definition of market power in the electricity market is not necessarily the same across different studies. Karthikeyan et al. (2013) provide a comprehensive review of the various methodologies that have been used for studying market power. In an assessment of NETA, Giulietti et al. (2010b) provide empirical evidence showing that, rather than improving the competitiveness of the market, the shift to NETA '…*merely rearranged where money was made in the system*' (p.1165). The data they provide are consistent with Toke's theoretical argument that no drastic changes should be expected by the reforms in the electricity market (Toke, 2011).

This paper estimates the impact of market power on pricing decisions in the wholesale and retail segments of the UK electricity industry, employing a Vector Error Correction Model (VECM) of demand and supply over 1998–2012. The paper is organised as follows: Section 2 provides a discussion of the existing literature on the subject matter. Section 3 describes the model, the assumptions and the methodology we use to study pricing decisions in the retail and wholesale electricity sector in relation to the suppliers' market power. Section 4 presents and discusses the results and Section 5 concludes by focusing on the policy implications of our findings.

2. Market power in the UK electricity industry

There is a consensus that market power was a major issue in the UK power market in the years following the privatisation and the implementation of the Pool. For example, Sweeting, (2001, 2007) compares the actual Pool prices with the estimated competitive prices and provides evidence of coordinated, tacit collusion by the generators in the second half of the 1990s. This claim is supported by a number of studies that arrive at the same conclusion using different methodologies (for instance, Wolfram, 1999, or Bunn and Martoccia, 2005). Green (2006) offers a comprehensive review of the problem of market power in the UK electricity industry from the privatisation and until the end of the Pool.

Generally, the literature on the UK power market has mainly considered three different factors in the analysis of prices:

a) prices of incumbents in comparison to other suppliers operating in the same area,
b) firm level or industry level price-cost margins
c) competitive pressure from the demand side; i.e. switching customers.

For example, Salies and Waddams-Price (2004) show that the incumbents charged between 4–13% more for credit and direct debit customers, despite the fact that they faced greater level of competition for these customers from the non-incumbents than for pre-paying customers. The difference for credit and direct debit customers is explained on the basis of the reluctance of some customers to switch to another supplier even if there are considerable gains. The pre-payment services, on the other hand, are more costly and subsidised, and the incumbents with larger market share are in better position to maintain these subsidies. Giulietti et al. (2010b) report similar findings about persistent advantage of the incumbents that allowed them to mark up prices by about 10% in comparison to non-incumbents, largely because of search costs.

Moreover, Salies (2008) tests the response of real tariffs to supply factors in the UK electricity industry over January 2004. Such factors refer to distribution and transmission costs, consumer density and the length of low voltage underground circuit. The model investigates the effect of ownership group through dummies on simulated electricity retail bills to capture the effect of market power through vertical integration. The findings suggest that the retail price of integrated suppliers vary according to the nature of integrated networks. Nevertheless, there is a significant negative effect on the price level when there is a change in the number of costumers and a positive effect of charges in rural areas.

Other studies indicate that the increases in retail prices might be reflecting a rebalancing of revenues, costs and profits across highly integrated retail and wholesale activities. For example, Ofgem (2013d) hints at the possibility that the rising bills might be a way for the suppliers to make up for the quite dramatic decrease of the average margin (by about 50%) from 2011 to 2012 in the non-domestic market. Giulietti et al. (2010b) use price-cost margins to trace the developments in the pricing strategies of electricity companies. Their findings suggest that the shift to the bilateral contract system brought about the intended benefits of lower prices in the wholesale electricity market, but the decline in wholesale prices have been counterbalanced by rising retail prices and profit margins.

Research into retail electricity prices does not support the claim that increases in prices are solely accounted by cost factors. Instead, supply side factors, market domination and power might be considered to explain the price increases, along with a number of demand side factors (Otero and Waddams-Price, 2001). Despite the domination of the Big Six, the market has seen periods of entry and exits. For example, there was a phase when initial entrants into the retail market either exited or merged with other companies and as a result the share of the Big Six suppliers rose to 99% of the demand (Giulietti et al., 2010a). Other researchers viewed the growing tendency for vertical integration (or physical hedging) in the sector as a risk management strategy in an environment in which demand risks are high and there are limits to other potential hedging strategies (Finon and Boroumand, 2011). Interestingly, in the last few years, entry in the power sector has been growing again largely because of exemptions provided by the government although the share of the Big 6 still remains high (around 90%) (CMA, 2016).

More recent work by Boroumand (2015) concludes that retail competition is not satisfactory in the UK electricity industry because of its multimarket setting. This setting, in conjunction with vertical integration, promotes oligopolistic profits for the retail firms by utilising parallel pricing strategies. The author juxtaposes his analysis of the UK market with Norway's electricity industry which he uses as a benchmark for being very fragmented (about 150 suppliers in 2008) and much less concentrated than the UK (the largest 6 suppliers only account for 45–50% of the market share). Despite the example of Norway, it appears that market power in the electricity industry is a problem in most developed countries. Olsen et al. (2006) argue that the Swedish and Finnish retail markets are not performing as well as Norway's, mainly because of weak consumer engagement and market structure. With regards to EU countries, a report by the ECME Consortium (2010) asserts that there is limited price competition in the EU-27 countries (based on consumers' ratings in these countries) and finds that Germany, Finland and the Netherlands are the member states with the highest level of price competition, and to a lesser extent Austria, Belgium, Ireland, Sweden and the UK. In Spain, the regulations that were introduced in 2006 in an attempt to mitigate the market power of the two main electricity producers (Endesa and Iberdrola) were only partly successful (Moutinho et al., 2014). Karthikeyan et al. (2013) include a review of market power in the electricity industry across a selection of countries.

In terms of methodology, a wide range of techniques such as the Herfindahl Index, market share analysis, price cost margins and econometric models have been used in the literature to investigate absence or presence of market power. A detailed review of the studies on market power with reference to the electricity industry can be found in Twomey et al. (2005) and Karthikeyan et al. (2013).

3. Method of estimation and data

Many contributions in the empirical literature on the energy industry employ a system of interdependent equations to identify the presence of causal relationship amongst various market variables (Salies and Waddams-Price, 2003, 2004; Apergis and Payne, 2009).[1] Given the presence of non-stationarity in the time series of the sample, the VECM of this study takes into account the vertical integration of the wholesale and the retail electricity industry as a dynamic demand and supply system. In order to construct this system, stationarity must be satisfied by all the constituent time series (Granger and Newbold, 1974), as non-stationary series would result in incorrect estimates of the standard errors. For this reason, the Augmented Dickey-Fuller (Dickey and Fuller, 1981) and the Phillips-Perron (Phillips and Perron, 1988) unit root tests are used to identify the order of integration in the time series.

As is also discussed in Section 4, the ADF test shows that four out of six series are $I(1)$ except for the market power indicators (see Table 1). Following the Engle and Granger (1987) principle that a linear transformation of two or more non-stationary series with the same integration order may be stationary, we use the procedure developed by Johansen and Juselius (1992) to identify the order of cointegration in the VECM of the wholesale and the retail electricity industry.

Given the presence of cointegration in our data, we use stationary time series to formulate a dynamic demand and supply VECM of the following form

$$\Delta pr_t = \sum_{i=1}^{k} a_{11i}\Delta pr_{t-i} + \sum_{i=1}^{k} a_{12i}\Delta fc_{t-i} + \sum_{i=1}^{k} a_{13i}\Delta mw_{t-i} + \sum_{i=1}^{k} a_{14i}\Delta eg_{t-i} + \sum_{i=1}^{k} a_{15i}\Delta cr_{t-i} + \sum_{i=1}^{k} a_{16i}\Delta cw_{t-i} - s_{11}ECM_{1,t-1} - s_{12}ECM_{2,t-1} + \varepsilon_{1t} \quad (1)$$

$$\Delta fc_t = \sum_{i=1}^{k} a_{21i}\Delta pr_{t-i} + \sum_{i=1}^{k} a_{22i}\Delta fc_{t-i} + \sum_{i=1}^{k} a_{23i}\Delta mw_{t-i} + \sum_{i=1}^{k} a_{24i}\Delta eg_{t-i} + \sum_{i=1}^{k} a_{25i}\Delta cr_{t-i} + \sum_{i=1}^{k} a_{26i}\Delta cw_{t-i} - s_{21}ECM_{1,t-1} - s_{22}ECM_{2,t-1} + \varepsilon_{2t} \quad (2)$$

$$\Delta mw_t = \sum_{i=1}^{k} a_{31i}\Delta pr_{t-i} + \sum_{i=1}^{k} a_{32i}\Delta fc_{t-i} + \sum_{i=1}^{k} a_{33i}\Delta mw_{t-i} + \sum_{i=1}^{k} a_{34i}\Delta eg_{t-i} + \sum_{i=1}^{k} a_{35i}\Delta cr_{t-i} + \sum_{i=1}^{k} a_{36i}\Delta cw_{t-i} - s_{31}ECM_{1,t-1} - s_{32}ECM_{2,t-1} + \varepsilon_{3t} \quad (3)$$

$$\Delta eg_t = \sum_{i=1}^{k} a_{41i}\Delta pr_{t-i} + \sum_{i=1}^{k} a_{42i}\Delta fc_{t-i} + \sum_{i=1}^{k} a_{43i}\Delta mw_{t-i} + \sum_{i=1}^{k} a_{44i}\Delta eg_{t-i} + \sum_{i=1}^{k} a_{45i}\Delta cr_{t-i} + \sum_{i=1}^{k} a_{46i}\Delta cw_{t-i} - s_{41}ECM_{1,t-1} - s_{42}ECM_{2,t-1} + \varepsilon_{4t} \quad (4)$$

[1] In particular, Salies and Waddams-Price (2003, 2004) employed a SURE model to simultaneously capture the interactions of two payment methods, while Apergis and Payne (2009) used a panel Vector Error Correction Model.

Table 1
Unit root tests.

Variables	ADF		PP	
Services				
pr	−2.431	[0.3601]	−2.127	[0.5199]
Δ*pr*	−4.118*	[0.0103]	−4.230**	[0.0076]
fc	−0.820	[0.9566]	−6.569**	[0.0000]
Δ*fc*	−5.851**	[0.0001]	−21.72**	[0.0001]
mw	−2.991	[0.4175]	−2.749	[0.2217]
Δ*mw*	−3.753*	[0.0275]	−13.47**	[0.0000]
eg	−0.605	[0.9743]	−6.635**	[0.0000]
Δ*eg*	−5.644**	[0.0001]	−22.28**	[0.0001]
cr	−3.907**	[0.0001]	−6.331**	[0.0000]
Δ*cr*	−4.279**	[0.0071]	−14.16**	[0.0000]
cw	−4.945**	[0.0010]	−5.885**	[0.0000]
Δ*cw*	−4.597**	[0.0000]	−14.98**	[0.0000]

Notes: ADF refers to the Augmented Dickey Fuller test (Dickey and Fuller, 1979). PP is the Phillips-Perron test (Phillips and Perron, 1988). The hypotheses of both tests assume that H_0: Non-stationary series (presence of unit root) versus H_1: Stationary series. The time series include a trend and intercept.
The calculated statistics correspond to the ones reported in Dickey and Fuller (1981). The unit root tests have been conducted according to the indications of the Schwarz Information Criteria (Schwarz, 1978).
The numbers in brackets indicate *p-values*.
* Significant at the 5% level of significance.
** Significant at the 1% level of significance.

$$\Delta cr_t = \sum_{i=1}^{k} a_{51i}\Delta pr_{t-i} + \sum_{i=1}^{k} a_{52i}\Delta fc_{t-i} + \sum_{i=1}^{k} a_{53i}\Delta mw_{t-i} + \sum_{i=1}^{k} a_{54i}\Delta eg_{t-i} + \sum_{i=1}^{k} a_{55i}\Delta cr_{t-i} + \sum_{i=1}^{k} a_{56i}\Delta cw_{t-i} - s_{51}ECM_{1,t-1} - s_{52}ECM_{2,t-1} + \varepsilon_{5t} \quad (5)$$

$$\Delta cw_t = \sum_{i=1}^{k} a_{61i}\Delta pr_{t-i} + \sum_{i=1}^{k} a_{62i}\Delta fc_{t-i} + \sum_{i=1}^{k} a_{63i}\Delta mw_{t-i} + \sum_{i=1}^{k} a_{64i}\Delta eg_{t-i} + \sum_{i=1}^{k} a_{65i}\Delta cr_{t-i} + \sum_{i=1}^{k} a_{66i}\Delta cw_{t-i} - s_{61}ECM_{1,t-1} - s_{62}ECM_{2,t-1} + \varepsilon_{6t} \quad (6)$$

$$ECM_{1,t-1} = pr_{t-1} - b_{11}mw_{t-1} - b_{12}eg_{t-1} - b_{13}cr_{t-1} - b_{14}cw_{t-1} - c_1 \quad (7a)$$

$$ECM_{2,t-1} = fc_{t-1} - b_{21}mw_{t-1} - b_{22}eg_{t-1} - b_{23}cr_{t-1} - b_{24}cw_{t-1} - c_2 \quad (7b)$$

Note that these equations will not reveal much about the consequences of multimarket structure, except for the retail and wholesale segments of the electricity market. They indicate very little about how the regional division of supply and how the interactions and relative market positions of incumbents and other suppliers (some of which themselves are incumbents in other regions) are reflected onto prices. Instead, the estimations will reflect the influence of selected variables at aggregate price levels.

The variables are expressed in logarithmic forms and the notations are as follows: *pr* is the aggregate retail price index of industries and households, *fc* is the final consumption index of electricity supplied by the retail industry, *mw* is the wholesale price markup over the fuel cost of oil, natural gas and coal, *eg* is the electricity generated by the wholesale industry, *cr* and *cw* are the market share of the biggest generators and suppliers in the retail and wholesale industry respectively, and ε_{it} are *i.i.d.* random error terms that are assumed to account for all the non-systematic and non-measurable influences. Under perfect competition with instantaneous price adjustments, the price level would be equal to the cost of inputs and thus, the price-cost margin would be equal to unity. As the energy sector has an oligopolistic market structure, it is worth investigating how the cost of inputs and market concentration influence the pricing decisions of the wholesale and retail electricity industry.[2] The VECM employed here captures the disequilibrium and incorporates the most important market factors in the pricing decisions of the industries. In particular, the constituent equations capture the relationship between the UK electricity prices, demand and supply variables and the degree of market power in the both industries. The theoretical interpretation of these equations reflects that industrial prices are expressed as markups over input costs and market power.

Eqs. (1)–(6) correspond to the components of the VECM for the wholesale and the retail electricity industry. The coefficients a_{ji} are constants that represent a short-run relationship with the dependent variable and s_{ji} denote the speed of price adjustment of each equation to equilibrium. Equations for $ECM_{i,t-1}$ and $ECM_{i,t-2}$ are the cointegrating equations which enter the VECM. Finally, b_{ji} are coefficients of the long-run relationships, with the $b_{j0}'s$ which are normalized to one.

The final step of the estimation process employs the Granger causality test in order to identify short-run causal effects running from the independent to the dependent variables of the system. It is a simple and straightforward test which can detect the presence of a causal relationship between two variables y and x. Time series y is Granger-causing time series x when there is joint significance of the lagged values of y on x. As in Johansen's test, this test can only be applied on stationary variables in order to avoid inefficient results, as proposed by Granger and Newbold (1974).

The empirical study employs time series quarterly data for the UK wholesale and retail electricity industry over the period 1998Q1-2012Q2. The observations of the price and fuel cost variables have been obtained from the Ofgem database. Price indices use 2005Q3 as the base quarter. It is worth noting that the aggregate retail price index also includes distribution and transmission charges. Unlike Salies and Waddams-Price (2004), these measures are not included in the system as explanatory variables due to the limitations of observations and the significance of the concentration ratios. Thereby, part of the fluctuations of the retail price index in the VECM may remain unexplained. The variables of electricity generation and consumption have been obtained from the DECC historical electricity database. Electricity generation and consumption are expressed in terawatt hours (TW h). The observations would naturally lead to more accurate results if the time interval was on hourly or basis; but while this would have been possible for the wholesale industry as the *Ofgem* database provides hourly price and generation data, such observations are not available for the retail industry as prices are not set on a daily basis.

4. Empirical results and findings

The results of the unit root tests for the constituent time series are presented in Table 1 and show that all variables are $I(1)$ with the exception of cr and cw which are stationary in level. Hence, the Johansen's (Johansen and Juselius, 1992) test is employed in order to test the presence and order of cointegration for the wholesale and retail electricity industry over the sample period.[3] The results are presented in Table 2 and they suggest that two cointegrating equations emerge. Consequently, the VECM for the retail and wholesale electricity industry exhibits two equilibria where the retail price and final consumption level are used as dependent variables. This means that by including the selected variables in first differences in a VECM framework will enable to examine the presence of long-run and short-run relationship amongst the constituent variables.

The VECM reflects the long and short-run effects on the pricing decisions of the wholesale and the retail industry respectively. Given that the wholesale industry provides the input of the retail industry, effect of vertical integration can be captured by a system of this form. In addition, pricing decisions are affected by production decisions and thus, market concentration of the biggest firms in the industry could significantly contribute to fluctuations in the price level both in the long-run and in the short-run.[4] For this reason, any possible form of endogeneity emerging from the explanatory variables is taken into account across Eqs. (1)–(6).

Table 2
Johansen and Juselius cointegration test.

No. of Cointegrating equation (s)	Eigen value	Trace	Critical Value (Trace)	Max-Eigen Statistic	Critical Value (Max-Eigen Statistic)
$r = 0$	0.7089	173.216** [0.0000]	125.75	106.77** [0.0071]	80.075
$r \leq 1$	0.3272	74.512* [0.0281]	70.893	40.822* [0.0323]	37.827
$r \leq 2$	0.1506	33.778 [0.2251]	51.133	20.303 [0.1766]	29.348

Notes: The Trace statistic and the Max-Eigen statistic are calculated including an intercept and a linear trend. Given the finite sample size of the data set, the trace statistics have been calculated according to the indications of Cheung and Lai (1993). The numbers in brackets indicate *p-values*.
* Significant at the 5% level of significance.
** Significant at the 1% level of significance.

The VECM is estimated in a two-stage procedure similar to the single error correction model estimation as proposed by Kremers et al. (1992). The estimates obtained by this process correspond to the long-run and short-run effects of the explanatory variables on the dependent variables. In particular, Table 3 presents the long-run relationship identified by the cointegrating Eqs. (7a) and (7b).

The most interesting result in the first cointegrating equation is that the retail prices are affected positively by concentration in the retail market but negatively by concentration in the wholesale market in the long-run. These effects are statistically significant. This finding provides support for the previously mentioned arguments about 'revenue rebalancing' in vertically integrated industries. That is, low market concentration in the wholesale industry, for example, may reduce the wholesale revenues and lead the Big Six to rebalance their overall desired profitability through higher prices in the retail sector. The results show that a one percent decline in the market share of the Big Six in the wholesale industry tends to raise the retail price level by 0.35 per cent. If lower market power in the wholesale sector is accompanied by higher concentration in the retail sector, then the results imply a double pressure on retail prices. The coefficient on retail market concentration indicates that as the biggest suppliers increase their market share, the aggregate price level of the industry increases by another 0.35%. Even if that influence is inelastic, the effect is significant reflecting the imperfect competitive conduct of the constituent firms (Giulietti et al., 2010a, 2010b; Boroumand, 2015).

This interpretation is further strengthened by the relationship between retail prices and the wholesale mark-up. While the latter variable has positive impact on retail prices in the long run, this is statistically insignificant, suggesting that the effect of market power on retail prices is not passed through particular forms of pricing strategy in the wholesale market but direct manipulation of prices in the retail market. On the other hand, the results show that as the volume of electricity generated is reduced by the wholesale industry, the retail price level tend to increase. This is consistent with the theory in that

[2] The main input of the wholesale industry is the fuel cost index, while the input of the retail industry is the wholesale price which reflects the purchase cost of electricity.

[3] In contrast with Johansen's (1992) proposition that the constituent time series must $I(1)$ Lütkepohl and Krätzig (2004) argue that in many cases it is convenient to test the cointegration of both $I(1)$ and $I(0)$ series in systems. As a result, the Johansen cointegration test can be conducted amongst time series of different order of integration.

[4] See Salies (2008) for more information on using ownership dummies as proxy of market power.

Table 3
Long run estimates.

	$Ecm_{1,t-1}$	$Ecm_{2,t-1}$
Variables		
mw_{t-1}	0.075(1.161)	0.084**(3.905)
eg_{t-1}	−2.899**(−16.45)	1.730**(29.40)
cr_{t-1}	0.351**(5.242)	− 0.140**(−6.281)
cw_{t-1}	−0.350**(−6.181)	0.132**(6.967)
Diagnostic tests		
LM test[a]	4.742[0.09]	2.649[0.26]
White's test[b]	7.527[0.10]	8.356[0.08]
RESET[c]	2.024[0.16]	0.170[0.68]

Notes: The numbers in parentheses refer to *t*-statistics. The numbers in brackets indicate *p*-values following the chi-squared distribution.
*Significant at the 5% level of significance.
[a] H_0: No serial correlation versus H_1: Serial correlation of k=2 lag order.
[b] H_0: Homoskedasticity versus H_1: Heteroskedasticity of unknown form.
[c] H_0: No misspecification versus H_1: Misspecification in the error term (non-linear combinations of the independent variables explain the dependent variable).
** Significant at the 1% level of significance.

retail firms can restrain their capacity in order to increase the price level and thus, increase their profit.

The Cointegrating Eq. (2) shows that every variable has a significant longrun effect on the level of final electricity consumption by the residential and non-residential customers. In particular, the wholesale price markup has an inelastic and positive effect on electricity supplied by the retail industry. This means that as the margin between the wholesale price and the fuel cost increases, electricity consumption rises as well. While this may seem a contradiction, when it is considered in connection with the discussion about the Cointegrating Eq. (1) it is easy to see the consistency. That is, higher mark-ups in the wholesale sector may reduce the need for revenue rebalancing and keep the retail prices low which in turn would motivate higher electricity consumption. The relationship between generation and final electricity consumption is positive as expected, that is, quantity adjustments on the supply side are positively related to the quantity adjustments on the demand side through opposite changes in the price levels. In other words, reduction of generation increases consumption, through its negative impact on final prices. Finally, the market share of the biggest retailers has a negative effect on final consumption, which is in accordance with the findings in the former cointegrating equation. Higher concentration in retail market leads to higher prices which in turn lead to adjustments on the demand side. On the other hand, higher concentration in the wholesale market reduces the need for rebalancing in the retail market and hence lowers the retail prices which in return motivates greater consumption.

Table 4 presents the results of causality for the wholesale and the retail electricity industry both in the long-run and in the short-run. These show that in the short run retail prices are not affected by changes in market share of the Big Six (i.e. market concentration ratios). Neither are they influenced by changes in final consumption. Unlike the findings related to the long-run estimations, the results for the short run suggest that the only statistically significant Granger causation with respect to the retail electricity prices is due to the changes in wholesale price markup. On the other hand, the wholesale market share of the Big Six determine the wholesale mark-ups. The influence of market concentration ratio on wholesale price is positive with estimates suggesting a significant effect at the one percent level of significance.

This finding is consistent with the findings of previous studies highlighting the failures in the wholesale industry with respect to competition (Woo et al., 2003). However, it contradicts the recent judgement made by the CMA following its investigation of the energy market. Finally, the concentration ratios in retail and wholesale electricity market in the short run seem to be independent of most factors included in the estimations. The only exception is the weak significance of retail market concentration in determining the market power in the wholesale industry. This means that as the retail industry becomes more concentrated, the wholesale industry becomes less concentrated as the retailers acquire monopsony power.[5]

The results in relation to the final consumption do not confirm our expectations. These suggest that the growth in retail prices, mark-up and concentration ratios trigger positive impact on final consumption of electricity. Although this is in contrast to theoretical prediction, it may be reflecting the inability of customers to make quantity adjustments in the very short-term due to low elasticity on the demand side, which is a well-known aspect of essential services such as electricity. On the other hand, there is also significant evidence of long-run causality running from the cointegrating Eqs. (7a) and (7b) to the short-run equations of the VECM. In particular, the final consumption equation, electricity generation and wholesale concentration are Granger caused by (7a), suggesting that they converge to this particular equilibrium point.

The time of adjustment is calculated as noted by Olive (2008) using the mean lag formula $[1 + (1 - |s_i|)/|s_i|]$. It identifies the maximum number of quarters needed to converge to the long-run state price level, assuming that no additional changes occur in the market. Thereby, the adjustment in retail price levels predicted by (7a) require a little less than two quarters. The second cointegrating equation only causes final consumption, suggesting that every other equation does not converge to this particular long-run condition.

On the other hand, the equations of retail price, wholesale markup and retail concentration have an insignificant value of adjustment to both cointegrating equations. This shows that there is no convergence to either long-run condition, thus these variables can be viewed as weakly exogenous. Consequently, they may be determined outside the present system of equations by additional market factors which have not been included in our analysis. This means that in the context of the model, Eqs. (1) and (3) reflect a short-run causality running from the wholesale markup and the wholesale concentration indicators respectively without converging to the long-run conditions captured by the two cointegrating equations.

Overall, the results of this study suggest two cointegrating equations where the retail price level is affected in the long-run by the market shares of the Big Six in both the retail and the whole sale market rather than the mark-up in the wholesale price. The estimates suggest the Big Six employ a 'rebalancing strategy'. On the other hand, in the short-run the mark-up in the wholesale market is the only factor with impact on the retail prices. Moreover, the market concentration by the Big Six has a strong influence on the mark-up in the short run. Electricity generation and final consumption appear a positive relationship only in the long-run as market rigidities may restrict any short-run interactions and decisions.

5. Conclusions and policy implications

This paper analysed the influence of market power on the formation of retail and wholesale pricing decisions in the UK on the basis of quarterly data extending from 1998 to 2012. The estimations are based on Vector Error Correction Method (VECM) in order to consider the interactions of electricity demand and supply. Market concentration of the biggest generators and suppliers is used as a proxy of market power.

Broadly, the results suggest that there are significant market failures arising from market power in both the retail and wholesale elements of the electricity industry. A number of findings in this paper merit highlighting. An important result is that market concentration by

[5] This holds because the short-run coefficient is negative. The short-run estimates and relevant material are available upon request.

Table 4
Short-run and long-run causality tests.

Dependent Variables	Sources of short-run causation						Adjustment to $Ecm_{1,t-1}$	Adjustment to $Ecm_{2,t-1}$
	Δpr	Δfc	Δmw	Δeg	Δcr	Δcw		
Δpr	–	0.541	4.230*	0.236	0.750	1.326	0.003	0.017
		[0.46]	[0.03]	[0.62]	[0.38]	[0.24]	(0.362)	(0.538)
Δfc	9.114**	–	10.97**	1.433	8.700**	13.44**	−0.943**	−1.278*
	[0.00]		[0.00]	[0.23]	[0.00]	[0.00]	(−6.213)	(−2.154)
Δmw	2.083	0.715	–	0.547	2.547	6.680**	−0.317	−0.365
	[0.14]	[0.39]		[0.45]	[0.11]	[0.00]	(−1.821)	(−0.537)
Δeg	8.833**	0.003	11.59**	–	13.64**	17.88**	−0.762**	−0.393
	[0.00]	[0.95]	[0.00]		[0.00]	[0.00]	(−4.791)	(−0.633)
Δcr	3.010	0.081	0.734	0.858	–	2.262	−1.342	0.912
	[0.08]	[0.77]	[0.39]	[0.35]		[0.13]	(−0.800)	(0.902)
Δcw	1.503	0.051	0.175	2.207	3.827*	–	−3.856*	−1.873
	[0.22]	[0.82]	[0.67]	[0.13]	[0.04]		(−2.00)	(−0.249)

Notes: The numbers of short-run causation indicate the *F*-statistic values of the joint hypothesis of causality by incorporating the lagged values of the representative short-run changes. The numbers in parentheses refer to *t*-statistics.
The numbers in brackets refer to the *p*-values following the chi-squared distribution.
* Significant at the 5% level of significance.
** Significant at the 1% level of significance.

the Big Six in both segments of the electricity market exerts a significant influence on the retail prices in the long-run. This impact is direct with respect to the market power in the retail segment of the market but indirect with respect to the market concentration in the wholesale segment, not through wholesale mark-up but through 'revenue rebalancing'. More specifically, lower market power in the wholesale electricity sector results in lower wholesale mark-up and increases the need for higher prices in the retail sector. 'Revenue rebalancing' is further confirmed by the positive relationship between wholesale markup and final consumption. That is lower wholesale mark-ups are counterbalanced with higher retail prices which then lead to lower consumption of electricity.

In the short run, however, market power has a significant effect on retail prices, passed through the wholesale mark-up rather than market concentration in either segment of the electricity industry. Moreover, wholesale market concentration by the Big Six has a positive and statistically significant impact on wholesale price mark-up. Overall then, a significant overpricing pattern emerge in retail and wholesale electricity markets both in the short run and the long-run.

These findings have a number of policy implications for the UK electricity market. First and foremost is the result about the market power and pricing in the wholesale electricity market. While the recent investigation by the CMA concluded that the UK wholesale market does not suffer from adverse effect on competition (AEC) our estimations raise significant doubts about the validity of this conclusion and call for a re-examination of the wholesale market, using a dynamic estimation method, as done in this paper.

Secondly, the CMA's results are based on a disintegrated / isolated analysis of wholesale and retail segments of the electricity industry as discussed by Amountzias et al. (2017). Given the Big Six are vertically integrated companies, any investigation into AEC requires a method that allows for interdependent interactions between wholesale and retail sectors as in our estimations. The findings in this paper in favour of 'revenue rebalancing' arising from vertical integration is particularly challenging for the CMA's conclusions.

Finally, this paper shows that market dynamics differ in the long and the short term. Such differences can be important for structural (corresponding to long-run) and transitional policy instruments (corresponding to short-run). Misleading policies may be applied if short-term analysis is used to devise longer–term solutions. For example, our short run analysis indicated that market concentration ratios have no significant impact on retail prices. However, the incompleteness of this analysis becomes clear with opposite findings in the long-run. In the full picture, market power impacts retail prices through market concentration in the long-run but through wholesale price mark-up in the short run. The fact that CMA's investigation covered a limited period of time (starting from 2009 unlike our estimations) raise doubts about its results capturing the market dynamics in the long-run.

The overall conclusion is that it is likely that the UK electricity market will continue to suffer from significant market failures. This is especially because the remedies devised by the CMA heavily rely on customer mobility instead of directly addressing the issues associated with vertical integration and market concentration by the Big Six. Any future investigation due to ongoing market power abuses should be open to a range of policy options, including nationalisation, breaking up large companies and market regulation.

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