Competitive non-linear pricing: retail electricity in the UK

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Outline

• Motivation
• Literature review on non-linear pricing
• UK Retail Electricity 1999-2004: an interesting natural experiment
• Two-part tariffs: the ‘best-buy’ frontier
• Empirics:
  (i) convergence or dispersion of tariffs?
  (ii) estimating frontier, foggy pricing
• Conclusions
Motivation

• UK retail electricity liberalised in 1998. Previously monopolised regional markets replaced by competition between up to 14 firms. Has this benefited the consumer?

• Given firms have always set non-linear prices, how has competition affected the structure of tariffs? Electricity homogeneous, we might expect Bertrand pricing. How has it impacted on tariff structures?

• We continue to observe not only non-linear prices, but also different firms setting *different* prices (tariff structures.) Analogous to product differentiation - firms selecting different tariffs to segment the market, and soften competition?

• More generally, a fast growing academic literature on competitive non-linear pricing. Are its predictions borne out in this case?
The literature: (i) non-linear pricing by monopolist

- **Tirole (1988):** monopolist sets 1 two-part tariff two types of consumer:
  - Low vol. $X_1 = 1 - p/\theta_1 \quad \lambda\%$
  - High vol. $X_2 = 1 - p/\theta_2 \quad (1-\lambda)\%$
  where $\theta_2 > \theta_1 > c$ (MC)
  Solution: $SC = (\theta_1 - p)2/\theta_1, P = c/(2 - \theta/\theta_1)$
  where $\theta$ weighted average of $\theta_1$ and $\theta_2$

- P & SC both rise with MC and market size; increasing asymmetry between consumers raises P but lowers SC (to cover market)

- Continuous distribution of consumers: Tirole and Miravete & Roller (2004) show optimal tariff structure amounts to finite number of 2-part tariffs, approximated by quadratic relationship between $T$ (consumer's expenditure) and $X$ (volume consumed)

- In fact, most of the consumer surplus can be appropriated using a fairly small number of alternative 2-part tariffs (Miravete, 2003)
(ii) Non-linear pricing by oligopolists

Theory
• Mostly concerned with welfare implications of non-linear versus uniform pricing, but part compares competition with monopoly:
• Mandy (1992): Bertrand free entry => single uniform price
• Jensen & Sorgard (2005) – heterogeneous consumers, SC increases with competition
• Armstrong & Vickers (2001) – Hotelling competitors (differentiated products), as t falls, P=>MC and SC=>0.
• Not terribly helpful for present purposes, since models all result in all competitors setting same 2-part tariff. Often, 2-part tariffs disappear.
(iii) non-linear pricing by oligopolists

**Empirical**

- “Although competitive NLP a very common practice, empirical economists have found serious difficulties in evaluating the extent of competition in markets where pricing strategies are drawn from a space of non-linear functions” *Roller and Miravete (eg 2004)*

- Miravete & Roller (2004): mobiles in US. Mainly concerned with using information on structure of tariffs to infer the (unobserved) distribution of consumers’ heterogeneity, and drawing welfare implications cf. uniform pricing. However, they do find that competition reduces both marginal prices and subscription fees.

- Busse & Rysman (2005): Yellow pages advertising in US. Competition reduces prices, most substantially for largest advertisements.


- Miravete (2004): firms offer more dominated tariffs in competitive market
UK Retail Electricity industry

• Residential electricity industry comprises four vertical stages, here we’re interested only in retail

• Retail traditionally separated into 14 geographical regions (fig)

• Traditionally, incumbent monopolists set 2 part tariffs: a fixed rate (SC) per consumer and a single per unit charge (P) WHY? (fig)

• Opened to competition between August 98 and May 99

• Following liberalization, all original regional incumbent monopolists entered each other’s market, as did the incumbent gas monopolist, plus a few small independent firms (Table)
Originally
14 regional monopolies
Incumbents’ tariffs Feb 1998
### Number of separately owned firms active in the market

<table>
<thead>
<tr>
<th>Date</th>
<th>Majors</th>
<th>Independents</th>
<th>Brit. Gas</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 99</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Oct 99</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Jun 00</td>
<td>11</td>
<td>3</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Dec 00</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Jun 01</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Dec 01</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Jun 02</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Dec 02</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Jun 03</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Dec 03</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Jun 04</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Dec 04</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>
Three distinct sub-periods

Phase I, Feb 99–Jun 01: ‘Settling in’
- Almost 100% cross-entry of regional incumbents into each others’ markets. Handful of small independents enter, some very short-term. 2 acquisitions of smallest original regional incumbents.

Phase II, Jun 01 – Jun 03: ‘Consolidation’
- 5 more original incumbents acquired, 1 independent also exits. Resulting in all markets populated by 6 effective competitors.

Jun 03-Dec 04: Stable structure
- No more acquisitions of original incumbents. 1 independent exits.

- 2 part tariffs continue to be the norm WHY? *Add qualification*
  Considerable variation between companies & regions in structure of these tariffs ( fig)
Pooled scatter of SC vs P

Pooled scatter: all regions & dates

SC (£) vs P (pence)
Natural experiment on NLP

Key features
• Monopoly replaced by ‘competition’; over the period, different phases where firm numbers differ significantly (and maybe the intensity of competition too)
• NLP survived in the new competitive world
• Competitors typically offer different tariff structures
• Multi-market contact is pervasive, all markets same players, but different incumbents

Opportunity to:
• Test hypotheses/results from existing literature on NLP:
  has competition led to lower prices?
  do some consumers benefit more than others?
  how prevalent (if at all) is foggy pricing?

• also deduce something about the intensity of competition by observing tariff structures offered by different firms. Dispersed, or convergence? Does competition reduce the tendency for firms to offer ‘inefficient’ tariffs (‘bad buys’)?
The tariff structure (‘best buy’) frontier

This is not a ‘theory’ per se, more a way of assembling the ‘facts’

**Monopoly**

- Pre-liberalisation, all consumers purchase from incumbent monopolist (A) who offers a single two part tariff. For a customer consuming quantity \( X \), expenditure is \( E \):
  \[
  E = SC + PX
  \]

- Assuming 3 customers (hi, med, lo), with consumptions \( X_{hi} \), \( X_{med} \) and \( X_{lo} \) (\( X_{hi} > X_{med} > X_{lo} \)). Each has an iso-expenditure line:
  \[
  SC = E_i - P X_i
  \]

- Each faces same \( \{SC, P\} \) tariff, but slopes of their lines differ with \( X \), as do their intercepts – the vertical denoting expenditure, and the horizontal denoting average expenditure per unit consumed (\( E/X \)).
Entry

- Suppose two new firms (B and C) enter. Should they locate close to A or differentiate by offering alternative price structures?

- Suppose C offers a lower SC and higher P than the incumbent, while B does the opposite. As drawn, this effectively segments the market. Consumer med continues to buy from A (placing him on his lowest attainable iso-expenditure line*), while hi and lo now switch to entrants, B & C respectively.

* Assuming A sets prices marginally lower than this, to break indifference.
Generalising to many consumers and firms

• With >3 consumers, $X_{hi}$, $X_{med}$ and $X_{lo}$ now interpreted as critical consumption levels:
  B sells to all consumers with $X > X_{hi}$
  A sells to all consumers with $X_{hi} > X > X_{lo}$
  C sells to all consumers with $X < X_{lo}$

• (Note, for future empirical purposes that the slope of line joining any 2 points identifies these critical consumption levels).

• With >3 firms, assuming none offers a tariff structure dominated by that of another firm (Z), then each will be the ‘best buy’ for at least one consumer. Thus, the points sketch out a ‘best buy’ (or efficient) frontier.

• Firms effectively segment the market. Analogous to locating along a Hotelling type beach, with horizontal tastes replaced by desired consumption levels.

N firms map out the efficient frontier
Empirical questions in terms of the frontier

• How will competition affect the distribution of firms along the frontier? Is there convergence to a single point, or dispersion, with firms segmenting the market?

• Are all firms located on the frontier? Or do some locate above (foggy prices)? Does competition affect the likelihood of foggy pricing?

• No conclusive leads from theory, but can we speculate how things might differ in collusive and competitive settings?
Collusive v Competitive Outcomes?

Collusive equilibrium
• In any given region, a collusive group might position themselves along the frontier and emulate the optimal tariff structure of a multi 2-part tariff monopolist. The original incumbent would cede part of its original monopoly profit to the entrants, but it would gain a share of monopoly profits in the other 13 markets in which it was an entrant.
• In such an equilibrium, joint profits would be greater across the 14 markets than sum of the 14 monopoly profits pre-entry. In each market the group would have replaced 1 two-part tariff with a schedule of 14 two-part tariffs. (‘fly in the ointment’ if time.)

Alternative competitive equilibria
• Previous literature tends to point towards a single 2-part tariff offered by all firms (i.e. no dispersion). Often, non-linear pricing gives way to single uniform price, SC=0.
• However, one can conceive of a potential competitive equilibrium, where firms enter sequentially and position themselves increasingly further away from the first mover.
• (A la ‘competitive’ positioning in location models.)

Off frontier tariffs
• If there is a persistent tendency for firms to set foggy prices, this might be indicative of ‘soft’ competition - dominated tariffs might be evidence of switching costs, and/or mutual forbearance amongst incumbents – offering deliberately non-competitive prices in rivals’ back yards.
Two-stage empirical methodology

• Stage 1: Dispersion of Ratios
  Measure dispersion of firms’ tariff structures by variance of SC/P. How does it change over time, & differ between firms?

• Step 2: Estimate ‘best-buy’ frontier (all regions over time)
  How does it change over time? Are most firms on or off-frontier? Significant differences between firms? Foggy pricing?
Dataset

SC & P (standard credit customers):
• t 12 periods (biannual 1999-2004)
• j 14 regions
• i 7-16 companies
• 1847 observations (including ‘virtual SC’)

At this stage, very little other data available:
• Personal distribution of electricity consumption (lognormal)
• Limited information on costs at industry level
• No data on firm-level costs or precise dates of price changes.
• Future work to investigate more precisely tariff setting at the individual firm level (using familiar New IO empirical methodologies, e.g. Slade (1987), Bresnahan (1989)
Stage 1: Dispersion
Time Series of Mean & Var (SC/P):

- At liberalisation, immediate jump in both mean and variance
- Relative stability in Phase 1
- Mean roughly constant throughout the three phases
- Dramatic increase in dispersion, especially Phase 2 (intense mergers)
The sources of increased dispersion: decomposition of overall variance

Variance (of SC/P) can be decomposed:

By region: \( \text{VAR} = \text{WR} + \text{BR} \)
- Within region (WR), average variance of ratio: how much companies’ ratios vary within a typical region (market)
- Between regions (BR): variance of average ratio – how much regions’ mean ratios differ. Region heterogeneity

By company: \( \text{VAR} = \text{WC} + \text{BC} \)
- Within company (WC): average variance of the ratio: how much typical company’s ratios differ across regions. Measure of extent to which companies’ strategies are regional-specific or national.
- Between companies (BC): variance of average ratio - how much companies’ mean ratios differ. Company heterogeneity.

Decomposition of Overall Variance

<table>
<thead>
<tr>
<th></th>
<th>Total Var</th>
<th>Between Var</th>
<th>Between %</th>
<th>Within Var</th>
<th>Within %</th>
<th>Between Var</th>
<th>Between %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb-99</td>
<td>44.9</td>
<td>5.4</td>
<td>12</td>
<td>39.4</td>
<td>88</td>
<td>13.9</td>
<td>31</td>
</tr>
<tr>
<td>Jun-01</td>
<td>47.5</td>
<td>5.2</td>
<td>11</td>
<td>41.7</td>
<td>89</td>
<td>25.1</td>
<td>52</td>
</tr>
<tr>
<td>Jun-03</td>
<td>112.3</td>
<td>8.8</td>
<td>8</td>
<td>103.5</td>
<td>92</td>
<td>26.6</td>
<td>22</td>
</tr>
<tr>
<td>Dec04</td>
<td>107.7</td>
<td>6.6</td>
<td>6</td>
<td>100.5</td>
<td>94</td>
<td>23.3</td>
<td>21</td>
</tr>
</tbody>
</table>

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Within region/between company dispersion dominates
Key findings from decomposition of dispersion

• **By region**
  Within-region variance dominates - most dispersion is within individual markets, and this accounts for virtually all of the increase, especially in phase 2. Region heterogeneity fairly constant.

• **By company**
  Between-company tends to dominates – firms clearly adopt different strategies from each other.
  Nevertheless, within-company variance also significant – they use different strategies in different regions: not ‘national pricing’. All of the increase in the crucial Phase 2 period was accounted for by increasing BC – firms distancing themselves from each other within individual markets.

• **Conclusion**: Phase 1 settling down, Phase 2 a period of significant dispersion – firms distanced themselves from each other, both nationally and regionally, Phase 3 stabilisation.
A Priori stylisation of firm types

Characterisation of the four types of firm

- **Incumbents**: 1st mover advantage, brand loyalty, benefit from switching costs
- **British Gas**: although an entrant in electricity, the incumbent in adjacent gas market – a known brand name. To the extent that consumers switch to bundled offerings (both gas & electricity from same supplier), British Gas ‘less risky’ than buying both fuels from new supplier?
- **Majorsaway**: (incumbents outside their own region). To the consumer, most incumbents from other regions seen as entirely new entities? – hard to transfer brand loyalty across regions. Also face switching costs. Crucially, any aggressive move away from home might provoke retaliation in company’s home market. Arguably, a soft competitor?
- **Independents**: as for majorsaway, but no ‘strategic motive’ – fears of retaliation in (non-existent) home region.
Mean ratio by Firm Type

All entrant types tend to offer higher ratios

- **Incumbents**: consistently the lowest ratios, increasingly so over the period, especially in phase 3.
- **British Gas**: high ratio, stable throughout (after the first year),
- **Independents**: pronounced tendency to increase ratios through the period, and latterly setting the highest ratios
- **Majorsaway**: ratios always higher than incumbents, but increasingly lower than either British Gas or Independents; tendency to decline in phases 2 and 3.

- All pairwise differences significant, except B Gas & Independents
Differences between broad type

- By the end of the second phase, & through phase 3, the four types have distanced themselves, with Independents and B Gas targeting high volume consumers.

- Majorsaway typically set higher ratios when selling outside ‘home’ region.

- Inside their home region, they have lowered their ratios.
Differences within types: decomposition of variance

- Significant proportion of overall variance accounted for by differences *between* type means

- But outweighed by variance *within* types (84%) Most important, amongst majorsaway.

- This is increasing in the later periods

- May be misleading to treat majorsaways as homogenous

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**Decomposition of total variance by company type**

<table>
<thead>
<tr>
<th></th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between types: Variance of type means</td>
<td>15.</td>
</tr>
<tr>
<td>Within types: Variance within types</td>
<td>84.</td>
</tr>
<tr>
<td>Of which, accounted for by:</td>
<td></td>
</tr>
<tr>
<td>Incumbents</td>
<td>5.1</td>
</tr>
<tr>
<td>British Gas</td>
<td>2.3</td>
</tr>
<tr>
<td>Incumbents away from home region (Majorsaway)</td>
<td>51.7</td>
</tr>
<tr>
<td>Independents</td>
<td>25.5</td>
</tr>
</tbody>
</table>

**Variance of ratio by firm type**

- Incumbent
- B Gas
- Independents
- Majorsaway
Simple ‘model’ of different strategies amongst majoraways

Suppose incumbent from i prices outside own regions as follows:

\[ R_{ij} = a + b \text{HR}_i + c \text{IR}_j, \quad j \neq i \]

R its ratio in j, HR its home ratio, IR the incumbent’s ratio in j

1. National pricing – same ratio in all regions as at home: \( a=c=0, b=1 \)
2. National pricing away from home: \( a \neq 0, b=1, c=0 \)
3. Distance itself, always by the same amount, from incumbent: \( a \neq 0, b=0, c=1 \)
4. Meet incumbent ‘head-on’ - set same ratio: \( a=b=0, c=1 \)

In terms of ‘region-awareness’: (4)&(3)>(2)>(1); (4) more aggressive than (3)
Regression analysis of
\[ R_{ij} = a + b \, HR_i + c \, IR_j \]

- I: assume \( a, b \) and \( c \) do not vary across firms – low fit
- II: add company fixed effects, fit rises to 48%, confirming importance of within-type differences. Also, \( b + c = 1 \)
- III: allow slope to vary between firms: explains 65% of variance
- IV: re-estimate using accepted restrictions from III. Distinctly different strategies amongst majors:

Strategy 1: Powergen

Strategy 2: SPower & NPower

Strategy 3/4: EDF & S&S: S&S the most responsive of all majoraways to IR: in that sense, the ‘maverick’
Regression analysis of \( R_{ij} = a + b \, HR_i + c \, IR_j \)

<table>
<thead>
<tr>
<th>Dependent:</th>
<th>R</th>
<th>(R-IR)</th>
<th>(R-IR)</th>
<th>(R-IR)</th>
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<tr>
<td>Constant</td>
<td>591</td>
<td>241</td>
<td>240</td>
<td>239</td>
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<tr>
<td>HR</td>
<td>.076</td>
<td>.830</td>
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<tr>
<td>IR</td>
<td>.181</td>
<td>.172</td>
<td></td>
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<tr>
<td>HR-IR</td>
<td></td>
<td>.807</td>
<td>.801</td>
<td></td>
</tr>
<tr>
<td>EDF</td>
<td>-180</td>
<td>-178</td>
<td>-177</td>
<td></td>
</tr>
<tr>
<td>NPower</td>
<td>265</td>
<td>326</td>
<td>302</td>
<td></td>
</tr>
<tr>
<td>Powergen</td>
<td>-226</td>
<td>-221</td>
<td>-218</td>
<td></td>
</tr>
<tr>
<td>S&amp;S</td>
<td>-632</td>
<td>-319</td>
<td>-318</td>
<td></td>
</tr>
<tr>
<td>SPower</td>
<td>110</td>
<td>105</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>EDF*(HR-IR)</td>
<td></td>
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<td>NPower*(HR-IR)</td>
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<td>.248</td>
<td>.159</td>
<td></td>
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<tr>
<td>Powergen*(HR-IR)</td>
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<td>.095</td>
<td>.159</td>
<td></td>
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<tr>
<td>S&amp;S*(HR-IR)</td>
<td></td>
<td>-.311</td>
<td>-.305</td>
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<tr>
<td>SPower*(HR-IR)</td>
<td></td>
<td>.132</td>
<td>.159</td>
<td></td>
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<tr>
<td>R Sq corrected</td>
<td>.022</td>
<td>.484</td>
<td>.654</td>
<td>.654</td>
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</table>

*Coefficients in italics denote not significant at 5% level*
Differing strategies of Majoraways

![Graph showing different strategies of energy companies.](www.ccp.uea.ac.uk)
Stage 2 The ‘best-buy frontier

- For each region, each point in time, fitted a frontier to the scatter of (SC, P) points using Data Envelopment analysis (DEA). Identifies which firms lie on-frontier and how far off the frontier are the others.

- For consistency with the literature using DEA, we refer to an off-frontier firm as ‘inefficient’, and the extent of its inefficiency is measured in the traditional Farrell way (see earlier fig – slide 19).

- On average (at a point in time in a given region) the number of firms on-frontier is only 3.9 (varying between 3 and 6). **Typically, about three quarters of firms offer a tariff which is dominated - not ‘best’ for any consumer.** Foggy pricing is the norm.
Shape of the frontier

As the typical region/time point may only involve 3 or 4 observations, we pool the sample across regions & time periods to fit the curve:

\[ P_{ijt} = a_{jt} + b_{jt} \left( SC \right)_{ijt}^{1/2} \]

This is fitted only to observations lying on frontier

Functional form: consistent with a quadratic relationship between \( T(X) \) and \( X \). Since this the optimal relationship for a monopolist using \( N*2 \)-part tariffs (see earlier), it describes the \{\( P,SC \)\} pairs that would be offered by such a monopolist (or perfectly colluding set of firms)

We also include region fixed effects and various alternative time trends
Frontier results

• Very close fit: R squared 0.918

• Quadratic time trend appears to fit best (t values 15): U shaped with minimum at t=6.3 (Dec 01)

• Frontier moving inwards in phase 1 - best-buy tariffs becoming cheaper, but during next merger consolidation phase, the reverse was true
Efficiency by company type

- Typically, only 1 in 4 firms offer non-dominated tariff
- Incumbents and British Gas ‘perform’ significantly worse
- Independents perform significantly better

<table>
<thead>
<tr>
<th>Type</th>
<th>Probability of being on-frontier</th>
<th>Mean efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incumbent</td>
<td>.08</td>
<td>91.5</td>
</tr>
<tr>
<td>B Gas</td>
<td>.11</td>
<td>91.0</td>
</tr>
<tr>
<td>Majoraway</td>
<td>.27</td>
<td>95.3</td>
</tr>
<tr>
<td>Independent</td>
<td>.46</td>
<td>97.0</td>
</tr>
<tr>
<td>Total</td>
<td>.26</td>
<td>94.6</td>
</tr>
</tbody>
</table>
Efficiency of majoraways

Within majoraways:

• Scottish Power significantly less likely to be on frontier (competing in same area as Independents)

• S&S significantly more likely than the average to be on-frontier. (Npower too, but only weakly significant.)

<table>
<thead>
<tr>
<th>Company</th>
<th>Probability of being on-frontier</th>
<th>Mean efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>S&amp;S</td>
<td>0.688</td>
<td>98.7</td>
</tr>
<tr>
<td>NPower</td>
<td>0.350</td>
<td>94.4</td>
</tr>
<tr>
<td>Scottish Power</td>
<td>0.076</td>
<td>94.1</td>
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<tr>
<td>EDF</td>
<td>0.313</td>
<td>96.4</td>
</tr>
<tr>
<td>Powergen</td>
<td>0.261</td>
<td>96.3</td>
</tr>
</tbody>
</table>
Conclusions

• No convergence to a single tariff structure – quite the reverse, especially in sub-period in which most mergers occurred
• Typically, Independents offered best buy to large volume consumers – opting for ‘niche’ market? Unsuccessful – all exited
• British Gas price nationally, and rarely offer a ‘good buy’ (leverage of brand loyalty from adjacent market?)
• Original incumbents tended to lower their standing charges relatively, and rarely offer a good-buy in their home regions – an incumbency premium?
• Outside home regions, incumbents typically distanced themselves from home region incumbent by setting relatively higher SC. Although tended to offer a better buy away than at home, not as competitive as independents. Since neither independents nor majoraways enjoy brand loyalty or switching costs, suggestive of mutual forbearance? At the least, they’re softer competitors
• Arguably, S&S played a maverick role, appearing to target the incumbent more directly and offering a better buy to consumers
Further work

(i) Database currently being extended to June 06, also re-estimated on direct-debit and dual-fuel tariffs (early sensitivity tests on latter suggest no significant differences)

(ii) Focus on incumbents and majoraways to construct a ‘proper’ panel to identify the dynamic relationships underlying the simple ratio regressions

(iii) Potentially, an analysis of how the mixed bundling option (gas and electricity) impacts on strategies