

ESTIMATION OF SEARCH FRICTIONS IN THE BRITISH ELECTRICITY MARKET*

MONICA GIULIETTI[†]

MICHAEL WATERSON[‡]

MATTHIJS WILDENBEEST[§]

This paper studies consumer search and pricing behavior in the British domestic electricity market following its opening to competition in 1999. We develop a sequential search model in which an incumbent and an entrant group compete for consumers who find it costly to obtain information on prices other than from their current supplier. We use a large data set on prices and input costs to structurally estimate the model. Our estimates indicate that consumer search costs must be relatively high in order to rationalize observed pricing patterns. We confront our estimates with observed switching behavior and find they match well.

I. INTRODUCTION

FROM THE CONSUMER'S POINT OF VIEW, ELECTRICITY IS ONE of life's essentials. It also seems a very homogeneous product; one company's electricity is the same as any other's.¹ Bertrand-type economic arguments would then suggest that if supplier prices differ, all con-

*We are grateful to the Editor and three anonymous referees for comments and suggestions that have substantially improved this paper. In addition, we are indebted to Mike Baye, Greg Crawford, José Luis Moraga-González, Richard Green, Ali Hortaçsu, Maarten Janssen, Graham Loomes, Régis Renault, Patrick Rey, Michael Rauh, Andrew Rhodes, and Chris Wilson for useful comments and discussion. Our paper has been improved by comments arising from presentations at Indiana University, the Tinbergen Institute Rotterdam, the University of Warwick, EARIE 2010, Istanbul, the 2010 Safe International Workshop on Quantitative Analysis of Energy Markets, Verona, IOOC 2011, Boston, and the 2011 Royal Economic Society Annual Conference, Royal Holloway. Our research was facilitated by ESRC grant RES 00-22-1686 to Giulietti and Waterson that, amongst other things, funded Wildenbeest's visit to Warwick.

[†]Authors' affiliations: Warwick Business School, University of Warwick, Coventry, CV4 7AL, United Kingdom.

e-mail: monica.giulietti@wbs.ac.uk

[‡]Department of Economics, University of Warwick, Coventry, CV4 7AL, United Kingdom.

e-mail: michael.watson@warwick.ac.uk

[§]Kelley School of Business, Indiana University, 1309 E 10th St, Bloomington, IN 47401, U.S.A.

e-mail: mwildenb@indiana.edu

¹This is particularly so if, as in our case, (i) each supplier's electricity would come through the same distributor's wires so that suppliers do not differ amongst themselves in terms of service reliability, and (ii) green electricity does not command a premium from consumers.

sumers flock to their cheapest. In Britain, this has not happened, despite every consumer having had the opportunity to switch for over 10 years and despite a higher proportion switching than in any other European country or US state (Defeuilley [2009]) and a majority of consumers no longer being with their incumbent supplier. In this sense, market competition has not worked well. Faced with six major suppliers offering different prices, significant switching continues to occur but a majority of consumers still pay over the odds and company prices still diverge considerably, something that has prompted several enquiries.² Within the period and bill type we investigate, the price range consistently exceeds 20 percent, but it continues beyond this. For example, in January 2013 a consumer living in the East Midlands, anticipating a use of 4,565kWh of electricity a year (an average quantity for this region) and paying by direct debit, would pay between £588 and £740 per year.³ Why do we see such large price ranges?

Our analysis of this significant price divergence focuses on search costs as a candidate explanation. To this end we structurally estimate a consumer search model that is tailored to the British electricity market. Our estimates suggest that even search costs at the lower quartile are high and significant as a fraction of the bill, though falling through time. A particular novelty of our paper is that we can independently verify the characteristics of these estimated costs using market information on changes in supplier shares, finding an excellent match between the two. Even though the objective of our paper is to estimate how big search costs would have to be in order to rationalize the significant price dispersion we observe in the data, we also examine several other factors that are of potential importance, for example switching costs, service quality, and promotional activity.

In the theoretical part of our paper we develop a search model that, in line with institutional details, revolves around the inherent asymmetry between the incumbent and the set of firms that entered in each regional electricity market in Britain after the market opened up in 1999. The model focuses on optimal price setting behavior of the entrants under the presence of costly sequential consumer search. In our model, both the incumbent and the entrants have a proportion of consumers that does not find it worthwhile to search for a better deal, the difference being that by definition the incumbent has a bigger set of such consumers to

²The proportion of consumers who have ‘ever switched’ by 2005 varies across regions of the country, with the lowest proportion being 31 percent, the highest 56 percent and a simple mean of 46 percent (Ofgem [2006]).

³Price (i.e. annual bill) quotes retrieved online from uSwitch.com on 23 January 2013, rounded to whole pounds. For comparison, the annual bill at the incumbent E.ON would be £669, so moving to the cheapest gives a 12 percent saving.

start with than each of the entrants. Although the model is tailored to the early years of the consumer electricity market in Britain, in principle it applies to many markets across the world that have been recently liberalized (for instance telecommunications and gas). Our theoretical results show that given the price charged by the incumbent, entrants compete by employing a mixed strategy in prices (see also Burdett and Judd [1983]; Stahl [1989]). Simulations indicate that entrant prices are increasing in the number of consumers being served by the entrants.

In the empirical part of our study we use the equilibrium of the theoretical search model to structurally estimate search costs in the British electricity market. For this purpose we use a large data set of prices collected in the period between 2002 and 2005, as well as information on cost side variables and information on the market share of each region's incumbent.⁴ Our results indicate that even though average margins went up for most of the sampling period, search costs have gone down over time. Although this may seem surprising at first, our model is able to reconcile these findings through a declining share of households buying electricity through the incumbent: the lower this share, the less competitively the market entrants behave. This means that as long as the share of households at the incumbent is declining rapidly enough, higher margins over time can go together with decreasing search costs.

The paper builds on both the theoretical and empirical literature on consumer search. Our theory model has its origins in Stahl [1996], who develops a sequential search model for homogenous goods, allowing for a continuous distribution of search cost.⁵ One important difference with Stahl's model is that while in his model all firms are symmetric, we allow for asymmetry. More specifically, as in Baye, Kovenock and De Vries [1992] and Kocas and Kiyak [2006] we assume consumers do not allocate themselves equally across firms: the incumbent in our model has a bigger share of consumers to begin with, which we show to have interesting implications for the pricing strategies of the entrants.

Related empirical papers include Hortaçsu and Syverson [2004] and Honka [2013], who both estimate search costs in markets in which search and switching costs are deemed important (mutual funds and the US auto insurance market, respectively). Whereas Hortaçsu and Syverson use aggregate data on market shares and prices to estimate their model, Honka has detailed information on the consumers' search process, which allows her to obtain estimates of switching costs as well. Methodologically our paper is closest to Hong and Shum [2006]

⁴The date range is deliberate, as we explain below. It lies between the final liberalization move and significant structural changes.

⁵The sequential search model in Stahl [1989] assumes a two-type distribution of search cost.

and Moraga-González and Wildenbeest [2008] who develop methods to estimate consumer search models using only price data. Moraga-González and Wildenbeest focus on the estimation of a non-sequential search model, whereas Hong and Shum show how to exploit equilibrium restrictions imposed by both non-sequential and sequential search models. However, unlike the sequential search model in Hong and Shum's paper, our search model allows for heterogeneity in the pricing strategies across incumbent and entrants. This comes at a cost: while Hong and Shum's model can be estimated (parametrically) using only price data, estimation of our model requires additional data on marginal costs.

Our paper also fits into the literature on the competitiveness of retail electricity markets and how that relates to consumer search and switching behavior. Waddams and Wilson [2010] provide evidence of misguided choice of supplier by electricity consumers in the UK, leading to monetary losses rather than gains, which the authors attribute to decision errors and inattention on the part of consumers. Giulietti, Otero and Waterson [2010] demonstrate the basic features of the market we investigate here, but focus on description rather than estimation. Perhaps the closest related is Hortaçsu, Madanizadeh and Puller [2011], who investigate the determinants of supplier choice for electricity consumers in Texas. An important difference with our paper is that while our search model is 'structural,' they have a 'reduced form' search specification. Another difference is that Hortaçsu, Madanizadeh and Puller take non-price differentiation factors into account, in addition to search and switching costs.

Price for a given quantity may vary between suppliers for several reasons. We focus on search costs as the prime driver of differences, whilst acknowledging that other factors may play a role. Thus, in our model and estimation we evaluate the magnitude of search costs required to rationalize observed price differences.⁶ Clearly, there are other candidate explanations but, whilst not dismissing these, we argue they cannot provide a good explanation for the price patterns we observe in isolation.

An obvious candidate alternative is switching costs. Although for most consumers there will be costs associated with moving from one provider to another, switching in this industry is designed to be relatively straightforward: the new supplier carries out the switching process on behalf of the consumer and there are no penalties for switching. Furthermore, the consumer was legally required to give only 28 days' notice before switching to a new supplier (or moving back to the incum-

⁶In this market it is natural to conceptualize search costs as the cost of investigating suppliers as well as the cost of finding out the information required to make a comparison across providers (annual consumption). See also Section II.

bent). Moreover, switching by itself cannot explain differences between prices of the firms a consumer might switch to, since in the absence of search costs, someone who switches will choose the cheapest alternative, other things equal.

Another explanation is cost differences, but one institutional feature of the market is that most of these costs are common across suppliers. A third area of explanation is product differentiation, for example through advertising, brand recognition, service differences, or marketing strategies, but we argue that whilst this might explain the failure of independent providers to make much headway in the market, it is unlikely to be important in explaining differences between large established firms selling such a fundamentally homogenous product. This is also supported by our estimation results; one of our specifications uses quality-adjusted prices and even though search costs are uniformly lower, especially for the earlier years, qualitatively our results do not change. So we analyze how well search costs perform as an explanation without claiming they are a complete explanation.

If, as a result of search costs, consumer prices contain significant divergences from each other and from costs, why does it matter? Competition was introduced into the electricity supply market largely in order to avoid the burden of regulation that previously existed (and still exists in many parts of the world, given the consumer welfare impact of the market). Our results, echoing concerns expressed more broadly in Stern [2010] and leading to Ofgem's Energy Supply Probe [2008],⁷ suggest caution in the assumption that competition will do the job, even if well-engineered, to reduce the burden on consumers to a minimum.

The setup of our paper is as follows. In the next section we give an overview of the British electricity market. In Section III, we discuss our data and present some preliminary findings on prices and price dispersion and how they relate to search frictions. We develop our model in Section IV. In Section V, we present our estimation method, which we apply to the data on the British electricity market in Section VI. Section VII contains our test of the implications of our estimated search costs for switching activity against actual switching behavior. Section VIII concludes.

II. THE BRITISH ELECTRICITY MARKET

The UK was one of the first countries to liberalize its consumer electricity markets, by separating the activities of supply and of distribution and regulating the latter. This led to a significant increase in the num-

⁷Also, Conservative Prime Ministerial intervention in the autumn of 2012.

ber of competitors offering to supply domestic consumers in each of the fourteen geographical regions.^{8,9} Regional incumbents did not only start competing in other regions, becoming entrants in those regions, but US, German, French, and Spanish firms have entered or have taken over existing firms as well. Consumer switching started in 1999 and since March 2002 all supply price regulation has disappeared.¹⁰ The average number of suppliers in each region has decreased since then, from 13 in the beginning of 2002 to, on average, 8 near the end of 2005, but since late 2002, the largest six have consistently accounted for over 99 percent of supplies to domestic consumers (Ofgem [2003]) and all significant independents have exited, so we can view the number of effective competitors as essentially fixed. Table I contains the market shares at the national level for the largest six suppliers. Each controls shares of between 10 and 23 percent of the British market, whereas the independent suppliers never exceeded the 1 percent level in aggregate.

[Table 1 about here.]

Switching rates are significant, averaging around 20 percent per year. Switching from one provider to another is relatively straightforward: once a preferred supplier is identified and the customer has committed to switch, the chosen new supplier would contact the existing supplier and carry out the switching process on behalf of the customer. Nevertheless, identifying which provider to switch to can be a cumbersome task: a consumer first has to search for information about alternative suppliers to be able to make the switch.¹¹ Given the nature of the industry, it is natural to conceptualize search costs as including both the cost of finding the information that is necessary to make a comparison, most importantly the consumer's annual consumption level, as well as the cost of investigating appropriate suppliers for that given consumption level. This is because one company may provide a relatively competitive tariff for a low consumption level, but a relatively uncompetitive tariff for high consumption levels, given nonlinear tariffs.

Since prices are in general not similar across the available providers, once aware of their requirements consumers then have to (decide how much to) gather information on prices before making a decision to which

⁸We do not consider supply to non-domestic properties in this paper.

⁹The fourteen regions are: Eastern, East Midlands, London, Midlands, Merseyside (& North Wales), Northern, North West, South East, North Scotland, South Scotland, Southern, South Wales, South West, and Yorkshire. Note that this list does not include Northern Ireland, where the whole electricity regime is substantially different.

¹⁰Regulation of high voltage transmission and of local distribution prices remains in place—for more details see Giulietti, Otero and Waterson [2010].

¹¹See Wilson [2012] for a discussion on how switching relates to searching.

supplier to switch. This information gathering can go through several channels. For example, a consumer could talk with a sales person, phone a company or visit the website of an electricity provider or, more recently, could go to one of the many comprehensive price comparison sites.

The search process undertaken by consumers in order to identify the best deal/price on offer in the market has changed over the time period that we consider. Various Ofgem reports about developments in the competitive retail market reveal that the information on suppliers' prices was most commonly obtained from a salesperson (for a particular supplier) coming to the customer's door; about 80 percent of customers had been approached by a salesperson about changing supplier. However, while in 2002 and 2003 around 25 percent of customers obtained quotations directly from the companies and only about 8 percent used the Internet, in mid 2005 30 percent of surveyed consumers had used the Internet to obtain price information while around 29 percent obtained it from a mailing or the media (Accent [2005]). Advertising is rather unspecific and plays a small part in this market.¹² The most common method of obtaining information has remained a company sales representative.

Search is perceived by consumers as being significantly more difficult than switching. Thus only 11 percent of those who had switched reported finding the switching (as opposed to search) process as fairly or very difficult whereas 27 percent of those who had switched reported suppliers' prices to be fairly or very difficult to compare. Over half of those who had not switched had never compared prices (Accent [2005]). Several features of the market are designed to make switching cost low, including the fact that there is no contract penalty for leaving (for all standard tariffs), there is no need for a home visit, and the process is led by the gaining party.

Moreover, there is significant independent evidence that search costs are substantial in this industry, and remain so despite the growth of the Internet. A recent Parliamentary Committee heard evidence from the Chief Executive of Ofgem saying that 40 percent of consumers who switched had switched to a 'weaker deal' (House of Commons Energy and Climate Change Committee [2011], at para 18) and in written evidence we find that 'Our latest domestic consumer engagement survey found that of those consumers that switched supplier in order to save money, around a third did not know whether or not they had saved money following their switch' (Ofgem [2011], para 2.14).¹³ This can

¹²See Appendix B for more on this issue.

¹³Discovery of the best price deal for their circumstances continues to be a problematic issue for consumers, of whom only 8 percent are able to make the required

be explained by the fact that many consumers rely on potentially biased sources of supplier comparison information such as a company's representative (38 percent of switchers), the media or advertising campaigns (19 percent), or family and friends (7 percent) who may have different energy needs when making the decision to switch (Accent [2005]). Thus, consumers differ in their opportunity cost of time and search method. This is a market where, we argue, modeling search costs is necessary in order to explain observed price distributions.

III. DATA AND PRELIMINARY ANALYSIS

III(i). *Data*

Our analysis is based on data from a variety of public and commercial sources. Our price data as well as the names of different suppliers serving each region (incumbents and entrants) were collected from the consumer watchdog's 'energywatch' website for the time period between April 2001, when the final price controls on direct debit prices were removed (others followed in 2002), and December 2005 inclusive. The data have been collected on a bi-monthly basis for consumers using the direct debit payment method¹⁴ and using the average amount of electricity used in the region in a year, for all suppliers in each of the fourteen regions across which prices differ. The annual bill (our 'price') figures include VAT at a 5 percent rate. Our data exclude Internet-only-tariffs¹⁵ since these represented only a small proportion of the subscribed tariffs even by the end of our period.

We stop our analysis at the end of 2005 because after that period, the market became somewhat different in character. By March 2006, only 4 percent of consumers had arranged their electricity supplier directly through the Internet. Since then, this number has increased rapidly, with reports that in 2009, 26 percent of consumers purchased electricity in this way. The proportion of customers on Internet-only-tariffs reached 12 percent in 2009 (Ofgem [2010]). Accompanying this change in consumer behavior, the suppliers have vastly increased the range and complexity of tariffs on offer. Whereas in the period we study here, each supplier effectively offered a single tariff, each supplier now offers

comparisons of differing two-part tariffs, according to the consumer magazine Which? in an article published on October 14, 2012.

¹⁴Consumers can pay their electricity bill using three methods: credit, direct debit, and prepayment. See also the next subsection for a discussion.

¹⁵By this we mean tariffs requiring complete management of the account via the Internet.

multiple tariffs.^{16,17}

In addition to the price data we have information on the incumbent's market share of domestic direct debit consumers for each region over the whole time period considered, which are published on a quarterly basis by the UK Department of energy (DECC). The number of electricity users (consumers) for each region is based on the number of domestic metering points (meter point administration numbers or MPANs) published by Ofgem as *meters in existence* in September 2005. The total number of switchers at the national level for each of the years in our analysis was obtained from Ofgem's (approximately) annual Domestic Retail Market Reports from 2003 to 2006.¹⁸

We estimated average consumption by region using data on average electricity consumption by local authority district obtained from DECC. This was weighted by population estimates across local authority districts obtained from the Census of Population. Choice of districts to include in each region involved visual matching. This was carried out by comparing maps of local authority districts with maps of local electricity distribution areas, since the geographies do not coincide neatly.

Finally, we have information on the main cost components affecting final consumers' bills (wholesale electricity prices, transmission costs, distribution costs, and other costs) which we use to calculate suppliers' margins. Given the lack of access to commercial information about suppliers' costs, the cost data comes from a variety of sources. To capture the effect of wholesale electricity prices on domestic bills we used a set of proprietary wholesale data kindly supplied by Platts, one of the three major energy data information companies. Given that all energy suppliers have a portfolio of forward contracts for delivery at various time horizons, we used the year-ahead price as our measure of electricity wholesale costs. Wholesale prices are determined at a national level so this variable has no geographical differentiation but only time variation at a bimonthly frequency in line with the frequency of observations for domestic bills. Transmission costs vary by point of entry (generation plant) and exit (distribution point for delivery to final consumers) so that in order to calculate approximate values of transmission costs at

¹⁶In the case noted in the Introduction, the website gave a listing of 63 tariffs for the consumer to choose amongst, including the six major companies with many tariffs each and a few additional 'virtual suppliers,' who have a tiny market share.

¹⁷Several recent papers (Ellison and Ellison [2009]; Wilson [2010]; Ellison and Wolitzky [2012]) have shown that firms may have an incentive to obfuscate by increasing search costs. Although the increased range of tariffs on offer after 2005 is suggestive of such behavior, it does not seem that firms were intentionally obfuscating in the period before 2005, which is the period we study.

¹⁸Ofgem publishes incumbent market shares by region and market shares of each firm at the national level, but does not publish non-incumbent market shares by region.

a regional level a series of assumptions about flows of power across different parts of the country and the percentage of electricity subject to the transmission charge were required. Average values of nationwide transmission costs were obtained from Cornwall Energy Associates (Cornwall Energy [2008]). To aggregate these values we applied weights for the different electricity regions. These weights have been calculated on the basis of information provided by National Grid, the company managing electricity transmission in the UK (based on power flows in 2006). Distribution costs, i.e. the costs of transmitting low voltage electricity at the regional level, on the other hand, are subject to regional price regulation set by the energy regulator Ofgem. We obtained data on distribution costs (both fixed and unit rate) for each of the 14 regions, from the UK Department of Energy (currently designated as DECC) and formerly from BERR and DTI over the entire period 2002-2005. Estimates relating to other costs faced by energy suppliers (balancing costs, network losses, metering costs, supplier costs to serve, and environment related levies such as renewable obligations and energy efficiency commitment) are based on the Cornwall Energy Associates report on energy costs to consumers which covers the years 2003 and 2006.¹⁹

III(ii). *Prices and price dispersion*

Consumer prices for electricity differ by payment method. Table II illustrates the proportion of customers using the three main forms of payment by region during the year 2005. While traditionally standard credit had been the prevailing form of payment in this market, by 2005 direct debit had become the dominant payment method, with the exception of the Yorkshire and the London areas. Generally, direct debit tariffs and standard credit tariffs follow each other exactly, with the difference being that direct debit incorporates a fixed discount not available to standard credit customers. Prepayment tariffs follow a slightly different path.

[Table 2 about here.]

Table III as well as Figure 1(a) show how average electricity retail prices have evolved over time for consumers who pay by direct debit. Since all retail prices are at least two-part we focus on the charge for the average regional consumption level (hereafter called price), which varies from 4,028 kWh/year (Northern) to 5,305 kWh/year (North Scotland). There is quite a bit of variation in prices, even within regions. As shown in Table III the percentage difference in retail prices between

¹⁹Charges for carbon emissions were introduced in April 2005.

the most and least expensive suppliers is on average between 18 and 23 percent. Given that an average user then spent about £325 per year on electricity this means that for some consumers substantial savings could be made by changing supplier. For instance, in June 2002 an average user of electricity living in Birmingham (Midlands) could save about £60 a year (17 percent of the consumer's electricity bill) by switching from the incumbent npower to SSE, which at that time was the least expensive supplier in the Midlands.

[Table 3 about here.]

[Figure 1 about here.]

During the sample period there were large fluctuations in input fuel prices—wholesale gas prices decreased in 2002, were relatively flat in 2003, but were rising in 2004 and 2005.²⁰ This is also illustrated by the cost curve plotted in Figure 1(a). Here our measure of cost also includes the cost of distributing the electricity as well as costs related to transmission, network losses, balancing, renewables obligation, carbon emission, metering, and energy efficiency commitment. The large fluctuations in marginal cost make the retail price rather uninformative about how the introduction of competition has affected pricing in the retail electricity market. Figure 1(b), however, shows how the average margin has evolved over time for direct debit consumers. Apart from the sharp drop in 2005, which is likely caused by a sudden increase in fuel input prices, margins have been increasing during most of the sample period.²¹ The graph also shows incumbents were setting above average prices throughout the sampling period. In fact, during the first two years the incumbents' prices were higher than those of all entrants, and even in the second half of the sample they were commonly the maximum. Given that most incumbents were also entrants in other regional markets, this is suggestive of an important asymmetry in price decisions between the incumbents and entrants. For instance, in the South East the incumbent Seeboard consistently set the highest price during the first 12 months of our data (Seeboard was acquired by EDF Energy in early 2003), but was pricing very aggressively in regions in which it had entered and was often found in the bottom quartile of the price distributions in those regions.

[Figure 2 about here.]

²⁰Note that gas is the most significant fuel, followed by coal.

²¹A fuller analysis of the development of average retail margins over time is contained in Giulietti, Grossi and Waterson [2012].

Figure 2 gives a more detailed picture of pricing patterns in the Midland region. As the graph illustrates, the incumbent firm (npower) charges higher prices than entrants during most of the sample period. But the key feature driving our approach is that there are very substantial differences in prices between entrant suppliers which change significantly in rank over time.²²

IV. THE MODEL

In this section we develop a model that takes search frictions as an important determinant in price setting behavior of electricity providers. In addition, because each regional market was a local monopoly before the liberalization of the market in 1999, our model makes a distinction between behavior of the incumbent and of the entrants to the market.

Price for a given quantity may vary between suppliers for several reasons. We focus on search costs as the prime driver of differences, whilst acknowledging that other factors may play a role. Thus, we evaluate the magnitude of search costs required to rationalize observed price differences.²³ As shown by a large number of theoretical papers (e.g., Varian [1980]; Burdett and Judd [1983]; Stahl [1989]; Baye and Morgan [2001]; Janssen and Moraga-González [2004]), price dispersion can result as an equilibrium outcome, even in markets with homogenous firms. If some consumers search more than others, firms have incentives to either set a high price and maximize surplus from consumers who do not search that much, or to set a low price and maximize surplus from price comparing consumers. As a result, it might be optimal for firms to start mixing prices, with price dispersion as a result.

Our model takes the sequential search model of Stahl [1996] as a starting point. We introduce asymmetry on the supply side of the market by modeling the strategic interaction a set of N symmetric entrants under the presence of an incumbent firm. More specifically, we assume a mass of consumers normalized to one inelastically demands at most one unit of electricity.²⁴ As in Stahl [1996] our model is static, i.e., the model consists of one period only. At the beginning of a period each consumer is local to one electricity provider. Assume that the incumbent provider has a market share of λ consumers at the beginning of the period, whereas all the entrants together have $1 - \lambda$ consumers. The common unit cost of the providers is denoted by r .

²²Basic Power, one of those depicted, went into administration in 2005.

²³As stated earlier, this magnitude may be influenced by erroneous views of expected consumption.

²⁴We are assuming consumption does not vary in the short run as a result of the price differences experienced.

Consumers in our model can be grouped into two segments. We assume a share η of consumers does not compare prices; this group of consumers includes consumers that are loyal to a specific provider, i.e., consumers who never switch, but may also include consumers who make a switch based on other factors than price.²⁵ The remaining share of $1 - \eta$ consumers are what we call ‘price comparers’ and, given their objective of finding a lower price, would only switch to a less expensive provider. It is important to make a distinction between the two segments: firms will have monopoly power over the η consumers, while firms have to compete for the $1 - \eta$ price comparers.

At the beginning of a period, consumers only observe the price of the firm that provided them with electricity in the previous period. To obtain additional price quotations consumers have to engage in costly search. We assume the price comparers search sequentially for additional price information, that is, they determine after each search whether to obtain an additional price quotation or not. Sequential search is typically optimal when price information can be collected fairly quickly (for instance, by visiting a website or making a phone call), since the decision on whether to continue searching can then be conditioned on observed prices. Furthermore, let the comparers be characterized by a search cost c which is drawn at the beginning of a period from some search cost distribution $G(c)$, with density $g(c) > 0$.

At the beginning of the period, each entrant sets a price taking consumer search and switching behavior as well as pricing strategies of the other firms as given. Let $F(p)$ denote the distribution from which prices are drawn by the entrants, with support between and \underline{p} and \bar{p} .²⁶ Let the price of the incumbent be equal to v .²⁷ We assume throughout that firms cannot or are not allowed to price discriminate between consumers.

First, consider optimal search behavior for the group of price comparers. Let $H(\hat{p})$ be the gains from searching after having observed a price \hat{p} , i.e.,

$$H(\hat{p}, F) = \int_{\underline{p}}^{\hat{p}} (\hat{p} - p) f(p) dp = \int_{\underline{p}}^{\hat{p}} F(p) dp.$$

²⁵Assuming each firm has an equal probability of attracting (and losing) such a non-price (or random) switcher, the net effect is zero, which means this group is observationally equivalent to the loyal consumers.

²⁶As shown by Stahl [1996] for the case of symmetric firms, if there is an (arbitrary small) atom of shoppers there are no pure-strategy symmetric Nash Equilibria. Moreover, for the equilibrium price distribution to be a symmetric Nash equilibrium it needs to be atomless.

²⁷Although we do not explicitly model the optimal pricing strategy of the incumbent, this can be rationalized by the incumbent setting her price equal to the (exogenously given) consumers’ willingness to pay.

The reservation price $\rho(c; F)$ is defined as the price at which the gains from searching one more time are equal to the cost of searching once more, that is, $\rho(c; F)$ is the solution to

$$(1) \quad H(\rho; F) - c = 0.$$

A price comparer will continue searching as long as observed prices are higher than her reservation price $\rho(c, F)$. If the consumer finds a firm that has set a lower price than her reservation value, she will stop searching and switch to that firm.

We now move on to the price setting behavior of the entrants. Each entrant that sets a price p will face $\eta(1 - \lambda)/N$ consumers that do not compare prices. Demand from the $1 - \eta$ consumers that are willing to make a price comparison if search costs are low enough originates from three sources: (i) local consumers that find it optimal to stay; (ii) switchers from other entrants; and (iii) switchers from the incumbent. For each of these sources the firm sells to a consumer with search cost c if either the consumer's reservation price exceeds the entrant's price p or if the entrant's price is higher than the consumer's reservation price, but the firm happens to have the lowest price in the market. The latter happens with a probability of $(1 - F(p))^{N-1}$, so the expected demand from consumers with a reservation price that is lower than price p is

$$G(H(p))(1 - F(p))^{N-1}.$$

Demand from the price comparers that have a reservation price that exceeds price p is as follows. Consider first the local consumers that find it optimal to stay. An entrant setting a price p serves only those of its own locals $(1 - \lambda)/N$ that have a reservation value higher than p , so the group of own local price comparers accepting the current price is

$$\frac{1 - \lambda}{N}(1 - G(H(p))).$$

To attract price comparers from other entrants, the entrant should have a price lower than the reservation price ρ of a consumer that visits. Such a consumer will only start searching if her reservation price is lower than the price being set by her local supplier, which happens with probability $1 - F(\rho)$. Conditionally on searching, this consumer might visit the entrant's supplier at her first search, second search, third search, and so on, so the probability of selling is given by $\sum_{k=1}^{N-1} (1 - F(\rho(c, F)))^k$, where k is the number of visits. Summing up over all consumers that have a reservation value higher than p , but lower than the maximum price charged by the entrants, \bar{p} , and multiplying by the sampling probability

$(1 - \lambda)/N$ gives

$$\frac{1 - \lambda}{N} \int_{H(p)}^{H(\bar{p})} \sum_{k=1}^{N-1} (1 - F(\rho(c, F)))^k g(c) dc.$$

Consumers served by the incumbent will only switch if the expected gains from switching are bigger than zero, i.e., $v - E[p] - c > 0$, where $E[p]$ is the expected price of the entrants, so the expected number of switchers from the incumbent is given by

$$\frac{\lambda}{N} \int_{H(p)}^{v-E[p]} \sum_{k=1}^N (1 - F(\rho(c, F)))^{k-1} g(c) dc.$$

Notice that compared to the previous expression, the sampling probability is now λ/N . Moreover, since a consumer that is local to the incumbent firm faces N entrants, there might be consumers that search N times. Notice also that if a consumer searches only once the probability that the entrant serves this consumer, conditional on being sampled, is 1.

Total demand can be summarized in the following profit equation, i.e., the profit of each entrant is given by

$$\begin{aligned} \pi_E(p) = & (p - r) \left[(1 - \eta) \left(\underbrace{\frac{1 - \lambda}{N} (1 - G(H(p)))}_{\text{locals accepting current price}} \right) \right. \\ & + \underbrace{\frac{1 - \lambda}{N} \int_{H(p)}^{H(\bar{p})} \sum_{k=1}^{N-1} (1 - F(\rho(c, F)))^k g(c) dc}_{\text{switchers from other entrants}} \\ & + \underbrace{\frac{\lambda}{N} \int_{H(p)}^{v-E[p]} \sum_{k=1}^N (1 - F(\rho(c, F)))^{k-1} g(c) dc}_{\text{switchers from incumbent}} \\ & \left. + \underbrace{G(H(p))(1 - F(p))^{N-1}}_{\text{consumers with lower } \rho \text{ if lowest price}} \right) + \frac{\eta(1 - \lambda)}{N} \Big]. \end{aligned}$$

This equation can be simplified to

$$\begin{aligned} (2) \quad \pi_E(p) = & (p - r) \left[\frac{1 - \eta}{N} \left(\int_{H(p)}^{\infty} \sum_{k=1}^N (1 - F(\rho(c)))^{k-1} g(c) dc \right. \right. \\ & \left. \left. - \lambda[1 - G(H(v))] + NG(H(p))(1 - F(p))^{N-1} \right) \right. \\ & \left. + \frac{\eta(1 - \lambda)}{N} \right]. \end{aligned}$$

If there is no incumbent firm and if all consumers are price comparers, i.e., if both λ and η are zero, the profit equation simplifies to Stahl [1996] with unit demand. With an incumbent firm, part of the λ consumers are locked-in at the incumbent firm and, because of high search costs, will not switch to one of the entrants, which explains the $-\lambda[1 - G(H(v))]$ term in equation (2).

The upper bound of the price distribution of the entrants $F(p)$ is denoted by \bar{p} , where \bar{p} is the minimum of the monopoly price and the incumbent's price, i.e., $\bar{p} = \min\{p^m, v\}$. The monopoly price p^m can be found by taking the first order condition of the profit equation at the upper bound

$$\pi_E(p^m) = (p^m - r) \left[\frac{1 - \eta}{N} \left([1 - G(H(p^m))] - \lambda[1 - G(H(v))] \right) + \frac{\eta(1 - \lambda)}{N} \right]$$

with respect to p^m , which gives

$$p^m = \frac{[1 - G(H(p^m))] - \lambda[1 - G(H(v))] + \frac{\eta(1 - \lambda)}{1 - \eta}}{g(H(p^m))} + r.$$

An entrant will charge at most a price equal to \bar{p} . Setting such a price gives a profit

$$\pi_E(\bar{p}) = (\bar{p} - r) \left[\frac{1 - \eta}{N} \left([1 - G(H(\bar{p}))] - \lambda[1 - G(H(v))] \right) + \frac{\eta(1 - \lambda)}{N} \right].$$

In a mixed strategy equilibrium, the entrants should be indifferent between charging any price in the support of $F(p)$, which implies $\pi_E(p) = \pi_E(\bar{p})$. This indifference condition implicitly defines the entrants' equilibrium price distribution $F(p)$, i.e., for each p in the support of $F(p)$, $F(p)$ should solve

$$\begin{aligned} (3) \quad & (p - r) \left[\frac{1 - \eta}{N} \left(\int_{H(p)}^{\infty} \sum_{k=1}^N (1 - F(\rho(c)))^{k-1} g(c) dc \right. \right. \\ & \left. \left. - \lambda[1 - G(H(v))] + NG(H(p))(1 - F(p))^{N-1} \right) + \frac{\eta(1 - \lambda)}{N} \right] \\ & = (\bar{p} - r) \left[\frac{1 - \eta}{N} \left([1 - G(H(\bar{p}))] - \lambda[1 - G(H(v))] \right) + \frac{\eta(1 - \lambda)}{N} \right]. \end{aligned}$$

Note that this is a one-period model. When applying the model to the British electricity market in Section VI we assume, for analytical tractability, that the static game is unchanged over time so that consumers and firms view it as a repeated finite horizon game, yielding the same equilibrium framework each period. However, the outcome is different across years, since the underlying parameters are allowed to change.

Illustration

As an illustration, we have drawn the entrants' equilibrium price distribution for several values of λ , N , and parameters of the search cost distribution in Figure 3. In the examples, there is one incumbent selling at a price $v = 100$ with marginal cost of $r = 50$. We set η , the share of non-price comparers, to zero. A λ equal to one means that all consumers are being served by the incumbent. As a benchmark case, we also give the equilibrium distribution for λ equal to zero, which means that there is no incumbent.²⁸

[Figure 3 about here.]

All panels of Figure 3 show that a higher share of consumers at the incumbent results in lower prices being charged by the entrants. This is in line with intuition since a higher λ means fewer existing consumers, and therefore more incentives to price aggressively in order to make consumers switch from the incumbent to one of the entrants. A comparison of Figures 3(a) and 3(b) illustrates that, for a lognormal distribution with parameters $\mu = 1$ and $\sigma = 4$, an increase in the number of entrants leads to lower prices, although, at the same time, the entrants put more mass on the upper bound of the price distribution. The intuition for the latter is that it becomes increasingly difficult to attract consumers with relatively low search costs as the number of firms increases. Firms start putting more mass on high prices to maximize surplus from consumers with relatively high search costs.²⁹ At the same time, competition between the entrants will result in overall lower prices. Only when λ is zero do prices go up as a result of more firms, but that is because in the absence of an incumbent it can never be optimal to set the upper bound of the price distribution lower than v . Finally, Figures 3(c) and 3(d) show that both more dispersed search costs as well as higher mean search costs lead to higher prices being charged by the entrants.

V. ESTIMATION STRATEGY

In this section we describe how to estimate search costs using the structure of the search model developed in the previous section. As discussed in our data section we have data on prices, unit costs, the share of consumers served by the incumbent in each region, as well as the number of providers in each region, allowing us to fix corresponding parameters in

²⁸Here we assume consumers' maximum willingness to pay is equal to v .

²⁹See Janssen and Moraga-González [2004] for a similar result for a non-sequential search model.

our model. As we will discuss in more detail in the next section, available survey data allows us to pin down the share of non-price comparers. This means the only unknown in the model is the search cost distribution; in what follows we will describe how to retrieve search costs while taking as given prices p , unit costs r , the share of consumers at the incumbent λ , the share of non-price comparers η , as well as the number of providers N .

Equation (3) provides the equilibrium condition for the entrants in the model and as such it provides a starting point for the estimation of the model. The goal of the estimation is to find the parameters of the search cost distribution such that equation (3) holds for all observed prices and all other fixed parameters. Unfortunately, the model cannot be explicitly solved for the equilibrium price distribution $F(p)$, which makes it difficult to compute the integral in equation (3) and use this equation directly to back out search costs. As we show below in more detail, to deal with this issue we will use equation (1), which relates reservation prices to search costs, to approximate the integral. This allows us to solve the equilibrium condition for prices p as a function of the parameters to be estimated; our objective is then to find the parameters such that the difference between these prices and the observed prices are minimized.

Although in our application we will use a panel of prices to estimate the model, the estimation of the model is the most easily explained assuming we are using a cross-section. Suppose we observe M prices from the entrants and that these prices are ordered by increasing price level, i.e., $p_1 < p_2 < \dots < p_M$. Let $\tilde{F}(p)$ be the empirical price distribution, i.e., $\tilde{F}(p) = (1/M) \sum_{i=1}^M \mathbf{1}(p_i < p)$. The upper bound \bar{p} of $\tilde{F}(p)$ is given by $\bar{p} = p_M$.

If the model is correctly specified, at the true parameter values the entrants' predicted prices $p(\theta)$ should match observed prices \hat{p} , i.e.,

$$p(F, \theta) - \hat{p} = 0.$$

Solving the entrants' optimality equation (3) for price p_i gives

(4)

$$p_i = r + \frac{(\bar{p} - r) \left[[1 - G(H(\bar{p}))] - \lambda[1 - G(H(v))] + \frac{\eta(1-\lambda)}{1-\eta} \right]}{\Omega + NG(H(p_i))(1 - F(p_i))^{N-1} - \lambda[1 - G(H(v))] + \frac{\eta(1-\lambda)}{1-\eta}},$$

where $\Omega = \int_{H(p_i)}^{\infty} \sum_{k=1}^N (1 - F(\rho(c)))^{k-1} g(c) dc$. The main problem with using equation (4) directly for the estimation of the model is that we cannot solve the model explicitly for the equilibrium price distribution $F(p)$, which makes it difficult to obtain a closed-form expression for Ω , the integral in equation (4). To deal with this, notice that

we can split the integral into two parts, i.e., $\Omega = \int_{H(p_i)}^{H(\bar{p})} \sum_{k=1}^N (1 - F(\rho(c)))^{k-1} g(c) dc + (1 - G(H(\bar{p})))$; we approximate the first part by writing it as a Riemann sum, i.e.,

$$\int_{H(p_i)}^{H(\bar{p})} \sum_{k=1}^N (1 - F(\rho(c)))^{k-1} g(c) dc \approx \sum_{j=i}^M \sum_{k=1}^N (1 - F(p_j))^{k-1} \Delta G(c_j).$$

where we use equation (1) to partition the interval over which we are integrating. More specifically, according to equation (1) a consumer with reservation price ρ equal to an observed price p_j has a corresponding search cost value c_j such that $c_j = H(p_j)$, which can be calculated directly from the data using

$$(5) \quad c_j = \frac{1}{M} \sum_{k=1}^j (p_j - p_k).$$

To see how the search cost distribution $G(c)$ can be identified using available data assume $G(c)$ is distributed according to some distribution $G(c; \theta)$ with parameters θ . Using the calculated c_j 's from equation (5) this allows us to calculate p_i as follows

$$p_i = r + \frac{(\bar{p} - r) \left[[1 - G(c_M)] - \lambda [1 - G(\bar{c})] + \frac{\eta(1-\lambda)}{1-\eta} \right]}{R + NG(c_i)(1 - F(p_i))^{N-1} + (1 - G(c_M)) - \lambda [1 - G(\bar{c})] + \frac{\eta(1-\lambda)}{1-\eta}},$$

where $R = \sum_{j=i}^M \sum_{k=1}^N (1 - F(p_j))^{k-1} \Delta G(c_j)$ and $\bar{c} = \frac{1}{M} \sum_{k=1}^M (v - p_k)$.³⁰ We then let the optimization algorithm pick the search cost parameters θ in such a way that the difference between the p_i and the observed \hat{p}_i is minimal, which can be done using nonlinear least squares. Although the model can be estimated using a cross-section of prices, we will estimate the model using a panel of prices for two reasons: it allows to obtain more efficient estimates, and secondly, it allows to estimate the overall trend in search costs.

VI. ESTIMATION RESULTS

In this section, we apply our estimation procedure to the prices collected from British electricity suppliers. We have made several strong assumptions in our theoretical model, which might need additional justification

³⁰Note that we can only identify the search cost distribution up to \bar{c} . This means that the estimated search cost distribution for search cost values that exceed \bar{c} is based on parametric extrapolation only.

when applying our model to the electricity market. These include the assumptions of sequential search, symmetry across entrants, a parametric (lognormal) search cost distribution, and not allowing for switching costs. In discussing the results, we consider these issues.

We assume consumers search sequentially, which means consumers determine after each search whether to continue searching or not. As shown by Morgan and Manning [1985] sequential search is optimal when price information can be gathered relatively quickly because in that case the decision whether to search further at a given point in time can be conditioned on observed prices. If price quotations are observed with some delay, non-sequential search is typically optimal. It is unlikely that in the specific setting we are studying there is such a delay, but still non-sequential search might be a good approximation of search behavior if consumers commit to obtaining a certain number of price quotes before searching, or if consumers use price comparison sites. Unfortunately, our data does not allow us to directly observe the way in which consumers are searching. However, we note that even though price comparison websites have become more popular over the sampling period, the consumer surveys carried out for Ofgem over time show that, while a significant proportion of consumers ‘use the Internet to find suppliers prices,’ namely 30 percent by mid 2005, only 7 percent report ‘using comparison website’ (Accent [2005]). Thus, for the bulk of consumers, it appears that comparison sites are not used for conducting price research, and, in absence of direct data on consumers search patterns, modeling search as a sequential procedure seems reasonable.

Although we allow for the incumbent and the entrants to behave differently in our model, we assume entrants in a given region are symmetric. The assumption of symmetry does some violence to reality, but not much. The major outlier is British Gas, which is treated as an entrant in all electricity markets and in that role faces similar incentives to other entrants. Otherwise, all the other major players are broadly equally successful in capturing unattached customers, according to rough figures obtained by subtracting their size in the incumbent market from their total market penetration.³¹

Our model does not take switching costs into account. Switching costs can explain a price differential between the incumbent firm (or the household’s current supplier) and entrants (other firms) as a group. But switching costs cannot provide the explanation for different prices

³¹Table I has rough figures for the percentage share by firm across the whole of Britain. Ofgem also published the percentage share of the incumbent (but not others) in each market, as of September 2005 (Ofgem [2006]). Using this information together with numbers of consumers (MPANs) in each market yields each firm’s total percentage share outside their home territory, which is of the order of 5-6 percent.

amongst the firms a consumer might switch to—if there are several firms to which you can switch, but they reflect different prices, then if search costs are zero, everyone who does switch, will switch to the same firm, so there would be no point in setting a price above the lowest. Recall from Section II that there are several features of the market designed to make switching cost low, including absence of contract penalties, no home visit, and the process being gaining party led.

The entrants' equilibrium price distribution is in mixed strategies. In fact, in our sample, it is not possible to reject the hypothesis that price movements are consistent with a mixed strategy equilibrium. The reason is that companies move their relative price points significantly over time and also across region. Formally, a test using Kendall's coefficient of concordance cannot reject the null of mixed strategies; see Appendix A for more details.

We estimate the model using a panel of prices, with an observation being a price for firm i , in region s , for period t . We normalize prices using the average yearly consumption level in a region, which means that prices in our model reflect the average yearly electricity bill a customer would face when subscribing to firm i in region s during time period t , using the direct debit payment method. Price data are available at a bimonthly frequency, so we observe prices for 23 periods (all price controls were removed in April 2002, so we exclude February 2002). In 80 percent of these bimonthly periods a change in price by at least one company and in at least one of the fourteen regions was observed. In this sense, prices are not very persistent (indeed, the industry has been criticized for increasing prices several times in some years).

For our empirical analysis we assume the static equilibrium of the theoretical model described in Section IV is also the equilibrium of the repeated game with finite horizon. This allows us to estimate the model by taking prices from several periods together, as long as the fundamentals of the model do not change within a period. In our estimates below we combine the bimonthly price data to a full calendar year, which allows us to obtain yearly search cost estimates. This gives us a total of 2,360 observations. To take regional demand and supply side conditions into account, we allow search cost parameters to differ across regions.

[Table 4 about here.]

Table IV gives summary statistics for the most relevant variables. The number of firms N is obtained by taking the observed number of firms in each region. The number of providers in each of the fourteen regions has been going down steadily, from around 13 in 2002 to 7 or 8 in 2005, although recall that the largest six have consistently attracted over 99 percent of consumers. Margins have been increasing

up to 2004 and went back to 2002 levels in 2005. Although prices are somewhat persistent, marginal costs are continuously changing, which means that margins are showing considerable variation as well, as indicated by the standard deviation. For all regions, the incumbent's share of households, which we use for λ in our estimation, has been decreasing steadily between 2002 and 2005, although there is some variation in levels across regions. For instance, the incumbent in North Scotland still served 64 percent of households in 2005, while this was only 41 percent of households in the Yorkshire region.

Another key variable in our analyses is η , which is the share of non-price comparers and includes loyal consumers as well as non-price switchers. According to the 2005 Accent consumer experience survey (Accent [2005]), 67 percent of respondents who had switched in the past identified price as the main reason for switching. Of the non-switchers, 3 percent identified price as the main reason to stay with their current electricity provider, but another 63 percent gave satisfaction with their current supplier as the main reason not to switch (which may also include satisfaction with the current price). So approximately one-third of respondents switched or did not switch because of reasons unrelated to price, which corresponds to $\eta = 0.33$. Reasons not to switch other than price include not being able to switch because of meter type, customer service, or not trusting other providers. Non-price related reasons to switch are poor service and being able to buy gas and electricity from the same company.³²

For each of the fourteen regions we have estimated the mean and the standard deviation of the natural logarithm of the search costs using the lognormal distribution as our parametric specification. To allow for the mean and standard deviation to vary over time, we included two trend parameters. The estimation results are presented in Table V. A first observation is that all estimated parameters are highly significant. Notice that there is substantial variation among the regions in terms of mean log search costs and the standard deviation of the log search costs, with the mean ranging from 4.64 to 8.88 and the standard deviation from 2.23 to 4.25. All estimated mean trend parameters are smaller than zero, which means that median search costs within the population have been falling over time. Moreover, the negative standard deviation trend parameters indicate search costs became less dispersed over time.

[Table 5 about here.]

In Figure 4(a), we plot the estimated search cost distribution for 2005. The solid curve gives the average regional search cost CDF across the

³²Note that η may also include seemingly random switchers, i.e., those who do no search.

14 regions, whereas the shaded area gives the lower and upper bound of the estimated regional search cost CDFs (corresponding to North Scotland and North West, respectively). It is apparent from inspection of Figure 4(a) that search costs have to be relatively high to rationalize observed prices: according to the average search cost CDF, in 2005 roughly half the households had search costs exceeding £52. The relatively high margins we found by comparing observed prices with our measure of marginal cost already gave some indication that firms have a lot of market power, and this can only be rationalized by our model if consumers have relatively high search costs. Our estimates also suggest that there are substantial differences in search costs across regions.

[Figure 4 about here.]

In Figure 4(b), we plot the estimated average regional search cost distributions for all years between 2002 and 2005. Our estimates suggest that there has been a significant leftward shift in the search cost distribution over time. Figure 4(b) shows this for the average search cost CDF, but as indicated by the significant negative trend parameters in Table V this shift appears in all 14 regions. For instance, as measured by the lower quartile, search costs have gone down from £42.57 in 2002 to £16.16 in 2005 in the Midlands.³³ Search costs have also gone down substantially in other regions—Table V shows that, for most regions, lower quartile search costs in 2005 are around a quarter of what they were in 2002. This led to consumers searching more: simulations based on the estimated parameter values indicate the average number of searches went up from 0.5 in 2002 to 0.9 in 2005. However, conditional on searching at least once, the estimated number of searches went down from an average of 3.3 in 2002 to on average 2.6 in 2005. Since more consumers decided to search over time, also consumers with relatively high search costs were more likely to search, pushing down the average number of searches for those who search. One explanation for the shift in the search cost distribution could be the increased use of Internet sites over time. Since these sites make searching for the provider with the lowest price a lot easier, this might explain the substantial decrease in search costs.

[Figure 5 about here.]

³³We report the lower quartile instead of the mean or median of the estimated log-normal search cost distributions, because especially for the first two years most of the estimated parameters in Table V are such that the median and mean are larger than the upper bound of search costs that we can identify (corresponding to \bar{c} in Table V). Any inference based on the mean or median would therefore rely on parametric extrapolation. Thus our reliance on a particular parametric framework for estimation (the lognormal distribution) is minimized.

Even though we restrict the search cost distribution to be lognormal, the model explains the data very well: slightly over 94 percent of the variation in prices can be explained by the model. This is also illustrated in Figure 5, which compares the estimated margin distribution to the actual margin distribution for 2003 in Figure 5(a) and for 2005 in Figure 5(b). We have plotted the margin distributions instead of the price distributions to make sure we can compare and combine prices across the different regions. The model does particularly well for relatively high prices, but has some difficulties in fitting prices that are close to unit costs, as shown in the graph for 2005, Figure 5(b). The equilibrium condition in our search model is such that profits are equal across any price in support of the price distribution, which explains why the model has a hard time justifying margins that are close to zero.

Note that even though we estimate a static model, our model, and hence our estimation results, take into account that the share of consumers at the incumbent, denoted by λ , has been going down over time. As can be seen from Figure 3, it is important to take this changing value of λ into account. This is because a given price distribution can be rationalized by a relatively high λ (which in isolation puts downward pressure on prices), together with relatively high mean search costs, or low λ and low mean search costs. The fact that we observe λ therefore helps us in identifying search costs. This also helps to explain why our estimates suggest search costs are decreasing over time, while retail margins are broadly increasing (Figure 1(b)). The apparent paradox can be resolved by observing that as the market share of the incumbent (λ) falls, mean price above marginal cost would tend to rise (see Figure 3) because the entrants, having gained a larger market share, compete less aggressively, i.e., the tradeoffs represented in equation (2) are different, recalling that we re-evaluate λ each year.

[Table 6 about here.]

The estimates in Table V are based on average regional consumption levels. To see how sensitive our estimates are to the level of user intensity, Table VI gives estimates (averaged across regions) using alternative measures. More specifically, we distinguish between a so-called (by Ofgem) medium (3300 kWh per year) and high (4950 kWh per year) user intensity (see also Giulietti, Otero and Waterson [2010])—mean consumption is generally between these values. The estimates are very similar. Table VI also reports average parameter estimates for a slightly lower ($\eta = 0.25$) and higher value ($\eta = 0.40$) of the share of households that makes a switching decision based on non-price reasons. The estimation results are very similar, which suggests the estimates are not very sensitive to the level of η .

The estimates rely on the assumption of a homogeneous good. Although this seems a reasonable assumption for electricity, one might be worried that the firms providing the electricity are not homogeneous, but differ in aspects like the quality of service, extent of advertising, or whether dual service is offered.³⁴ Product differentiation can also explain price differentials and could be observationally equivalent to switching costs (I may stay with my current supplier either because I face high switching costs or because I view it as the best supplier for me). Product differentiation can also explain why someone who switches may not switch to the cheapest alternative.³⁵ To control for product differentiation we also estimated the model using the residuals of a fixed effects regression of prices on firm dummies and our marginal cost variable. Wildenbeest [2011] has shown for related equilibrium search models that the residuals of such a fixed effect regression can be interpreted as quality-controlled prices, assuming consumers have similar preferences toward quality, and quality input factors are obtained on perfectly competitive markets with a constant returns to scale quality production function. The results in Table VI show that if we use quality-controlled prices, even though we get qualitatively similar results, estimated search costs go down on average. This is intuitive: the part of the price variation that is attributed to search frictions goes down, which means search costs need to be uniformly lower to be able to explain the more competitive quality-controlled prices.

VII. INDEPENDENT VERIFICATION OF SEARCH COSTS

One issue that modelers attempting to quantify search costs largely through the distribution of observed prices face is a verification of whether the estimates are reasonable. In the present context, this issue is brought sharply into relief. Our estimates (Table V) indicate what may appear to be very high lower quartile values for search cost. At the same time, it must be presumed that substantial search has been taking place in the market, because there is a considerable degree of switching between electricity providers. Can these two findings be reconciled? Another potentially questionable finding is the very significant estimated reduction in these search costs over a rather short period of time.

We make use of a set of data to confront our estimates that is inde-

³⁴See Appendix B for some exploration of advertising in the industry.

³⁵In a survey conducted by Accent on behalf of Ofgem in mid-2005 67% of switchers claim to have switched due to cheaper prices while only 6% did so because of poor service from the previous supplier (Accent [2005]). Furthermore, recent Ofgem research seems to indicate that tariff complexity and limited financial competence can lead consumers to chose inferior tariffs when switching (Ofgem [2011], para 2.11).

pendent of the information used to generate our model estimates. This is Ofgem information on the total number of switches (of any type) by year at national level. We use this along with DECC information on λ to infer the distribution across regions. Note that the former captures gross switches, whereas the latter implicitly relates to net switches.

We also have some very limited information from a survey commissioned by Ofgem relating to June 2005. This reveals two interesting snippets of information: first, by then over 80 percent of electricity consumers had been approached by sales people (mostly a cold-call visit to the home), with the aim of making a commission-generating switch; second almost 30 percent of consumers who switched their supplier admitted to having never compared suppliers' prices! These phenomena suggest that there is a significant amount of essentially random switching, even involving switching to suppliers who are more expensive (for example, returning to a more expensive incumbent). Thus, gross switching will differ from net switching.

In taking these data on switches to our search cost estimates, we need to consider the distribution of savings that consumers will make from searching. Ignoring consumption levels, the gains from search for a customer currently at the incumbent are $s = v - E[p]$, where v is the price at the incumbent and $E[p]$ is the expected (or mean) price of the entrants. Unless a consumer is a random switcher, a consumer only switches from the incumbent to one of the entrants if $c < s$. Given our search cost estimate $G(c)$, this means a proportion $\lambda MG(s)$ will deliberately switch away from the incumbent, where the share of consumers at the incumbent is λ and M is the number of consumers.

However, it makes more sense to take consumption levels x into account. In general, the probability of switching will be given by the expression $\int G(s(x))dH(s(x))$, where H is the distribution of possible savings for consumers currently at the incumbent. We do not know enough about the distribution of savings across regions to estimate H , save in special cases; what we do know is mean consumption by region and hence $s(\hat{x})$. Under simplifying assumptions regarding the distribution, an explicit expression can be generated.

Uniform savings distribution

Denote by x a consumer's share of the savings s at the actual average consumption level we use to estimate the model. We assume $x \in [0, 2]$, which means that the savings are between zero and twice the mean value of calculated savings. Since $s = v - E[p]$, we get $s(x) = (v - E[p])x$. We assume x follows a uniform distribution with support between 0 and 2, so the PDF of x is given by $h(x) = \frac{1}{2}$.

A consumer with savings $s(x)$ will only switch if $c < s(x)$ which corresponds to a proportion $G(s(x))$, where $G(\cdot)$ is the search cost CDF. To get the total number of switchers S we want to integrate $G(s(x))$ over x between 0 and 2, i.e.,

$$\begin{aligned} S &= \int_0^2 G(s(x))h(x) dx; \\ &= \int_0^2 G((v - E[p])x)^{\frac{1}{2}} dx. \end{aligned}$$

In our estimation we assume the distribution of search costs is lognormal with parameters μ and σ , which results in the following expression for S :

$$S = \frac{1}{4} \left(\frac{e^{\mu + \frac{\sigma^2}{2}} \operatorname{erfc} \left(\alpha + \frac{\sigma^2}{\sqrt{2}\sigma} \right)}{E[p] - v} + 2 \cdot \operatorname{erfc}(\alpha) \right),$$

where $\alpha = \frac{\mu - \log(2(v - E[p]))}{\sqrt{2}\sigma}$ and erfc is the complementary error function, i.e., $\operatorname{erfc}(u) = \frac{2}{\sqrt{\pi}} \int_u^\infty e^{-t^2} dt$. Finally then, our prediction of the number switching (non-randomly) away from the incumbent in a particular region is $\lambda M \hat{S}$.

Table VII below reports the results of our calculations; Panel A relates to the total switching pattern over time whilst Panel B contains estimates of the differential effects across regions. These predictions are based on two possible scenarios, the first, prediction 1, where in each year we base the calculation on the actual value of λ for that year, the second where we take the initial λ as the starting value but then assume that if someone switches in year t , they then do not switch in year $t+1$ (though they may do in year $t+2$). This means that the λ for years following 2002 are generated within the model through previous switches rather than being drawn directly from the data each year.

[Table 7 about here.]

Turning to the results in Panel A, our model of search costs predicts quite closely the actual switching numbers moving between firms. However, there is some tendency to under-predict the trend in switching over time. Yet it is clear that without a fall in search costs, the predictions would be worse; the benefits of search are particularly high in 2004 which is captured in a slightly heightened level of predicted switching, which accords with reality. Of course, if our assumption of savings being uniformly distributed is substantially at variance from

reality, this is also likely to impact on the results in all periods. Nevertheless, our model's predictions are well within the ballpark of the true values throughout.

Turning to Panel B, we switch focus from absolute to relative predictions across regions. The results here are pleasing in that on either assumption, as the correlations show, we can predict closing rank very well using our model. A significantly tougher test is also passed well, namely that we can predict the proportionate change over the period. In particular, it is noteworthy that we are able to predict the very low number who switch away from SSE in North Scotland and South Wales, and the contrastingly large impact on E.ON in the North West and npower in the Yorkshire areas.

In sum, we suggest that this calibration exercise on actual switching behaviour is significant independent validation of the general character of our estimates of search costs, as estimated from the price distribution, in terms of the impact on market shares.

VIII. CONCLUSIONS

In the late nineties, the British electricity market was one of the first to completely open up for competition, leading to a substantial inflow of new suppliers. Moreover, a greater proportion of consumers than perhaps anywhere else in the world has switched. As such it provides an interesting case of how competition has affected pricing strategies, both those of the incumbent supplier of electricity and those of entrants. On the consumer side of the market, the inflow of new suppliers has led to changes as well, because consumers have the opportunity to look for better deals and eventually switch.

Our sequential search model distinguishes between an incumbent and a group of entrants. Using the structure of the model we estimated search cost distributions for each of the 14 regional electricity markets in Great Britain. Our estimates indicate that in order for the model to rationalize observed price patterns, search costs have to be relatively high implying that the modal consumer does not search or switch, consistent with the facts. Our estimates indicate that search costs have decreased over time. But at the same time, because entrants have gained a greater foothold in each market, their incentives to price keenly have been muted.

Taking the implications of the estimates of search costs for the amount of switching that should have been observed together with the actual amount of switching behavior that occurred shows a substantial correlation between the two, which leads us to greater confidence that our search cost estimates, which might be thought to be high, are indeed

consistent with consumer switching behavior. We leave for further work the possibility of a more dynamic approach to modeling and estimation.

More recently, the tariff structure has become more complex, rendering consumer decisions more difficult. This has likely countered the effect of consumers' search costs falling on average, as a result of increased use of Internet search engines. In consequence, substantial differences across tariffs remain.

The general lesson we draw from this analysis is that, however apparently homogenous the product and however straightforward search and switching appear to be, the results for consumers can be poor. This is true even if a substantial number of consumers switch, because consumer search for products such as an electricity supplier is perceived as costly (or, perhaps, simply boring). Firms, recognizing the limited nature of search, can exploit this in their charging structures. Of course, time is a precious resource, and we would not expect search opportunities to be captured exhaustively. However, for a product on which people spend a substantial proportion of their incomes, the result is surprising and shows the importance of consumer as well as firm behavior in determining competitive outcomes.

APPENDIX A: DO THE FIRMS PLAY MIXED STRATEGIES?

A fundamental feature of our model, as with most search models, is that the firms play mixed strategies with respect to pricing. In our case, we are able to assess whether this appears to be true within the data. The means by which we operationalize this is to convert the bi-monthly pricing data for the ‘big 6’ into ranks going from 1 to 6.³⁶ One aspect of where theory is unclear is *how often* prices are reassessed. Given the institutional regularities in this industry, we suggest that every two months is an appropriate period. (Although consumers would not be likely to reassess their situation this frequently so it is probably on the short side.) This gives us 24 observations, across 14 British regions. The question we ask is whether for each firm, the strategy it plays is concordant across the time period and across regions. If it is not significantly concordant, then this is indicative that a mixed strategy is being pursued. For the five firms that are incumbents, we do this with and without their incumbent areas (since it is fairly clear that, for the most part, they charged prices at the top of the distribution for this group). Our method of testing concordance, or its absence, is using Kendall’s coefficient of concordance (W).³⁷

An illustrative tabulation of ranks using the example of British Gas’s electricity prices is given below; the results for the other five companies are similar. Of course, British Gas is not an electricity incumbent in any area. We can calculate W using either columns (Is the strategy concordant or mixed across the 14 regions?) or rows (Is the strategy concordant or mixed across bimonthly time periods?). Then, given the degrees of freedom in these cases, we compare the relevant calculated value (a transformation of W) with the χ^2 distribution with $n-1$ degrees

³⁶Arguably, the rank of a firm in the set of prices is a convenient way of assessing its strategy—if a consumer is searching among a subset of prices, including for some exhaustive search, then the consumer will choose the lowest, all other things equal, whether it is significantly lower or slightly lower than other offers. In the earlier years, the firms had not necessarily merged or consolidated pricing across divisions of the firm. Here, our procedure is to take the lead partner value, except for the local area. To illustrate, a clear cut case is Scottish Power, where there was a ‘Manweb specific’ offering in the Merseyside area, while Scottish Power did not offer to serve the region. However, in other cases, for example EDF, there were sometimes two separate offerings in the area in some early periods.

³⁷The literature on testing for mixed strategies is not very helpful in suggesting approaches. The best-known stream of literature relates it to sports activities (e.g. penalty kicks in soccer, behavior in tennis serves) which is not very relevant for the British electricity market. A more promising approach in the present context is adopted by Lach [2002]—this is the approach used in Giulietti, Otero and Waterson [2010]. What we report in the main text is essentially an extension of this idea with the same results as in that paper.

of freedom, n being the number of cases. As can be seen, there is no evidence to reject the null hypothesis of mixed strategy in either dimension. This is obvious when we inspect the results by different regions, but less obvious in the time dimension. One thing this test does not make use of is the sequencing of time and it is clear that there is some time dependence in at least some regions.³⁸ The other regions give the same answer on the concordance test, once incumbency has been accounted for.

Our general conclusion from this analysis is that a model in which firms play mixed strategies does not do empirical violence to the actual experience. Whether this is conscious behavior on the part of the firms involved or not is unclear. We therefore do not claim that the firms deliberately pursue a mixed strategy in pricing, but simply that the outcome is as if they in fact do so.

[Table 8 about here.]

APPENDIX B: ADVERTISING AS A SOURCE OF PRICE INFORMATION

In addition to consumers being able to glean information for themselves from information providers such as energywatch and online switching services, and from sales people, information (or perhaps, invitations to obtain information) is also available via advertisements. To investigate this aspect, we obtained information from NMR Digest for the range of years since liberalization. NMR Digest is a quarterly publication that checks all significant (non-digital) media activity. Its methodology appears to be to scan a very wide range of print, poster, TV, and radio media outlets throughout the UK, recording the presence of advertisements and applying published rate-card information to get a figure for spending³⁹ (subject to a lower cut-off). Since categorization of the advertisement series is sometimes ambiguous (for example, as to whether it applies to electricity or gas, or both), we aggregated all relevant cases to get an annual figure per firm with the results shown in Table IX.

[Table 9 about here.]

Outside the ‘big 6’, there is remarkably little expenditure right from the outset. Even within this group, SSE seems to promote very little indeed by these means. Indeed, the average total expenditure can

³⁸In a market like electricity, where there is continuous purchasing, we would expect to see only gradual movements to being a better or worse buy rather than sudden changes.

³⁹This will tend to be an overestimate due to discounts being applied.

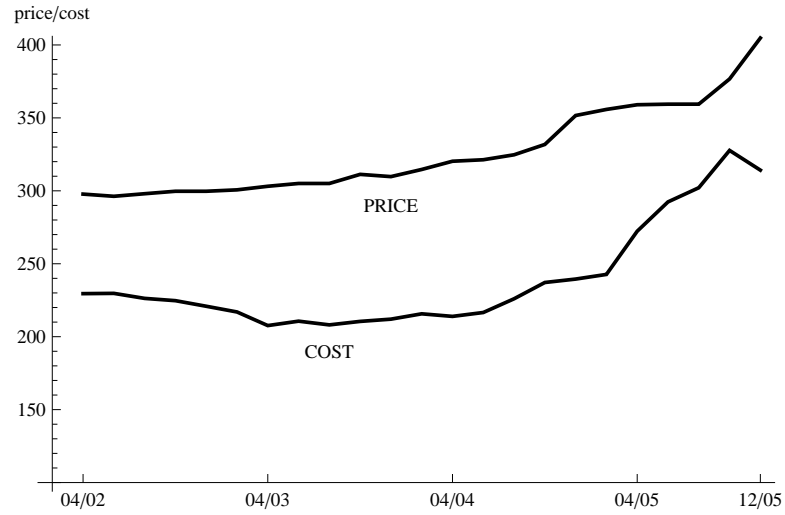
be viewed as modest, less than £1 per customer per year (so maybe 0.5 percent of turnover). On a more qualitative note, given the pricing structures employed by all of these players, it is not feasible to produce a simple comparative information advertisement. Thus the media tend to be selective at best in quoting pricing reasons for a switch and focus on awareness. All also claim excellent service, whereas Ofgem evidence [2006] is clear that there are differences between providers on this score. We conclude from this investigation that this form of promotional activity is not particularly important in the electricity industry relative to those we investigate.

REFERENCES

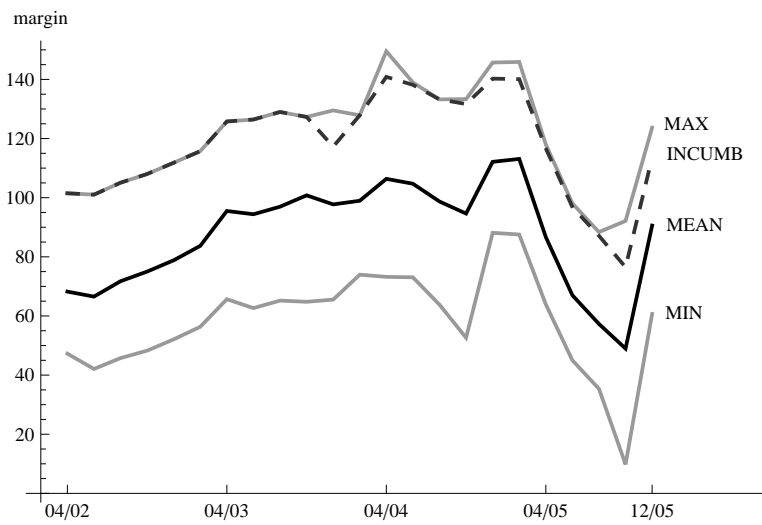
- Accent, 2005, *Customer Experience Survey Report (Key Findings)*, Accent, London. Appendix 6 to Ofgem [2006].
- Baye, M.R.; Kovenock, D. and De Vries, C.G., 1992, 'It Takes Two to Tango: Equilibria in a Model of Sales,' *Games and Economic Behavior*, 4, pp. 493–510.
- Baye, M.R. and Morgan, J., 2001, 'Information Gatekeepers on the Internet and the Competitiveness of Homogeneous Product Markets,' *American Economic Review*, 91, pp. 454–474.
- Burdett, K. and Judd, K.L., 1983, 'Equilibrium Price Dispersion,' *Econometrica*, 51, pp. 955–969.
- Cornwall Energy, 2008, *Gas and Electricity Costs to Consumers: a Report for the National Right to Fuel Campaign*, Cornwall Energy Associates, Norwich, U.K.
- Defeuilley, C., 2009, 'Retail Competition in Electricity Markets,' *Energy Policy*, 37, pp. 377–386.
- Ellison, G. and Ellison, S.F., 2009, 'Search, Obfuscation, and Price Elasticities on the Internet,' *Econometrica*, 77, pp. 427–452.
- Ellison, G. and Wolitzky, A., 2012, 'A Search Cost Model of Obfuscation,' *RAND Journal of Economics*, 43, pp. 417–441.
- Giulietti, M.; Otero, J. and Waterson, M., 2010, 'Pricing Behaviour under Competition in the UK Electricity Supply Industry,' *Oxford Economic Papers*, 62, pp. 478–503.
- Giulietti, M.; Grossi, L. and Waterson, M., 2012, 'Price Transmission in the UK Electricity Market: Was NETA Beneficial?' *Energy Economics*, 33, pp. 119–142.
- Hong, H. and Shum, M., 2006, 'Using Price Distributions to Estimate Search Costs,' *Rand Journal of Economics*, 37, pp. 257–275.
- Honka, E., 2013, 'Quantifying Search and Switching Costs in the US Auto Insurance Industry,' mimeo (Jindal School of Management, University of Texas at Dallas).
- Hortaçsu, A. and Syverson, S., 2004, 'Product Differentiation, Search Costs, and Competition in the Mutual Fund Industry: a Case Study of S&P 500 Index Funds,' *Quarterly Journal of Economics*, 119, pp. 403–456.

- Hortaçsu, A.; Madanizadeh, S.H. and Puller, S.L., 2011, 'Power to Choose: An Analysis of Consumer Behavior in the Texas Retail Electricity Market,' mimeo.
- House of Commons Energy and Climate Change Committee, 2011, *Ofgem's Retail Market Review, 6th report of session 2010-12*, HC1046.
- Janssen, M.C.W. and Moraga-González, J.L., 2004, 'Strategic Pricing, Consumer Search and the Number of Firms,' *Review of Economic Studies*, 71, pp. 1089–1118.
- Kocas, C. and Kiyak, T., 2006, 'Theory and Evidence on Pricing by Asymmetric Oligopolies,' *International Journal of Industrial Organization*, 24, pp. 83–105.
- Lach, S., 2002, 'Existence and Persistence of Price Dispersion: An Empirical Analysis,' *Review of Economics and Statistics*, 84, pp. 433–444.
- Moraga-González, J.L. and Wildenbeest, M.R., 2008, 'Maximum Likelihood Estimation of Search Costs,' *European Economic Review*, 52, pp. 820–848.
- Morgan, P. and Manning, R., 1985, 'Optimal Search,' *Econometrica*, 53, pp. 923–955.
- Ofgem, 2003, *Domestic Gas and Electricity Supply Competition*, Ofgem, London.
- Ofgem, 2006, *Domestic Retail Market Report—June 2005*, Ofgem, London.
- Ofgem, 2008, *Energy Supply Probe: Initial Findings Report*, No. 140/08, Ofgem, London.
- Ofgem, 2010, *Update on Probe Monitoring: Tariff Differentials and Consumer Switching*, No. 79/10, Ofgem, London.
- Ofgem, 2011, *The Retail Market Review—Findings and initial proposals*, Ofgem, London.
- Stahl, D.O., 1989, 'Oligopolistic Pricing with Sequential Consumer Search,' *American Economic Review* 79, 700–12, 1989.
- Stahl, D.O., 1996, 'Oligopolistic Pricing with Heterogeneous Consumer Search,' *International Journal of Industrial Organization*, 13, pp. 243–268.

- Stern, N., 2010, 'Imperfections in the Economics of Public Policy, Imperfections in Markets, and Climate Change,' *Journal of the European Economic Association*, 8, pp. 253–288.
- Varian, H., 1980, 'A model of sales,' *American Economic Review*, 70, pp. 651–659.
- Wildenbeest, M.R., 2011, 'An Empirical Model of Search with Vertically Differentiated Products,' *RAND Journal of Economics*, 42, pp. 729–757.
- Waddams, C. and Wilson, C., 2010, 'Do Consumers Switch to the Best Supplier?' *Oxford Economic Papers*, 62, pp. 647–668.
- Wilson, C., 2010, 'Ordered Search and Equilibrium Obfuscation,' *International Journal of Industrial Organization*, 28, pp. 496–506.
- Wilson, C., 2012, 'Market Frictions: A Unified Model of Search and Switching Costs,' *European Economic Review*, 56, pp. 1070–1086.



(a) Prices and Costs



(b) Margins

Figure 1
Retail Prices and Margins over Time (in £/year)

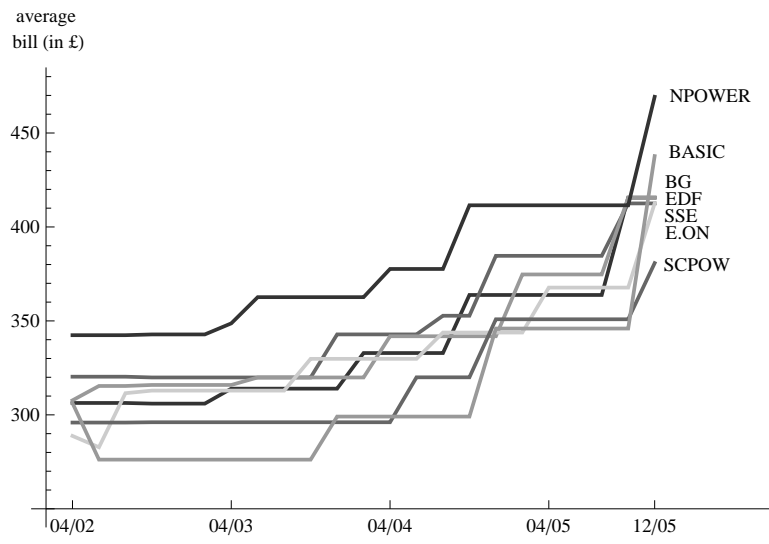


Figure 2
Pricing Patterns Midland Region

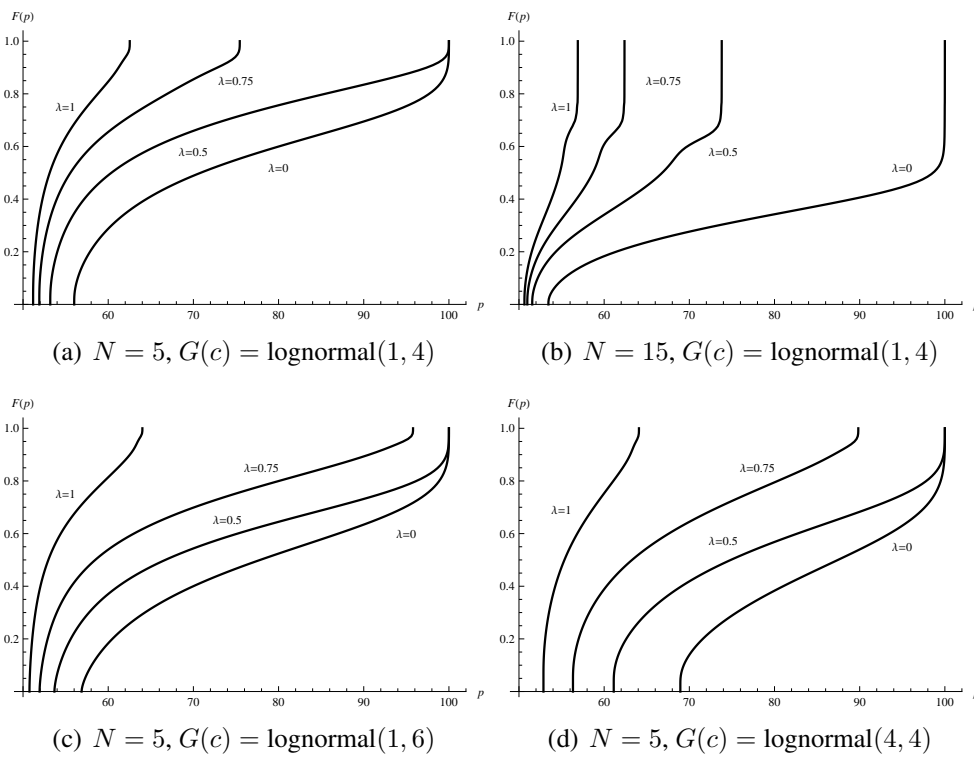
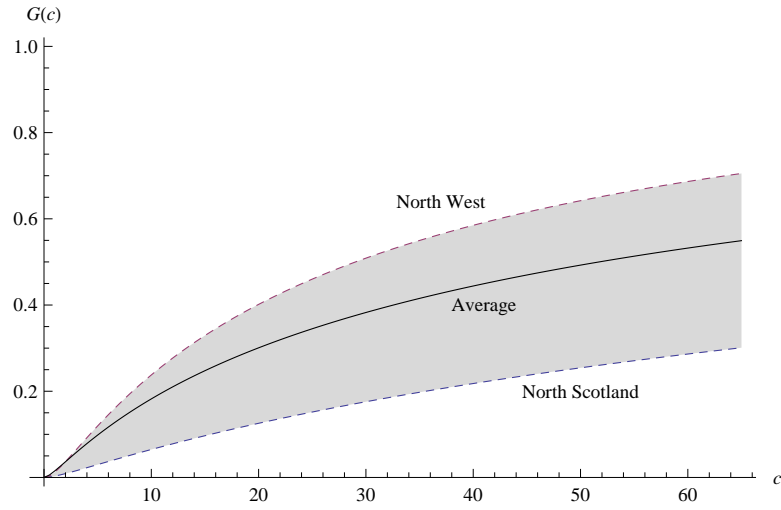
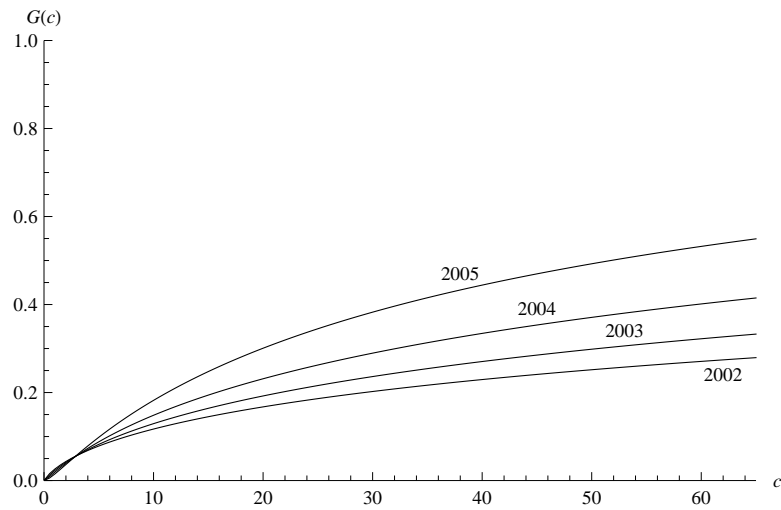


Figure 3
Price CDF of the Entrants for Several Values of λ

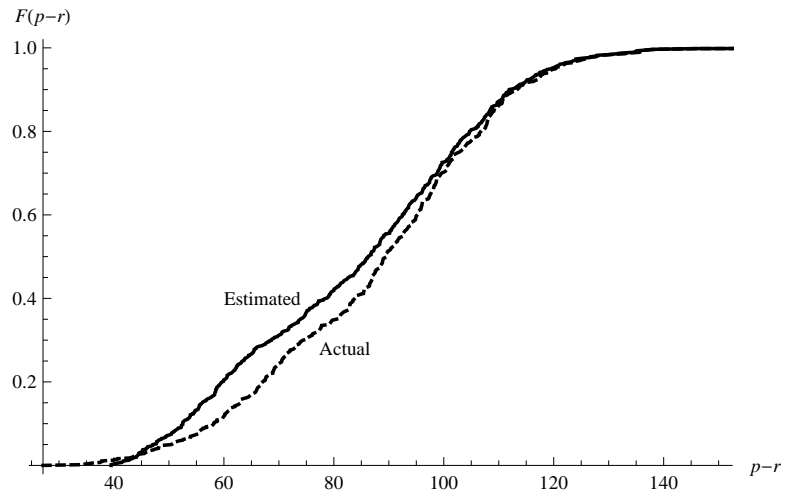


(a) Search Cost CDF (2005)

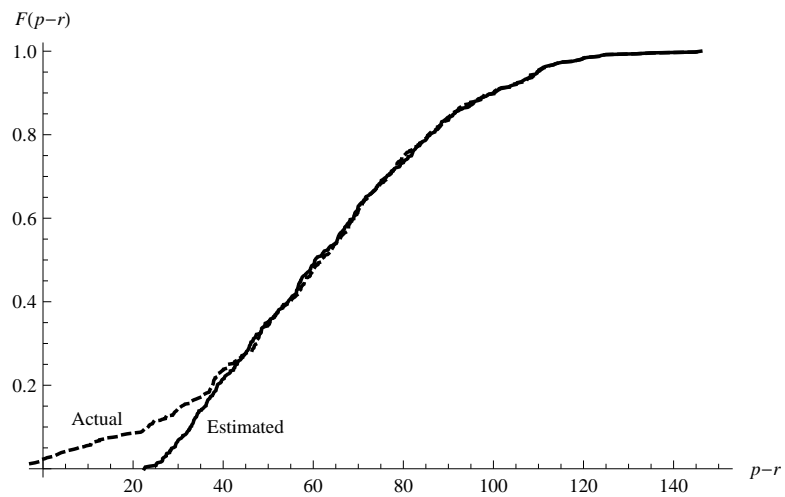


(b) Search Cost CDF (2002-2005)

Figure 4
Estimated Search Costs (in £)



(a) Margin CDF (2003)



(b) Margin CDF (2005)

Figure 5
Goodness of Fit

TABLE I
BRITISH MARKET SHARES OF DOMESTIC ELECTRICITY SUPPLIERS

Company	Percentage market share			
	2002	2003	2004	2005
British Gas (BG)	22	23	23	22
E.ON	23	22	21	20
npower	17	16	15	15
EDF	15	14	13	13
SSE	13	14	15	16
Scottish Power	10	10	13	13
Others	0	1	0	1

Source: Ofgem Domestic market report (various issues)—subject to rounding errors.

TABLE II
REGIONAL VARIATION IN PAYMENT METHOD (2005)

Region (incumbent)	Percentage of customers		
	Credit	Direct debit	Pre-payment
Eastern (E.ON)	46	48	6
East Midlands (E.ON)	43	44	13
London (EDF)	49	30	21
Midlands (npower)	41	43	16
Merseyside (Scottish Power)	36	42	22
Northern (npower)	40	45	15
North West (E.ON)	42	45	13
South East (EDF)	45	52	3
North Scotland (SSE)	38	44	18
South Scotland (Scottish Power)	36	44	20
Southern (SSE)	36	53	11
South Wales (SSE)	36	46	18
South West (EDF)	44	50	6
Yorkshire (npower)	45	42	13

Source: DECC quarterly energy prices.

TABLE III
RETAIL PRICES AND MARGINS (DIRECT DEBIT)

	2002	2003	2004	2005
<i>Retail prices</i>				
mean	298.28	305.81	327.39	369.17
max	331.69	336.59	362.91	402.93
incumbent	331.69	334.55	360.15	397.02
2nd highest	313.04	320.97	344.55	385.06
min	273.29	274.33	295.61	342.28
(max-min)/min	21.5%	23.0%	23.3%	17.9%
<i>Unit cost</i>				
distribution	73.72	72.84	69.70	73.38
wholesale	88.54	76.55	87.25	127.00
other	63.95	61.59	67.85	91.52
total	226.21	210.97	224.80	291.90
<i>Margins</i>				
mean	72.07	94.85	102.59	77.27
max	105.48	125.63	138.10	111.03
incumbent	105.48	123.58	135.35	105.12
2nd highest	86.84	110.01	119.75	93.16
min	47.09	63.37	70.81	50.39
price-cost margin	24.1%	30.9%	31.3%	21.0%
Market share incumbent	0.63	0.60	0.55	0.51

Notes: Retail prices and costs are denoted in British pounds and calculated using average regional consumption (on average 4,612kWh/year). All figures are averages over all suppliers and regions. Averages over 2002 exclude February.

TABLE IV
SUMMARY STATISTICS

Region	number of firms N				average margin $p - r$ (std.dev.)				market share incumbent λ			
	2002	2003	2004	2005	2002	2003	2004	2005	2002	2003	2004	2005
Eastern	13	12	9	8	58.65 (13.30)	79.02 (14.14)	84.78 (17.98)	51.55 (30.73)	0.62	0.57	0.51	0.46
East Midlands	13	12	9	8	53.92 (13.39)	71.87 (14.31)	75.36 (16.82)	55.60 (27.10)	0.65	0.60	0.52	0.45
London	12	11	9	8	54.61 (11.31)	76.77 (13.79)	78.06 (19.45)	61.20 (24.59)	0.65	0.59	0.56	0.52
Midlands	13	12	9	8	62.63 (13.38)	85.21 (17.27)	89.00 (20.37)	68.72 (27.65)	0.63	0.58	0.53	0.50
Merseyside	13	12	9	8	68.83 (12.82)	91.97 (15.66)	98.27 (16.20)	63.25 (29.74)	0.60	0.56	0.54	0.55
Northern	13	12	9	8	48.02 (13.58)	63.38 (16.91)	74.75 (19.71)	52.76 (25.27)	0.57	0.53	0.50	0.48
North West	13	12	9	8	48.31 (10.48)	69.39 (16.03)	83.46 (28.06)	51.80 (26.57)	0.59	0.52	0.48	0.43
South East	13	11	9	8	62.70 (13.39)	87.72 (17.34)	98.26 (20.73)	73.45 (28.24)	0.65	0.63	0.56	0.49
North Scotland	12	11	8	7	81.27 (18.59)	106.25 (20.30)	113.06 (17.85)	83.28 (32.30)	0.74	0.80	0.75	0.69
South Scotland	12	11	8	7	56.14 (11.60)	81.25 (13.85)	92.46 (21.30)	72.82 (22.49)	0.55	0.52	0.48	0.50
Southern	13	12	9	8	62.83 (13.48)	84.98 (17.68)	86.63 (23.03)	56.14 (32.25)	0.67	0.66	0.61	0.60
South Wales	13	12	9	8	65.23 (10.40)	81.04 (13.83)	83.03 (19.07)	54.01 (30.83)	0.70	0.74	0.63	0.64
South West	12	11	9	8	65.28 (14.41)	91.36 (15.95)	95.88 (20.17)	61.10 (33.55)	0.61	0.56	0.49	0.45
Yorkshire	13	12	9	8	48.16 (14.52)	70.92 (16.60)	76.48 (18.32)	57.51 (24.25)	0.63	0.58	0.48	0.41

TABLE V
ESTIMATION RESULTS

Region	Log search costs				Lower quartile $G(c)$ (in £)				
	mean	st.dev	trend mean	trend st.dev.	2002	2003	2004	2005	\bar{c} (in £)
Eastern	6.00 (0.18)	3.14 (0.19)	-0.81 (0.07)	-0.56 (0.07)	48.37	31.28	20.23	13.08	59.99
East Midlands	5.99 (0.17)	3.22 (0.19)	-0.79 (0.07)	-0.51 (0.07)	45.53	29.32	18.87	12.15	55.44
London	6.20 (0.21)	3.21 (0.21)	-0.70 (0.08)	-0.37 (0.09)	56.53	35.99	22.91	14.59	43.95
Midlands	5.62 (0.11)	2.76 (0.13)	-0.50 (0.05)	-0.26 (0.06)	42.57	30.82	22.32	16.16	55.20
Merseyside	6.05 (0.17)	2.97 (0.17)	-0.63 (0.06)	-0.43 (0.06)	57.30	40.87	29.15	20.79	61.69
Northern	4.65 (0.10)	2.61 (0.15)	-0.32 (0.05)	-0.27 (0.06)	17.92	15.63	13.63	11.88	51.46
North West	4.64 (0.07)	2.23 (0.08)	-0.42 (0.04)	-0.24 (0.04)	23.15	17.84	13.75	10.60	146.73
South East	6.55 (0.19)	3.34 (0.19)	-0.77 (0.07)	-0.48 (0.07)	73.47	47.15	30.26	19.42	50.07
North Scotland	8.88 (0.31)	4.21 (0.24)	-1.24 (0.11)	-0.78 (0.09)	422.21	205.57	100.10	48.74	62.76
South Scotland	5.47 (0.19)	2.87 (0.21)	-0.33 (0.07)	-0.24 (0.09)	34.18	28.91	24.46	20.69	45.48
Southern	6.98 (0.20)	3.64 (0.19)	-1.02 (0.08)	-0.57 (0.07)	92.31	48.87	25.87	13.70	65.18
South Wales	8.74 (0.38)	4.25 (0.27)	-1.60 (0.14)	-0.73 (0.09)	355.49	118.09	39.23	13.03	59.66
South West	6.17 (0.13)	3.23 (0.15)	-0.82 (0.05)	-0.57 (0.05)	54.20	35.07	22.69	14.68	70.76
Yorkshire	5.41 (0.13)	3.05 (0.17)	-0.57 (0.05)	-0.44 (0.07)	28.41	21.56	16.36	12.41	50.10
Average	6.24	3.20	-0.75	-0.46	96.55	50.50	28.56	17.28	62.75
R^2	0.945								

Notes: Standard errors in parenthesis. \bar{c} is the maximum search cost that can be identified throughout the sample period.

TABLE VI
OVERVIEW ALTERNATIVE SPECIFICATIONS

	user intensity			actual user intensity		
	actual	medium	high	$\eta = 0.25$	$\eta = 0.40$	prod. diff.
Mean log search costs	6.24	6.01	6.23	6.57	5.92	5.32
St.dev log search costs	3.20	3.18	3.17	3.29	3.10	2.92
Trend mean search costs	-0.75	-0.80	-0.73	-0.77	-0.73	-0.63
Trend st.dev. search cost	-0.46	-0.49	-0.45	-0.45	-0.48	-0.55
<i>Lower quartile</i>						
2002	96.55	70.57	88.09	129.90	72.57	36.82
2003	50.50	37.00	48.86	65.04	39.72	25.90
2004	28.56	20.71	28.79	35.33	23.44	18.69
2005	17.28	12.33	17.87	20.63	14.73	13.87
\bar{c}	62.75	48.64	69.37	62.75	62.75	69.93
R^2	0.945	0.944	0.943	0.945	0.943	0.901

TABLE VII
PREDICTED AND ACTUAL DIRECT DEBIT CUSTOMERS BASED ON YEARS
2002-2005

<i>Panel A</i>				
Total switchers Millions	Year			
	2002	2003	2004	2005
Prediction 1	3.56	3.79	4.33	5.09
Prediction 2	3.56	3.50	4.39	5.44
Actual	3.70	4.20	4.21	4.31
% over-prediction 1	-3.83	-9.68	2.97	18.01
% over-prediction 2	-3.83	-16.71	4.36	26.32

<i>Panel B</i>				
Region (group)	Predicted Rank		Actual Rank	
	Relative % switch		% stay	% change
	Pred 1	Pred 2		
Eastern (E.ON)	8	9	11	11
East Midlands (E.ON)	7	8	9	12
London (EDF)	6	6	5	6
Midlands (npower)	12	11	8	9
Merseyside (Scottish Power)	5	4	5	5
Northern (npower)	14	14	12	6
North West (E.ON)	13	13	14	14
South East (EDF)	4	4	7	8
North Scotland (SSE)	1	1	1	2
South Scotland (Scottish Power)	9	7	3	1
Southern (SSE)	3	3	3	4
South Wales (SSE)	2	2	2	3
South West (EDF)	10	10	9	9
Yorkshire (npower)	11	12	13	13

Rank correlation	Actual	
	% stay	% change
Prediction 1	0.818	0.568
Prediction 2	0.909	0.691

Note: Prediction 1 relates to actual shares each year, Prediction 2 subtracts last year's prediction from total (see text) Rank: 1 = smallest change/ switch, highest remaining share.

TABLE VIII
RANKS

Company: BG																									
Region	2002					2003					2004					2005									
	feb	apr	jun	aug	oct	dec	feb	apr	jun	aug	oct	dec	feb	apr	jun	aug	oct	dec	feb	apr	jun	aug	oct	dec	
Eastern	5	5	4	4	4	4	4	5	5	5	5	5	5	4	4	4	4	6	5	4	4	4	4	6	6
East Midlands	4	4	4	4	3	3	2	3	2	2	2	2	5	3	3	3	6	5	4	4	4	4	4	4	4
London	3	3	3	3	3	3	3	5	5	5	5	4	5	5	3	2	4	2	2	2	2	2	2	5	4
Midlands	4	4	3	3	2	2	2	4	3	3	2	2	4	3	3	2	5	4	3	3	3	3	3	6	5
Merseyside	3	3	3	2	2	2	2	1	1	1	1	4	4	2	2	1	5	4	3	3	3	3	3	5	4
Northern	4	4	4	3	3	3	3	4	4	4	4	3	5	5	5	3	5	4	4	4	4	4	4	6	5
North West	5	5	5	5	4	4	4	5	4	4	4	3	5	3	4	4	6	5	5	5	5	5	5	6	6
South East	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	4	4	4	4	4	4	4	4	5	4
North Scotland	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	4	2	2	2	2	2	2	4
South Scotland	2	2	2	1	1	1	1	1	1	1	1	1	2	1	1	1	4	3	2	1	1	1	1	5	4
Southern	4	4	3	3	3	3	3	5	3	3	3	2	4	2	2	6	5	4	3	3	3	3	6	5	5
South Wales	5	5	4	4	4	4	4	5	3	3	3	2	6	5	5	4	6	6	5	4	4	4	4	6	6
South West	4	4	4	4	4	4	4	5	4	4	4	3	4	3	2	2	4	3	3	3	3	3	3	3	4
Yorkshire	4	4	4	3	3	3	3	5	5	5	5	4	4	4	4	4	5	4	4	4	4	4	4	6	5

Region	$k = 24$	$n = 14$	critical
χ^2	4.7		20
Time	$k = 14$	$n = 24$	
χ^2	11		32

TABLE IX
MEDIA SPEND

Company	1999	2000	2001	2002	2003	2004	2005	Average per year
EDF	2,986	2,390	2,069	4,827	1,119	3,537	1,891	2,688
npower	4,010	10,944	5,809	2,370	583	5,015	8,184	5,274
EON	2,973	4,983	10,168	8,580	5,491	4,518	8,372	6,441
SSE	717	162	0	236	88	92	88	198
Scottish Power	4,549	837	666	600	733	2,419	2,219	1,718
BG	17,868	5,682	13,345	10,306	810	4,466	5,012	8,213
Average	5,517	4,166	5,343	4,487	1,471	3,341	4,294	

Source: NMR Digest, various issues, after aggregation. Data are in £'000s.