The effect of future price expectations on customers’ willingness to make sunk investments in reliance on a monopoly service

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ABSTRACT

Regulatory agencies routinely seek to promote price stability. Such practices have no clear rationale under the neoclassical approach to public utility regulation. An alternative view, which can justify price stability, is that public utility regulation exists to protect customers’ relationship-specific sunk investments. Using data from the Swedish district heating sector during the 1998-2007 period, we find evidence that customers make predictions about future prices and that they are more reluctant to take up the monopoly service when the probability for future price increases and price variability go up. These results suggest that a primary benefit of public utility regulation is the assurance of stability in future prices.

Keywords: Forward-looking consumers, pricing behaviour, regulation, district heating, Sweden

JEL Classifications: D42, L51, L52, L97

\textsuperscript{1}The views expressed in this paper are the views of the authors and do not necessarily reflect the views of the ACCC or the AER.
1. INTRODUCTION

This paper explores an issue at the foundations of public utility regulation. According to neoclassical theory, the primary economic objective for public utility regulation is to reduce or eliminate deadweight loss (e.g. Crew and Kleindorfer, 2006). However, this approach cannot explain certain aspects of the way public utility regulators tend to behave in practice – such as their historic focus on promoting intertemporal stability in regulated prices.²

As an alternative, it has been suggested that a primary rationale of public utility regulation is to protect and promote sunk complementary investment by potential and existing consumers of the regulated firm (Goldberg, 1976; Biggar, 2009). The logic is that customers of the public utility must make sunk investments in order to extract the most value from the monopoly service, such as investments in specialised equipment, human capital, or in a particular location. Once these investments are sunk they are subject to the risk that the public utility will increase its prices and expropriate the value of the investments. When this hold-up problem cannot be solved through vertical integration or vertical long-term contracting, there may be a role for public utility regulation. Price control regulation, by providing customers an assurance as to the long-run path of future prices, resolves the hold-up problem by protecting and thereby promoting sunk investments by customers.

To date there has been no empirical test on whether there is economic substance in this alternative justification for price control regulation and hence, whether regulators’ focus on price stability is economically meaningful. In this paper we provide such a test by investigating whether customers’ decisions to make sunk investments are affected by their expectations about future prices. Importantly, two features of future prices are relevant in this context: price level and price uncertainty. If lower expected prices lead to higher sunk investments by consumers, we interpret this as supportive of the view that price stability is a primary rationale for public utility regulation. However, consumers’ degree of certainty with which they can form future price expectations can vary and the more uncertain they are, the less likely they are to make sunk investments. To identify the true impact from future expected price levels, empirical models must therefore control for price uncertainty.

We construct two measures that capture these two price features: (i) the slope of the long-term price trend and (ii) variation around this long-term trend. If the slope of the long-term trend is close to 0, then the average price change is small and the price can be considered ‘stable’. Variation relative to this trend measures the incidence and magnitude of short-term price changes. When this variation is

² Crew and Kleindorfer (2006) suggest that regulators should emphasise “...some degree of price stability” (p. 72), but they do not elaborate on why that would be advantageous.
low, prices will closely follow the long-term trend. Following our argument above, we hypothesise that the incidence of sunk investments will depend on consumers’ future price expectations, which are formed based on current and past prices. More specifically, we predict that when the long-term price trend is positive (negative), consumers will have disincentives (incentives) to make required sunk investments. In addition, when future prices are uncertain, i.e. when variability around the long-term price trend is high, consumers have less opportunity to form credible price expectations and their incentives to invest will reduce.

We utilise a data set from the district heating sector in Sweden where the locally monopolised utilities have enjoyed a high degree of pricing flexibility and where the networks have expanded heavily in the last decade. This stands in contrast to most utility sectors in the developed world where customers have already made most of their sunk investments and where prices are subject to price control regulation by an independent regulatory agency. Customers who wish to make use of district heating must purchase and install customer premises equipment, which can cost more than ten times the annual consumption expenditure on heating. In Sweden, this has given rise to concerns that customers are locked in to the district heating service (EI, 2007; Henning, 2006) and that they might be reluctant to make the necessary investments – potentially choosing environmentally or economically inferior heating alternatives (SOU 2004, p. 15; EI, 2007, p.41). As a result there have been calls for price controls by the Swedish Competition Authority and the Swedish Energy Markets Inspectorate (SCA, 2009; EI, 2007).

We investigate the ratio between residential property owners that invest in district heating and those that are in a state to invest in a new heating system in each local market. Using the transformation suggested by Berry (1994) we can regress this ratio on price characteristics, the market share of the outside option and other controls such as time and firm fixed effects. An important feature of our data is that the observed price in period \( t \) is determined in period \( t-1 \). This implies that we are able to

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3 The district heating technology is projected to grow in many European countries, e.g. in the UK (Hawkey, 2009).

4 Concerns about contractual lock-in have also been voiced by potential district heating customer in the UK (Upham and Jones, 2012).

5 In principle, a substitute price can work as a disciplinary tool in this situation. However, electricity, which is the main substitute to district heating in Sweden, requires costly up-grades of the installed power to be used as the main source of heating.

6 The Energy Markets Inspectorate, in arguing the need for regulation, explicitly argues that district heating customers are in a “weak position” with respect to their suppliers and that regulation would “build long-term confidence in district heating as a product” (EI, 2007, p. 66).
circumvent the endogeneity problem typically encountered in similar demand models. As a practical consequence, this allows us to exploit detailed price characteristics by simultaneously evaluate the effects of the price level, the long term price trend and the price variability on the demand for district heating installation. Such detailed investigation of the role of price characteristics is difficult in most circumstances since identification relies on a unique instrument for each endogenous price variable.

Foreshadowing the main results, our predictions are consistent with our empirical results. We find that both the long-term price trend and the price variability are negatively related to consumers’ inclination to take up district heating. Interestingly, the price level does not seem to play a significant role, indicating that regulators should focus on price stability over price level in order to influence market outcome.

Our modelling approach builds on the idea that consumers are forward-looking and form expectations about the likely future path of prices. Several studies have found that when there is scope for inter-temporal substitution of purchases, past purchases, together with expectations about future price paths, have an effect on present demand. This literature has focused on both the case where the goods are storable and consumers can hold inventories (Erdem, Keane and Imai, 2003; Sun, Neslin and Srinivasan, 2003; Hendel and Nevo, 2004, 2006a, 2006b; and Su, 2010) and the case where goods are durable (Chah, Ramey and Starr, 1995; Nair, 2007; Chevalier and Goolsbee, 2009; and Gowrisankaran and Rysman, 2009). In the next section we review the more specific literature on consumer behaviour in Sweden when they make investments in district heating, but our fundamental assumption that consumers are forward looking is strongly supported in that literature as well.

While we do not study the drivers of utilities’ price setting behaviour in this paper, we add to the large literature on ‘price stickiness’ and ‘price rigidity’ by providing empirical evidence that such pricing behaviour is economically relevant. Our argument is also related to the problem of consumer habit formation studied by Nakamura and Steinsson (2011). Nakamura and Steinsson emphasise that if the supplier of a habit-forming product cannot commit to a price path, customers face a time-inconsistency problem – the decision to consume in the first period increases their subsequent demand which the supplying firm may exploit with a higher price in subsequent periods. In their model the firm is able to partially overcome the time-inconsistency problem using an implicit contract which involves a form of price rigidity: “...price rigidity serves as a partial commitment device that helps firms overcome their desire to price gouge locked-in consumers.” (p. 26).

In our view, the contribution of this paper is twofold. First, in the context of the broader literature on price stability, this paper supports the implicit contracts perspective on price stability. In this case the
implicit contract is necessary to protect an explicit sunk investment by customers. We show empirically that price stability (in the form of both the long-term price trend and variability around that trend) increases consumers’ willingness to take up the district heating service. Second, these results lend support to the common regulatory practice of promoting price stability – a practice which has no clear rationale under the neoclassical approach to public utility regulation. These results support the view that public utility regulation can be viewed as a form of long-term contract seeking to protect and promote the sunk relationship-specific investments of the monopoly service provider and its customers.

The paper continues with a description of the Swedish district heating sector. In Section 3 we investigate the take-up rate of district heating empirically and Section 4 concludes.

2. DISTRICT HEATING IN SWEDEN
The Swedish district heating utilities are vertically integrated local monopolies that produce heat in a heat centre and distribute it under high pressure to customers’ properties through a network of underground pipelines carrying hot water or steam. At the customer’s property a heat exchanger extracts heat energy and the cooler water is returned to the heat centre to be re-heated and re-distributed. District heating in Sweden meets approximately 50% (or 47 TWh) of the total heat demand. It is the most common form of heating for multi-dwelling houses in 234 out of the 290 Swedish municipalities (SCA, 2009; SCB, 2009). District heating is only economical in relatively densely populated areas. These are the same areas where emission and land intensive substitutes (e.g. wood-fired and ground-based technologies) are subject to stronger restrictions or are more costly to install. This may explain why Swedish district heating utilities do not, in practice, subsidise the cost of purchasing a heat exchange device for new customers. The fact that district heating networks are confined to the larger urban areas means that they rarely cross municipality boarders. Municipalities and utilities are therefore synonyms in this context and we use the two words interchangeably in the paper.

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7 This section reports statistics from a number of sources. When not explicitly stated, data can be accessed from either ‘Nils Holgersson’s annual price comparisons’ (www.nilsholgersson.nu), Statistics Sweden (www.scb.se), the Energy Markets Inspectorate (www.ei.se), and the Swedish District Heating Association (www.svenskfjarrvarme.se).
The district heating tariffs were exempted from sector specific price regulation in 1996, on the basis that electricity is a competing source of energy for heating purposes. In the same year private investors were allowed to enter the sector. Privately supplied heat amounted to 20% of the total heat produced in the district heating sector in 2007. The remaining heat was supplied by utilities entirely owned by municipalities. Prices have risen steadily since 1996. ‘Nils Holgersson’s annual price comparisons’, that has published all Swedish utility prices for each municipality since 1996, report a real average increase of the list price of approximately 12% over the ten year period from 1998 to 2007. Detailed plant level statistics collected by Statistics Sweden confirms this increase in the average consumption price. This increase can be compared with the regulated electricity distribution price, which has only increased by 1% in real terms during the same ten-year period. Customers and media have expressed concerns that the price increase of district heating is driven by an increasing mass of locked-in customers. The number of district heating customers at the national level has increased from 149,000 in 1998 (SCB, 2001) to 289,000 in 2007 (SCB, 2009) and the average network expansion has increased from 4-5 km of lines per annum at the end of the 1990s to 7-10 km in 2006-07. Hence, despite price increases there is no sign of the utilities reaching a slowdown in the demand for connections.

The utilities that are included in the descriptive and econometric analyses of this paper are those that have reported complete data for the variables of interest (see Section 3) during at least two years and those that have had district heating networks for at least five years. The data set, which is unbalanced, covers the period from 1997 to 2007. This sample, which contains 126 municipalities, has a slightly smaller number of inhabitants and density compared to the population of municipalities with a district heating network. The characteristics of price variables in the sample and population are generally very similar, both in terms of mean and range.

It is of interest to see what pricing strategies utilities have adopted; and in particular how the price level, price trend and price variability are distributed across utilities and also how the price has developed over time. In Table 1 we report average price, standard deviation for the detrended price

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8 The electricity distribution tariffs are regulated by the Swedish Energy Markets Inspectorate which is required to take into account customers’ interest in low and stable electricity prices (SOU, 1995). See Jamasb and Söderberg (2010) for further details on the Swedish electricity market and how it is regulated.

9 We classify a utility as private when private investors hold any proportion of the shares. Söderberg (2011) shows that private investors tend to determine the economic behaviour of Swedish energy utilities irrespective of whether they are minority or majority owners.

10 These reports are freely available to everyone online (www.nilsholgersson.nu). This means that past list prices are available to all consumers considering to connect to the network.
series and the percentage change from the first to the last reported prices for each utility. The statistics indicate noticeable heterogeneity across utilities with the highest average price being almost double that of the lowest price. However, the distribution is negatively skewed with fewer utilities in the low compared to the high price region. The average standard deviation around the long-term price trend has been close to two but the positively skewed distribution vary from zero, i.e. a situation where the price series almost exactly follows the long-term trend, to seven. As mentioned above, the utilities have generally increased their real prices over the period by a bit more than 10% on average. The distribution of the price difference is relatively symmetric, with some utilities also having reduced their prices, and in one case by as much as 50%. The maximum price increase is of the same magnitude.

Table 1. Average price characteristics over utilities.

| Variable                                    | Mean  | S.D.  | Min   | Max   | Shapiro-Wilk test, Prob>|z |
|---------------------------------------------|-------|-------|-------|-------|--------------------------|
| Average price                               | 54.720| 5.878 | 34.672| 67.176| 0.011                    |
| Standard deviation of de-trended price      | 2.079 | 1.178 | 0.255 | 7.051 | 0.000                    |
| % diff between first and last reported prices | 11.390| 16.298| -51.290| 56.312| 0.199                    |

Notes: a The average time span between the first and last reported prices is 9.55 years.

Is there any sign that these variables have affected property-owners inclination to connect to the district heating network? We begin by calculating the average market share of district heating for each utility as the ratio between ‘the number of property owners installing district heating’, and ‘the total number of property owners installing a new heating technology’. Then we compute the correlations between the market share and the three price characteristics described in Table 1. It turns out that the correlation between market share and average price is -0.327. The other two correlations are very close to zero. Hence, this descriptive analysis suggests that a high price reduces consumers propensity to make a sunk investment in district heating, whereas the price trend and price variability have no clear impact on consumers.

However, these results are at odds with what have been found in the previous empirical investigations. For example, it has been found that consumers do indeed take future financial conditions into consideration when they decide what heating technology to invest in and that consumers and that consumers are negatively affected by uncertain contractual conditions (Forsaeus Nilsson et al., 2008; Isaksson, 2005). More specifically, Mahapatra and Gustavsson (2007) investigated what factors
property owners are influenced by when they choose heating technology. They found that the annual consumption price was the single most important factor. Based on interviews with representatives from Swedish district heating utilities Jörgensen (2009) concludes that consumers do form expectations about future prices based on past prices.

3. EMPIRICAL INVESTIGATION

The infrequent nature of heating investments has generated a group of studies that use individual-level choice experiments as a way to determine consumers’ price sensitivity (Sadler, 2003; Dubin, 1986; Nesbakken, 2001). Few studies have used revealed data, like this study does.

We take as a starting point that consumers choose the technology that maximizes utility. The indirect utility of consumer $i$ who invest in technology $j$ in year $t$ can be written as $U_{i,j,t} = V_{j,t} + \omega_{i,j,t}$, where $V_{j,t}$ is the average utility and $\omega_{i,j,t}$ is consumer $i$’s unobserved heterogeneity. $V_{j,t}$ consists of usage value for technology $j$ over its lifetime, denoted $u_{j,t}$, and usage cost that we decomposed into the current price level, the expected future price levels and uncertainty about the future price levels. Obviously, the expected future price levels and price uncertainty are unobserved and the particular calculation methods used by consumers are unknown. Similar to Branch (2004) we assume that consumers behave like econometricians and fit a straight line through observed prices and extrapolate to form their expectations. The slope coefficient of this line indicates what price levels consumers expect in the future, relative to observed prices. To measure price variation we use the sample standard deviation of actual prices relative to the fitted trend values. This allows us to formulate the average utility as:

$$V_{j,t} = u_{j,t} + \alpha_1 p_{j,t-1} + \alpha_2 p_{j,t-1}^{slope} + \alpha_3 p_{j,t-1}^{sd},$$

where $p_{t-1}$ is the observed consumption price in period $t-1$, $p_{t-1}^{slope}$ is the slope coefficient of the long-term price trend formed in period $t-1$, and $p_{t-1}^{sd}$ is the price variation relative to $p_{t-1}^{slope}$, also formed in period $t-1$. The price variables are lagged one period because of the delay between when consumers decide to connect and when the actual connection takes place. However, the most essential point about the model is that prices are set in the previous period (normally in the third quarter of the previous year), implying that the prices that affect average utilities $V_{j,t}$ in period $t$ are set in period $t-2$. Econometrically, this means that the prices consumers respond to are exogenous in relation to the decisions to make the sunk investment. The connection price is not considered since the within-variation has been practically constant over the short time period we consider here and differences
across utilities are captured by fixed effects. Not all characteristics of the technologies are observed, which implies that we can write $u_{j,t} = u_j + \xi_{j,t}$, where $\xi_{j,t}$ captures the time-varying effect of unobserved technology characteristics. Hence, we have:

$$V_{j,t} = u_j + \alpha_1 p_{j,t-1} + \alpha_2 p_{j,t-1}^{slope} + \alpha_3 p_{j,t-1}^{sd} + \xi_{j,t} \quad (1)$$

To estimate (1) we utilise Berry’s (1994) generalisation of McFadden’s (1973) discrete-choice demand model by transforming the multinomial logit model into a linear model. In Berry’s framework the probability that good $j$ is purchased asymptotically corresponds to its market share at time $t$. Hence, one can write:

$$s_{j,t} \equiv e^{V_{j,t}} / \sum_{k \neq j} e^{V_{k,t}}.$$ 

However, this expression assumes that every household has access to all technologies but that is an unrealistically strong assumption in our situation. For district heating, it is only the households that are located at a certain distance from the network that have the opportunity to connect. The number of properties that can be connection in each time period is proportional to the expansion of the network. Other technologies are also subject to restrictions, e.g. wood-fired heating is not allowed in high density urban areas. When we adjust for the availability $A_{j,t}$ of each technology $j$ in period $t$, we can formulate the market share equation as:

$$s_{j,t} \equiv e^{V_{j,t}A_{j,t}} / \sum_{k \neq j} e^{V_{k,t}A_{k,t}}. \quad (2)$$

A consumer can also choose an outside option, indexed with 0, which corresponds to not investing in any heating technology (e.g. households could choose a passive heating technology that only relies on heat generated by humans or use portable devices). Normalizing the utility of the outside option $V_{0,t}$ to zero and expressing the utility of technology $j$ relative to the outside option, implies that: $s_{j,t} / s_{0,t} = e^{V_{j,t}A_{j,t}}$. This has the important econometric advantage of eliminating substitute characteristics from the equation. Taking the natural logarithm, this simplifies to:

$$\ln(s_{j,t}) - \ln(s_{0,t}) = V_{j,t} = u_j + \alpha_1 p_{j,t-1} + \alpha_2 p_{j,t-1}^{slope} + \alpha_3 p_{j,t-1}^{sd} + \alpha_4 \Delta leng_{j,t} + \xi_{j,t}, \quad (3)$$

11 The Energy Markets Inspectorate has developed principles for how to determine connection prices to physical energy networks and these principles are largely used by district heating utilities. Two primary cost components are: material/equipment and the distance between the network and the connecting property. The market for material/equipment is national (i.e. covered by year fixed effects) and the distance is strongly correlated with population density, which exhibit very little within-variation. Including density in the empirical evaluation shows that it is not even vaguely related to the number of connections. Hence, we assume that connection prices have been constant.
where $\Delta l\text{eg}$ is the network expansion between period $t-1$ and $t$ that corresponds to $A$ in (2). Network expansion is a reasonable proxy for availability since consumers have to pay a premium if they connect in a later period. The whole market consists of all households that are in the state of selecting a new heating technology. Those are the sum of newly constructed residential houses between period $t-1$ and $t$, plus 5\% of the existing housing stock since the average heating equipment is assumed to last 20 years. The outside option is calculated as unity minus the market shares for district heating and electricity based heating technologies.

The final challenge before (3) can be estimated is to determine how many past prices consumers take into consideration when they calculate $p_t^{\text{slope}}$ and $p_t^{\text{sd}}$. We set this number to three, i.e. that consumers use $p_t$, $p_{t-1}$ and $p_{t-2}$, since two prices would create a perfect fit between the line and the observations (i.e. resulting in no price variation) and four prices reduce the estimable sample by over 50\% compared to three prices. This procedure assumes that consumers attach equal weights to the three prices and ignore more historical prices. A motivation for this assumption is that many utilities publish annual reports, including past prices, for the last 2-3 years on their homepages, making those easily accessible while more historical prices are substantially more costly to access. Descriptive statistics for variables in (3), including variables used to test the robustness of the specification, are included in Table A1 in the Appendix.

Without further considerations we estimate (3) using standard errors (SE) clustered over utilities, where the output is displayed in column (1) in Table 2. A potential objection against these estimates is that the pricing behaviour may be correlated across utilities since municipalities occasionally collaborate on purchases of materials and resources used for maintenance. If there is cross-sectional dependence, SE will be biased. Direct tests of cross-sectional dependence are not available when data is unbalanced and has gaps, which is the case in in our situation. As an alternative, we use the standard error correction method suggested by Driscoll and Kraay (1998). Their correction is consistent for cross-sectional dependence when both T and N can be considered large. They argue that

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12 This specification assumes that consumers have the same preferences for falling and raising price trends. In the case of investments with long lifetimes, one cannot form strong expectations about the influential direction of past price decreases since a fall in the price may merely be interpreted by the consumer as there is room to increase prices in the future (e.g. Adeyemi and Hunt (2007) find a negative effect on demand from cumulative price decreases in one of their models). We explored specifications where the effects from negative and positive slopes were allowed to be different but there is no indication that consumers have different preferences for falling and raising price trends. Results are available from authors upon request.
when T is small, as it is in our case, and when there is no correlation across units, their standard errors are biased downwards. The output of this estimation is displayed in column (2) in Table 1 and one can easily see that these standard errors are substantially smaller than those in column (1). We treat this as an indirect test of cross-sectional dependence and conclude that there is no meaningful correlation across utilities.

A further objection that can be raised against the estimates in column (1) is that there is a mass point of observations at 0. No property-owner invested in district heating in 47 of the 664 utility-year observations, creating a censored data set. A Tobit model could address this issue but no unbiased standardised estimation procedure exists for FE Tobit. However Greene (2004a; b) finds that it is not the slope parameters that are biased in a FE Tobit, but the disturbance variance. One can therefore assess the sensitiveness of using an uncensored model by comparing its slope parameters with those of a FE Tobit. Column (3) shows the estimates of the FE Tobit and the results are very similar to those in column (1). Hence, there is no sign that a linear model leads to biased results.

Table 2. Estimation output for (3).

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1) FE</th>
<th>(2) FE</th>
<th>(3) Tobit FE</th>
<th>(4) System GMM</th>
<th>(5) FE</th>
<th>(6) FE</th>
<th>(7) FE</th>
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<td></td>
<td>Coef (S.E.)*</td>
<td>Coef (S.E.)*</td>
<td>Coef (S.E.)*</td>
<td>Coef (S.E.)*</td>
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<td>-0.00014 (0.00124)</td>
<td>-0.00014 (0.00053)</td>
<td>-0.00009 (0.00134)</td>
<td>-0.00157 (0.00088)</td>
<td>-0.00014 (0.00123)</td>
<td>-0.00014 (0.00124)</td>
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<td>p_{slope}</td>
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<td>-0.00562 (0.00186) ***</td>
<td>-0.00641 (0.00249) ***</td>
<td>-0.00422 (0.00229) **</td>
<td>-0.00563 (0.00236) **</td>
<td>-0.00552 (0.00235) **</td>
<td>-0.00566 (0.00236) ***</td>
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<td>p_{d}</td>
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<td>-0.02169 (0.00282) ***</td>
<td>-0.02398 (0.00501) ***</td>
<td>-0.01324 (0.00392) ***</td>
<td>-0.02169 (0.00445) ***</td>
<td>-0.02161 (0.00450) ***</td>
<td>-0.02179 (0.00445) ***</td>
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<tr>
<td>Δleng_{c-1}</td>
<td>0.00061 (0.00025) **</td>
<td>0.00061 (0.00010) ***</td>
<td>0.00059 (0.00026) **</td>
<td>0.00063 (0.00031) **</td>
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<td>ln(m.sh_{c}\hat{p})</td>
<td>-0.85593 (0.27432) ***</td>
<td>-0.85593 (0.19384) ***</td>
<td>-0.92206 (0.28829) ***</td>
<td>-0.32553 (0.09135) ***</td>
<td>-0.85709 (0.27279) ***</td>
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<td>-0.85391 (0.27593) ***</td>
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<td>ln(m.sh_{c}\hat{p}_1)</td>
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<td>-2.13128 (0.69771) ***</td>
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<td>No obs</td>
<td>664</td>
<td>664</td>
<td>664</td>
<td>639</td>
<td>664</td>
<td>663</td>
<td>664</td>
</tr>
</tbody>
</table>

Notes. * p < 0.10, ** p < 0.05, *** p < 0.01. * Standard errors are clustered over utilities. # Driscoll-Kraay standard errors. ∗ Standard errors are based on Windmeijer (2005) correction. The P-value of the Arellano-Bond test for AR(2) is 0.216. The P-value of the Hansen-test is 0.091.
When available we use clustered SE to control for potential correlation within panels. Such SEs are robust to arbitrary correlation, but that arbitrariness leaves us uncertain about where the potential correlation comes from. We can potentially increase the efficiency of the estimation by imposing more precise structures on the variance-covariance matrix. One possibility is that connections in one period are correlated with connections in the subsequent period due to spill-over effects across neighbours in the same geographical area (e.g. a connected property-owner may share its experiences with neighbours). While we argued previously that there are relatively strong reasons to assume that property-owners only get one chance to connect due to the premium they have to pay if they connect in later periods, it cannot be ruled out that the experiences of neighbours are considered so valuable it out-weights that price premium. Column (4) displays the results of a System GMM estimation where the market share in the previous period is included as an explanatory variable. Market share in periods $t-2$ and $t-3$ and the first-difference of the market share in period $t-1$ are used as instruments for the lagged dependent variable. As expected, there is no sign that market share in the previous period has any effect on market share in the current period.

In columns (5) and (6) we test if temperature conditions affect the propensity to invest in district heating. Column (5) includes local heating degree days and column (6) includes the change in heating degree days from one period to the next. The results do not indicate that temperature conditions affect property-owners’ decisions to invest in district heating.

As a last test of estimation/specification robustness we include local income (net of taxes). This estimation, which is displayed in column (7), does not indicate that income has any significant impact on district heating investments.

As additional tests of robustness we investigate whether there are utilities that have response patterns that are distinctly different from that of the majority. For example, large urban areas can have more favourable cost conditions due to higher property density and/or different demand characteristics due to less indoor space and a higher share of rented properties where heating cost is included in the rent. In column (1) in Table 3 we present the results where utilities in the three largest municipalities are excluded. In column 2 we exclude utilities that operate in municipalities with an urban density below 10 inhabitants per square hectare. Neither columns (1) nor (2) seem to respond differently to the three price variables compared to the full sample displayed in column (1) of Table 2.

It is also possible that the substantially colder climate in the most northern municipalities create demand responses that are distinct from the ones in south. To test this we exclude the 41 most northern municipalities (from Dalarna county and north). These results, which are provided in column
(3) in Table 3, are not noticeably different from what has been presented earlier. Finally, we also exclude utilities that are owned by private investors. As for the robustness estimations described above, the coefficients do not change in a way that make us suspect that there is a statistically different response behaviour across ownership types.

Table 3. Estimation output for (3) using restricted samples.

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1) FE</th>
<th>(2) FE</th>
<th>(3) FE</th>
<th>(4) FE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{t-1} )</td>
<td>0.00034 (0.00129)</td>
<td>-0.00048 (0.00134)</td>
<td>-0.00085 (0.00123)</td>
<td>-0.00040 (0.00147)</td>
</tr>
<tr>
<td>( p_{t-1}^{\text{slope}} )</td>
<td>-0.00625 ** (0.00241)</td>
<td>-0.00543 ** (0.00270)</td>
<td>-0.00460 (0.00286)</td>
<td>-0.00564 ** (0.00251)</td>
</tr>
<tr>
<td>( p_{t-1}^{\text{std}} )</td>
<td>-0.02198 ** (0.00458)</td>
<td>-0.01891 *** (0.00508)</td>
<td>-0.02038 *** (0.00529)</td>
<td>-0.02081 *** (0.00530)</td>
</tr>
<tr>
<td>( \Delta \text{length}_{t-1} )</td>
<td>0.00091 *** (0.00029)</td>
<td>0.00043 ** (0.00021)</td>
<td>0.00046 ** (0.00023)</td>
<td>0.00084 *** (0.00031)</td>
</tr>
<tr>
<td>( \ln(\text{msh}_t^{\text{out}}) )</td>
<td>-0.87223 *** (0.28761)</td>
<td>-0.82363 *** (0.32089)</td>
<td>-1.02015 *** (0.22866)</td>
<td>-0.90370 *** (0.41524)</td>
</tr>
<tr>
<td>( \text{const} )</td>
<td>-1.92351 *** (0.68699)</td>
<td>-1.77515 *** (0.72721)</td>
<td>-2.20576 *** (0.54208)</td>
<td>-1.99668 *** (0.98381)</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Utility FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R(^2) (within)</td>
<td>0.1805</td>
<td>0.1667</td>
<td>0.2055</td>
<td>0.1617</td>
</tr>
<tr>
<td>No obs</td>
<td>646</td>
<td>404</td>
<td>542</td>
<td>564</td>
</tr>
</tbody>
</table>

Notes. * \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \). a Standard errors are clustered over utilities. (1)The three municipalities with highest population (Stockholm, Gothenburg and Malmo) excluded. (2) Municipalities with urban density below 10 inhabitants per square hectare excluded. (3) 41 most northern municipalities excluded. (4) Privately owned utilities excluded (20 municipalities excluded).

To conclude, the results in Tables 2 and 3 provide statistically significant results that are consistent with our hypothesis that consumers’ sunk investments are negatively related to the slope of the long-term price trend and the price variability around that trend. Next, it is relevant to ask whether the results are also economically significant. To investigate that we use the results in column (1) in Table 2 and calculate predictions at the sample mean of all explanatory variables except for \( p_t^{\text{slope}} \) and \( p_t^{\text{std}} \) that we vary over the sample range, except for the 1% most extreme absolute values that are excluded: \( p_t^{\text{slope}} \in \{-5, 0, 5\} \) and \( p_t^{\text{std}} \in \{0, 1.8, 3.6\} \). When \( p_t^{\text{slope}} = 0 \), the market share of district heating vary between 4.5% and 13.0%. When \( p_t^{\text{std}} = 0 \), the market share vary in the range from 9.2% to 14.8%. When \( p_t^{\text{slope}} = 5 \) and \( p_t^{\text{std}} = 3.6 \), the market share is 1.6%, but it is not significantly different from 0. Hence, it is clear that both the long-term price trend and the price variability around that trend have economically significant influences on property-owners that are in a state to invest in heating technologies.
4. CONCLUSIONS

In the presence of customer lock-in to a specific supplier, customers care not just about the present price but also the future path of prices they are likely to face. The literature on customer markets focuses on the implicit contract between firms and their customers as an explanation for observed price rigidity. We focus on the implicit contract that arises from the need for a sunk investment by customers considering taking up district heating service in Sweden. In the absence of formal price regulation we suggest that customers form a view as to the future path of prices based on (i) the slope of the long-term price trend and (ii) variation around this trend. We hypothesise that where the pricing rule followed by the district heating utility provides greater assurance to customers that they won’t face an unexpected price rise in the future, they will be more likely to invest in taking up district heating service.

Our empirical results are robust and consistent with this hypothesis. Specifically, we find that as the slope of the long-term price trend increases (i.e. consumers believe future prices will increase), then fewer consumers make investments to connect the district heating network. Moreover, when the variability around the long-term price trend increases (i.e. uncertainty about future prices increases), then there will also be fewer consumers deciding to connect to the district heating network.

We interpret this evidence as consistent with the view that, at least in the case where customers must make a material sunk investment to take-up the services of a local monopoly, future price expectations matter. In this context, there may be a role for conventional public utility regulation. However the primary rationale for that regulation is not, as the textbooks suggest, the control of deadweight loss, but rather to provide potential customers some assurance as to the likely future path of prices, so as to encourage sunk complementary investment, and therefore to encourage take-up of the public utility service.
REFERENCES


Biggar, D., (2009), Is protecting sunk investment by consumers a key rationale for natural monopoly regulation?. Review of Network Economics 8, 128-152.


Erdem, T., M. Keane and S. Imai, (2003), Consumer Price and Promotion Expectations: Capturing Consumer Brand and Quantity Choice Dynamics under Price Uncertainty. Quantitative Marketing and Economics 1, 5-64.


Hawkey, J.C., (2009), Will “district heating come to town”? Analysis of current opportunities and challenges in the UK, MSc thesis, The University of Edinburg.


Sadler, M., (2003), Home energy preferences & policy: applying stated choice modelling to a hybrid energy model economy model. MSc project no. 342, Simon Fraser University.


SCB, (2009), Electricity supply, district heating and supply of natural and gasworks gas 2007, EN 11 SM 0901.


## APPENDIX

Table A1. Descriptive statistics for variables used to estimate (3).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description (measurement unit)</th>
<th>n</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p)</td>
<td>Average price of district heating (öre/kWh)</td>
<td>664</td>
<td>54.525</td>
<td>7.380</td>
<td>32.990</td>
<td>72.892</td>
</tr>
<tr>
<td>(p_{\text{slope}})</td>
<td>Slope of line fitted through three most recently available prices</td>
<td>664</td>
<td>0.8075</td>
<td>1.8609</td>
<td>-9.3079</td>
<td>7.2469</td>
</tr>
<tr>
<td>(p_{\text{sd}})</td>
<td>Sum of squared deviations between (p) and (p_{\text{slope}}) based on three most recently available prices</td>
<td>664</td>
<td>0.6299</td>
<td>0.7469</td>
<td>0.0007</td>
<td>8.5111</td>
</tr>
<tr>
<td>(\Delta\text{leng})</td>
<td>Network expansion from period (t-1) to (t) (km)</td>
<td>664</td>
<td>7.9624</td>
<td>14.587</td>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>(msh_{\text{out}})</td>
<td>(Residential properties not choosing electricity or district heating based technology) / (Residential properties in a state to choose heating technology)</td>
<td>664</td>
<td>0.1006</td>
<td>0.0073</td>
<td>0.0757</td>
<td>0.1193</td>
</tr>
<tr>
<td>(msh^{\text{DH}})</td>
<td>(Residential properties connecting to district heating network) / (Residential properties in a state to choose heating technology)</td>
<td>664</td>
<td>0.1124</td>
<td>0.1156</td>
<td>0</td>
<td>0.7621</td>
</tr>
<tr>
<td>(hdd)</td>
<td>No of heating degree days</td>
<td>664</td>
<td>3598.2</td>
<td>634.45</td>
<td>2416</td>
<td>5177</td>
</tr>
<tr>
<td>(inco)</td>
<td>Average individual income net taxes (kSEK)</td>
<td>664</td>
<td>190.3</td>
<td>14.788</td>
<td>149.95</td>
<td>254.91</td>
</tr>
</tbody>
</table>

* Source: Statistics Sweden.

\(b\) Source: Statistics Sweden. Number of consumers who are in a state to choose heating technology in year \(t\) consists of all new buildings completed in \(t + 5\) % of existing buildings. This assumes the practical life time of an average heating technology is equal to 20 years.


\(c\) Source: Annual reports; homepages.