Regulatory threat in the Swedish district heating sector: a test of spatially correlated prices

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Preliminary

Abstract
This paper investigates to what extent unregulated monopolies attempt not to evoke the introduction of a formal price regulation by conforming to customers’ and authorities’ expectations. The evaluation separates the potential influences from customers and authorities by the application of separate spatial processes. These processes vary as a function of flexible (nonlinear) specifications of distance and relative size between local jurisdictions. The Swedish district heating utilities are found to be insensitive to customer complaints but significantly influenced by the passive monitoring by authorities. The policy implication is to focus monitoring resources on the largest utilities.

Keywords: regulatory threat, spatial correlation, price, district heating, Sweden

JEL Classification: L11, L33, L97

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1. Introduction

Network utilities are typically subject to price regulation based on the belief that no price restrictions would lead to excessively high prices. However, unregulated monopolies can choose not to maximise their profits if the threat of introducing price regulation in the near future is sufficiently strong (Brunekreeft, 2004; Block and Feinstein, 1986). The justification for such behaviour can be that firms have a willingness to transfer scrutiny to other firms (Decker, 1998) and/or to forestall more stringent regulatory activity in the future (Lutz et al, 1998). These arguments are related to the theory of contestable markets (Baumol, 1982), but rather than facing the threat of (new) competitors, incumbents face the risk of agency intervention. Such threats can exist in sectors consisting of several local monopolies since customers can compare prices in neighbouring jurisdictions and passive authorities can compare prices in jurisdictions that have similar operating characteristics. This can give rise to spatially correlated prices that weaken the need for fully fledged regulatory regimes that have been widely introduced in the reregulated network sectors over the last decades.

The Swedish heating sector provides a suitable setting for investigating to what extent the threat of imposing formal price regulation affects the real pricing behaviour. While it has been debated for several years to introduce price regulation, the locally monopolised district heating (DH) utilities are currently unregulated. This is a highly unorthodox practice given that the sector consists of a mixture of public and private utilities, that short-term substitutes are generally not available (customers face substantial sunk cost) and that technical restrictions exist for the use of some substitutes in multi-dwellings in urban areas.

Based on observed behaviour in regulated monopoly markets where customers can formally dispute utility conditions, it is known that customers are naïve in their monitoring and primarily compare price levels in their immediate surroundings. Authorities, on the other hand, must account for demand and supply heterogeneity that can justify price variation. The largest proportion of the relevant heterogeneity is, however, unobservable for a passive authority and factors that proxy these can therefore provide a workable compromise. It can be hypothesised that jurisdictions that are geographically close and those that are of similar size are more likely to have similar heterogeneity (this is investigated in Section 2.2). If this holds, the probability of a dutiful agency intervening will increase as the distance and size difference between two utilities decreases (according to public interest theory). However, a vast literature suggests that agencies can be captured by interest groups consisting of relatively larger firms. It cannot be ruled out, therefore, that utilities’ pricing behaviour is more influenced by relatively larger neighbours.

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2 Block and Feinstein (1986) show that the cost of highway construction is reduced after antitrust enforcement in neighbouring jurisdictions.
3 District heating is based on the principle of water being heated at production plants and subsequently distributed through underground pipes to buildings connected to the network where the water heats the buildings. The water is sent back to the production plant for reheating.
Hence, a utility can respond to these threats and set a price that takes prices in neighbouring jurisdictions into account, adjusted for geographical proximity and relative size. More specifically, the hypotheses this study attempts to test are whether utilities attempt to conform to:

1) Customers expectations by taking the price of the closest neighbour into account. The influence decreases as a function of distance but it is unaffected by the neighbours degree of similarity.

2) Authorities expectations by taking the average price of a larger subset of neighbours into account. The influence decreases as a function of distance and degree of dissimilarity to average neighbour.

Because the hypothesis is that customers and authorities pay attention to different geographical areas and attach different weights to distance and relative size, it is possible to identify these effects separately.

This study contributes to the field by empirically investigating the role of regulatory threat. Previous empirical investigations have relied on one or a limited number of case studies rather than the rigour provided by econometric estimations. It also relaxes the common assumption that neighbours carry an equal weight when the distributed lag model is applied and it demonstrates that a more flexible 2-stage, non-linear model specification can generate robust estimations.

This paper continues with some validity issues and describes the relevant empirical and theoretical literature in Section 2. It then moves on to Section 3 where the model specification is outlined together with data exploration and estimations. Section 4 contains conclusions and policy implications.

2. Background

2.1 The source of spatial behaviour in local utility sectors

One central assumption made in this paper is that spatial correlation exists because neighbouring jurisdictions share common traits. This similarity (and spatial correlation that is associated with it) is hypothesised to be more pronounced the geographically closer and similar in size the neighbours are.

2.2 Validity of size as proxy for degree of similarity

A second assumption is that size, i.e. total number of inhabitants living a municipality, is a workable proxy for factors that can plausibly explain price variation. Apart from variation in input cost (labour and fuel), one can assume that urban density is a significant determinant of the cost level since economies of density are frequently found in sectors involving physical networks.
2.3 Previous studies
Spatially correlated economic indicators, including prices, have found widespread support.⁴ In a study of hospital prices in the US by Mobley (2003), it is found that when the average price of the six closest hospitals increases by 1 %, the hospital under study increases its price by 0.22 %. Here only the order of closeness, rather than absolute distance, is considered and the weight attached to each hospital does not include any other economic factor. A more elaborate methodology is applied by Pinkse et al. (2002) as they allow the closest neighbour, neighbours who share border and neighbours who share second-order border to carry different weights in their study of the US gasoline market. They also allow the weights from neighbours to vary as a function of distance. They conclude that only the closest neighbour affects the price substantially and that distance has a very limited influence.

Both these price studies investigate competitive markets and it should come as no surprise that profit-maximising firms take competitors’ prices into consideration when customers can switch between firms. The hypothesis of unregulated monopoly prices being spatially correlated is a novelty.

2.4 Theoretical framework
While there is little empirical work on whether real firm behaviour is influenced by regulatory threat, a number of theoretical models have been proposed which conclude that it can effectively cap prices (e.g. Brunekreeft, 2004). More specifically, Bawa and Sibley (1980) suggest that there may be limited incentives to inefficiency, even as the firm uses a rate of return that is different from the efficient level. They also find that in case the firm produces a single output, price converge to the average cost (as opposed to marginal cost). This is a valuable conclusion for the case of district heating which is unusually homogenous, even in comparison with other utility services.

Glazer and McMillan (1992) stress that firm behaviour is sensitive not only to the probability of imposing price regulation, but also how the marginal effects of changes in price level affects that probability. This can make the firm absorb (a proportion of) the increase in input cost which justifies flatter relationships between cost components and price than what intuition suggests.

Also, Chisari and Kessides (2009) show that utilities tend to adopt a low-price policy as long as the network is expanding and subsequently, increase their prices when the coverage reaches maturity. This is indeed relevant for the Swedish district heating sector which is currently subject to substantial expansion in some jurisdictions.

⁴ See Gamerman and Moreira (2004) for a recent survey of spatial models.
The Swedish district heating utilities are assumed to maximise their profits but are constrained by cost and price of primary substitute. Also, they want to minimise the risk of formal price regulation. The price decision for utility $i$ can therefore be formulated as a bi-level optimisation problem:

Max: $(P_i - C_i)Q_i$ \hfill (1)

Subject to:

$C_i \leq P_i \leq Pel$ \hfill (2)

Min: $P_i \theta_1 + (C_G / P_G - C_i / P_i) \theta_2 \lambda G + (P_i - P_g) \theta_3$ \hfill (3)

$\sum_{n=1}^{\theta_n} = 1$ \hfill (4)

where $P_i$, $C_i$ and $Q_i$ are price, cost and delivered quantity for utility $i$, respectively. $Pel$ is the price of electricity which is the main substitute for district heating. Constraint (3) is the lower level goal function which states that the probability of regulatory intervention is increasing in $P_i$, the margin relative to $G$ and the price relative to $g$ increase. $\theta_1$, $\theta_2$, and $\theta_3$ allow for utility specific perceptions on how the probability of regulatory intervention is minimised. $\lambda G$ allows utilities to attach different weights to neighbours with different characteristics (e.g. different size).

### 3. Analysis

#### 3.1 Model specification

Spatial regression models are normally specified as:

$$P_i = \rho \sum w_{ij}P_j + X_i \beta + \varepsilon_i$$ \hfill (5)

where $w_{ij}$ is the weight neighbour $j$ carries in its relation to $i$. $w_{ij}$ is typically a function of distance and determined a priori to avoid the complications associated with nonlinear specifications, e.g. $w_{ij} = 1 / d_{ij}$ where $d_{ij}$ is the distance between $i$ and $j$. This obviously imposes strong restrictions on the influence from distance, but it has the advantage of allowing OLS to be used in estimating (5). More elaborate forms that allow for a parameterisation of $w_{ij}$ have been proposed (e.g. O’Sullivan and Unwin, 2003; Anselin, 2002), with $w_{ij} = 1 / d_{ij}^k$, ($k$ is a parameter to be estimated), being a natural extension. However, in this study the $w_{ij}$ also need to contain the relative size difference between $i$ and $j$ and it has to be able to distinguish between if the largest influence comes from neighbours that are similar in size or from those that are relatively larger. The manipulation of relative size according to $|1 - \text{Size}_j / \text{Size}_i|^h$ meets this requirement since $h > 0$ suggests that relatively larger neighbours are more
Influential whereas \( h<0 \) suggests that neighbours of similar size influence \( i \) more. Now, \( w_{ij} \) can be written as:

\[
  w_{ij} = 1/d_{ij}^h \cdot |1 - \text{Size}_j / \text{Size}_i|^h
\]  

(6)

In order to evaluate the influence from customers and authorities separately, eq (5) is extended according to:

\[
  P_i = \rho_g \sum w_g P_g + \rho_G \sum w_G P_G + X_i \beta + \epsilon_i
\]  

(7)

where \( \rho_g \) indicates the spatial influence from conforming to customers’ expectations (i.e. \( g \) denote the interaction between \( i \) and ‘the closest neighbour’) and \( \rho_G \) is the influence from conforming to authorities expectations (i.e. \( G \) denote the association between \( i \) and ‘the average of a larger subset of neighbours’).

Before eq (7) can be estimated it is necessary to determine a principle for which neighbours to include in \( G \). Common strategies are (i) those that share borders, (ii) those that are within a certain distance, and (iii) a fixed number of (closest) neighbours. This study relies on the principle of a fixed number of closest neighbours which is also the principle most widely applied in the literature. When estimating (7) \( G \) is assumed to consist of the \( k \) closest neighbours (including the closest). The choice of neighbours in \( G \) is pragmatic and does not rest on statistical testing. Similar “intuitive” models are standard in the contemporary applied spatial field. A conservative number of neighbours are included because it is uncertain when the spatial influence drops off. While the drop off value/region is important to identify in practical applications, it is without the scope of this study to look at that in any depth.

Finally, the \( X \) vector is assumed to consist of a dummy for private investor ownership, district heating market share, price of electricity, and exogenous product and customer characteristics. Ownership is included since there are both publicly and investor owned utilities and utilities with private investors have stronger incentives to increase prices because of their profit-maximising objective. The market share is justified based on the fact that some jurisdictions are currently expanding their networks and a utility with a low market share can therefore justify a higher price level since comparatively large capital investments are required. Customers can choose between a few heating alternatives but the alternatives to district heating largely rely on electricity. The price of electricity is therefore included. This allows us to estimate eq (7), and the results are displayed in Table 4.
3.2 Data

Data is collected from The Energy Markets Inspectorate, Statistics Sweden and the annual price survey “Nils Holgersson”. Data is cross-sectional for the year 2007 (price variables for 2006 are also available and will be used in subsequent analyses as instruments to address the endogeneity in eq (7)). Data represents all municipalities where district heating is a significant source of heating in the largest urban area (n=242), excluding Gotland which is an island. Descriptive statistics for all variables are provided in Appendix 1.

3.3 Estimation

Because the spatial weights contain parameters to be estimated, a non-linear estimator is required. Non-linear least square (NLLS) is used as a benchmark and NL2SLS is applied to address the endogeneity from having the neighbours’ prices on the RHS. As indicated earlier, neighbours’ prices from 2006 are used as instruments in the NL2SLS. NLLS, and the 2-stage version of it, relies on a second-order Taylor series expansion. The first-order conditions of the expansion determine the iterative procedure which can be formulated as $\beta_{j+1} = \beta_j + \alpha (Z'Z)^{-1}Z'u$ where $u$ is the random error term and $Z$ is the matrix of derivates.5

<table>
<thead>
<tr>
<th>Variable</th>
<th>NLLS Mean</th>
<th>Std.err.</th>
<th>NL2SLS Mean</th>
<th>Std.err.</th>
<th>NLLS Mean</th>
<th>Std.err.</th>
<th>NL2SLS Mean</th>
<th>Std.err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_g$</td>
<td>0.0856</td>
<td>0.0818</td>
<td>-0.0581</td>
<td>0.0958</td>
<td>0.0692</td>
<td>0.0815</td>
<td>-0.0480</td>
<td>0.0941</td>
</tr>
<tr>
<td>$k_g$</td>
<td>-0.5798</td>
<td>0.4496</td>
<td>0.0704</td>
<td>0.3365</td>
<td>-0.5566</td>
<td>0.5547</td>
<td>0.0371</td>
<td>0.4184</td>
</tr>
<tr>
<td>$h_g$</td>
<td>-0.2763</td>
<td>0.3535</td>
<td>0.1583</td>
<td>0.1543</td>
<td>-0.2582</td>
<td>0.4180</td>
<td>0.1743</td>
<td>0.2140</td>
</tr>
<tr>
<td>$\rho_u$</td>
<td>0.2955 ***</td>
<td>0.1111</td>
<td>0.3739 ***</td>
<td>0.1534</td>
<td>0.3101 ***</td>
<td>0.1146</td>
<td>0.3739 ***</td>
<td>0.1448</td>
</tr>
<tr>
<td>$k_u$</td>
<td>-0.0066</td>
<td>0.0553</td>
<td>-0.0162</td>
<td>0.0753</td>
<td>-0.0126</td>
<td>0.0539</td>
<td>-0.0196</td>
<td>0.0722</td>
</tr>
<tr>
<td>$h_u$</td>
<td>0.0732 **</td>
<td>0.0329</td>
<td>0.0598 **</td>
<td>0.0295</td>
<td>0.0763 **</td>
<td>0.0330</td>
<td>0.0700 **</td>
<td>0.0307</td>
</tr>
<tr>
<td>Market share</td>
<td>-74.287 ***</td>
<td>25.257</td>
<td>-69.620 ***</td>
<td>25.221</td>
<td>-73.248 ***</td>
<td>25.536</td>
<td>-68.250 ***</td>
<td>25.274</td>
</tr>
<tr>
<td>Price electricity</td>
<td>0.1519</td>
<td>0.0393</td>
<td>0.1510 ***</td>
<td>0.0398</td>
<td>0.1562 ***</td>
<td>0.0392</td>
<td>0.1529 ***</td>
<td>0.0395</td>
</tr>
<tr>
<td>Fuel price</td>
<td>0.1224 ***</td>
<td>0.0441</td>
<td>0.1389 ***</td>
<td>0.0440</td>
<td>0.1180 ***</td>
<td>0.0442</td>
<td>0.1294 ***</td>
<td>0.0441</td>
</tr>
<tr>
<td>Labour price</td>
<td>0.0098 ***</td>
<td>0.0036</td>
<td>0.0104 ***</td>
<td>0.0037</td>
<td>0.0094 ***</td>
<td>0.0036</td>
<td>0.0099 ***</td>
<td>0.0037</td>
</tr>
<tr>
<td>Sargan stat</td>
<td>7.036</td>
<td></td>
<td></td>
<td></td>
<td>5.617</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan p-value</td>
<td>0.994</td>
<td></td>
<td></td>
<td></td>
<td>0.999</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>242</td>
<td>242</td>
<td>242</td>
<td>242</td>
<td>242</td>
<td>242</td>
<td>242</td>
<td>242</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-1314.42</td>
<td></td>
<td>-1314.86</td>
<td></td>
<td>-1314.03</td>
<td></td>
<td>-1313.46</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.10, ** p < 0.05, *** p < 0.01

5 All estimations that follow also include 8 dummy variables that control for some companies owning the district heating facilities in more than one jurisdiction. The parameters for these dummies are not reported.
The output of the NLLS and NL2SLS estimations are displayed in Tables 1. Estimations are performed for when G consists of the 5 and 6 closest neighbours to investigate the sensitivity of varying the scope of the set of neighbours. From the output in Table 1 one can conclude that all four models produce similar results in terms of significance and sign. The IV-specifications, which are forcefully accepted by the Sargan-tests, generate higher point estimate of the $\rho_G$-coefficient which suggests that ignoring the endogeneity problem in (7) leads to an underestimation of the spatial association.

The neighbour being closest ($g$) does not have a stronger influence than the larger group of neighbours (G). There is also firm consistency of no significant influence from the distance to the average G neighbours, but relative size is significant at the 5 % level for all models with $h$ being around 0.07. More specifically, the larger the neighbour is, the more weight it carries. This influence is illustrated in Figure 1. Hence, one is lead to believe that utilities’ pricing behaviour is consistent with predictions made by the capture theory, rather than the public interest theory.

![Figure 1. Weight as a function of J neighbours relative size difference.](image)

A further insight gained from looking at Table 1 is that prices tend to decrease as the market share increases. In addition, there is no conclusive evidence that private investors set higher prices than publicly owned utilities.

### 4. Conclusions
There is evidence to suggest that utilities are influenced by authorities passive monitoring but no empirical support exists for customers having a separate influence. Consistent with many other empirical studies on agents’ behaviour in regulated markets, relatively powerful firms are more
influential than peers that are similar. This suggests that authorities should focus their resources on monitoring the largest utilities. Overall, one can conclude that there is no obvious evidence of predatory pricing behaviour in the Swedish district heating sector.

References


**Appendix 1.**

Table 1. Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description and measurement unit</th>
<th>Mean (Std.dev.)</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Average district heating price (SEK/MWh)</td>
<td>669 (75.73)</td>
<td>405</td>
<td>815</td>
</tr>
<tr>
<td>d1</td>
<td>Distance to closest utility (km)</td>
<td>22.62 (13.93)</td>
<td>0.39</td>
<td>82.19</td>
</tr>
<tr>
<td>d1-5</td>
<td>Average distance to five closest utilities (km)</td>
<td>37.04 (21.28)</td>
<td>4.77</td>
<td>176.6</td>
</tr>
<tr>
<td>d1-6</td>
<td>Average distance to six closest utilities (km)</td>
<td>40.06 (22.91)</td>
<td>5.58</td>
<td>188.0</td>
</tr>
<tr>
<td>Pop1/Popi</td>
<td>Urban population in closest municipality relative urban population in i</td>
<td>2.09 (3.18)</td>
<td>0.04</td>
<td>18.66</td>
</tr>
<tr>
<td>Pop1-5/Popi</td>
<td>Urban population in five closest municipalities relative to urban population in i</td>
<td>2.56 (2.98)</td>
<td>0.06</td>
<td>30.54</td>
</tr>
<tr>
<td>Pop1-6/Popi</td>
<td>Urban population in six closest municipalities relative to urban population in i</td>
<td>2.60 (2.77)</td>
<td>0.07</td>
<td>26.96</td>
</tr>
<tr>
<td>Msh</td>
<td>District heating’s share of electricity and district heating consumption</td>
<td>0.3163 (0.1731)</td>
<td>0.0155</td>
<td>0.9329</td>
</tr>
<tr>
<td>Pel</td>
<td>Average price of electricity (SEK/MWh)</td>
<td>1542 (98.15)</td>
<td>1294</td>
<td>1851</td>
</tr>
<tr>
<td>IO</td>
<td>Dummy var. to indicate investor owned utility</td>
<td>0.3004 (0.4594)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cf</td>
<td>Average district heating fuel cost (SEK)</td>
<td>170.01 (98.31)</td>
<td>-126.22</td>
<td>711.98</td>
</tr>
<tr>
<td>Cl</td>
<td>Average local labour cost (monthly net salary, SEK)</td>
<td>21512 (651)</td>
<td>20100</td>
<td>24100</td>
</tr>
</tbody>
</table>