Informal Benchmarks as a Source of Regulatory Threat in Unregulated Utility Sectors

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Abstract

This paper investigates to what extent unregulated local monopolies attempt not to evoke the introduction of a formal price regulation by conforming to customers' and authorities' expectations. It is argued that utilities can meet expectations by setting prices that imitate neighbours' prices. The empirical evaluation rests on a cross-sectional data set representing all Swedish district heating utilities, and on a flexible nonlinear IV specification. It is found that while utilities' price setting schemes are insensitive to customer complaints, they are significantly influenced by the passive monitoring by authorities. The spillover effect from the 5-6 closest neighbours is around 40 %.

JEL-Code: L11, L33, L97.

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

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1. Introduction

Utilities responsible for network services are typically subject to price regulation based on the belief that no price restriction will lead to inefficiently 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 prevent more stringent regulatory activity in the future (Lutz et al., 1998). Hence, regulatory threat can be viewed as an analogy to the threat of new market entrants, as described by Baumol (1982).

The literature has traditionally assumed that the threat of introducing regulation is a function increasing in the monopoly's own price. While that is correct in theory, assessments of own-price variations tend to ignore the insufficient access to firm-level information, which is a prominent feature of practical regulatory work, and consequently, the predicted change in regulatory threat for a given price adjustment is likely to be overestimated. A potentially more substantive threat exists if there are several local monopolies where customers and passive agencies with authority to raise public policy concerns can compare prices in neighbouring jurisdictions, thereby reducing their information disadvantage. Relatively larger price variations among neighbours, all else equal, can then increase the probability of regulatory intervention. If utilities internalise this probability function into their profit optimisation, they will set prices that correlate with their neighbours' prices and consequently, if prices are found to be spatially correlated, one may infer that firms are influenced by a threat of regulatory intervention. The empirical literature shows that firms increase their efficiency when neighbours have been subject to real regulatory intervention. For example, Block and Feinstein (1986) show that the cost of highway construction is reduced after antitrust enforcement in neighbouring jurisdictions, and Eckert and Eckert (2010) find that firms are more likely to comply with environmental regulations when neighbours have recently been found to violate those regulations. However, it is uncertain whether an entire sector is sensitive to more subtle threats originating from media coverage, requirements to report more detailed statistics, pro-regulatory views of interest groups etc.

With the exception of anecdotal evidence,[3] there are few examples of completely unregulated utility prices.[4] The Swedish heating sector is an exception as the locally monopolised district heating utilities operate entirely without price restrictions. This practice is highly unorthodox 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 the use of some substitutes in urban multi-

[3] Before deregulation of the Swedish electricity sector in 1996, the utilities had never been subject to any price regulation. Despite this, prices charged to consumers during the pre-deregulatory period (approx. 100 years), were relatively low in international comparison (Kaiser, 1994).

[4] Even in cases of public ownership, utilities have typically been subject to the constraint of cost recovery.

dwellings is subject to technical and environmental restrictions (e.g. wood-fired heating technologies are generally not allowed in urban areas). However, it is reasonable to assume that the utilities have been exposed to regulatory threat, since the introduction of price regulation has been debated for several years[5] and investigations have recently been conducted by the Swedish Competition Authority (SCA) to assess the utilities' degree of market power. Both the SCA and the electricity regulator, the Energy Markets Inspectorate (EMI), have recommended that the prices be subject to regulation (SCA, 2009; EMI, 2007), and the customers' most influential interest group, the Association of Property Owners, has argued that third party providers be allowed to access the networks. Although individual utilities have been targeted in much of the debate/investigations, it is reasonable to assume that any future intervention will follow the Swedish tradition of regulating all utilities according to the same principles. Hence, it seems natural that the threat is equally distributed across all utilities.

Based on observed behaviour in other regulated monopoly markets where customers can formally dispute utility conditions, it is known that the average customer is inclined to compare his/her price level with that of the closest neighbour (Söderberg, 2008).[6] It is uncertain, but quite possible, that customers are also sensitive to how geographically distant the closest neighbour is. Yet, they seem to be ignorant about other heterogeneous factors that potentially explain price differences. Agencies are likely to be more sophisticated in their performance assessments and it can be inferred that they consider prices set by a larger number of neighbours since demand and supply conditions are likely to be correlated over a wider area (we return to this in Section 4). This resembles the notion of benchmark regulation first laid out by Shleifer (1985). Also, agencies might be subject to influences from interest groups, and the mainstream prediction, based on ideas suggested by Stigler (1971), is that relatively larger firms are inclined to lobby more successfully. Several empirical studies have confirmed that resource-rich actors come out better when heterogeneous actors are under scrutiny by the bureaucratic machinery (Knittel, 2003; Klein and Sweeney, 1999; Yeager, 1987; Garvie and Keeler, 1994). It has also been claimed that the interest group theory has been more successful than alternative theories in predicting the behaviour in regulated markets (Francis, 1993). Hence, one can expect the probability of agency intervention to fall when a utility changes its price so that it becomes more similar to that of a nearby and relatively larger neighbour. More specifically, the hypotheses this study attempts to test are whether utilities attempt to avoid regulation by paying attention to customers' and agencies' passive monitoring of prices:

> **H1**: Utilities are influenced by the price charged by the closest neighbour. This influence decreases with distance, but is unaffected by the size of the neighbour.

[5] This led to the enactment of the District Heating Law (SFS 2008:263) in 2008, which stipulates, e.g. that prices should be made publicly available (Chapter 5) and that district heating utilities must report network-level statistics to the EMI (Chapter 40).

[6] Söderberg (2008) reviews all dispute cases between 1980 and 2004, including the arguments put forward by customers and utilities, handled by the Swedish electricity regulator.

H2: Utilities are influenced by the prices charged by their neighbours (i.e. in addition to the prediction in H1). This influence decreases with the distance to the neighbours and when the neighbours are relatively smaller.

This study contributes to the existing literature in several ways. First, rather than relying on one or a limited number of case studies, which most of previous empirical evaluations have done, it uses the rigour provided by econometric estimations to empirically investigate the role of regulatory threat in utility sectors. Second, it relaxes the common assumption made in empirical studies that neighbours carry an equal or predetermined weight when the distributed lag model is applied (further described in Section 4.1). Third, it demonstrates how a more flexible non-linear model specification can be used in spatial studies and that it can reveal valuable information about agents' behaviour. Fourth, it provides policy implications as it adds novel information about whether and how to design a formal regulatory regime.

The paper continues with a description of the Swedish district heating sector in Section 2 and a review of the literature in Section 3. It then moves on to Section 4, where the model specification is outlined together with data exploration and estimations. Section 5 concludes the paper and elaborates on some policy implications.

2. The Swedish district heating sector

District heating consists of a production plant where water is heated and a physical network that distributes the heated water to buildings. The water is then returned to the plant for reheating. A few of the plants also generate electricity, but the fact that their share of the total energy production is very small makes strategic pricing issues of little practical interest.

The Nils Holgersson annual reports on local utility services report a real average price increase of around 12 % from 1998 to 2007 for district heating.[7] This increase is almost double that for the regulated electricity distribution sector during the same period (based on regulatory statistics provided by EMI). The number of district heating customers increased from 149 000 in 1998 (SCB, 2001) to 289 000 in 2007 (SCB, 2009), and the average network expansion increased from 4-5 km of lines annually at the end of the 1990s to 7-10 km in 2006-07 (based on statistics collected by the Swedish District Heating Association). At present, district heating meets approximately 50 % (or 47 TWh) of the total heat demand in Sweden and it is the most common heating alternative for multi-dwelling houses in 234 out of the 290 Swedish municipalities (SCA, 2009; SCB, 2009). Hence, a substantial

[7] Available at www.nilsholgersson.nu

and increasing proportion of the population relies on the contract conditions determined solely by the district heating utilities.

Of relevance to this study is how the causal relationship between a particular price and the prices charged by the neighbours operate. In particular, it is important to establish whether the utilities are primarily engaged in a simultaneous ‘game’ of price setting or react to observed (i.e. historical) prices. A strong case can be made for the simultaneous behaviour since, first, utilities want to avoid erratic or unsynchronised zigzag price patterns that can result from using neighbours’ past prices as the guiding principle. Second, average prices are influenced by multi-period price guarantees that are publicly offered to new customers (with many networks still expanding, these are likely to substantially influence future prices). Third, prices charged in a given period are typically posted in advance and for publicly owned utilities there are also council announcements and public debates on next year’s prices.

3. Previous studies

From the above, it follows that a central assumption in this study is that prices are spatially correlated due to utilities’ conscious and selective behaviour governed by a desire to minimise regulatory intervention. An alternative explanation for spatial association is based on the social network theory (Hägerstrand, 1953), which claims that spatially correlated behaviours occur as a result of geographic proximity with the correlation being decreasing for longer distances (Erlingsson, 2008). The unselected human interactions that the network theory rest on is therefore incomplete in making predictions about more selective correlations, for example based on actor characteristics. In addition, while both the network and benchmark theories predict that only neighbours in relatively close geographic proximity impose an influence on a given price, the network theory has *a priori* very little to say on the number of neighbours that are likely to have a significant impact. Spatial correlations of supply and demand conditions, on the other hand, can be determined from available statistics to form expectations on agencies’ and utilities’ behaviour.

More detailed insights gained from previous research are drawn from two different fields of research: 1) empirical investigations of simultaneous spatial associations, and 2) theoretical expositions of monopolies’ response to the threat of regulatory intervention. Spatially correlated economic indicators, including prices, have found widespread support.[8] In a study of hospital prices in the U.S., Mobley (2003) finds a statistically significant relationship between neighbouring prices. However, the analysis ignores the distance between neighbours and only considers the order of closeness, and the weight attached to each hospital does not include any other economic factor. Pinkse et al. (2002) apply more elaborate methodology as they allow the closest neighbour, neighbours who share a border and

[8] See Gamerman and Moreira (2004) for a recent survey of spatial models.

neighbours who share a second-order border to carry different weights in their study of the US gasoline market. They also allow the weights of 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 markets where customers can switch between providers and it is therefore natural to expect spatially related prices. The hypothesis of local monopoly prices being spatially correlated has not yet been tested empirically.

While there is limited empirical work on whether real firm behaviour is influenced by regulatory threat, a number of theoretical models have concluded that it can effectively cap prices (e.g. Brunekreeft, 2004), and Bawa and Sibley (1980) argue that there may be limited incentives to inefficiency when firms are subject to threat. Glazer and McMillan (1992) stress that firm behaviour is sensitive not only to the probability of imposing price regulation, but also to how the marginal effects of changes in price level affect that probability. This can make the firm absorb (a proportion of) an increase in input cost, which justifies flatter relationships between cost components and price than what intuition suggests.

Also, Chisari and Kessides (2009) show that a utility is likely to first employ a low-price policy for as long as its network is expanding and then increase its prices as its network coverage reaches maturity. This is indeed relevant for the Swedish district heating sector where the level of maturity varies substantially. Their conclusions are based on the assumptions of profit-maximisation and a price ceiling caused by a substitute, which mirrors the conditions in the Swedish district heating sector well. Their derivation of the optimal price is therefore used as a basis for the model specification applied in the subsequent section. Stated very briefly, utilities' dynamic objective function is formulated as:

$$\max\ \pi(0) = \int_0^{\infty} e^{-rt} \{\pi(P_i, N)[1-\Psi(t)] + \bar{\pi}\,\Psi(t)\} dt \qquad (1)$$

where π is the unregulated profit, which is reduced to $\bar{\pi}$ if regulation is introduced. The probability of regulatory intervention is denoted Ψ; N is the number of customers; r is the rate of depreciation and t is time. A constraint is that the utilities' rate of expansion N' is equal to the difference between the substitute price $\xi(N)$ and its own price P_i. Also, the assumption is that the probability of regulatory intervention is a function of the monopoly's own price, $h(P_i)$.[9] After manipulation, Chisari and Kessides (2009) formulate the optimal price as:

[9] Chisari and Kessides (2009) also formulate constraints that define initial and terminating constraints on the size of the network.

$$\frac{\partial \pi}{\partial P_i} - \frac{\gamma}{r + h(P_i) - \gamma \xi'(N)} \times \frac{\partial \pi}{\partial N} - \frac{h'(P_i)}{r + h(P_i)} \times (\pi - \bar{\pi}) = 0 \qquad (2)$$

The first term in eq. (2) represents the marginal increase in profit following a price increase. The second term denotes the marginal decrease in future profits following the reduction in network size caused by a price increase. The last term indicates that the marginal profit is reduced by the increased probability of regulatory intervention that occurs as a result of a price increase. This suggests that the profit is a function of own price, the lowest substitute price, level of network coverage, and the monitoring agents' response to price variation.

4. Analysis

Pair-wise correlations between district heating prices in municipality *i* and its neighbours *j* (with *j*=1 being the closest neighbour) display an erratic pattern with significant correlations only for *j*=1, 5 and 7. Hence, a well-behaved spatial pattern can only appear if heterogeneous conditions are considered. Two such conditions are urban population density, which is associated with the price of electricity[10] (the primary substitute for district heating), and the unit price of labour. Pair-wise correlations for these variables reveal more consistent patterns of significant correlations and as expected, the correlations are subject to decay. Table 1 shows that the significant correlations have disappeared for *j* larger than approximately 5.

Table 1. Pair-wise correlation of supply characteristics.

Ordered neighbours (closest denoted '1')	Urban population density	Unit price of labour
	Corr. (Sig.)	Corr. (Sig.)
1	0.168 (0.011)	0.246 (0.000)
2	0.094 (0.158)	0.119 (0.072)
3	0.209 (0.002)	0.145 (0.029)
4	0.320 (0.000)	0.032 (0.637)
5	0.158 (0.017)	0.102 (0.126)
6	0.015 (0.823)	0.072 (0.282)
7	0.044 (0.508)	0.052 (0.438)
8	0.053 (0.431)	-0.021 (0.757)
9	-0.004 (0.948)	0.095 (0.152)
10	-0.025 (0.704)	0.035 (0.601)
15	-0.071 (0.287)	-0.049 (0.463)
20	0.039 (0.562)	-0.058 (0.387)

[10] Jamasb and Söderberg (forthcoming) show that customer density is negatively related to prices in the Swedish electricity distribution sector.

4.1 Specification

Based on the earlier discussion, eq. (2) is modified by replacing the $h(P_i)$ expression with the prices charged by the utilities' neighbours *j*, conditioned on a representative distance d_{ij} between utility *i* and *j*, and size S_j of the neighbours, $h(P_j^n \mid d_{ij}, S_j)$. Under the assumption that utilities are engaged in a simultaneous price game, and with P_1^n and P_J^n denoting the price of the closest neighbour and a representative price of the group of closest neighbours, respectively, one can formulate a general price equation for utility *i* as:

$$P_i = \rho_1 W_1 P_1^n + \rho_J W_J P_J^n + \mathbf{X}_i \boldsymbol{\beta} + \varepsilon_i \qquad (3)$$

where W_1 and W_J are weight matrixes with $w_{i,1}$ and $w_{i,J}$ representing the weights carried by the individual neighbours; ρ_1 and ρ_J are the spatial associations between P_i and its two different sets of neighbours and $\mathbf{X}_i$ is a vector of network heterogeneity. The existing spatial literature typically assumes that w_{ij} is a function of distance that is determined *a priori* to avoid the complications associated with nonlinear specifications, e.g. $w_{ij} = 1/d_{ij}$. This obviously imposes strong restrictions on the influence from distance, but if all covariates are assumed to be exogenous, it has the advantage of allowing OLS to be used in estimating (3). More elaborate forms that allow for a parameterisation of w_{ij} have been proposed (e.g. O'Sullivan and Unwin, 2003; Anselin, 2002), with $w_{ij} = 1/d_{ij}^{\alpha}$ being a natural extension. However, in this case w_{ij}, also needs to control for the neighbours' size, and two ways of specifying size seem plausible. One is to build on the principle that comparisons are locally constrained and that neighbours of equal relative size are equally influential. The alternative is to view size globally, which implies that the neighbours' absolute size is used. It is not obvious which one of these is preferred, but the relative measure is used initially. The sensitivity of this choice is evaluated in sub-section 4.4, where neighbours' absolute sizes are used as a comparison. Hence, for now w_{ij}, is written as:

$$w_{ij} = 1/d_{ij}^{\alpha} \times (S_j / S_i)^{\delta} \qquad (4)$$

The two parameters in eq. (4), i.e. α and δ, increase the model flexibility and reduce the problems associated with misspecification of the weights in small samples (as explained by Florax and Rey, 1995). Based on the correlations outlined at the beginning of this Section, *J* is set to 5 in the base case, but there is also a need to determine a principle for calculating the P_J^n, d_{iJ} and S_J values before eq. (3) can be estimated. A risk-neutral utility would incorporate information about all neighbours, and average values would therefore be a natural choice. However, it cannot be ruled out that utilities have asymmetric risk preferences and attribute more weight to lower or higher price levels among their neighbours. All three risk principles are evaluated for the estimations presented in Table 2, but only the risk neutral principle is reported since the other two generate significantly inferior fits or do not even converge.

Finally, the **X** vector is assumed to consist of district heating market share, price of electricity, a dummy for private investor ownership, and exogenous cost characteristics. The market share is justified by reference to eq. (2) and the sign is expected to be positive following the prediction by Chisari and Kessides (2009) that a profit-maximising utility will keep its price low as long as the network is expanding and then raise the price once the expansion reaches maturity in order to capitalise on the sunk investment made by customers. However, a negative relationship might occur since less financial resources are needed once the large initial investments have been made in production and distribution facilities. A potential concern with market share is that it can depend on own and substitute prices and maybe even on prices from the recent past since these can contribute to expectations about future prices. However, most networks have existed for several decades, which is likely to reduce this problem substantially. A further concern about including market share in a price equation is that high market shares are associated with lower costs because of the economies of scale that typically exist in network sectors. In the base specification it is assumed that there are no scale effects since heated water cannot be distributed far without losing effectiveness (this is further explored in sub-section 4.4). If regulation can be imposed on individual utilities, there is also a potential risk of increased regulatory threat as the market share increases. However, as explained in Section 1, that situation is unlikely in Sweden.

Although customers can choose among several heating alternatives when investing in new technologies, many of them rely on electricity. The price of electricity is therefore included to investigate utilities' inclination to set prices according to alternatives. Ownership is included to reflect that private investors might have stronger incentives to increase prices because of their stronger focus on financial performance. Exogenous cost variations consist of fuel costs and labour cost.

4.2 Data

Data is collected from EMI, Statistics Sweden and the annual price survey Nils Holgersson. The data set is cross-sectional for the year 2007 and 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 are provided in Appendix 1.

Further discussion of some of the variables is warranted. First, market share is based on total energy (kWh) consumed by residential customers. However, there is little reason to believe that there are noticeable cross-sectional variations in the use of electrical appliances or in the consumption of different heating technologies that could bias this measure. Private ownership is a dummy indicating whether private investors own any share of the firm. Private ownership was also evaluated as a share variable. Multiple dummies to indicate whether private investors hold minority, majority and full control were also evaluated, although all of these measures turned out to be inferior fits.[11] Labour price is average municipal salary (net local taxes) in the public sector. This is preferred to figures based on accountancy statements since it eliminates the risk of including rents captured by strong unions and self-rewards by executives.

4.3 Estimation

The derivation of an estimable spatial lag model is not covered here since it has been thoroughly dealt with elsewhere (e.g. Mobley, 2003; Revelli, 2006; Zhou and Kockelman, 2009). The nonlinear specification does however require a nonlinear estimation technique, which is more novel in the field. Non-linear least square (NLLS) is used as a benchmark estimator and the 2-stage version (NL2SLS) is applied to address the endogeneity from having the neighbours' prices on the RHS.[12] The choice of instruments is not trivial in spatial lag models, but neighbours' prices from previous years are natural candidates, and Kelejian and Prucha (1998) argue that a subset of neighbours' covariates can be used to arrive at consistent spatial parameters. The first price lag is avoided to eliminate potential influences from neighbours' most recent observed prices. Hence, neighbours' prices lagged two years and their prices of labour in present year are used as instruments.

The output from the NLLS and NL2SLS estimations are displayed in Table 2. Estimations are performed for when J consists of the 5 and 6 closest neighbours in order to investigate the sensitivity of varying the scope of the set of neighbours. One can conclude that all four models produce similar results in terms of significance and sign and that no parameter has an unreasonable sign. The IV-specifications, which are forcefully accepted by the Sargan-tests, generate a higher point estimate of the ρ_J-coefficient, which suggests that ignoring the endogeneity tends to underestimate the spatial association.

The ρ parameters suggest that the closest neighbour has no unique influence, but the average price charged by the 5-6 closest neighbours and their average relative size are both significant across models. ρ_J is 0.40 and δ_J is around 0.06 for the IV-models, suggesting that an increase in P_J by 10 SEK

[11] The same exercise was performed in a study of cost levels in the Swedish electricity distribution sector (Söderberg, forthcoming), and the same conclusion was drawn.

[12] All estimations reported in Tables 2 and 3 also include 6 dummy variables that control for some companies being responsible for the district heating operation in more than one municipality. The parameters for these dummies are not reported.

will increase P_i by 4 SEK if $S_i = S_J$. If S_J is ten times larger than S_i, the neighbours will carry a weight that is 1.15 times larger, and P_i goes up by 4.6 SEK when P_J increases by 10 SEK. The relative size interval for the full sample indicates that P_i could increase from 3.3 SEK to 4.9 SEK for a 10 SEK increase in P_J. Hence, one is led to conclude that utilities' pricing behaviour is consistent with predictions made by the interest group theory.

Table 2. Estimation output for eq (3).

	J consists of 5 closest neighbours				J consists of 6 closest neighbours			
	NLLS		NL2SLS		NLLS		NL2SLS	
Variable	Mean	Std.err.	Mean	Std.err.	Mean	Std.err.	Mean	Std.err.
ρ_1	0.0758	0.0740	-0.0566	0.0858	0.0636	0.0672	-0.0524	0.0843
α_1	-0.4809	0.3098	0.1236	0.3013	-0.4691	0.3080	0.0934	0.3294
δ_1	-0.4105	0.3402	0.1548	0.1280	-0.4787	0.3523	0.1658	0.1528
ρ_J	0.2866 ***	0.1053	0.3981 ***	0.1573	0.3096 ***	0.1043	0.4131 ***	0.1505
α_J	-0.0154	0.0542	-0.0028	0.0740	-0.0180	0.0496	-0.0103	0.0702
δ_J	0.0821 **	0.0392	0.0562 **	0.0284	0.0860 **	0.0370	0.0636 **	0.0278
Market share	-76.314 ***	26.889	-62.869 ***	27.725	-73.585 ***	26.841	-57.062 ***	27.754
Electricity price	0.1421 ***	0.0398	0.1501 ***	0.0413	0.1436 ***	0.0395	0.1467 ***	0.0409
Privately owned	16.648 *	9.6402	17.229 **	9.9019	14.634	9.6561	15.192 *	9.9541
Fuel price	0.1247 ***	0.0446	0.1457 ***	0.0451	0.1204 ***	0.0445	0.1372 ***	0.0450
Labour price	0.0109 ***	0.0036	0.0094 ***	0.0045	0.0103 ***	0.0036	0.0091 ***	0.0045
Sargan stat			7.058				6.027	
Sargan p-value								
AIC	8.1797		8.1798		8.1677		8.1704	
Log likelihood	-1316.10		-1316.14		-1314.67		-1315.01	
R^2	0.4573		0.4571		0.4637		0.4622	
n	242		242		242		242	

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

A further insight gained from looking at Table 2 is that a utility enjoying full customer coverage (i.e. 100 % market share) will charge its customers around 9 % less compared to a newly established utility. This contradicts the theoretical predication made by Chisari and Kessides (2009) and adds further support to the view that utilities are under economic pressure not to expropriate customers' sunk investment. In addition, there is some indication that private investors set prices that are on average 2-3 % higher than publicly owned utilities, yet this is insignificant at the 5 % level for J=6.

Also, the district heating price increases by 1.5 SEK if the price of electricity increases by 10 SEK. This finding suggests that utilities may set prices that reflect price variations of the main substitute, but caution should be applied since the distribution of electricity is also local and can be influenced by the same unobserved heterogeneous conditions as district heating (e.g. ground characteristics are likely to influence the cost of all underground networks).[13]

4.4 Robustness

This sub-section tests the strength of some of the assumptions made to arrive at the estimates in Table 2. First, while a thorough investigation of the scale properties of district heating has not yet been presented in the literature, it is clear that the impact from market share will be ambiguous if economies of scale exist. If average cost declines at a diminishing rate and if price is cost-based, one could control for the scale economies by including a measure of output in level and squared form. With delivered amount of energy (Q) used as output, eq. (3) can be extended to:

$$P_i = \rho_1 W_1 P_1^n + \rho_J W_J P_J^n + \mathbf{X}_i\boldsymbol{\beta} + \gamma_1 Q_i + \gamma_2 Q_i^2 + \varepsilon_i \qquad (5)$$

Using the NL2SLS with J set to 6, one can see in Table 3 that there is no significant relationship between price and level of output. While more detailed cost investigations may reach a different conclusion, it is not unrealistic that district heating has limited scale properties since heated water cannot be distributed very far with maintained effectiveness, and compared to electricity distribution there have been very few mergers among networks, which suggests that large networks have limited cost advantages. Hence, there is no apparent sign of scale economies and the conclusion about market share presented in the previous sub-section still holds.

An additional assumption made was that utilities are engaged in a simultaneous game of price setting. A plausible alternative is that utilities react to neighbours' real prices set in the previous year. With slight modifications to eq. (3), such a specification can be written:

$$P_{i,t} = \rho_1 W_{1,t-1} P_{1,t-1}^n + \rho_J W_{J,t-1} P_{J,t-1}^n + \mathbf{X}_{i,t}\boldsymbol{\beta} + \varepsilon_{i,t}. \qquad (6)$$

This model indicates less association with the 6 closest neighbours (38% reduction of ρ_J) and less significance of relative size. The factors in the **X** vector are virtually unchanged and the AIC value is somewhat higher. Hence, there is no indication that this model should invalidate the arguments presented in Section 2. It is also worth pointing out that the significant correlation, notwithstanding its substantial reduction, confirms that the one-year lag of neighbours' prices is inappropriate as an instrument.

[13] There is no straightforward way of handling this analytically since electricity distribution networks are not confined to municipal borders.

Finally, it is investigated whether utilities respond to neighbours' absolute size rather than relative size. The specification is identical to the one in Table 2 with *J*=6 and is estimated with NL2SLS, but with the exception that w_{ij} is now assumed to be:

$$w_{ij} = 1/d_{ij}^{\alpha} \times (S_j)^{\delta} \qquad (7)$$

Table 3 shows that the results found for the relative size difference in Table 2 breaks down almost completely. Hence, it seems far-fetched that utilities are sensitive to neighbours' absolute size.

Table 3. Test of alternative hypotheses.

	Eq (5)			Eq (6)			Eq (3), using eq (7)		
Variable	Mean		Std.err.	Mean		Std.err.	Mean		Std.err.
ρ_1	-0.0429		0.0825	0.0740		0.0730	9.0981		139.51
α_1	0.1128		0.3842	-0.5174		0.3194	-1.2968		1.1413
δ_1	0.1805		0.1881	-0.4321		0.3550	-0.2916		1.4051
ρ_J	0.4109	***	0.1488	0.2471	**	0.1006	0.0518		0.0920
α_J	-0.0022		0.0692	-0.0196		0.0657	0.0770		0.1317
δ_J	0.0611	**	0.0290	0.0911	*	0.0478	0.1251		0.1140
Market share	-57.620	**	28.828	-77.924	***	27.047	-142.28		119.30
Electricity price	0.1474	***	0.0411	0.1559	***	0.0392	0.1531	**	0.0669
Investor owned	14.437		10.023	18.217	*	9.6217	19.768		12.248
Fuel price	0.1354	***	0.0448	0.1219	***	0.0448	0.1119		0.1487
Labour price	0.0086	***	0.0047	0.0114	***	0.0037	0.0126		0.0091
Delivered heat	-0.0084		0.0276						
(Delivered heat)^2	0.3357×10^{-5}		0.3876×10^{-5}						
Sargan stat	4.434						4.206		
Sargan p-value									
AIC	8.1743			8.1888			8.6021		
Log likelihood	-1313.48			-1317.20			-1367.24		
R^2	0.4689			0.4524			0.1719		
n	242			242			242		

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

5. Conclusions and discussions

There is evidence suggesting that utilities are influenced by administrative agencies' passive monitoring but that they are unaffected by customers' inclination to complain. Consistent with many previous empirical studies on direct and indirect involvement of agencies, relatively powerful firms are more influential in shaping the collective market outcome than their smaller counterparts. Considering that utilities also tend to decrease their prices when there is less need for large investments further underlines that utilities are under economic pressure.

If utilities perceive that the threat of regulatory intervention is sufficiently strong, and if the largest (private) utilities do not implement large price increases, policy makers might well consider the threat of price regulation as a viable alternative to the establishment of a costly agency with uncertain ability to significantly increase welfare.[14] However, continuous monitoring is required, not least if electricity prices and privately supplied heat continue to increase at a pace similar to what they have during the last decade.

In order to make longer-term predictions based on these findings, it is necessary to consider the magnitude of the threat and how it might vary in a cross-section. For example, the Swedish Competition Authority has been investigating the prices in Uppsala and Stockholm since 2005. These are two of the largest district heating utilities and in Stockholm the provider is privately owned. It is conceivable that these two will experience a reduced threat once the investigations close, and this will provide some indication of how sensitive prices are to variation in threat.

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[14] Joskow (1989, p. 143) argues that regulators frequently fail to achieve short-term objectives and Vogelsang (2010) suggests that regulatory activity is reduced in order to improve the fulfillment of long-term objectives.

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Appendix 1.

Table 1. Descriptive statistics

Variable	**Source**	**Description and measurement unit**	**Mean (Std.dev.)**	**Min**	**Max**
P	Nils Holgersson price survey[b]	Average district heating price (SEK/MWh)	669 (75.73)	405	815
d_1	Coordinates collected at kartor.eniro.se	Distance to closest utility (km)	22.62 (13.93)	0.39	82.19
d_{1-5}	Coordinates collected at kartor.eniro.se	Average distance to five closest utilities (km)	37.04 (21.28)	4.77	176.6
d_{1-6}	Coordinates collected at kartor.eniro.se	Average distance to six closest utilities (km)	40.06 (22.91)	5.58	188.0
S_1/S_i	Statistics Sweden	Urban population in closest municipality relative to urban population in *i*	2.09 (3.18)	0.04	18.66
S_{1-5}/S_i	Statistics Sweden	Urban population in five closest municipalities relative to urban population in *i*	2.56 (2.98)	0.06	30.54
S_{1-6}/S_i	Statistics Sweden	Urban population in six closest municipalities relative to urban population in *i*	2.60 (2.77)	0.07	26.96
Msh	Statistics Sweden	District heating's share of total electricity and district heating consumption	0.3163 (0.1731)	0.0155	0.9329
Pel	Nils Holgersson price survey[b] and EMI	Average price of electricity (SEK/MWh)	1 542 (98.15)	1 294	1 851
IO	Annual reports and web-information	Dummy var. to indicate investor owned utility	0.3004 (0.4594)	0	1
Cf[a]	Statistics Sweden	Average district heating fuel cost (SEK/kWh)	170.01 (98.31)	-126.22	711.98
Cl	Statistics Sweden	Average local labour cost (monthly net salary, SEK)	21 512 (651)	20 100	24 100
Q	EMI	Amount of delivered energy (MWh)	201.6 (545.5)	8.4279	6 997

[a] Note that the unit price of fuel can be negative since some utilities are paid to dispose of residential waste.
[b] Available at www.nilsholgersson.nu

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