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Abstract

We claim that a reason for why unregulated investor-owned local monopolies do not always charge the monopoly price is that they are threatened by customer complaints that may lead to retaliations from local elected officials. When investor-owned monopolies are exposed to this threat they will mimic the price(s) of their neighbour(s); the stronger the threat, the higher the spatial price correlation. The threat increases when elected officials have pro-consumer preferences and neighbours are geographically close. The empirical analysis, based on a complete cross-sectional data set from the Swedish district heating sector in 2007, confirms the theoretical predictions.

Keywords: regulatory threat, district heating, Sweden

JEL Classification: L12, L21, L51, L97

1. INTRODUCTION

It has been noted that local monopolies owned by private investors do not always charge prices that are significantly higher than those charged by publicly owned monopolies, and/or that the introduction of formal price regulations does not always reduce prices (Edwards and Waverman, 2006; Stigler and Friedland, 1962; Wallsten, 2001). One may ask, therefore, why local monopolies owned by private investors (IOMs) do not always set their prices at a higher level. Some commentators have suggested that the explanation may be that local monopolies owned by public bodies (POMs) are not relevant benchmarks since they might not maximise social welfare,[1] and others have pointed at the difficulty of designing regulatory models that appropriately incentivise price reductions (e.g. Joskow, 2008). These explanations assume that the price-setting incentives are primarily homogenous within sectors, whereas empirical studies have pointed at substantial price-setting heterogeneity within monopolistic (network) sectors (Altissimo et al., 2006; White, 1996). In the present paper, we propose a new explanation to why IOMs depart from the textbook behaviour, an explanation that is based on heterogeneous threat of regulatory intervention.

Our claim is that locally, unregulated IOMs voluntarily hold back their prices when they are threatened by complaints from customers that are likely to result in retaliations from local elected officials. The probability of a customer complaint is positively correlated with the heterogeneity in pricing behaviour that the customer observes when comparing the price in her/his jurisdiction with the price(s) in neighbouring jurisdiction(s). Vote-maximising elected officials typically have an arsenal of different responses to choose from in this situation, ranging from relatively soft interventions such as more restrictive building/location permit processes and use of fuel types to more extreme interventions such as receivership (i.e. that the local public administration takes over the responsibility of the utility's operative work) and expropriation (i.e. that ownership is legally transferred to the local council).[2] However, elected officials are either pro-consumer or pro-firm, which affects their probability to intervene. IOMs respond to this threat by mimicking the prices set by their neighbours, with the level of threat being positively correlated with the spatial price correlation.

Our claim is related to the literature on regulatory threat, which says that firms self-regulate their present profits to gain higher profits in the future (Brunekreeft, 2004; Leidy, 1994; Block and Feinstein, 1986). Firms' incentive to react to threat has been justified from their desire to reduce the

[1] Two established arguments are Niskanen's (1968) budget-maximising principle and Stigler's (1971) suggestion about industry capture.

[2] Both receivership and expropriation have been used in the locally monopolized electricity distribution sector in Sweden, and re-municipalisation (not renewal of concession contracts) has occurred in the German electricity distribution sector and the French water sector in recent years in response to high consumer prices.

overall degree of scrutiny from outside agents, transfer scrutiny to other firms (Decker, 1998) and/or prevent more stringent regulatory activity in the future (Lutz et al., 1998). In previous studies it has been taken as given that a firm's exposure to threat is positively correlated with its price level, or price cost margin (Glazer and McMillan, 1992; Brunekreeft, 2004; Bawa and Sibley, 1980).[3] The validity of this claim hinges on the assumption that an isolated price level is informative to policy makers. However, even if one imposes the weaker assumption that policy makers can react to price *changes*, this can be an unrealistically strong assumption when outside agents suffer from a lack of cost information.[4] As an alternative, it has been suggested that monitoring agents can compare conditions set simultaneously by (many) firms and that this can explain firms' behaviour relatively well (Gilpatric et al., 2011).[5] In an unregulated market where customers cannot rely on policy makers to effectively monitor monopolies, they can themselves form expectations about the monopolies' degree of 'abusiveness'. If customers compare conditions set simultaneously by different monopolies, they can compare their own conditions with those set in neighbouring jurisdictions. The preference for closer neighbours follows from Dixit's (2003) random matching model, which postulates that individuals are more likely to 'match' the closer (according to physical distance or some socioeconomic criteria) they are located. The presence of strategic interaction between neighbouring jurisdictions has been confirmed empirically in studies on a broad range of local policy setting (e.g. Bordignon et al., 2003; Buettner, 2001; Brueckner, 1998). Customers' tendency to use conditions in neighbouring jurisdictions as a basis for why they complain about monopolistic conditions was also observed by Söderberg (2008) in his review of a large number of customer complaints in the regulated Swedish electricity distribution sector.

Several studies in the marketing literature suggest that when a price is perceived as unfair, it provokes anger and increases the likelihood of customer responses, e.g. switching of supplier (Antón et al., 2007; Athanassopoulos, 2000; Campbell, 1999).[6] Similar arguments have been used to build theoretical models in the economic literature (Di Tella and Durba, 2009; Rotemberg, forthcoming,

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[3] More recent theoretical studies have extended the earlier models of regulatory threat in different directions, e.g. the pricing decision under the threat of potential divestiture of firms (Tanaka, 2011) and the pricing of a utility with an expanding network facing a threat of regulatory intervention (Chisari and Kessides, 2009).

[4] For example, it has been claimed that the lack of relevant (cost) information is the primary complication involved in regulating locally monopolistic utility sectors (Joskow, 2005).

[5] Gilpatric et al. (2011) compare two regulatory evaluation mechanisms – one where firms' present conditions are evaluated based on their previous conditions and one where several firms are compared with each other based on conditions set simultaneously.

[6] In the context of local monopoly services, it has been demonstrated that demand is positively related to regulatory compliance (Stafford, 2007).

2005). In Rotemberg's (2005) model, firms internalise that customers react negatively when they become convinced that a price is unfair. Di Tella and Dubra (2009) reach a similar conclusion and show that equilibria exist where customers are not angry.[7] Rotemberg (forthcoming) introduces the notion of a reference price that the current price is compared with to form an opinion about whether a price is fair or not. He suggests that this reference price can be a price charged previously by the firm. As pointed out above, the present paper takes an alternative position as it uses prices set simultaneously by neighbours as reference price(s).

Lastly, we also draw on the literature that focuses on the influence of local political ideology on regulatory decisions. These studies have suggested that left-wing governments tend to be relatively more pro-consumer (Holburn and Spiller, 2002; Holburn and Vanden Bergh, 2006, Besley and Coate, 2003; Cambini and Rondi, 2010). Similar to Biggar and Söderberg (2011), we highlight the influence of local political ideology on the pricing strategies of district heating utilities, even in the absence of any formal regulatory mechanism.

The claim that spatial price heterogeneity is a source of regulatory threat in local monopolistic sectors has not yet been modelled theoretically, and it has only received sporadic empirical attention. The purpose of this paper is to provide a theoretical foundation for this mechanism and to evaluate its existence empirically based on the Swedish district heating sector. This sector consists of a mixture of unregulated IOMs and POMs that are confined by municipal borders. The Swedish district heating sector provides a unique setting for studying monopolies' price incentives since, contrary to most network sectors, the IOMs are not subject to formal price control mechanisms. Also, the Swedish electoral system can be characterised as bi-partisan where the ruling party/coalition is either left- or right-wing. There is empirical evidence that left-wing local councils in Sweden generally intervene more in markets (Pettersson-Lidbom, 2008), and Biggar and Söderberg (2011) find that the Swedish district heating utilities adopt a more pro-consumer pricing behaviour under left-wing local councils. We utilise a complete cross-sectional data set from 2007 that has not been used before in published work.

Our theoretical model, which can be viewed as a new variant of the Bertrand model, complements existing theoretical explanations for regulatory threat by showing that local monopolists, under certain conditions, have incentives to mimic the prices set by their neighbours. Similar 'neighbouring' effects have been observed previously in the context of regulatory threat. For example, Block and Feinstein

[7] This is confirmed empirically by Arora and Cason (1996) as they show that firms are more inclined to voluntarily comply with regulatory conditions when they have relatively more customer contacts.

(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 in violation.

Several empirical studies have looked at firms' pricing behaviour in response to policy makers' (likely) actions (Olmstead and Rhode, 1985; Erfle and McMillan, 1990; Driffield and Ioannidis, 2000). The study that is most similar to ours is Ellison and Wolfram's (2006) investigation of pharmaceutical prices in the U.S. during a period of a relatively intense scrutiny from policy makers. Similar to our study, they suggest that firms voluntarily hold back prices to reduce the threat of regulatory intervention and that firms' responses are positively correlated with their degree of regulatory vulnerability. However, our study differs from Ellison and Wolfram's (2006) in terms of both market structure and source of threat since they consider a market subject to competition and when the level of threat is related to the firms' own price levels.

The paper proceeds with a section that lays the foundation of our theoretical model. Our propositions are presented in Section 3. A background on the Swedish district heating sector is given in Section 4, and the empirical analysis is presented in Section 5. Section 6 concludes.

2. THE MODEL

Consider a set of unregulated locally monopolistic firms *i* where each firm faces its own demand for heat, $q_i(p_i)$, and p_i denotes the price. We assume that $q_i' < 0$ and $\lim_{p_i \to \infty} q_i(p_i) = 0$. The cost of providing the heat is denoted $c_i(q_i(p_i))$. If the firm is an IOM, its profit is expressed as $\pi_i(p_i) = p_i q_i(p_i) - c_i(q_i(p_i))$, where $\pi_i(p_i)$ is strictly concave, i.e. $\pi_i''(p_i) < 0$. The monopoly price is denoted $p_i^m = \arg\max \pi_i(p_i)$, where $\pi_i'(p_i^m) = 0$. The relevant price range for the firm is $p_i \le p_i^m$ since raising the price beyond the monopoly price decreases its profit. Note that $\pi_i'(p_i) > 0$ holds for $p_i < p_i^m$. Consumer surplus in each district is expressed as $cs_i(p_i) = \int_{p_i}^{\infty} q_i(p_i')dp_i'$, where $cs_i'(p_i) = -q_i(p_i) < 0$ and $cs_i''(p_i) = -q_i'(p_i) > 0$ for the relevant price range. Thus, $cs_i(p_i)$ is strictly convex. Social surplus in each district is then represented by the sum of the profit and consumer surplus: $sw_i(p_i) = \pi_i(p_i) + cs_i(p_i)$. The welfare-maximising price is denoted $\overline{p}_i = \arg\max sw_i(p_i)$, where $sw_i'(\overline{p}_i) = 0$. Maximised social surplus is denoted $\overline{sw}_i \equiv sw_i(\overline{p}_i) + cs_i(\overline{p}_i) \equiv \overline{\pi}_i + \overline{cs}_i$. As the price increases beyond $\overline{p}_i$, the social surplus decreases due to the increase in the deadweight loss, i.e. $sw_i'(p_i) = \pi_i'(p_i) + cs_i'(p_i) < 0$ for $\overline{p}_i < p_i$. We

assume that $sw_i(p_i)$ is strictly concave, i.e. $sw_i''(p_i) = \pi_i''(p_i) + cs_i''(p_i) < 0$. Lastly, we mention some relevant facts that we will come back to later: $\overline{p}_i < p_i < p_i^m$, $\pi_i(p_i) > \overline{\pi}_i$, $cs_i(p_i) < \overline{cs}_i$ and $sw_i(p_i) < \overline{sw}_i$ hold, since $\pi_i' > 0$, $cs_i' < 0$ and $sw_i' < 0$, respectively.

2.1 Structure of firms

A fully privately owned firm is only concerned with its own profit. A public firm, on the other hand, is concerned with consumer surplus as well as its own profit. Considering the private and public structures of firms, we define the surplus of firm *i* as follows:

$$S_i(p_i) = \pi_i(p_i) + \alpha_i cs_i(p_i), \tag{1}$$

where $\alpha_i \in [0,1)$.[8] When $\alpha_i = 0$, the firm is fully private and only seeks to maximise its profit. When $0 < \alpha_i$, the firm is a public firm that maximises the weighted sum of its profit and consumer surplus. A larger α_i implies that the firm has a more public character, putting more emphasis on consumer surplus.[9] When α_i approaches 1, the firm becomes the (local) council itself and seeks to maximise full social surplus. We will discuss this extreme case later.

Noting that $cs_i''(p_i) > 0$ and $\alpha_i \in [0,1)$, $\alpha_i cs_i''(p_i) < cs_i''(p_i)$ holds. After adding $\pi_i(p_i)$ on both sides, we obtain

$$\begin{aligned} S_i''(p_i) &= \pi_i''(p_i) + \alpha_i cs_i''(p_i) \\ &< \pi_i''(p_i) + cs''(p_i) \\ &< 0, \end{aligned} \tag{2}$$

where the last inequality comes from the strict concavity of $sw_i(p_i)$. Thus, $S_i(p_i)$ is strictly concave. The maximiser of the firm's surplus is denoted $p_i^s = \arg\max S_i(p_i)$. p_i^s is unique since $S_i(p_i)$ is strictly concave. Obviously, the maximiser p_i^s for the firm is greater than the full welfare-maximising price $\overline{p}_i$ for the council, and less than or equal to the full profit-maximising price p_i^m for the fully private firm, i.e. $\overline{p}_i < p_i^s \le p_i^m$. p_i^s coincides with p_i^m when α_i is 0.

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[8] This type of formulation is usually employed in the literature on mixed markets involving private and public firms (e.g. De Fraja and Delbono 1989; Matsumura 1998).

[9] α_i can represent the share of public ownership.

Note that $S_i'(p_i^s) = 0$. It follows from the strict concavity of $S_i(p_i)$ that $S_i(p_i)$ is increasing for $p_i < p_i^s$, i.e.

$$S_i'(p_i) = \pi_i'(p_i) + \alpha_i cs_i'(p_i) > 0 \tag{3}$$

for $p_i < p_i^s$. Furthermore, $S_i(p_i) > \overline{S}_i$ holds for $\overline{p}_i < p_i < p_i^s$ since $S_i'(p_i) > 0$ for this price range.

2.2 Expected surplus of firms

Next we introduce a functional relationship between the probability of regulatory intervention and the prices set by the firms. The probability of regulatory intervention is assumed to be a function of the price difference between two neighbouring firms, i.e. $\theta_i(p_i - p_{-i})$. The regulatory authority observes prices as well as introduces price regulation in district *i* with probability $\theta_i(p_i - p_{-i})$ where $\theta_i(\cdot)$ is increasing, i.e. $\theta_i' > 0$. $p_i - p_{-i}$ can be both positive and negative. We consider the range of probability, $0 < \theta_i < 1$, for the relevant price range.[10] It should be noted that the probability of intervention is positive even when firm i charges a price below the neighbour's price. Furthermore, we assume that $\theta_i(\cdot)$ is strictly convex, i.e. $\theta_i'' > 0$ for the relevant range.

Once the regulatory authority decides to intervene in district *i*, price regulation is introduced. We consider that the price will be regulated at $\overline{p}_i$. At this level, the firm obtains a constant surplus, $\overline{S}_i \equiv S_i(\overline{p}_i) = \pi_i(\overline{p}_i) + \alpha_i cs_i(\overline{p}_i) \equiv \overline{\pi}_i + \alpha_i \overline{cs}_i$. Considering a risk-neutral firm, we can now express its expected surplus as

$$\begin{aligned} ES_i(p_i, p_{-i}) &= (1 - \theta_i(p_i - p_{-i}))S_i(p_i) + \theta_i(p_i - p_{-i})\overline{S}_i \\ &= S_i(p_i) - \theta_i(p_i - p_{-i})(S_i(p_i) - \overline{S}_i). \end{aligned} \tag{4}$$

The second term on the second line of (4) can be interpreted as a form of expected penalty. When firm *i* chooses some price level p_i given p_{-i}, its surplus $S_i(p_i)$ is reduced by $S_i(p_i) - \overline{S}_i$ with probability $\theta_i(p_i - p_{-i})$. This highlights that the expected surplus of firm *i* depends not only on its

[10] We rule out the extreme cases when the regulatory authority intervenes with 100 percent certainty (θ_i=1), and when there is no risk of intervention (θ_i=0).

own price p_i, but also on p_{-i} in the neighbouring district –*i*. Using the terms of profit and consumer surplus, expected surplus can be written as

$$ES = \pi_i + \alpha_i cs_i - \theta_i(\pi_i + \alpha_i cs_i - (\overline{\pi}_i + \alpha_i \overline{cs}_i)). \tag{5}$$

Firm *i* maximises its expected surplus given the price of neighbouring firm –*i*. The first-order condition for firm *i* can be written as

$$\frac{\partial ES_i}{\partial p_i} = (1-\theta_i)S_i' - \theta_i'(S_i - \overline{S}_i) = 0. \tag{6}$$

Recall that $S_i(p_i) > \overline{S}_i$ for $\overline{p}_i < p_i < p_i^s$, $S_i' > 0$ for $p_i < p_i^s$, and $S'' < 0$, as discussed in subsection 2.1. Moreover, note that $0 < \theta_i < 1$, $\theta_i' > 0$, and $\theta_i'' > 0$, as discussed here. We then have

$$\phi_i \equiv \frac{\partial^2 ES_i}{\partial p_i^2} = (1-\theta_i)S_i'' - 2\theta_i' S_i' - \theta_i''(S_i - \overline{S}_i) < 0 \tag{7}$$

for $\overline{p}_i < p_i < p_i^s$ regarding the second-order condition.

2.3 The council

Before turning to the analysis of regulatory threat, we explore the decision of the council in relation to the model of the firm. As discussed in the introduction of this section, the council wants to set the price at $\overline{p}_i$ to maximise the social surplus $sw_i(p_i)$ in district *i*. This coincides with the decision of the firm, which wants to maximise its expected surplus $ES_i(p_i, p_{-i})$ when α_i approaches 1.

When α_i approaches 1, we have $ES_i = sw_i - \theta_i(sw_i - \overline{sw}_i) = \pi_i + cs_i - \theta_i(\pi_i + cs_i - (\overline{\pi}_i + \overline{cs}_i))$ and $\frac{\partial ES_i}{\partial p_i} = (1-\theta_i)sw_i' - \theta_i'(sw_i - \overline{sw}_i)$. Noting that $sw_i'(\overline{p}_i) = 0$ and $\overline{sw}_i \equiv sw_i(\overline{p}_i)$, we can easily verify that $\overline{p}_i$ satisfies the first-order condition of firm *i*, i.e. $\frac{\partial ES_i}{\partial p_i} = 0$, when α_i approaches 1. Here we assume that ES_i with $\alpha_i = 1$ is strictly concave for the relevant range, i.e.

$$(1-\theta_i)sw_i'' - 2\theta_i' sw_i' - \theta_i''(sw_i - \overline{sw}_i) < 0. \tag{8}$$

3. EFFECTS OF REGULATORY THREAT

We investigate the effects of regulatory threat in detail. As discussed in the previous section, the expected surplus of the firm is affected by the neighbouring price through the probability of regulatory intervention. Thus, even though the firm is a local monopolist, each firm strategically chooses its price in each jurisdiction, taking into account the price(s) of neighbouring jurisdiction(s). This can be regarded as a new variation of the Bertrand model where spatial price competition is driven by regulatory threat.

Technically, we can obtain the Nash equilibrium by solving the first-order conditions (6) simultaneously. Let us characterise the equilibrium prices (p_i^*, p_{-i}^*) in the following proposition:

Proposition 1. The equilibrium price p_i^* is such that $\overline{p}_i < p_i^* < p_i^S$.

Proof. Noting that $S_i'(p_i^S) = 0$, $S_i(p_i^S) > \overline{S}_i$ and $\theta_i' > 0$, we have

$$\left.\frac{\partial ES_i}{\partial p_i}\right|_{\substack{p_i = p_i^S \\ p_{-i} = p_{-i}^*}} = -\theta_i'(S_i(p_i^S) - \overline{S}_i) < 0 .$$

Thus, firm *i* can make more profit by choosing a price less than p_i^S for any given p_{-i}^*. Next, noting that $0 < \theta_i < 1$ and $S_i'(\overline{p}_i) > 0$, we have

$$\left.\frac{\partial ES_i}{\partial p_i}\right|_{\substack{p_i = \overline{p}_{-i} \\ p_{-i} = p_{-i}^*}} = (1 - \theta_i) S_i'(\overline{p}_i) > 0 .$$

This implies that firm *i* can make more profit by choosing a price greater than $\overline{p}_i$ for any given p_{-i}^*. Therefore, p_i^* is such that $\overline{p}_i < p_i^* < p_i^S$. ■

Without any regulatory threat, the firm would have chosen p_i^S. However, once the firm faces some regulatory threat, it strategically charges a price lower than p_i^S, even though it is a local monopolist.

In what follows, our analysis is concerned with the relevant price range of $\overline{p}_i < p_i < p_i^S$ unless otherwise stated.

We further examine the strategic reaction of the firm under regulatory threat. The first-order condition (6) for firm *i* yields the best response function $p_i = BR_i(p_{-i})$. When the decisions of the firms are 'strategic complements', the slope of the best response curve is positive. In contrast, when the decisions of the firms are 'strategic substitutes', the slope of the best response curve is negative.[11] In the next proposition we show that p_i and p_{-i} are strategic complements.

Proposition 2. Prices are strategic complements, i.e. $\frac{\partial^2 ES_i}{\partial p_{-i}\partial p_i} > 0$.

Proof. Noting that $S_i(p_i) > \overline{S}_i$, $S_i' > 0$, $\theta_i' > 0$ and $\theta_i'' > 0$, we have

$$\psi_i \equiv \frac{\partial^2 ES_i}{\partial p_{-i}\partial p_i} = \theta_i' S_i' + \theta_i''(S_i - \overline{S}_i) > 0 . \tag{9}$$

■

This proposition implies that the slope of the best response curve is positive:

$$BR_i'(p_{-i}) = -\frac{\psi_i}{\phi_i} = -\frac{\frac{\partial^2 ES_i}{\partial p_{-i}\partial p_i}}{\frac{\partial^2 ES_i}{\partial p_i^2}} > 0 . \tag{10}$$

The current model is different from the standard Bertrand model. Each firm is a local monopolist that faces its own demand. Despite this fact, regulatory threat induces each local monopolist to react strategically, taking into account the price(s) of neighbouring jurisdiction(s). As a result, regulatory threat leads to a positive price correlation among jurisdictions. An interesting question is how the structure of the firm affects its strategic reaction. Thus, we next examine the effects of changing α_i on the slope of the best response curve, $BR_i'(p_{-i})$. We obtain the following results:

Proposition 3. When α_i increases, the slope of the best response curve decreases, i.e. $\frac{\partial BR_i'}{\partial \alpha_i} < 0$.

[11] See e.g. Tirole (1988).

Proof. See Appendix 1. ■

If a firm is fully private with $\alpha_i = 0$, the slope of the best response curve is the steepest. If a firm gains a more public character with a larger α_i, the slope of the best response curve becomes flatter. These results follow from the publicly owned firm's incentive to restrain its price, taking account of the consumer surplus in its district. Therefore, when α_i increases, the slope of the best response curve decreases, and hence the positive correlation of prices among districts becomes weaker.

As discussed in Section 2, when α_i approaches 1, the firm becomes the council itself, and the price it chooses approaches $\overline{p}_i$. $\overline{p}_i$ is determined irrespective of the neighbouring price since $\overline{p}_i$ is the maximiser of full social surplus $sw_i(p_i)$. Consequently, $\frac{\partial BR_i'}{\partial \alpha_i}$ approaches 0 when α_i approaches 1.

Lastly, we extend and refine our model by introducing a proxy parameter $\mu_i \in (0,1)$ that represents the strength of regulatory threat. We assume that a higher value of μ_i corresponds to a situation where the regulatory threat is stronger. Specifically, two situations are worth noting, based on descriptive statistics presented in Section 4. First, utilities operating under pro-consumer councils will face more severe downward pressure on prices than those operating under pro-firm councils. Thus, it is assumed that μ_i takes a higher value when elected officials have more consumer-friendly preferences. Second, neighbours located relatively close to each other are subject to more serious price comparison than distant neighbours. Hence, it is assumed that μ_i takes a higher value when neighbouring jurisdictions are geographically closer.

Given some observed level of price difference between two districts, the probability of regulatory intervention should be higher when μ_i is larger. Thus, it is straightforward to rewrite the probability of intervention as $\mu_i \theta_i(p_i - p_{-i})$.[12] The expected surplus of firm *i* can now be rewritten as

$$\overline{\overline{ES}}_i(p_i, p_{-i}) = S_i(p_i) - \mu_i \theta_i(p_i - p_{-i})(S_i(p_i) - \overline{S}_i). \tag{11}$$

[12] We can also assume multiple parameters for the strength of the regulatory threat: for example, $\mu_i^a \in (0,1)$ for the preferences of elected officials and $\mu_i^b \in (0,1)$ for the geographical proximity of neighbouring districts. Then the probability of intervention can be expressed as $\mu_i^a \mu_i^b \theta_i(p_i - p_{-i})$. However, this alteration does not change the main results of the model.

In the following, the double bars are used to express all corresponding terms that include μ_i. We then obtain the following results regarding the effects of changing μ_i on the slope of the best response curve, $\overline{\overline{BR'}}_i(p_{-i})$:

Proposition 4. When μ_i increases, the slope of the best response curve increases, i.e. $\frac{\partial \overline{\overline{BR'}}_i}{\partial \mu_i} > 0$.

Proof. See Appendix 1. ■

This proposition implies that the response of a firm to the neighbouring price is positively related to the strength of the regulatory threat. Firms are exposed to stronger regulatory threat when elected officials are more pro-consumer and neighbouring jurisdictions are geographically closer. When μ_i increases, the slope of the best response curve increases and hence the positive correlation of prices among districts becomes stronger.

4. THE SWEDISH DISTRICT HEATING SECTOR

The district heating technology builds on the principle of centralised heat production where the heat is distributed 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 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 of the total 290 municipalities (SCA, 2009; SCB, 2009). Networks only exist in densely populated areas over a certain size and it is rare that networks are connected over municipal borders.

In 2007, 30 % of the utilities were IOM and 36% operated in municipalities with a right-wing dominated council. [13] While ideological composition of the local council must be treated as endogenous in the subsequent analysis, we will argue that IOMs and POMs are structurally similar and can be considered as random samples. This argument is based on the high degree of similarity

[13] In our empirical investigation, an investor-owned district heating utility is defined as a utility where private investors control any share > 0 of the utility. 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.

between the two sub-samples in terms of climate conditions, population characteristics, input price levels and network characteristics (detailed statistics are provided in Table A2.1 in Appendix 2).

Municipal-level data from 2007 shows that the average price per MWh for a multi-dwelling property that consumes 193 MWh of heat is 653 SEK and 663 SEK when the utility is a POM and operating under left- and right-wing councils, respectively.[14] When the utility is IOM, the price is 688 SEK when the council is left-wing and 710 SEK when the council is right-wing. Although these prices are not statistically different, they do indicate that utilities under left-wing councils charge lower prices than those under right-wing councils, and that POMs charge lower prices than IOMs.

Pair-wise correlations between prices in municipality *i* and its neighbours $-i$, where i is IOM and $-i = \{1, 2, ..., i-1\}$ is ordered in distance between i and $-i$, show that the correlation is 0.44 between i and $-i = 1$ and 0.28 between i and $-i = 2$ (the results are similar when *i* operates under left- and right-wing councils). The correlations for higher values of $-i$ are insignificant. Similar calculations for when i is POM show that the correlation is 0.31 when $-i = 1$ and the council is left-wing. Correlations for higher values of $-i$, and when the local council is right-wing, are insignificantly different from 0. The picture that emerges from these descriptive figures is that (*i*) neighbouring prices are significantly correlated, yet the correlation is generally confined to the closest neighbour, (*ii*) IOMs are substantially more affected by neighbours' prices than are their POM counterparts, and (*iii*) utilities operating under left-wing (rather than right-wing) councils attach more weight to the price of their closest neighbour.

There is no statistics available on complaints about district heating prices, but a recent study on the characteristics of district heating coverage in local and national Swedish newspapers shows that prices are the most frequently covered topic and that the tone is more critical when the utility is an IOM (Palm and Magnusson, 2009). This shows that customers have an effective channel to reach out with their complaints to elected officials. Anecdotal evidence from utility representatives and media reporting also indicates that municipalities can (and do) make decisions that have a substantial impact on utilities' financial performance.

[14] These prices represent the price paid by a multi-dwelling property that is considered to be a 'national average property'. See Section 5.1 for further details.

5. EMPIRICAL EVALUATION

Based on the insights from Section 4, we want to empirically investigate whether p_i is influenced by $p_{-i=1}$, i.e. the price charged by *i*'s closest neighbour. Propositions 3 and 4 postulate that the relationship between p_i and $p_{-i=1}$ is stronger when *i* is an IOM and when *i* faces a stronger regulatory threat. This translates into a functional form that can be written as $p_i = \gamma \mathbf{W} p_{-i=1} + \mathbf{x}_i \boldsymbol{\beta}$, where γ is the parameter denoting the spatial association between p_i and $p_{-i=1}$. **W** is a weight matrix consisting of predetermined proxies for the level of threat between i and all $-i$.

To allow public and private utilities to have different values of γ, and for private utilities to respond differently to left- and right-wing dominated local councils, it is necessary to add two additional spatial terms where the elements in the second and third weight matrixes are multiplied with the type of ownership and ownership/political majority, respectively. The measures of ownership and political orientation can be continuous, as in the theoretical model, yet here we use two binary variables where *b* takes the value 1 if the utility is classified as an IOM and *r* takes the value 1 if the local council has a right-wing majority.[15] To increase flexibility, we allow the price variables to be transformed by λ, where $\lambda = [-1, 1]$ and where λ=0 represents the natural logarithm. Hence, the general model that we want to estimate is formulated as

$$p_i^{\lambda} = \gamma_1 \mathbf{W}_1 p_{-i=1}^{\lambda} + \gamma_2 \mathbf{W}_2 p_{-i=1}^{\lambda} + \gamma_3 \mathbf{W}_3 p_{-i=1}^{\lambda} + \mathbf{x}_i \boldsymbol{\beta} + \varepsilon_i, \tag{12}$$

where the elements in $\mathbf{W}_1$, $\mathbf{W}_2$, and $\mathbf{W}_3$ are calculated as

$$w_{1,i,-i} = \begin{cases} d_{i,-i}^{-1} & \text{for} - i = 1 \\ 0 & \text{otherwise} \end{cases}, \quad w_{2,i,-i} = \begin{cases} b_i d_{i,-i}^{-1} & \text{for} - i = 1 \\ 0 & \text{otherwise} \end{cases} \text{ and } w_{3,i,-i} = \begin{cases} r_i b_i d_{i,-i}^{-1} & \text{for} - i = 1 \\ 0 & \text{otherwise} \end{cases}.$$

$d_{i,-i}$ is the Euclidian distance between the centres of the largest urban communities in *i* and –*i*. The inversed distance reduces the weight for more distant neighbours. Similar weighting structures are common in the applied spatial literature (e.g. Lambert et al., 2010; Zhou and Kockelman, 2009; Lee and Yu, 2009).[16] However, when only –*i*=1 is included on the RHS, it is possible that distance is already internalised in the model, and hence the value of including the distance will be investigated more closely.

[15] Note that α used in Sections 2 and 3 is related to *b* as *b*=1-α.

[16] Lee and Yu (2010) use a piecewise function that is decreasing in the distance between *i* and –*i*.

The **x** vector consists of b, r and cost characteristics. Cost is assumed to be influenced by the unit costs of fuel (p_i^f) and labour (p_i^l).[17] In addition, firms that rely on physical networks typically have a cost structure that depends on network characteristics. We include the amount of energy produced (q_i) to account for economies of scale in the production, and total network length (ℓ_i) to account for scale effects in the distribution. Also, two strategic behaviours can influence the pricing behaviour when networks are subject to expansion. First, Chisari and Kessides (2009) point out that a utility can have incentives to keep its price low to attract customers during the initial phase of the expansion, and then raise the price as the network approaches its optimum size. This suggests that price and market share are positively related. However, non-adopters of district heating would prefer a high price to increase public revenue, yet this group will only dominate as long as district heating has a market share below 50% in the heating market. Once the market share exceeds 50%, adopters will be in majority and will lobby for lower prices. This line of argument suggests that the relation between market share and price is negative. To control for these potential effects, we add a variable m_i for the district heating's market share in the local residential energy market. Utilities' mix of customer types is accounted for by including share of detached houses, s_i. Nine firm dummies are also included to control for instances when a particular utility is responsible for the district heating operation in more than one municipality.

5.1 Data

Data is collected from the Swedish Energy Markets Inspectorate, The Swedish District Heating Association, Statistics Sweden, the 'Nils Holgersson's annual price comparisons', and the utilities/municipalities directly. The data set is cross-sectional for the year 2007 and represents all 242 municipalities where district heating is a significant source of heating in the largest urban area, excluding Gotland, which is an island. Descriptive statistics and further details about the variables in (12) are provided in Table A2.2 in Appendix 2.

The price p_i is the average price (fixed plus variable) paid per MWh for a multi-dwelling property that consumes 193 MWh of heat and requires 3 860 m^3 of water pass-through per year. The correlations with prices for other standardised customer types (80MWh, 500 MWh and 1 000 MWh) are high (between 0.94 and 0.96), which means that p_i can be viewed as the average price for all multi-dwelling properties.

[17] Cost of capital is not considered since it is not subject to geographical heterogeneity.

Fuel price is total costs of fuels divided by total amount of kWh produced. This price can be negative since utilities are paid to dispose of public waste, which sometimes is a substantial fuel type. Labour price is average municipal salary (net local taxes) in the public sector. This is preferred to figures based on utilities' own accounting statements since it eliminates the risk of including rents captured by strong unions and self-rewards by executives.

5.2 Estimation

The derivation of an estimable spatial autoregressive model is not covered here since it has been thoroughly dealt with elsewhere (e.g. Mobley, 2003; Revelli, 2006; Zhou and Kockelman, 2009). Estimating (12) with the non-linear least square estimator, i.e. assuming strict exogeneity, shows that the specification suffers from over-parameterisation. A grid search approach starting with $\lambda = -1$ and increasing in steps of 0.1 until λ=1 is therefore applied, showing that the residual sum of squared (RSS) for λ=1 is not significantly higher than the RSS for any other value of λ. This confirms previous findings that linear price models perform well in comparison with unconstrained transformations when firm heterogeneity is unobserved (Cropper et al., 1988).

As we proceed, two problems can be noted. First, the three terms containing p_{-i} are endogenous by construction (LeSage and Pace, 2009) and, second, the residuals ε_i are likely to be heteroscedastic.[18] Instrumental variable approaches with heteroscedasticity-consistent standard errors are offered by both 2SLS and two-stage, or 'optimal', GMM (OGMM),[19] yet Lin and Lee (2010) note that OGMM is more efficient and potentially more robust. Kelejian and Prucha (1998) argue that a subset of neighbours' covariates can be used as instruments to arrive at consistent spatial parameters. We chose this strategy and use neighbours' fuel and labour prices as instruments for p_{-i}. Further endogeneity problems can occur if q_i is correlated with ε_i. Such correlation can occur from unobserved property characteristics. We use share of energy delivered to industrial customers (ind_i) and population in urban areas (pop_i) to control for this potential endogeneity. Although utilities determine the size of the network themselves, ℓ_i is treated as exogenous since decisions to extend the network are typically made several years prior to the actual construction. In Section 4 we showed that public and private utilities are similar when comparing fundamental supply and demand conditions. b_i is therefore treated as exogenous. Ideological composition of the local council can be endogenous to local

[18] For example, heteroscedasticity can occur from unobserved variation in network age since some recently established utilities might want to use revenues to finance network expansions. Utilities operating mature networks can therefore be expected to have lower price variability.

[19] Kelejian and Prucha (2010) report that the maximum likelihood estimator is significantly biased in the presence of heteroscedasticity.

government tariffs.[20] The indicator variable for right-wing majority (r_i) is instrumented with $r_{i,t-2}$, which refers to the situation in the previous electoral period.

An OLS estimation is displayed in Column (a) in Table 1. Column (b) shows the output for when p_{-i}, q_i and r_i are treated as endogenous, using the OGMM estimator. The results are consistent in terms of signs and significance levels, but γ_2 (γ_3) increases (decreases) in magnitude as the exogeneity assumptions are relaxed. Column (c) shows (12) when $d_{i,-i}$ is excluded from the weight matrices. Comparing the RSS values for Column (b) and (c) shows that including $d_{i,-i}$ reduces RSS by over 6 %. One can also observe that (c) is not as well-behaved as (a) and (b), which shows that it is important to incorporate the distance between neighbours in order to arrive at reasonable estimates. This finding supports Proposition 4.

Based on estimates in Column (b), the average predicted price charged by POMs (669.2 SEK/MWh) is lower than the price set by IOM under left-wing councils (670.4 SEK/MWh), which in turn is lower than the price set by IOMs under right-wing councils (713.4 SEK/MWh). Although these prices are not statistically different, they point in the same direction as Proposition 1. As expected, there is no evidence that POMs take the prices of their closest neighbours into consideration. IOMs operating under left-wing councils ($\gamma_1 + \gamma_2$), i.e. when the councils are relatively pro-consumer, internalise 50% of the price adjustments made by their closest neighbours. The positive sign of $\gamma_1 + \gamma_2$ lends support to Proposition 2 and the fact that $\gamma_1 < \gamma_1 + \gamma_2$ is consistent with Proposition 3. We have already established that $d_{i,-i=1}^{-1}$ has a substantial role in identifying the relation between p_i and $p_{-i=1}$ and that this supports Proposition 4. Further support for Proposition 4 is provided by the fact that $\gamma_1 + \gamma_2 > \gamma_1 + \gamma_2 + \gamma_3$, i.e. that pro-consumer preferences of elected officials increase the threat. The combination of private ownership and the pro-firm preferences of right-wing councils ($\gamma_1 + \gamma_2 + \gamma_3$) is apparently strong enough to statistically eliminate the threat of intervention.

[20] A strategically behaving council can increase the price when income goes up, and Leigh (2005) shows that income (among several other socio-economics factors) influences voting behaviour.

Table 1. Estimation output.

	OLS (a)			OGMM [a] (b)			OGMM (c)		
Variable	**Mean**		**SE**	**Mean**		**SE**	**Mean**		**SE**
$d_{i,-i=1}^{-1} p_{-i=1}$	0.0245		0.0239	0.0161		0.0235			
$b_i d_{i,-i=1}^{-1} p_{-i=1}$	0.3275	**	0.1450	0.4843	**	0.2059			
$r_i b_i d_{i,-i=1}^{-1} p_{-i=1}$	-0.0227		0.2672	-0.6252		0.4779			
$p_{-i=1}$							0.2707		0.2502
$b_i p_{-i=1}$							0.6741		0.5182
$r_i b_i p_{-i=1}$							-0.9566	*	0.4921
b_i	12.011		16.161	1.1954		21.248	-453.87		354.52
$r_i b_i$	14.697		19.346	50.794		34.914	687.66	**	341.47
q_i	0.0464	**	0.0194	0.0576	***	0.0203	0.0647	***	0.0218
ℓ_i	-0.2552	**	0.0886	-0.2763	***	0.0876	-0.2863	***	0.0901
p_i^f	0.1065	**	0.0528	0.0994	**	0.0479	0.1073	*	0.0556
p_i^l	0.0114	*	0.0067	0.0121	*	0.0063	0.0053		0.0080
m_i	-49.450		30.854	-34.654		30.775	-31.138		29.391
s_i	-207.85	***	70.907	-219.44	***	68.247	-185.68	**	79.268
Constant	437.38	***	142.44	421.10	***	133.01	382.11	***	166.92
Ownership dummies	Yes			Yes			Yes		
Hansen's J				8.245			5.522		
Hansen's P>J				0.221			0.238		
R^2	0.453			0.446			0.375		
No. obs.	242			242			242		

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. SE are robust to arbitrary heteroscedasticity.

[a] Instruments: $d_{i,-i=1}^{-1} p_{-i=1}^{f}$, $b_i d_{i,-i=1}^{-1} p_{-i=1}^{f}$, $r_{i,t-2} b_i d_{i,-i=1}^{-1} p_{-i=1}^{f}$, $d_{i,-i=1}^{-1} p_{-i=1}^{l}$, $b_i d_{i,-i=1}^{-1} p_{-i=1}^{l}$, $r_{i,t-2} b_i d_{i,-i=1}^{-1} p_{-i=1}^{l}$, ind_i, pop_i, $r_{i,t-2} b_i$.

Other coefficients reveal that p_i increases for higher q_i and decreases for higher ℓ_i which is consistent with the view held by industry representatives and the results by Biggar and Söderberg (2011). Input prices are positively correlated with p_i. The tests of Hansen's J show that instruments are correctly excluded from the main equation and uncorrelated with ε_i in both Columns (b) and (c).

6. CONCLUSIONS

In this paper we claim that a plausible explanation for why unregulated investor-owned local monopolies do not always charge the monopoly price is that doing so may lead to customer complaints that in turn may lead to retaliations from local elected officials. Customers compare their

prices with those in neighbouring jurisdictions, and the probability of a complaint is positively correlated with the degree of spatial price heterogeneity. Elected officials have incentives to intervene when customers (i.e. voters) complain, yet the probability of intervention is reduced when elected officials have pro-firm preferences. We show that when utilities are subject to regulatory threat that originates from spatial price comparisons, the equilibrium price is located between the efficient and monopoly prices. Also, prices charged by neighbouring utilities are strategic complements, meaning that their prices are positively correlated. The spatial price correlation between neighbours increases when IOMs are exposed to relatively strong threat, i.e. when elected officials have pro-consumer preferences and neighbours are geographically close.

The empirical analysis is based on a complete cross-sectional data set from the Swedish district heating sector in 2007. This sector is unique in that it consists of local monopolies that are owned by both private investors (IOM) and municipalities (POM), yet the monopolies are not subject to any formal price regulation. The analysis supports the theoretical predictions by showing that 1) POMs tend to set lower prices than IOMs; 2) IOMs that operate under left-wing councils (i.e. councils that are relatively pro-consumer) have lower prices than IOMs under right-wing councils; 3) IOMs under left-wing councils internalise as much as 50% of their neighbours' prices; and 4) when the threat of intervention is lower, i.e. when IOMs operate under right-wing councils, there is no sign that they take their neighbours' prices into consideration.

Policy-wise one can conclude that the threat of regulatory intervention can effectively reduce IOMs' incentive to use their marker power, yet a favourable situation for consumers is fragile since a change in the council's ideological preferences can reduce the threat, which may lead to a substantial price increase.

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APPENDIX 1

Proof of Proposition 3

Note that $\pi_i' > 0$, $\pi_i'' < 0$, $cs_i' < 0$ and $cs_i'' > 0$, as stated in the beginning of Section 2. It follows from $sw_i' < 0$ and $sw_i'' < 0$ in the beginning of Section 2 that $0 < \pi_i' < -cs_i'$, and $0 < cs_i'' < -\pi_i''$. Thus, we obtain

$$\pi_i' cs_i'' < \pi_i'' cs_i' . \tag{13}$$

Note that $\pi_i > \overline{\pi}_i$, and $cs_i < \overline{cs}_i'$, as stated in the beginning of Section 2. It follows from $sw_i = \pi_i + cs_i < \overline{\pi}_i + \overline{cs}_i = \overline{sw}_i$, that

$$0 < \pi_i - \overline{\pi}_i < -(cs_i - \overline{cs}_i) . \tag{14}$$

Next, rearranging (8) in subsection 2.3 yields

$$0 < -\theta_i' sw_i' - \theta_i''(sw_i - \overline{sw}_i) < \theta_i' sw_i' - (1-\theta_i) sw_i'' \tag{15}$$

The first inequality comes from $sw_i' < 0$, $sw_i < \overline{sw}_i$, $\theta_i' > 0$, and $\theta_i'' > 0$. Thus, $0 < \theta_i' sw_i' - (1-\theta_i) sw_i''$ holds. Noting this and $0 < \theta_i < 1$, we have

$$0 < (1-\theta_i) cs_i'' - \theta_i' cs_i' < \theta_i' \pi_i' - (1-\theta_i)\pi_i'' \tag{16}$$

Then, it follows from (14) and (16) that:

$$(\pi_i - \overline{\pi}_i)((1-\theta_i) cs_i'' - \theta_i' cs_i') < -(cs_i - \overline{cs}_i)(\theta_i' \pi_i' - (1-\theta_i)\pi_i'') . \tag{17}$$

We now check the sign of $\frac{\partial BR_i'}{\partial \alpha_i} = \frac{1}{\phi_i^2}\left(-\frac{\partial \psi_i}{\partial \alpha_i}\phi_i + \psi_i \frac{\partial \phi_i}{\partial \alpha_i} \right)$. The sign of $\frac{\partial BR_i'}{\partial \alpha_i}$ depends on the sign inside the bracket. Noting that (13) and (17) hold, we obtain:

$$\begin{aligned} -\frac{\partial \psi_i}{\partial \alpha_i}\phi_i + \psi_i \frac{\partial \phi_i}{\partial \alpha_i} &= \theta_i'(1-\theta_i)(\pi_i' cs_i'' - \pi_i'' cs_i') \\ &\quad + \theta_i''\big[(\pi_i - \overline{\pi}_i)((1-\theta_i) cs_i'' - \theta_i' cs_i') \\ &\quad + (cs_i - \overline{cs}_i)(\theta_i' \pi_i' + (1-\theta_i)\pi_i'')\big] \\ &< 0 . \end{aligned} \tag{18}$$

Therefore, $\frac{\partial BR_i'}{\partial \alpha_i} < 0$. ■

Proof of proposition 4

Recall that $S_i > \bar{S}_i$, $S_i^{'} > 0$, and $S_i^{''} < 0$, as stated in Subsection 2.1. Also recall that $\theta_i^{'} > 0$ and $\theta_i^{''} > 0$, as stated in Subsection 2.2. We then calculate $\bar{\bar{\phi}}_i$ and $\bar{\bar{\psi}}_i$ as follows:

$$\bar{\bar{\phi}}_i \equiv \frac{\partial^2 \overline{\overline{ES}}_i}{\partial p_i^2} = \left(1-\mu_i\theta_i\right)S_i^{''} - 2\mu_i\theta_i^{'}S_i^{'} - \mu_i\theta_i^{''}\left(S_i - \bar{S}_i\right) < 0, \tag{19}$$

$$\bar{\bar{\psi}}_i \equiv \frac{\partial^2 \overline{\overline{ES}}_i}{\partial p_{-i}\partial p_i} = \mu_i\theta_i^{'}S_i^{'} + \mu_i\theta_i^{''}\left(S_i - \bar{S}_i\right) > 0. \tag{20}$$

Next, we obtain

$$\begin{aligned}\frac{\partial\bar{\bar{\phi}}_i}{\partial\mu_i} &= -\theta_i S_i^{''} - 2\theta_i^{'}S_i^{'} - \theta_i^{''}\left(S_i - \bar{S}_i\right) \\ &= \frac{1}{\mu_i}\left(\bar{\bar{\phi}}_i - S_i^{''}\right).\end{aligned} \tag{21}$$

Moreover, we have

$$\begin{aligned}\frac{\partial\bar{\bar{\psi}}_i}{\partial\mu_i} &= \theta_i^{'}S_i^{'} + \theta_i^{''}\left(S_i - \bar{S}_i\right) \\ &= \frac{\bar{\bar{\psi}}_i}{\mu_i} \\ &> 0.\end{aligned} \tag{22}$$

We now check the sign of $\frac{\partial\overline{\overline{BR'}}_i}{\partial\mu_i}$. Using (21) and (22), we obtain

$$\begin{aligned}\frac{\partial\overline{\overline{BR'}}_i}{\partial\mu_i} &= \frac{1}{\bar{\bar{\phi}}_i^2}\left(-\frac{\partial\bar{\bar{\psi}}_i}{\partial\mu_i}\bar{\bar{\phi}}_i + \bar{\bar{\psi}}_i\frac{\partial\bar{\bar{\phi}}_i}{\partial\mu_i}\right) \\ &= -\frac{1}{\bar{\bar{\phi}}_i^2}\frac{\partial\bar{\bar{\psi}}_i}{\partial\mu_i}S_i^{''} \\ &> 0.\end{aligned} \tag{23}$$

■

APPENDIX 2

Table A2.1. Sample statistics for privately and publicly owned utilities.

	Mean	Std. Dev.	Min	Max
Publicly owned utilities (n=169)				
District heating list price	656.4	81.148	405.3	815.0
Heating degree days	3 416	620.7	2 479	4 767
Urban population	29 220	44 870	987	478 900
Urban density	11.746	5.7443	3.6073	50.412
Unit price of labour	21 510	626.1	20 100	24 100
Unit price of fuel	174.61	103.8	-126.2	712.0
Share of customers living in detached houses	0.1153	0.0731	0	0.3437
Network length	89.301	127.6	4	932.5
Privately owned utilities (n=73)				
District heating list price	697.6	51.260	543.6	783.7
Heating degree days	3 333	498.3	2 479	4 408
Urban population	30 090	94 960	1 571	770 900
Urban density	11.822	7.0582	3.9585	44.756
Unit price of labour	21 520	711.1	20 100	23 600
Unit price of fuel	160.8	84.107	-59.771	525.17
Share of customers living in detached houses	0.0920	0.0523	0.0061	0.2839
Network length	64.814	162.02	3.2	1 200

Table A2.2 Descriptive statistics.

Variable	Mean	Std.dev.	Min	Max
p_i	668.85	75.730	405.25	815.00
$d_{i,-i=1}^{-1} p_{-i=1}$	57.047	155.13	6.7036	1 712.6
$b_i d_{i,-i=1}^{-1} p_{-i=1}$	14.607	29.755	0	165.55
$r_i b_i d_{i,-i=1}^{-1} p_{-i=1}$	6.9246	21.805	0	164.53
b_i	0.6983	0.4599	0	1
$r_i b_i$	0.1364	0.3439	0	1
q_i	195.01	513.53	3.5	6 464
ℓ_i	81.914	138.97	3.2	1 200
p_i^f	170.45	98.271	-126.22	711.98
p_i^l	21 512	651.42	20 100	24 100
m_i	0.3164	0.1734	0.0155	0.9329
s_i	0.1083	0.0682	0	0.3437
Instruments				
$d_{i,-i=1}^{-1} p_{-i=1}^f$	21.068	121.08	-7.4644	1 807.6
$b_i d_{i,-i=1}^{-1} p_{-i=1}^f$	16.997	121.13	-7.4644	1 807.6
$r_{i,t-2} b_i d_{i,-i=1}^{-1} p_{-i=1}^f$	1.1314	4.2282	0	34.615
$d_{i,-i=1}^{-1} p_{-i=1}^l$	1 866.8	5 364.2	265.25	59 916
$b_i d_{i,-i=1}^{-1} p_{-i=1}^l$	1 408.4	5 402.5	0	59 916
$r_{i,t-2} b_i d_{i,-i=1}^{-1} p_{-i=1}^l$	128.52	473.47	0	4 349
$r_{i,t-2} b_i$	0.0909	0.2881	0	1
pop_i	29 482	64 013	987	770 889
ind_i	0.1116	0 1041	0	0 6546

Sources: p_i (Nils Holgersson's annual price comparisons, www.nilsholgersson.nu); $d_{i,-i=1}$ (based on coordinates recorded at www.eniro.se); b (annual reports, utilities/municipalities directly); q, ℓ (the Swedish District Heating Association (www.svenskfjarrvarme.se); p_i^f (Statistics Sweden and utilities/municipalities directly); p_i^l, m_i, s_i, pop_i, ind_i, r_i (Statistics Sweden, www.scb.se).