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

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ABSTRACT

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

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

JEL Classifications: D42, L51, L52, L97

[1] The views expressed in this paper are the views of the authors and do not necessarily reflect the views of the ACCC or the AER.

1. INTRODUCTION

This paper explores an issue at the foundations of public utility regulation. According to neoclassical theory, the primary economic objective for public utility regulation is to reduce or eliminate deadweight loss (e.g. Crew and Kleindorfer, 2006). However, this approach cannot explain certain aspects of the way public utility regulators tend to behave in practice – such as their historic focus on promoting stability in regulated prices.[2] As an alternative, it has been suggested that a primary rationale of public utility regulation is to protect and promote sunk complementary investment by potential and existing consumers of the regulated firm (Goldberg, 1976; Biggar, 2009). The logic is that, in public utility industries, customers of the public utility must make sunk investments in order to extract the most value from the monopoly service, such as investments in specialised equipment, human capital, or in a particular location. Once these investments are sunk they are subject to the risk that the public utility will increase its prices and therefore expropriate the value of the investments. When this hold-up problem cannot be solved through vertical integration or vertical long-term contracting, there may be a role for public utility regulation.

We utilise a data set from the highly unique district heating sector in Sweden where the locally monopolised utilities enjoy a high degree of pricing flexibility and where the networks have expanded heavily in the last decade. This stands in contrast to most utility sectors in the developed world where customers have already made most of their sunk investments and where prices are subject to price control regulation by an independent regulatory agency. Customers who wish to make use of district heating must purchase and install customer premises equipment, which can cost more than ten times the annual consumption expenditure on heating. This has given rise to concerns that customers are locked in to the district heating service (EI, 2007; Henning, 2006) and that they might be reluctant to make the necessary investments – potentially choosing environmentally or economically inferior heating alternatives – out of fear of future price increases (SOU 2004, p. 15; EI, 2007, p.41).[3] As a result there have been calls for price controls by the Swedish Competition Authority and the Swedish Energy Markets Inspectorate (SCA, 2009; EI, 2007).[4]

[2] Crew and Kleindorfer (2006) suggest that regulators should emphasise "...some degree of price stability" (p. 72), but they do not elaborate on why that would be advantageous.

[3] District heating is seen as being more energy efficient and less emissions-intensive than local boilers or electrical heating (Bruckner et al., 1997; Joelsson and Gustavsson, 2009).

[4] The Energy Markets Inspectorate, in arguing the need for regulation, explicitly argues that district heating customers are in a "weak position" with respect to their suppliers and that regulation would "build long-term confidence in district heating as a product" (EI, 2007, p. 66).

We assume that, in making a decision whether or not to take-up district heating (and therefore whether or not to make the necessary sunk investments) consumers are forward-looking, and form expectations about the likely future path of prices for district heating service. Several studies in the economics and marketing literature have found that when there is scope for inter-temporal substitution of purchases, past purchases, together with expectations about future price paths, have an effect on present demand.[5]

More specifically, this paper can be related to the literature on price stickiness and price rigidity – particularly the literature emphasising the presence of an "implicit contract" between the service provider and its customers. Okun (1981) proposed the "invisible handshake" notion that firms have "...implicit agreements with their customers not to take advantage of tight market conditions by raising their price in exchange for stable prices in weak markets" (Nakamura and Steinsson, 2011, p. 6). Blinder et al (1998) report that 64.5% of firms say they have implicit contracts with their consumers and 79% of these firms indicate that these contracts are an important source of price rigidity. The possible reasons for these implicit contracts include various forms of relationship-specific sunk investment, such as consumer switching costs (Klemperer, 1995; Eber, 1999; Kleshchelski and Vincent, 2009), good-specific habit-formation (Ravn et al., 2006; Nakamura and Steinsson, 2011), and consumer learning in the case of experience goods (Bils, 1989; Renner and Tyran, 2004; Villas-Boas, 2004)

The investment by a customer in district heating service has certain parallels to the problem of consumer habit formation studied by Nakamura and Steinsson (2011). Nakamura and Steinsson emphasise that if the supplier of a habit-forming product cannot commit to a price path, customers face a time-inconsistency problem - the decision to consume in the first period increases their subsequent demand which the supplying firm may exploit with a higher price in subsequent periods. In their model the firm is able to partially overcome the time-inconsistency problem using an implicit contract which involves a form of price rigidity: "...price rigidity serves as a partial commitment device that helps firms overcome their desire to price gouge locked-in consumers." (p. 26).[6]

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[5] This literature has focused on both the case where the goods are storable and consumers can hold inventories (Erdem, Keane and Imai, 2003; Sun, Neslin and Srinivasan, 2003; Hendel and Nevo, 2004, 2006a, 2006b; and Su, 2010) and the case where goods are durable (Chah, Ramey and Starr, 1995; Nair, 2007; Chevalier and Goolsbee, 2009; and Gowrisankaran and Rysman, 2009).

[6] The approach which views price stability as a partial commitment device can also be found in Eber (1999), Kleshchelski and Vincent (2009) and Renner and Tyran (2004).

The decision to form a firm-specific habit, as studied by Nakamura and Steinsson is closely related to the decision to make a physical sunk investment which increases demand for the services of a firm. In this paper we focus on an explicit sunk relationship-specific investment by customers (in a heat-exchange device). Using the language of transactions cost economics we emphasise the threat of hold-up faced by customers of the monopoly firm. In the absence of formal public utility regulation of prices, we suggest that implicit contracts with a degree of price rigidity – as reflected in the pricing behaviour of district heating utilities – are a partial commitment device that helps the district heating utility to overcome its desire to gouge locked-in consumers.

Foreshadowing our main results, we show empirically that different district heating utilities in Sweden follow different pricing strategies. In the case of public ownership, the ideological composition of the local council is a key determinant of the pricing strategy they choose. This is in line with the literature which focuses on the influence of local political ideology on regulatory decisions (Holburn and Spiller, 2002; Holburn and Vanden Bergh, 2006). In our case, however, 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.

Specifically, we show that in municipalities with a greater number of left-wing members, past price changes are a strong signal of likely future price changes. District heating utilities in left-wing municipalities tend to smooth prices over time. We therefore predict that in left-wing dominated municipalities, past price increases are a strong disincentive to the take-up of district heating service (conversely, periods of stable prices provide *stronger* incentives to take up the service). On the other hand, we show that in municipalities with a right-wing majority, or with a privately owned utility, past price changes provide no statistically significant signal of future price changes. We therefore predict that in these, past price increases would have no significant effect on customer take-up rates.

These predictions are consistent with the empirical results. We find that the impact of past price increases depends on the composition of the local council. In left-wing dominated municipalities, past price increases have a statistically significant and negative effect on the rate of customer connections, whereas in right-wing dominated municipalities and where the utility is privately owned, past price increases have no significant impact on the rate of customer connections.

In our view, the contribution of this paper is fourfold. First, in the context of the broader literature on price rigidity, this paper supports the implicit contracts perspective on price rigidity. In this case the implicit contract is necessary to protect an explicit sunk investment by customers. We show empirically that price stability increases consumers' trust and therefore willingness to take up the district heating service. Second, we show that, in the case of publicly owned utilities, the political composition of the local municipality affects the pricing behaviour of the corresponding utility even in the absence of any other formal regulatory mechanisms. Privately-owned utilities and utilities in right-wing municipalities follow a pricing strategy which involves less price-smoothing over time. This affects consumers' incentives to make necessary investments. Prices are higher, network length shorter, and overall penetration of district heating lower in the municipalities with right-wing governments or privately-owned utilities. Third, these results lend support for the common regulatory practice of promoting price stability – a practice which has no clear rationale under the neoclassical approach to public utility regulation. Finally, we suggest that these results do not support the view that, as many textbooks suggest, the primary rationale for public utility regulation is the minimisation of deadweight loss. Rather, in our view, these results support the view that public utility regulation is best viewed as a form of long-term contract seeking to protect and promote the sunk relationship-specific investments of the monopoly service provider and its customers.

The paper continues with a description of the Swedish district heating sector. Section 3 sets out a simple pricing model by a district heating utility, which affects how customers draw inferences about future price changes, and presents empirical evidence on the impact of local council composition and ownership on the pricing behaviour. Section 4 derives a specification for the take-up rate and presents the main empirical results. Section 5 concludes.

2. DISTRICT HEATING IN SWEDEN

District heating meets approximately 50% (or 47 TWh) of the total heat demand in Sweden. It is the most common form of heating for multi-dwelling houses in 234 out of the 290 Swedish municipalities (SCA, 2009; SCB, 2009).[7] District heating is only economical in relatively densely populated areas. These are the same areas where emission intensive and land-intensive substitutes (e.g. wood-fired and ground-based technologies) are subject to stronger restrictions or are more costly to install. This implies that utilities can pass on a large proportion of their risk onto consumers.[8] The fact that district heating networks are confined to the larger urban areas means that they rarely cross municipality

[7] This section reports statistics from a number of sources. When not explicitly stated, data can be accessed from either 'Nils Holgersson's annual price comparisons' (www.nilsholgersson.nu), Statistics Sweden (www.scb.se), the Energy Markets Inspectorate (www.ei.se), and the Swedish District Heating Association (www.svenskfjarrvarme.se).

[8] This may explain why Swedish district heating utilities do not, in practice, subsidise the cost of purchasing a heat exchange device for new customers.

boarders, and when they do, it is relatively uncomplicated to control for this by adding indicator variables.

The district heating tariffs were exempted from sector specific price regulation in 1996, on the basis that electricity is a competing source of energy for heating purposes.[9] In the same year private investors were allowed to enter the sector. Privately supplied heat amounted to 20 % of the total heat produced in the district heating sector in 2007.[10] The remaining heat was supplied by utilities entirely owned by municipalities. Prices have risen steadily since 1996. 'Nils Holgersson's annual price comparisons', that has published all Swedish utility prices for each municipality since 1996, report a real average increase of the list price of approximately 12% from 1998 to 2007 (an increase of 1.1% real per annum).[11] Detailed plant level statistics collected by Statistics Sweden confirms this increase in the average consumption price. This increase can be compared with the regulated electricity distribution price, which has only increased by 1% (0.1% per annum) in real terms during the same period. Customers and media have expressed concerns the price increase of district heating is driven by an increasing mass of locked-in customers. The number of district heating customers at the national level has increased from 149,000 in 1998 (SCB, 2001) to 289,000 in 2007 (SCB, 2009) and the average network expansion has increased from 4-5 km of lines per annum at the end of the 1990s to 7-10 km in 2006-07. Hence, despite price increases there is no sign of the utilities reaching a slowdown in the demand for connections.

We hypothesise that the pricing behaviour of district heating utilities may depend both on its ownership status (whether it is entirely owned by the local government or whether there is some private shareholding) and the political composition of the local council. There is a small literature which shows that local government ideology influences regulatory outcomes and which suggests that left-wing governments tend to be relatively more pro-consumer (e.g., Holburn and Spiller, 2002; Holburn and Vanden Bergh, 2006, Besley and Coate, 2003; Cambini and Rondi, 2010). The Swedish electoral system can be characterised as bi-partisan where the ruling party/coalition is either left- or

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

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

[11] These reports are freely available to everyone online (www.nilsholgersson.nu). This means that past prices are available to all consumers considering to connect to the network.

right-wing.[12] There is empirical evidence that left-wing local councils in Sweden generally intervene more in markets (Pettersson-Lidbom, 2008).

A closer look at the statistics reveals that publicly owned utilities in right-wing dominated councils and those that are privately owned charge higher average prices than publicly owned utilities in left-wing dominated councils (2% and 1% respectively) during the sample period (1998-2007).[13] The average number of price changes (both increases and decreases) are similar for all utility sub-groups. That is likely to be influenced by the long tradition of making price decisions once every year in the Swedish utility sectors.[14] Also, while left-wing dominated municipalities have increased their average price by 1.1% on an annual basis, right-wing municipalities and privately owned utilities have increased their prices by 1.2% and 1.5%, respectively.

The data also shows that the average number of district heating customers is 4% lower in municipalities with a right-wing profile and 20% lower for privately owned utilities compared to municipalities with a left-wing profile. The same findings are reflected in average network line length: right-wing municipalities and privately owned utilities have 8% and 11% shorter networks than left-wing municipalities. In summary, it seems that publicly owned utilities operating under a left-wing council have relatively low and stable prices and that they tend to have more customers and longer networks. Of course, more formal econometric analysis is needed to rule out the possibility that these findings are not caused by omitted variables and/or endogeneity.

Data covers the period from 1998 to 2007 and only includes those municipalities that have had district heating service for at least five years. The unbalanced sample consists of 1015 observations with complete data, including values used as instruments and lags.[15] Those observations come from 143 different municipalities. The sample contains municipalities with a slightly smaller number of inhabitants and density compared to the population of municipalities with a district heating network.

[12] See Pettersson-Lidblom (2008) for more details on the Swedish electoral system.

[13] Numbers reported in this paragraph are based on regressing the relevant variable against indicator variables for right-wing majority and private ownership with year dummies. The qualitative results are not sensitive to whether utilities that have changed from public to private ownership (or vice versa) during the sample period are excluded.

[14] Utilities typically announce prices that apply for year *t* in the third quarter of year *t*-1.

[15] We do not exclude utilities being fully owned by private investors although local councils will have no direct influence on those prices. However, we argue that municipalities can still exert strong influences on utilities through, for example, construction permit processes, use of fuel types, and plant location. Excluding fully privately owned utilities only changes parameter estimates in Tables 1 and 2 marginally.

The characteristics of variables in the sample and population are generally very similar, both in terms of average and range. Descriptive statistics are provided in Table A.1 in the Appendix.

3. PRICING BEHAVIOR

This section sets out an empirical model of the pricing behaviour of different types of district heating firms. We propose that, in setting the tariff for district heating service, district heating utilities take into account three factors: (i) the past prices of district heating; (*ii*) the price of the closest substitute in the previous period – in this case, the price of electricity; and (*iii*) the expected future unit cost. Past district heating prices are included as it allows the district heating utility to smooth prices over time. The price of electricity is included as it reflects the short-run profit-maximising price for the service. Both smoothing of prices and pricing in relation to underlying unit costs are broadly consistent with a desire to avoid abusive pricing behaviour. In the spirit of Kalt and Zupan (1984),[16] the degree of smoothing decided by the local councils can be viewed as a measure of the weight attached to altruistic motives, such as left-wing governments' tendency to be pro-consumer. Survey responses from representatives of Swedish energy utilities do indeed reveal a willingness to take wider perspectives such as fairness and social/environmental well-being, into consideration (Sandoff, 2008).

Specifically, we propose that each utility sets its prices as a linear combination of the previous district heating and electricity prices, and the present discounted value of future expected unit costs. Sbordone (2002) derives this pricing strategy from an optimizing model in the presence of smoothed prices.[17] When utilities set the district heating price for period *t* (which, as pointed out earlier, is done during *t*-1), it only has partial knowledge of the (representative) electricity price in period *t*-1. This is because the total price of electricity is the sum of the prices for production and distribution services, where the production price is determined on a spot market and the distribution price is set by the utilities once per year. Because of seasonal spot price cycles district heating utilities must use the electricity prices from both period *t*-1 and *t*-2 to arrive at a representative annual electricity price. We assume that they use an arithmetic average of prices in these two periods. Cost realisations in period *t*-1, i.e. the most recent costs, are used as proxies for future cost expectations. Cost is assumed to be determined by scale in production (quantity produced) and distribution (network length).[18] We also add income to control for utilities' incentive to take advantage of customers' willingness to pay. Finally, two strategic considerations can influence pricing behaviour when networks are subject to expansion.

[16] Kalt and Zupan (1984) show that regulatory decisions made by policy makers can be influenced by genuine public interest concerns that are distinct from self-interest objectives such as vote maximisation.

[17] See Sbordone (2002) equation 2.10, Sbordone (2005) equation 2.1 and Korenok (2005), equation (13).

[18] No reliable input price statistics is available.

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 subsequently 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, but non-adopters 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 they 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 an indicator variable that takes the value 1 when district heating has a market share above 50% in the local residential energy market.

When we allow the influence from previous district heating and electricity prices to depend on political ideology in the local council and utility ownership, we can specify the function for the price in level as:[19]

$$
\begin{aligned}
P_{dh,j,t} = {} & \alpha_1 P_{dh,j,t-1} + \alpha_2 P_{dh,j,t-1} R_{j,t-1} + \alpha_3 P_{dh,j,t-1} \Gamma_{j,t-1} + \alpha_4 P^{*}_{el,j,t-1} + \alpha_5 P^{*}_{el,j,t-1} R_{j,t-1} + \\
& \alpha_6 P^{*}_{el,j,t-1} \Gamma_{j,t-1} + \alpha_7 R_{j,t-1} + \alpha_8 \Gamma_{j,t-1} + \alpha_9 M_{j,t-1} + \alpha_{10} I_{j,t-1} + \alpha_{11} Q_{j,t-1} + \\
& \alpha_{12} L_{j,t-1} + Y_t \pi_t + (\mu_j + \upsilon_{j,t})
\end{aligned} \tag{1}
$$

where j is utility and t is year; P_{dh} is the price for district heating; $P^{*}_{el,j,t-1} = 0.5(P_{el,j,t-1} + P_{el,j,t-2})$ and P_{el} is the electricity price; R is an indicator for right-wing majority in the municipal council; Γ is an indicator for private ownership of the district heating utility; M is the indicator for when district heating's market share is above 50%; I is net average income in the municipality; Q is total amount of energy produced by district heating utilities; L is length of the district heating network; Y_t is a vector of year fixed effects; μ_j are the utility-specific time-invariant effects. $\upsilon_{j,t}$ are the idiosyncratic errors which are assumed to be independent across utilities and serially uncorrelated.

Since μ_j are stochastic they will be correlated with $P_{dh,j,t-1}$. This implies that OLS is inconsistent and the within-estimator makes $P_{dh,j,t-1}$ endogenous to every other observation of $P_{dh,j}$.[20] Estimators

[19] There is no evidence that political ideology of incumbent coalition has a structural influence on type of customers. The correlation between share of detached houses and share of right-wing representatives is 0.168 and adding share of detached houses to eq. (1) only inflates standard errors.

[20] See Bond (2002) for details.

based on GMM can produce consistent estimates by eliminating the μ_j through first-differencing and using values of $P_{dh,j,t}$ lagged two or more periods as instruments for $\Delta P_{dh,j,t-1}$. A problem with this estimator is that the correlation between the lagged dependent variable and the instruments $\rightarrow 0$ as the parameter of the lagged dependent variable $\rightarrow 1$. When estimating eq. (1) α_1 is 0.9823, indicating a problem with weak instruments.[21] One can circumvent this problem by adding further moment conditions that allow the first-differenced equation to be combined with the equation in level (Arellano and Bover, 1995; Blundell and Bond, 1998). This estimator, which is denoted 'system GMM' in the literature, adds lagged values of the differenced equation as further instruments. The validity of these extra moment conditions relies on all variables being mean stationary. Since many of the variables in eq. (1), including $P_{dh,j,t}$, are strongly trended we de-trend eq. (1) by first-differencing and consider a function of price changes:

$$\begin{aligned}\Delta P_{dh,j,t} = {} & \alpha_1^{\Delta}\Delta P_{dh,j,t-1} + \alpha_2^{\Delta}\Delta P_{dh,j,t-1}R_{j,t-1} + \alpha_3^{\Delta}\Delta P_{dh,j,t-1}\Gamma_{j,t-1} + \alpha_4^{\Delta}\Delta P^{*}_{el,j,t-1} + \\ & \alpha_5^{\Delta}\Delta P^{*}_{el,j,t-1}R_{j,t-1} + \alpha_6^{\Delta}\Delta P^{*}_{el,j,t-1}\Gamma_{j,t-1} + \alpha_7^{\Delta}R_{j,t-1} + \alpha_8^{\Delta}\Gamma_{j,t-1} + \alpha_9^{\Delta}M_{j,t-1} + \\ & \alpha_{10}^{\Delta}\Delta I_{j,t-1} + \alpha_{11}^{\Delta}\Delta Q_{j,t-1} + \alpha_{12}^{\Delta}\Delta L_{j,t-1} + Y_t\pi_t^{\Delta} + (\mu_j + \Delta\upsilon_{j,t}) \qquad (2)\end{aligned}$$

The fixed effects μ_j can be included in eq. (2) when eq. (1) includes utility-specific trends. Such trends were removed from eq. (1) because it led to severe over-fitting, but the trends can be included on conceptual grounds since prices do indeed exhibit clear municipality level trend heterogeneity and the potential to take advantage of cost reductions from technological progress depends on (the unobserved) network age which varies substantially between municipalities. We impose the mild assumption (relative to eq. (1)) that μ_j are uncorrelated with the differenced RHS variables. Analogous to estimation of eq. (1), the μ_j in eq. (2) can be removed by differencing, i.e. a second-difference of eq. (1).

Before proceeding to the estimation it is necessary to address issues of correlation between $\upsilon_{j,t}$ and explanatory variables. $\Delta P_{dh,j,t-1}$ is correlated with $\Delta\upsilon_{j,t}$ by construction but $\Delta P_{dh,j,t-2}$ and deeper lags can be used as instruments for $\Delta P_{dh,j,t-1}$. In the second-differenced equation (where Δ^2 is denoted 'second difference') $\Delta^2 P_{dh,j,t-3}$ and deeper lags are valid instruments for $\Delta^2 P_{dh,j,t-1}$. $\Delta P^{*}_{el,j,t-1}$

[21] The estimation output is available from the authors upon request.

, $R_{j,t-1}$, $\Gamma_{j,t-1}$, $M_{j,t-1}$, and $\Delta Q_{j,t-1}$ are all endogenous in eq. (2) and the available instruments are symmetrical with those for the dependent variable. Because financial status can effect voting behaviour (Leigh, 2005), we add 'share of population above 66 years of age' and 'share of population being unemployed' in period *t*-1, as external instruments for $R_{j,t-1}$. No external instruments are used for $\Gamma_{j,t-1}$ but Potrafke (2010) and Biais and Perotti (2002) claim that $R_{j,t-1}$ is related to $\Gamma_{j,t-1}$. $\Delta I_{j,t-1}$ and $\Delta L_{j,t-1}$ are treated as exogenous. While utilities determine $\Delta L_{j,t-1}$ themselves, the decision to extend a network is typically made several years prior to the actual construction taking place.

The system GMM estimator creates a large number of overidentifying restrictions that increases the risk of poor finite sample properties (Wooldridge, 2002). To reduce this problem we restrict the set of instruments to the first available lag for each endogenous variable. Further, when the data set has gaps, as in our case, we follow the suggestion by Arellano and Bover (1995) to use a transformation based on orthogonal deviations where each observation is subtracted from the average of all future available observations for each variable.

Consistency of this estimator depends on validity of the instruments and we therefore report the Hansen test and the test of serial correlation in errors alongside the estimation output. Windmeijer (2005) corrected standard errors are used to reduce the biased two-step covariance. The full output from eq. (2) is reported in column (d) in Table 1. Columns (a)-(c) report the output from eq. (2) when either cost, political orientation/utility ownership, or both are excluded. Hansen's test and the test for serial correlation confirm the validity of the instruments in all models.

The columns in Table 1 consistently suggest that the smoothing parameter for utilities operating in left-wing municipalities (α_1^Δ) is positive and significant at least at the 5% level. The smoothing is not significantly different from 0 when the council has a right-wing majority $(\alpha_1^\Delta + \alpha_2^\Delta)$ or when the utility is privately owned $(\alpha_1^\Delta + \alpha_3^\Delta)$. None of the utility sub-categories react conclusively to variation in the price of electricity. Consistent with the view held by industry representatives, there seems to be dis-economies of scale in production $(\alpha_{11}^\Delta > 0)$, and economies of scale in distribution $(\alpha_{12}^\Delta < 0)$.

Table 1. Estimation output for eq. (2).

Variable	(a)		(b)		(c)		(d)	
$\Delta P_{dh,t-1}$	0.1026	***	0.1335	**	0.1658	***	0.1342	**
	(0.0397)		(0.0659)		(0.0555)		(0.0625)	
$\Delta P_{dh,t-1}R_{t-1}$			-0.2210	**			-0.2520	**
			(0.1073)				(0.1272)	
$\Delta P_{dh,t-1}\Gamma_{t-1}$			-0.1571				-0.0816	
			(0.1034)				(0.1186)	
$\Delta P_{el,t-1}$	-0.1053		0.0739		-0.1620		-0.0352	
	(0.1079)		(0.1379)		(0.1491)		(0.1402)	
$\Delta P_{el,t-1}R_{t-1}$			0.0951	***			0.0992	**
			(0.0366)				(0.0473)	
$\Delta P_{el,t-1}\Gamma_{t-1}$			0.0951				0.0456	
			(0.0366)				(0.0484)	
R_{t-1}			-0.1150				0.0456	
			(0.3066)				(0.3260)	
Γ_{t-1}			0.2740				0.3258	
			(0.3038)				(0.3238)	
M_{t-1}			-0.0533		0.3368		0.5371	
			(0.5584)		(0.4041)		(0.5289)	
ΔI_{t-1}					-0.4877	**	-0.0240	
					(0.2064)		(0.0607)	
ΔQ_{t-1}					2.3E-6	**	2.0E-6	**
					(9.4E-7)		(9.5E-7)	
ΔL_{t-1}					-0.0088	**	-0.0150	*
					(0.0044)		(0.0079)	
Year dummies	Yes		Yes		Yes		Yes	
Hansen P > J	0.902		0.545		0.525		0.657	
AR(2): P>z	0.751		0.779		0.388		0.612	
No. obs.	746		746		673		673	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. $\Delta P_{dh,t}$ is dependent variable. Windmeijer (2005) corrected SE in brackets. Constants not reported.

The results on price smoothing are consistent with the view that left-wing municipalities are somehow influencing the pricing strategies of their local district heating utility and are doing so in a manner which is broadly consistent with conventional public utility regulation. Specifically, left-wing municipalities are inducing the local district heating utility to pursue stable prices whereas right-wing municipalities are allowing their local district heating utilities a greater degree of pricing independence.

These differences in pricing behaviour have important implications for the inferences of customers about likely future price changes. In the case of left-wing municipalities, previous price increases are a signal of likely future price increases. In these municipalities we predict that past price increases will have a significant and negative effect on the rate of connection to district heating services. On the other hand, in the case of right-wing municipalities or when the utility is privately owned, past price increases provide little or no signal of likely future price increases. We therefore predict that, for those utilities, past price increases will have little or no negative impact on the rate of connections. In the next section we test these predictions empirically.

4. CUSTOMER CONNECTIONS

We now explore the impact of price changes on the rate of take-up of district heating service. The empirical convention when evaluating the choice of heating technology is to assume that consumers are influenced by the present level of own and substitute prices. The infrequent nature of heating investments have generated a group of studies that use choice experiments as a way to determine consumers' price sensitivity for various heating technologies (Sadler, 2003; Dubin, 1986; Nesbakken, 2001). The advantage of this approach is that the cost of installation and consumption can be separated, but the disadvantage, which is a particular limitation in this study, is that dynamic aspects are difficult to realistically incorporate.

Because customers face a substantial switching cost once they have signed up to a new heating technology it is realistic that only those who have an out-dated technology will be affected by variations in environmental factors (e.g. price variations). Since district heating is a relatively new heating alternative, the number of customers who have converted from district heating to any other heating alternative are negligible. Therefore, total number of customers C_t cannot be specified unless all past information is available. For that reason we use customer connections ΔC_t as our left-hand side variable.

At time *t*, let Ω_t be the size of the total population; Φ_t the probability/share of the population that is in a position to make a choice of the mode of heating; Ψ_t the share of the population that has the opportunity to connect to the district heating network; and let $S_t = f(P_{i,t}, g(P_{i,t-n}, P_{i,t-n}\Gamma_{t-n}, P_{i,t-n}R_{t-n}))$ be a (multinomial) logit function that specifies the probability that a consumer will choose heating mode *i*. $P_{i,t}$ is the current price, and $g(P_{i,t-n}, P_{i,t-n}\Gamma_{t-n}, P_{i,t-n}R_{t-n})$ is a function of price increases and decreases in the *n* previous periods where $P_{i,t-n}$ is considered to have an independent effect as well as an effect conditioned on private ownership (Γ_{t-n}) and right-wing majority in the local council (R_{t-n}).[22] Other factors that influence

[22] There is no reliable statistics on connection prices. However, utilities have incentives to only cover the cost to stimulate connection and the market for equipment and material is national. Also, the Energy Markets Inspectorate has developed principles for how to determine connection prices to physical networks. It seems

customers' choices (e.g. the noise level, start-up time, cleanliness and ease of use) are constant across the technologies considered here.

Φ_t is calculated as the share of new buildings plus 5% of existing building since we assume that the average life of a heating technology is 20 years. Φ_t will be influenced by the need for heating, which is affected by heating degree days (*H*), and consumers' ability to acquire a new technology, determined by their income (*I*). By using these as exponents for the share of the population that is in a position to make a choice of the mode of heating (Φ_t), one gets a transformed proportion of the population which increases in heating need and income. Both *H* and *I* are normalised relative to their sample means. *H* and *I* are lagged one year since comfort and budget experiences must be averaged over a full year when demand is relatively high at the end of the year. One can expect that customers connect to the district heating network only in the period when the network is first made available to them as they have to pay a premium if they connect in a later period. This means that the increase in network length from period *t*-1 to *t* (ΔL_t) can be used as a measure of the share of the population that has the opportunity to connect to the district heating network (Ψ_t). Because customer density is decreasing in network length we raise the network expansion to a falling trend: $(\Delta L_t)^{T_t^-}$ where $T_t^- = t_0 - t$ is a declining function of the time.[23] The change in the number of district heating connections from period *t-1* to *t* (with panel subscript *j* included) is then given by:

$$\Delta C_{j,t} = \alpha_0 \Omega_{j,t}^{\alpha_1} \Phi_{j,t}^{\alpha_2 H_{j,t-1} I_{j,t-1}} \Delta L_{j,t}^{\alpha_3 T_t^-} \Pr\left(S_{j,t} = dh \mid f(\cdot)\right) Y_t^{\pi_t} (\mu_j + \upsilon_{j,t}) \tag{3}$$

where notations are as in eq. (1). In an extreme value distributed choice model with *m* substitutes, the probability that a customer making a choice of heating will choose district heating is given by:

$$\Pr\left[S_{j,t} = dh \middle| f\left(P_{i,j,t}, g(P_{i,j,t-n}, P_{i,j,t-n}\Gamma_{j,t-n}, P_{i,j,t-n}R_{j,t-n}; \gamma_i); \beta_i\right)\right] =$$
$$= \frac{\exp(\beta_{dh} P_{dh,j,t} + g(P_{dh,j,t-n},\ P_{dh,j,t-n}\Gamma_{j,t-n},\ P_{dh,j,t-n}R_{j,t-n}; \gamma))}{\sum_{i=1}^{m} \exp(\beta_i P_{i,j,t} + g(P_{i,j,t-n},\ P_{i,j,t-n}\Gamma_{j,t-n},\ P_{i,j,t-n}R_{j,t-n}; \gamma_i))} \tag{4}$$

When formulating $g(\cdot)$ as an estimable function, $P_{i,t-n}$ is divided into average annual price increase ($\overline{P}_{i,t}^{+}$) and average annual price decrease ($\overline{P}_{i,t}^{-}$) over the last *n* periods, according to:

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reasonable, therefore, that connection prices can be considered constant across utilities and time for the relatively short period considered here.

[23] It is common practise, both for municipally and privately owned utilities, to build out denser areas first.

$$\overline{P}^{+}_{i,j,t} = \frac{1}{n}\sum_{k=1}^{n}\max\left\{P_{i,j,t} - P_{i,j,t-k}, 0\right\} \quad (5)$$

$$\overline{P}^{-}_{i,j,t} = abs\left[\frac{1}{n}\sum_{k=1}^{n}\min\left\{P_{i,j,t} - P_{i,j,t-k}, 0\right\}\right] \quad (6)$$

The interactions can then be formulated as $\overline{P}^{+}_{i,j,t}\overline{\Gamma}_{j,t}$ and $\overline{P}^{+}_{i,j,t}\overline{R}_{j,t}$ where $\overline{\Gamma}_{j,t}$ and $\overline{R}_{j,t}$ are the average of $\Gamma_{j,t}$ and $R_{j,t}$ over the preceding *n* periods.[24] $\overline{P}^{-}_{i,j,t}$ is only included as a main effect since there are relatively few price decreases during the sample period.[25] Because customers have two main heating technologies to choose from (district heating and electricity), the ln-transform of eq. (3) has a non-linear functional form after substituting in eqs. (4)-(6). However, a panel-specific autoregressive Prais-Winsten regression with $\Delta P_{dh,j,t}$ as the LHS and $\Delta P_{el,j,t}$ as the (only) RHS variable shows that the relationship between $\Delta P_{dh,j,t}$ and $\Delta P_{el,j,t}$ is negative and significant at the 10 % level. When estimating eq. (3) one might therefore assume that the denominator in eq. (4) is constant which would imply that it will be included in the constant term. This assumption has the advantage of allowing the use of the standard Within-estimator as the resulting function is linear in the parameters:

$$\begin{aligned}\ln\Delta C_{j,t} = {} & \alpha_0 + \alpha_1 \ln\Omega_{j,t} + \alpha_2 \ln\Phi_{j,t} H_{j,t-1} I_{j,t-1} + \alpha_3 \ln\Delta L_{j,t} T^{-}_{j,t} + \beta_{dh} P_{dh,j,t} + \\ & \gamma_{dh,1}\overline{P}^{+}_{dh,j,t} + \gamma_{dh,2}\overline{P}^{+}_{dh,j,t}\overline{R}_{j,t} + \gamma_{dh,3}\overline{P}^{+}_{dh,j,t}\overline{\Gamma}_{j,t} + \gamma_{dh,4}\overline{P}^{-}_{dh,j,t} + \gamma_{dh,5}\overline{R}_{j,t} + \\ & \gamma_{dh,6}\overline{\Gamma}_{j,t} + Y_t\pi_t + (\mu_j + \upsilon_{j,t}) \end{aligned} \quad (7)$$

As a test of robustness one can relax the assumption that $\sum_{i=1}^{m}\exp(\beta_i P_{i,j,t} + g(P_{i,j,t-n}, P_{i,j,t-n}\Gamma_{j,t-n}, P_{i,j,t-n}R_{j,t-n};\gamma_i))$ is constant and use a GMM estimator with clustered SE to account for correlation within panels. To avoid duplication of variables as implied by eq. (4), we use the fact that at eq. (4) can also be written as:

[24] *n* lags for each price increase and decrease with interactions were evaluated but resulted in over-specification. Reasonable estimates based on eq. (7) were obtained for the sub-sample restricted to municipality owned utilities. These are included in Table A2 of the Appendix.

[25] It should be noted that in the case of investments with long lifetimes, one cannot form strong expectations about the influential direction of past price decreases since a fall in the price may merely be interpreted by the consumer as there is room to increase prices in the future (e.g. Adeyemi and Hunt (2007) find a negative effect on demand from cumulative price decreases in one of their models).

$$\frac{1}{1+\exp\left(-\beta^{diff}(P_{dh,j,t}-P_{el,j,t})-\gamma^{diff}((g(\cdot\,|\,S=dh)-g(\cdot\,|\,S=el))\right)}$$

Because the monopolistic provision of electricity is regulated, customers have no reason to use past electricity prices to make predictions about future prices. Therefore, $\overline{P}^{+}_{el,j,t}=\overline{P}^{-}_{el,j,t}=0$, which allows eqs. (3)-(6) to be reformulated as:

$$\begin{aligned}\ln\Delta C_{j,t} &= \alpha_0+\alpha_1\ln\Omega_{j,t}+\alpha_2\ln\Phi_{j,t}H_{j,t-1}I_{j,t-1}+\alpha_3\ln\Delta L_{j,t}T_t^{-}+\beta_{dh}P_{dh,j,t}-\\ &\ln\Big(1+\exp\Big(-\beta^{diff}(P_{dh,j,t}-P_{el,j,t})-\gamma_1\overline{P}^{+}_{dh,j,t}-\gamma_2\overline{P}^{+}_{dh,j,t}\overline{R}_{j,t}-\gamma_3\overline{P}^{+}_{dh,j,t}\overline{\Gamma}_{j,t}-\\ &\gamma_4\overline{P}^{-}_{dh,j,t}-\gamma_5\overline{R}_{j,t}-\gamma_6\overline{\Gamma}_{j,t}\Big)\Big)+Y_t\pi_t+\upsilon_{j,t}\end{aligned} \qquad (8)$$

Descriptive statistics for variables in eqs. (7) and (8) are included in Table A1 in the Appendix. Before estimations can be performed it is necessary to address issues of endogeneity in eqs. (7) and (8). Theoretically there should be no concerns about $P_{dh,t}$ being endogenous, but since utilities typically negotiate with customers before contracts are written, it is likely that utilities are relatively well informed about unobserved factors having an influence on customers' inclination to connect to the network in period *t* when they set their prices in period *t*-1. Factors influencing both $P_{dh,t}$ and υ_t include variation in the attractiveness of substitutes and local environmental policies. In order to eliminate this potential endogeneity bias, we instrument $P_{dh,t}$ with (*i*) $P_{el,t-1}$ (this captures the influence from substitutes where relatively high $P_{el,t-1}$ may be due to less severe competitive pressure); (*ii*) the share of input fuel from biomass (Bio) to proxy local environmental preferences (the use of biomass increases the cost of district heating and may influence the willingness of local policy makers to promote environmentally friendly heating alternatives); (*iii*) and the lagged price of district heating $P_{dh,t-1}$. Because $P_{dh,j,t}$ is correlated with $\upsilon_{j,t}$, $\overline{P}^{+}_{dh,j,t}$ and $\overline{P}^{-}_{dh,j,t}$ will also be correlated with $\upsilon_{j,t}$. We use $\max\{P_{i,j,t-1}-P_{i,j,t-2},0\}$, $\max\{P_{i,j,t-2}-P_{i,j,t-3},0\}$, $abs[\min\{P_{i,j,t-1}-P_{i,j,t-2},0\}]$ and $abs[\min\{P_{i,j,t-2}-P_{i,j,t-3},0\}]$ as additional instruments to circumvent those endogeneity problems. Analogous to the model in Section 3, we also treat $\overline{R}_{j,t}$ and $\overline{\Gamma}_{j,t}$ as endogenous and use lagged values in period *t*-1, *t*-2, 'share of population above 66 years of age' and 'share of population being unemployed' in period *t*-1 as instruments.

SE are adjusted for arbitrary heteroscedasticity and autocorrelation in both eqs. (7) and (8).[26] n in eqs. (5) and (6) is set to 3 since it has the lowest sum of squared residuals for all estimable values (n = 1, 2, 3 are estimable). Furthermore, Table A2 in the Appendix indicates that an average based on the three past periods is sensible since the effects from individual lags in those years are similar and that further lags are statistically insignificant. Estimation outputs are provided in Table 2 with eq. (7) in column (a) and eq. (8) in column (b). The Kleibergen-Paap statistics for weak identification indicate a relative IV bias of just above 5 % for eq. (7). Hansen's test shows that instruments are uncorrelated with υ_t and are correctly excluded from both eqs. (7) and (8).

Both columns (a) and (b) show that there is a striking difference in connection behaviour between left- and right-wing dominated municipalities. The number of connections for utilities operating in municipalities with a left-wing majority is negatively affected by past price increases. No significant effect is observed from past price increases in right-wing municipalities or in municipalities with privately owned utilities. When past prices have not increased, one can observe that left-wing utilities have significantly higher take-up rates (i.e. negative sign for $\overline{R}_t$). Further, the price level in the present period negatively affects the rate of connections but the effect is only significant in column (b) when the difference between P_{dh} and P_{el} is considered. Since $\ln \Omega_t$, $\ln \Phi_t H_{t-1} I_{t-1}$ and $\ln \Delta L_t T_t^-$ are relatively stable within panels one can observe noticeable differences between parameters for those variables when comparing the models with and without utility fixed effects.

[26] The bandwidth (bw) for the Bartlett kernel is set to 2, based on the rule of thumb bw=$T^{1/3}$, where T is total observations for the panel (Baum et al., 2007).

Table 2. Estimation output for eqs. (7) and (8).

Variable	(a)		(b)	
$\ln \Omega_t$	-2.3636 (3.0353)		0.9047 (0.0974)	***
$\ln \Phi_t H_{t-1} I_{t-1}$	1.0939 (0.5696)	*	-0.1941 (0.4068)	
$\ln \Delta L_t T_t^-$	0.0244 (0.0102)	**	0.0252 (0.0187)	
$P_{dh,t}$	-0.0394 (0.0409)			
$P_{dh,t} - P_{el,t}$			-0.5198 (0.2616)	**
$\overline{P}^+_{dh,t}$	-0.2578 (0.1079)	**	-3.7176 (1.2589)	***
$\overline{P}^+_{dh,t}\overline{R}_t$	0.3260 (0.1109)	***	3.9314 (1.8193)	**
$\overline{P}^+_{dh,t}\overline{\Gamma}_t$	0.0342 (0.3318)		0.5465 (0.9197)	
$\overline{P}^-_{dh,j,t}$	-0.0019 (0.0727)		2.6845 (1.6605)	
$\overline{R}_t$	-0.5955 (0.2521)	**	-4.4680 (1.4313)	***
$\overline{\Gamma}_t$	-0.0091 (1.0321)		-4.0857 (2.1232)	*
Year dummies	Yes		Yes	
K-P Wald F [b]	22.458			
Hansen's J (P value)	0.750		0.9086	
No. obs.	673		673	
R^2 (within)	0.107			

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Dependent variable: $\ln \Delta C_t$. Constants not reported.
[b] Kleibergen-Paap Wald F statistic.

To rule out the possibility that customers respond to political ideology rather than past pricing behaviour, we perform one additional test of robustness. We divide the sample in three equally sized groups based on the degree of correlation between $P_{dh,t}$ and $P_{dh,t-1}$ and re-estimate eq. (7) with $\overline{P}^+_{i,t}$ included only as a main effect. This investigation shows that $\gamma_{dh,1}$ is negative (-0.4156) and significant at the 5% level (P>|z| = 0.012) for the sub-sample with the highest correlation, but it is not even vaguely significant when estimated with the sub-samples consisting of the lowest or medium sized correlations. This supports our claim that customers are indeed reacting to past prices when they are informative.

5. CONCLUSIONS

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

Importantly, we show that the ideological composition of the local council has a direct influence on the pricing strategy of publicly-owned district heating utilities. Specifically, district heating utilities in left-wing dominated municipalities pursue a pricing strategy which deliberately smoothes price changes over time. As a consequence, in such municipalities, observation of past price increases is a strong signal that further price increases are expected in the near future. In contrast, district heating utilities in right-wing dominated municipalities do not seem to smooth prices over time – so recent price changes provide little or no information about the likely future path of prices.

We find that new customers of district heating utilities respond to these pricing signals. In left-wing dominated municipalities customers are less (more) inclined to take up district heating service after observing a price increase (no price increase) in the recent past. In contrast, in right-wing municipalities, recent price increases have little or no impact on customer take-up decisions.

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

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APPENDIX

Table A1. Descriptive statistics (n=1015, incl. obs. used as instruments).

Variable	Description (measurement unit)	Mean	Std.dev.	Min	Max
P_{dh}	Average price of district heating (öre/kWh) [a]	55.088	7.2560	32.990	72.892
P_{el}	Average price of electricity (öre/kWh) [e]	76.615	15.892	45.070	108.91
R	1 if municipality council has right-wing majority [a]	0.2433	0.4293	0	1
Γ	1 if utility owned by private investors [d]	0.1182	0.3230	0	1
ΔC	No. of connections [a]	114.882	202.21	0	2 494
Ω	Urban population [a]	40 820	80 393	1 834	779 169
Φ	(Multi-dwelling buildings in a state to chose heating technology) / (Total stock of multi-dwelling buildings) [b]	0.0542	0.0067	0.0500	0.0989
H	No of heating degree days [a]	3 615	631.12	2 416	5 325
I	Average individual income net taxes (kSEK) [a]	186.37	17.377	138.87	293.16
M	1 if district heating market share is > 50% in local residential energy market [a]	0.3185	0.4661	0	1
L	Network length (km) [c]	99.940	145.69	0.1	1 112
$\overline{P}_{dh}^{+}$	Average annual price increase past 3 years (öre/kWh) [a]	1.2876	1.1320	0	5.7627
$\overline{P}_{dh}^{-}$	Average annual price decrease past 3 years (öre/kWh) [a]	0.5146	0.8487	0	6.8936
External Instruments					
Bio	Share of fuel kWh from biomass [a]	0.5298	0.3519	0	0.9914
Uemp	Share of population unemployed [f]	0.0251	0.0087	0.0071	0.0620
P66	Share of population over 66 years of age [a]	0.1854	0.0312	0.0913	0.2780

[a] Source: Statistics Sweden.
[b] Source: Statistics Sweden. No. of consumers who are in a state to chose heating technology in year *t* consists of all new buildings completed in *t* + 5 % of existing buildings. This assumes the practical life time of an average heating technology is equal to 20 years.
[c] Source: The Swedish District Heating Association.
[d] Source: Annual reports; homepages.
[e] Source: Energy Markets Inspectorate. The price is an aggregate of the regulated local distribution price, average national retail price and taxes.
[f] Source: Swedish Public Employment Service

Table A2. Estimation output for eq. (7) when past price increases enter separately and when the sample is restricted to municipality owned utilities. *n* is number of past price changes considered by customers (see eqs. (5) and (6)).

Variable	***n*=1**		***n*=2**		***n*=3**		***n*=4**	
$\ln \Omega_t$	4.0217		3.0851		0.4555		-4.6426	
	(3.3722)		(3.3604)		(3.4898)		(4.6550)	
$\ln \Phi_t H_{t-1} I_{t-1}$	0.3819		0.4215		0.3335		-0.1773	
	(0.5299)		(0.5404)		(0.5637)		(0.6444)	
$\ln \Delta L_t T_t^-$	0.0247	**	0.0227	**	0.0200	**	0.0062	
	(0.0099)		(0.0099)		(0.0100)		(0.0133)	
$P_{dh,t}$	-0.0315		-0.0208		0.0229		0.0264	
	(0.0257)		(0.0271)		(0.0272)		(0.0363)	
$\max\{P_{dh,t} - P_{dh,t-1}, 0\}$	-0.0411		-0.0580		-0.0948	**	-0.0902	*
	(0.0474)		(0.0492)		(0.0467)		(0.0535)	
$\max\{P_{dh,t-1} - P_{dh,t-2}, 0\}$			-0.0693		-0.1108	**	-0.1418	***
			(0.0487)		(0.0479)		(0.0542)	
$\max\{P_{dh,t-2} - P_{dh,t-3}, 0\}$					-0.1679	***	-0.1952	***
					(0.0545)		(0.0630)	
$\max\{P_{dh,t-3} - P_{dh,t-4}, 0\}$							0.0078	
							(0.0124)	
$\max\{P_{dh,t} - P_{dh,t-1}, 0\} R_t$	0.1273	**	0.1316	**	0.1077	**	0.1084	
	(0.0558)		(0.0545)		(0.0548)		(0.0663)	
$\max\{P_{dh,t-1} - P_{dh,t-2}, 0\} R_{t-1}$			0.1222	**	0.1443	**	0.1549	**
			(0.0561)		(0.0583)		(0.0665)	
$\max\{P_{dh,t-2} - P_{dh,t-3}, 0\} R_{t-2}$					0.1424	**	0.1706	**
					(0.0698)		(0.0815)	
$\max\{P_{dh,t-3} - P_{dh,t-4}, 0\} R_{t-3}$							0.0303	
							(0.0731)	
$\overline{R}_t$	-0.4560	**	-0.8549	**	-0.6630		-0.6802	
	(0.2194)		(0.3346)		(0.4145)		(0.5365)	
Year dummies	Yes		Yes		Yes		Yes	
K-P Wald F [b]	81.191		57.829		60.261		71.210	
Hansen's J (P value)	0.4041		0.4833		0.3335		0.8777	
No. obs.	569		569		566		454	
R^2 (within)	0.082		0.092		0.111		0.118	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Dependent variable: $\ln \Delta C_t$. Constants not reported.
[b] Kleibergen-Paap Wald F statistic.