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Do publicly owned companies have lower district heating prices? An empirical analysis for Germany

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ABSTRACT

District heating (DH) networks can provide climate-neutral heating if operated using renewable energy resources. However, their operation is monopolistic and thus without price competition. Publicly owned companies have been conjectured to offer DH at lower prices than privately owned companies, but the evidence is limited. Here, we empirically analyse over 500 DH prices of 184 DH companies in Germany. Controlling for energy carrier, network size and other factors, we demonstrate that prices of publicly owned DH companies are lower by 9–15 €/MWh (10–20 %). Thus, publicly owned DH can make a cost-efficient contribution to climate-neutral heating.

1. Introduction

Germany has ambitious climate mitigation and renewable energy targets aimed at a carbon-neutral energy sector by 2045 (Bundesregierung, 2024a). While the share of renewables in electricity generation has already increased, the heating sector still lags. In recent years, the share of renewables in the heating sector has increased only slightly. At the same time, heating accounts for more than half of Germany's final energy consumption (AG Energiebilanzen, 2022). Hence, a rapid transition to climate-neutral heating is essential if Germany is to meet its climate and energy targets by 2045. District heating (DH) networks play a key role in this transition. These are heating systems based on underground pipes that transport heat to multiple consumers. Especially in densely populated areas, DH can be an efficient and economically viable solution as it can integrate large-scale heat sources unsuitable for individual heating systems, such as deep geothermal energy or industrial excess heat (Lund et al., 2018). Accordingly, Germany is promoting the expansion of DH networks (Bundesregierung, 2024b). In 2021, Germany's DH share of final energy consumption reached 8.6 % but has hardly changed since 2011 (AG Energiebilanzen, 2022). This share is projected to rise to around 22 % by 2045 (Fraunhofer ISI et al., 2022), implying that Germany must more than double its DH in the coming years.

Meanwhile, the supply mix of the German DH networks is still based mainly on fossil fuels, with a share of more than 80 % (Bacquet et al., 2022). Therefore, in addition to expansion, there is a need to transform the generation structure and invest in climate-neutral DH supply. End-users must be willing to adopt the technology to increase the share of climate-neutral DH. However, its monopolistic market structure appears to be a barrier (Breitschopf and Billerbeck, 2023). In most cases, DH is supplied by a vertically integrated utility responsible for generation, network operation, and sales to end customers (Billerbeck et al., 2023). This monopolistic structure makes consumers dependent and does not require suppliers to compete, which can lead to excessive pricing. At the same time, Zaunbrecher et al. (2016) show that prices influence the perceptions of DH and, in turn, the likelihood of adoption. Regulations are used to secure consumer rights and increase the acceptance of DH.

Accordingly, Germany regulates DH prices (Billerbeck et al., 2023). The primary method of regulating DH prices in Germany is the established ex-post price control in cases of suspected abuse of market power. In addition, there is a price adjustment clause for DH prices, which regulates the adjustment of prices according to the main energy sources used in the DH system. If the market price for this energy source (e.g., coal or gas) rises, the DH price can also increase and vice versa. As a result, DH pricing in Germany is categorised as more market-oriented (Billerbeck et al., 2023). The DH price in Germany typically consists of two components: a fixed component and a variable one. Depending on the grid connection, the average DH price in Germany in 2021 was around 79 €/MWh for 600 kW and 83 €/MWh for 15 kW (Statista, 2023). Here, 600 kW corresponds to a large apartment building or business, while 15 kW reflects the typical consumption of a single-family home.

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There is a lack of literature on DH prices and their influencing factors. The German Federal Cartel Office conducted a sector inquiry in 2012 and found that DH prices are influenced by various factors, such as the size of the network or the main energy source (Bundeskartellamt, 2012). Furthermore, most of the scientific literature on DH prices and influencing factors is from Northern Europe. Table 1 summarizes the existing literature and key findings.

Table 1
Overview of scientific literature on DH prices and influencing factors.

Author, Country	Main findings
Johansen and Werner (2022), Denmark	The price of DH varies from company to company. The price is only slightly higher in single-family houses than in multi-family buildings or apartment blocks within each DH network. Denmark has the highest national average price of DH in Europe.
Egüez (2021), Sweden	The prices of privately owned DH companies are 3 % higher. The fixed prices of privately owned DH companies are 25 % higher.
Biggar and Söderberg (2020), Sweden	Social-democratic governments have a greater tendency to smooth DH prices over time than conservative governments. Privately owned DH companies are more likely to smooth prices for price stability reasons than publicly owned DH companies.
Odgaard and Djørup (2020), Denmark	Transnational DH companies set relatively higher prices.
Krog et al. (2020), Denmark	Consumers, as owners, have an interest in the organization and profitability of the DH company to secure low DH prices.
Hvelplund and Djørup (2019), Denmark	Consumer ownership has a positive potential in terms of maintaining low energy prices.
Åberg et al. (2016), Sweden	Prices of municipally owned DH companies vary more. Depending on the ownership structure, companies pursue different objectives. Municipally owned DH companies set prices that are lower than state- or privately-owned companies.
Chittum and Østergaard (2014), Denmark	DH companies establish prices that include all relevant expenses, including the cost of financing. The Danish Energy Agency regulates and monitors DH prices.
Werner (2013), worldwide	Economies of scale in the investment costs of heat generation capacities. Municipally owned DH companies require a lower return on investment than privately owned DH companies. Privately owned DH companies are more oriented to prices on the entire heating market.
Bundeskartellamt (2012), Germany	Price-increasing effect of mandatory consumer connection to the DH grid. Wage, capital goods index, and a fixed component have the strongest influence on fixed prices in price change clauses; fuel price index and wages have the strongest influence on variable prices in price change clauses. No correlation between the fuel price index and end-consumer DH prices based on the analysis. Network size is negatively correlated with the variable price component.
Colnerud Granström, Swede n	Privately owned DH companies set slightly higher prices.
Muren (2011), Sweden	Big DH companies that provide DH in several municipalities set higher prices than smaller companies.
Linden and Peltola-Ojala (2010), Finland	Deregulation has had permanent price-lowering effects. No price-increasing or price-decreasing effects were observed for combined heat and power (CHP). No price-increasing or price-decreasing effects were observed for economies of scale.
Biggerson (2004), Sweden	Privately owned DH companies set relatively higher prices.
Andersson and Werner (2003, 2005), Sweden	Privately owned DH companies set relatively higher prices.

The existing literature (cf. Table 1) indicates that several factors, such as network size, temperature level, energy source, and ownership structure, can influence the price of DH. Based on the existing literature, the conjecture is that publicly owned DH companies offer DH at lower prices than privately owned companies. The existing DH networks in Germany are mainly owned and operated by municipal utilities. Other suppliers are EnBW, Vattenfall, E.ON, Uniper, Innogy, Dalkia, Engie and Getec (Bacquet et al., 2022). However, compared to Denmark and other EU countries, there are fewer networks owned and operated by mainly public bodies (Bacquet et al., 2022). Moreover, compared to Denmark and the Netherlands, consumer-owned DH systems are scarce in Germany (Bacquet et al., 2022).

The empirical evidence for the correlation between price and ownership structure is thin and mainly based on data from Swedish DH networks. Empirical analysis for other markets is still lacking. Meanwhile, in Germany, some DH market experts have suggested that publicly owned DH companies cross-subsidise other municipal utilities, leading to higher prices than privately owned DH companies (Mohl, 2024). In this context, this paper contributes to the literature with an empirical analysis of 184 DH companies in Germany, the largest DH market in Europe in terms of heat demand (Bacquet et al., 2022) and addresses the following research question: Do DH prices differ between public and private companies in Germany?

Our study goes beyond the existing studies in several respects. First, it is the first empirical analysis to compare the prices of public and private DH networks in Germany. Second, we use an extensive dataset of DH prices. Third, we use multiple regression models to statistically control the price differences for various factors such as network size, energy source of heat generation, and DH connection level. One of the control variables considers the specific DH price regulation in Germany, i.e., the price adjustment clause (cf. details in Section 2).

This analysis requires data on DH prices and the respective DH networks' specific technological and operational factors. Generally, such data are owned by the respective companies and are usually not publicly available in Germany. For our analysis, we cooperated with the German District Heating Association (AGFW), whose members include publicly and privately owned DH companies. The AGFW provided several datasets for our research, enabling us to analyse the factors influencing DH prices in Germany and assess which factors can be classified as price drivers. We use the AGFW data to fit eight ordinary least squares (OLS) regression models and conducted robustness checks with random effects and pooled OLS models.

This paper is structured as follows: Section 2 describes the data and methodology. The results are presented and discussed in Section 3. We conclude with policy implications in Section 4.

2. Data and methods

This section focuses on data and methods. First, the data sources are described, and an overview of the data is given (cf. Section 2.1.). Second, the methodology is presented (cf. Section 2.2.).

2.1. Data

The German District Heating Association (AGFW) provided the primary data for our analysis. These data are collected annually by the AGFW through a voluntary survey of its members. These data were supplemented by desk research, which involved collecting publicly available data from the websites of the DH companies and data from the German Commercial Register. The data for 2021 were the latest data

Table 2
Overview of the data and sources.

Variable in datasets	Available years	Sources
DH price (for three tariffs)	2017–2021	Provided by AGFW
Heating degree days	2017–2021	Eurostat (2023)
Heat generation technology	2017–2021	Provided by AGFW
Primary energy source	2017–2021	Provided by AGFW
Prior year price index	2017–2021	Federal Statistical Office of Germany (Statistisches Bundesamt (Destatis), 2023)
Temperature	2017–2021	Provided by AGFW
Heat sales	2017–2021	Partly provided by AGFW, company websites, annual reports
Thermal power output	2021	Provided by AGFW
Heat network supply	2021	Provided by AGFW
Maximum heat output	2021	Provided by AGFW
Installed load	2017–2021	Provided by AGFW
Ownership	2017–2021	Commercial register, company websites

available on the websites at the time of our research.

As a result, this paper draws on two datasets: (1) the first cross-sectional dataset consists of comprehensive data on DH companies and their prices in the year 2021; (2) the second dataset comprises panel data that feature less information on DH companies and their prices but cover the period from 2017 to 2021. We use the first cross-sectional dataset for detailed regression analysis and the second panel dataset for robustness checks. Table 2 provides an overview of the data and sources.

The first dataset covers 184 DH companies operating in Germany in 2021 and their prices for end-consumers for three different connection levels (15 kW, 160 kW, and 600 kW). These 184 companies cover around 69 % of Germany's total DH network length.[1]

Please note that not every DH company has a price for every level. For example, some companies only offer DH at low connection levels (i.e., 15 kW). The first dataset contains 537 observations (i.e., prices or tariffs per company for up to three different connection loads).

The second dataset covers the prices of 145 DH companies operating in Germany from 2017 to 2021. It is an unbalanced panel dataset. The DH companies provided five-year data and were linked to 725 observations. Combined with the three levels of connection, the total number of observations in the second dataset is 2175.

(i) Dependent Variable

The dependent variable is the DH price. The datasets provided a mixed price in €/MWh, consisting of a fixed and a variable price component, as specified in Equation (1). In addition to the mixed price, the variable price share was reported as a percentage of the mixed price. The mixed prices include connection fees. All DH prices are shown without value-added tax.

$$\textit{mixed price} = \textit{fixed price} + \textit{variable price} \tag{1}$$

The mixed price is a calculated value that provides a standardised basis for evaluating and comparing prices. It is calculated by dividing the annual costs by the amount of heat consumed. The following example illustrates the calculation of the mixed price (AGFW, 2023).

$$\begin{aligned}
&\textit{variable costs}\,[\text{€}] = \textit{consumed heat}\,[MWh]\cdot\textit{variable price}\left[\frac{\text{€}}{MWh}\right]\\
&\text{e.g., } \textit{variable costs}\,[\text{€}] = 300\ MWh\cdot 50\ \frac{\text{€}}{MWh} = 15000\ \text{€}\\
&\textit{fixed costs}\,[\text{€}] = \textit{heat load}\,[kW]\cdot\textit{fixed price}\left[\frac{\text{€}}{kW}\right] + \textit{metering costs}\,[\text{€}]\\
&\text{e.g., } \textit{fixed costs}\,[\text{€}] = 200\ kW\cdot 30\ \frac{\text{€}}{kW} + 200\ \text{€} = 6200\ \text{€}\\
&\textit{annual costs}\,[\text{€}] = \textit{variable costs}\,[\text{€}] + \textit{fixed costs}\,[\text{€}]\\
&\text{e.g., } \textit{annual costs}\,[\text{€}] = 15000\ \text{€} + 6000\ \text{€} + 200\ \text{€} = 21200\ \text{€}\\
&\textit{mixed price}\left[\frac{\text{€}}{MWh}\right] = \frac{\textit{annual costs}\,[\text{€}]}{\textit{consumed heat}\,[MWh]}\\
&\text{e.g., } \textit{mixed price}\left[\frac{\text{€}}{MWh}\right] = \frac{21200\ \text{€}}{300\ MWh} = 70.67\ \frac{\text{€}}{MWh}
\end{aligned} \tag{2}$$

The DH prices provided are company-specific reference prices collected for three connection levels: 15 kW, 160 kW, and 600 kW. Table 3 illustrates the ranges by specifying the mean, maximum (max), minimum (min) and standard deviation (SD) of the prices per level in 2021.

(ii) Explanatory Variables

As the main research question of this paper is to assess the influence of ownership on DH prices, ownership is used as the explanatory variable. Following Djørup et al. (2021) and Billerbeck et al. (2024), DH companies were classified according to ownership structure. Private ownership refers to a DH network owned and operated by a private company. Public ownership refers to a DH network operated by a company owned by a municipality. Finally, consumer ownership means that consumers own the company that operates their local DH network. No consumer-owned networks (or cooperatives) are in the dataset used for the analysis, so the category consumer-owned is not considered. However, some networks in the dataset are owned by public entities that are not located in the same region (e.g., in the city of Kiel, DH is provided by Stadtwerke Kiel GmbH, which is 49 % owned by the city of Kiel, while 51 % is owned by MVV AG, which is not a local company). Therefore, our analysis distinguishes between the regional and non-regional public.

Specifically, if the DH company is at least 50 % owned by the local municipality, i.e., the local municipality owns the local DH network, it was classified as *regional.* The company is classified as *public* if the DH company is at least 50 % owned by a public authority or another public company not based within the same municipality. If neither of these was the case, i.e., the company is more than 50 % owned by a private actor, the company was defined as *private*. Thus, while *public* and *regional* both mean that a public company owns the DH network, *regional* further specifies that the public company is local.

Fig. 1 shows the distribution (as relative frequencies) of the DH prices of *private*, *public,* and *regional* companies per connection level. The figure indicates that *public* and *regional* DH companies offer relatively

Table 3
Summary of mixed prices for cross-sectional data for 2021.

Connection level	N	Mixed price in €/MWh			
		mean	SD	max	min
15 kW	181	83	14	151	50
160 kW	182	80	13	147	54
600 kW	174	78	14	147	46

[1] In our dataset, network length is the variable with the most comprehensive data and therefore the metric from which we were able to derive the overall statistical unit and our coverage.

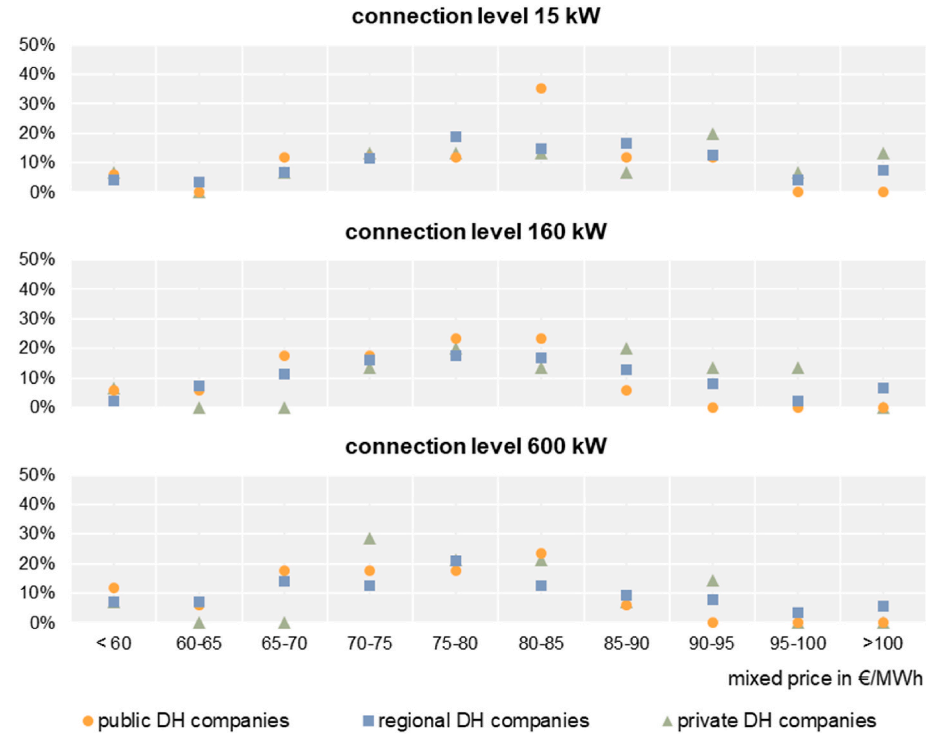

Fig. 1. Relative frequency of mixed DH prices in price intervals per ownership structure (orange circle: public, blue square: regional, green triangle: private) and connection level (top panel: 15 kW, middle: 160 kW, bottom: 600 kW). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

lower prices more frequently than *privately owned* DH companies. However, a difference in the mean values between groups does not imply a statistically robust or significant difference without controlling for further factors. For example, the higher shares of high prices for privately owned DH networks could stem from higher energy carrier costs or different network sizes. Thus, only a multiple linear regression analysis or similar statistical methods can correct the price differences between groups for different group properties. This paper aims to estimate price differences between *privately* and *publicly owned* DH companies when controlling for other influencing factors, such as energy carriers and network size.

Therefore, several *control* variables were included. First, DH prices depend on *network size,* with bigger networks leading to lower prices due to economies of scale. Four different size variables were analysed: heat sales [T€], thermal power output [MW], maximum heat load [MW] and heat network supply [GWh].

Second, DH prices depend on the energy demand within the DH network. The variable *heating degree days* was used as a proxy for the heat demand in each year. As the cross-sectional data only includes 2021 prices, this variable was not considered in the OLS models, but it was included in the panel dataset and thus in the robustness checks.

Third, DH prices depend on the *heat generation technology*. Here, we distinguished between heat-only plants (HP), combined heat and power plants (CHP) and heat purchased from external producers (EP).

Fourth, the energy source impacts the DH price, as different energy carriers have different wholesale prices. The variable *primary energy source* indicates the dominant energy source of the network. In principle, a DH network can be supplied by several sources with different energy carriers, but only the primary source was reported in the dataset.

Fifth, energy prices influence DH prices, so energy price indexes were included in the analysis. As no indexes were found for biogas, biomass, waste and geothermal energy, they were omitted. Because most DH companies procure energy sources early in the year, the *previous year's price index* was used for each primary energy source. This variable reflects the current price regulation in Germany, i.e., the price adjustment clause for DH prices. This mechanism adjusts the price depending on the (wholesale) price of the energy sources used in the DH system (cf. Section 1).

Lastly, the DH price depends on the network's temperature level, i.e., the *heat transfer medium*, a categorical variable for heated water (W) and steam (S). As stated above, the connection level, i.e., 15 kW, 160 kW or 600 kW, converts the dataset into a long format, resulting in 537 observations. Table 4 summarizes the statistics for all the explanatory variables.

2.2. Methods

We use regression analysis to compare the DH prices for end-consumers of *regional*, *publicly*, and *privately owned* DH companies. Our main model is the following cross-sectional regression model estimated by OLS (cf. Equation (3)):

$$Price_i = \beta_0 + \beta_1 Ownership_i + \beta_2 NetworkSize_i + \boldsymbol{\beta}\ \boldsymbol{FurtherControls_i} \tag{3}$$

Here, $Price_i$ denotes the price of DH for end-consumers in DH company *i*. As outlined above, the actual prices have a fixed and a variable component, and households will pay a mixed price (cf. Section 2.1). Thus, our principal regression uses the mixed price in €/MWh as the dependent metric variable. Ownership is the primary variable of interest and can take the values *regional*, *public*, or *private*.

We control for DH *network size,* which can be measured as total heat sales within the DH network, thermal power generation of the DH network, maximum heat load in the network, or total heat supply (cf. Table 4 in Section 2.1 and see results below). Furthermore, we include other control variables such as the prior year price index, the energy carrier used for heat generation, installed load, type of heat generation,

Table 4
Summary statistics of explanatory variables in detailed cross-sectional data for 2021.

Variables	Type	Values/Range	N	Mean or shares	SD
Ownership	categorical	private, public, regional	184	8 % private, 9 % public, 83 % regional	–
NetworkSize					
Heat sales [thousand €]	metric	0–391,000	116	35,427	57,218
Thermal power output [MW]	metric	2–5,796	116	355	691
Maximum heat load [MW]	metric	0–3,345	116	221	454
Heat network supply [GWh]	metric	3–10,622	116	642	1,273
FurtherControls					
Heating degree days	metric	2,741–3,114	184	2,886	143
Heat generation technology	categorical	CHP, HP, EP	183	59 % CHP, 14 % HP, 27 % EP	–
Primary energy source	categorical	biogas, biomass, hard coal, lignite, waste heat, excess heat, and other	184	1 % biogas, 11 % biomass, 9 % hard coal, 4 % lignite, 8 % waste heat, 2 % excess heat, 7 % other	–
Prior year price index	metric	96–104	131	96	13
Heat transfer medium	categorical	W, S	184	94 % W, 6 % S	–

and heat transfer medium summarized in a vector variable[2] $\boldsymbol{FurtherControls_i}$ (cf. Table 4 in Section 2.1).

We also apply pooled OLS and random effect panel models as robustness checks. Equation (4) specifies the random-effects panel-data regression model:

$$Price_{it} = \beta_0 + \beta_1 Ownership_{it} + \beta_2 NetworkSize_{it} + \boldsymbol{\beta}\ \boldsymbol{FurtherControls_{it}} \quad (4)$$

Here, $Price_{it}$ denotes the price of DH for end-consumers in a given DH company i in year t. We use the mixed price in network i and year t in €/MWh as the dependent metric variable. Ownership can again take *regional*, *public*, or *private* values into account. We likewise controlled for DH *network size* and other control variables summarized in a vector variable $\boldsymbol{FurtherControls_{it}}$. We computed the regression models in R using the plm package (R Core Team, 2023; Croissant and Millo, 2008).

[2] The vector variable is shown in bold in Equations (3) and (4) to indicate vector character.

3. Results

This section presents and discusses the main results. First, the results of the OLS regression models are presented (cf. Section 3.1), followed by the results of the robustness checks (cf. Section 3.2). The section ends with a discussion of the results (cf. Section 3.3).

3.1. Regression model for DH prices

We estimated eight OLS regression models by varying the control variables specified in Section 2. As six of our seven explanatory variables are categorical variables, including the ownership variable, calculating the model with the different control variables in eight model constellations helps eliminate random relations between DH ownership and prices. Table 5 shows the main results of all eight models. Table A1 in the Appendix shows the complete results of the OLS regression models. In addition, Tables A2 and A3 in the Appendix show the results of the OLS regression models with variable prices instead of mixed prices as the dependent variable.

All the models except Model 7 are statistically significant (F-statistics larger than zero at the 1 % level). Regarding model quality, the baseline model's adjusted R^2 is 0.053 with an F-statistic of 2.461 and 234 observations. Across all model constellations, the R^2 is between 0.022 and 0.195, explaining a low to medium variance in mixed DH prices.

The regression analysis shows that the ownership of DH companies does indeed influence DH prices. The results of all significant models show that DH prices are higher for *privately owned* DH companies, as the coefficients for *public* and *regional* are negative except for the non-significant Model 7 (cf. Table 5). The mixed price for DH is significantly lower (at the 1 % level) in *publicly owned* DH companies than *privately owned* DH companies in all statistically significant models. For DH companies identified as *public,* the price-reducing effect in the baseline Model 1 is estimated as −16.30 €/MWh. Across all models, the quantified effect is between −9.33 €/MWh and −17.30 €/MWh. The effect is higher for models that include the numeric variable *prior year price index* instead of the categorical variable *primary energy carrier*.

While the effect is also negative for *regional* ownership in all models, it is only marginally significant in Model 3. However, this effect is apparent across all model constellations and ranges between −1.68 €/MWh and −7.64 €/MWh.

3.2. Robustness checks

Various tests were carried out to check the robustness of the model results (cf. methodology in Section 2). Four pooled OLS and four random effects models were calculated (N between 1374 and 2542) to ensure that the observed effect was not just isolated to 2021 but a permanent one. Fewer model constellations were calculated due to the lower data availability for the *network size variables*, but more observations were included due to the larger number of years. The results of the robustness checks are presented in the Appendix (cf. Table A4 to Table A7).

The pooled OLS models show an R^2 between 0.085 and 0.125 and are thus in a similar range to the OLS models. Across all pooled OLS models, *regional* and *publicly owned* DH companies had lower mixed DH prices from 2017 to 2021 when controlling for different external factors.

In addition, the random effects models have an R^2 between 0.313 and 0.357. The variance the models explain is higher due to the inclusion of time effects. The signs of *regional* and *public* variables also remain negative in the random effects models. Once again, the effect is the strongest in Model 2 with *public* and −4.92 €/MWh. However, *public* and *regional* are statistically significant from zero this time.

In summary, we consider our results on the difference in DH prices between *privately* and *publicly owned* DH companies robust as the effect is negative in all calculated robustness checks and often statistically significant.

Table 5
Results of the OLS regression models (with the mixed price in €/MWh as the dependent variable).

Variable	Model							
	(1) baseline model	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ownership public	−16.30*** (3.268)	−10.58 *** (2.650)	−17.30 *** (4.004)	−11.20 *** (3.522)	−13.38 *** (2.910)	−9.33 *** (2.546)	16.16 *** (4.548)	−11.26 *** (3.124)
Ownership regional	−3.48 (2.165)	−1.86 (1.834)	−4.20* (2.129)	−2.87 (2.025)	−3.59 (2.173)	−1.68 (1.912)	−7.64** (3.377)	−6.32 (2.818)
Intercepts	−5.02 (29.661)	87.88*** (2.344)	−63.68* (32.701)	87.74*** (2.309)	27.21 (27.994)	86.99*** (2.366)	8.10 (24.279)	91.65*** (3.170)
NetworkSize	Thermal power	Thermal power	Max heat load	Max heat load	Heat supply	Heat supply	Heat sales	Heat sales
FurtherControls								
Prior year price index	yes	no	yes	no	yes	no	yes	no
Energy carrier controls	no	yes	no	yes	no	yes	no	yes
Observations	234	321	165	210	246	336	246	338
Adjusted R^2	0.053	0.054	0.195	0.137	0.040	0.045	0.022	0.068
F-statistic	2.461** (df = 9; 224)	2.210*** (df = 15; 305)	5.412*** (df = 9; 155)	3.375*** (df = 14; 195)	2.143** (df = 9; 236)	2.048** (df = 15; 320)	1.601 (df = 9; 236)	2.632*** (df = 15; 322)

(Note: Table shows coefficient (error); $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *).

3.3. Discussion

In this paper, we analysed DH prices in Germany. The analysis was based on company-specific DH prices and technological and operational controls for the DH networks. Existing literature based on Swedish DH price data indicates that publicly owned DH companies offer DH at lower prices than privately owned companies. In Germany, on the other hand, it has been suggested that publicly owned DH companies cross-subsidise other municipal utilities, leading to higher prices than privately owned DH companies (cf. Section 1). Therefore, our primary research interest was the effect of ownership structure on DH prices. We fit OLS regression models to address this research question and conducted robustness checks with pooled OLS and random effects models.

Our database covers 184 DH companies in Germany, which has the largest DH market in Europe, over five years (2017–2021) with more detailed analysis and more control variables for 2021. Our data cover around 70 % of the total German DH network length and were collected by the German District Heating Association (AGFW, 2022) using a voluntary survey among its members and enriched by the authors. Regarding the control variables *primary energy source* and *heat generation technology*, it is important to note that the DH networks could be supplied by several energy sources and different plants, but only the main energy source and the main heat generation type have been used. The control variable *price index* for the primary energy source reflects the current DH price regulation in Germany, which requires DH prices to be adjusted in line with the prices of the main energy sources used in the DH system (cf. Section 1). Our sample covers a large share of the German DH market and is thus considered reasonably representative, while also reflecting the current DH price regulation in Germany.

Overall, the results show that, in 2021, publicly owned DH companies had lower prices than privately owned companies (cf. Section 3.1). The prices of public companies were between 9.33 €/MWh and 17.30 €/MWh lower, i.e., more than 10 % and up to 20 % lower than the average DH price of privately owned DH companies in Germany. In addition, regional DH companies, i.e., DH networks owned by the local municipality, also had lower prices than privately owned DH companies in 2021, albeit with a minor price difference. The prices of regional DH companies were between 1.68 €/MWh and 7.64 €/MWh lower than those of privately owned DH companies.

In both cases, the variable price component is the source of the price reduction, leading to lower mixed prices (cf. results in Tables A2 and A3 in the Appendix). While Egüez (2021) found that the higher DH prices of private companies in Sweden came from higher fixed prices, our analysis shows that the higher mixed prices set by private companies were due to a higher variable price component. Apart from this difference, our results for Germany are in line with other studies, which found that the DH prices of public companies in Sweden and Finland are lower than those of private companies (cf., e.g., Åberg et al., 2016; Andersson and Werner, 2005; Biggar and Söderberg, 2020; Linden and Peltola-Ojala, 2010). In this context, the regulatory framework for DH prices must be considered. While Germany has a price adjustment clause for DH prices, Sweden and Finland rely on price transparency to a greater extent (Bacquet et al., 2022). These different approaches are likely to impact prices and should be a focus of future research. Our analysis included the German DH price regulation, i.e., the price adjustment clause, as a control variable. Future research could focus on DH prices under different price regimes, e.g., from different countries, to identify beneficial regulations for DH prices.

The lower prices of public and regional DH companies are relatively less pronounced when considering the period from 2017 to 2021 (cf. robustness checks in Section 3.2 and Table A4 to A7 in the Appendix). Nevertheless, all models point in the same direction, underlining the robustness of the results.

Suggested reasons for the price differences, which were also discussed by Werner (2013), include publicly owned companies requiring a lower return on investment and accepting extended payback periods than privately owned companies, resulting in lower financing costs. In addition, privately owned companies may be more influenced by prices on the overall heating market and thus may not fully utilise the cost advantages offered by DH. An analysis by Muren (2011) found that large DH companies in Sweden, which provide DH in several municipalities and are not necessarily private companies but are assumed to be profit-maximising, set higher prices than smaller companies. Their more dominant market position might allow them to set prices with less competitive pressure. They may also have higher costs associated with maintaining and operating extensive networks covering several municipalities, which are passed on to consumers. Biggar and Söderberg (2020) showed that privately owned DH companies tend to smooth prices for price stability reasons. Similarly, Åberg et al. (2016) showed that prices of privately owned DH companies are less volatile than those of municipally owned DH companies. In return for greater price stability, the higher prices may be justified. However, future research is needed to validate these hypotheses about the reasons for price differences. Our analysis indicates that public DH networks could be a more cost-effective option for climate-friendly heating in urban areas than private DH networks.

4. Conclusions and policy implications

Based on empirical data from 184 district heating (DH) companies in Germany that cover a large share of the German DH market, we found that publicly owned DH companies have lower end-user prices than privately owned DH companies. This finding is robust when controlling for network size, energy carrier, energy price, and various years. The answer to this paper's research question is that public companies in Germany offer DH at lower prices than privately owned DH companies.

Publicly owned DH providers could, therefore, play an important role in ensuring an affordable supply of DH. In addition, lower DH prices can lead to higher acceptance and, thus, a higher likelihood of adopting this technology. On this basis, we conclude that policy frameworks should promote public DH networks over private ones to support the expansion of DH. This strategy can play a role when developing new DH networks and organizing or tendering their operation. For example, in an open tender for a DH system for a new housing development, public or consumer participation in the planned DH network could be included as a pre-qualification for the tender or as a highly rated selection criterion (cf. policy brief on heat auctions by Blömer et al., 2022). Building on our findings, we recommend that if an existing DH network is up for sale, it should first be offered to the local public utility company. A similar regulation exists in Denmark, where DH networks for sale must be offered to local consumers or the municipality at a market price based on the Danish Heat Supply Act (Climate Change Laws).

A general limitation of our work is the impossibility of controlling for all possible variations between private and public DH networks and their respective prices. Hence, the results presented in this paper must be interpreted with the caveat that other factors might explain the price differences. Future research is needed to identify other factors potentially influencing DH prices. For example, additional regulatory, institutional, and market settings across different countries could be included to identify favourable policy frameworks for climate-friendly, low-price DH networks.

CRediT authorship contribution statement

Miguel Bänfer: Writing – original draft, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anna Billerbeck:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Investigation, Data curation, Conceptualization. **Patrick Plötz:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of AI and AI-assisted technologies in the writing process

While preparing this work, the authors used "deepl write" to correct potential grammar mistakes and improve readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A1
Comprehensive results of OLS regression models (cross-sectional dataset 2021)

Model	Variable							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ownership public	−16.30*** (3.268)	−10.58 *** (2.650)	−17.30 *** (4.004)	−11.20 *** (3.522)	−13.38 *** (2.910)	−9.33 *** (2.546)	16.16 *** (4.548)	−11.26 *** (3.124)
Ownership regional	−3.48 (2.165)	−1.86 (1.834)	−4.20* (2.129)	−2.87 (2.025)	−3.59 (2.173)	−1.68 (1.912)	−7.64** (3.377)	−6.32 (2.818)
PES Biogas		4.723** (2.117)		3.526 (2.810)		3.768* (2.083)		1.619 (2.032)
PES Biomass		1.331 (2.719)		−2.177 (3.993)		3.801 (2.555)		0.655 (2.447)
PES Excess heat		−2.172 (7.301)		None		−1.326 (7.222)		−0.993 (4.600)
PES Hard coal		−0.518 (2.554)		4.559** (2.190)		0.743 (2.283)		0.986 (2.577)
PES Lignite		6.610** (2.559)		11.690*** (2.729)		4.576* (2.655)		6.454*** (2.047)
PES Other		2.409 (3.238)		4.762 (3.100)		2.520 (3.087)		−5.776** (2.408)
PES Waste		−6.059** (2.532)		2.459 (3.323)		−5.454** (2.503)		−5.527** (2.408)
Prior year price index	0.991*** (0.309)		1.598*** (0.341)		0.651* (0.295)		0.889*** (0.255)	
External procurement	−6.286** (2.802)	−4.087* (2.427)	−12.034*** (1.972)	−10.649*** (2.089)	−6.214** (2.771)	−4.330* (2.351)	−5.899** (2.392)	4.960*** (1.842)
Heat-only plant	−9.550*** (2.779)	−6.458** (2.530)	−6.246* (3.250)	−3.862 (2.961)	−8.917*** (2.758)	−4.757** (2.410)	−4.271 (2.629)	−2.491 (2.271)
Steam	−6.765* (3.819)	−6.389 (3.936)	−3.568 (3.206)	−4.386* (2.481)	−6.335* (3.791)	−6.122* (3.710)	−1.806 (4.896)	−1.151 (3.286)
160 kW	−1.359 (2.635)	−1.888 (2.037)	−1.782 (2.065)	−2.290 (1.801)	−1.529 (2.548)	−1.991 (1.976)	−2.098 (2.231)	−2.455 (1.744)

(*continued on next page*)

Table A1 (*continued*)

Model	Variable							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
600 kW	−3.272 (2.741)	−4.123* (2.128)	−3.685* (2.169)	−4.416** (1.892)	−3.424 (2.646)	−4.186** (2.060)	−3.447 (2.335)	−4.056** (1.837)
Heat sales							−0.00001 (0.00001)	−0.00000 (0.00001)
Total thermal power	−0.001 (0.001)	−0.0003 (0.001)						
Maximum heat load			−0.001 (0.001)	−0.001 (0.001)				
Heat network supply					−0.0002 (0.0004)	0.0001 (0.0004)		
Intercepts	−5.020 (29.661)	87.876*** (2.344)	−63.681* (32.701)	87.739*** (2.309)	27.206 (27.994)	86.990*** (2.366)	8.098 (24.279)	91.653*** (3.170)
Observations	234	321	165	210	246	336	246	338
Adjusted R^2	0.053	0.054	0.195	0.137	0.040	0.045	0.022	0.068
F Statistic	2.461** (df = 9; 224)	2.210*** (df = 15; 305)	5.412*** (df = 9; 155)	3.375*** (df = 14; 195)	2.143** (df = 9; 236)	2.048** (df = 15; 320)	1.601 (df = 9; 236)	2.632*** (df = 15; 322)

(Note: Table shows coefficient (error); p < 0.01 ***, p < 0.05 **, p < 0.1 *).

Table A2
OLS of variable prices without robust standard errors (cross-sectional dataset, 2021)

Variable	Model							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ownership public	−16.923*** (5.243)	−14.612*** (3.889)	−23.001*** (4.327)	−19.862*** (3.509)	−9.781** (4.905)	−9.717** (3.825)	−13.898** (5.874)	−16.026*** (4.456)
Ownership regional	−3.390 (3.568)	−4.653 (2.918)	−5.682* (3.094)	−6.750** (2.626)	−3.810 (3.645)	−3.890 (2.996)	−9.407** (4.605)	−11.212*** (3.820)
PES Biogas		−0.397 (8.799)		−1.736 (6.746)		−2.132 (9.061)		−3.592 (7.885)
PES Biomass		−3.961 (3.683)		−7.623* (3.983)		−0.011 (3.509)		4.456 (2.762)
PES Hard coal		−6.938** (3.082)		−0.808 (2.883)		−1.298 (2.963)		2.635 (2.887)
PES Lignite		5.152 (4.092)		14.867*** (3.678)		3.130 (3.903)		7.571** (3.755)
PES Other		−7.652* (4.021)		−6.942** (3.409)		−6.966* (4.143)		−1.652 (3.437)
PES Waste		−4.547* (2.678)		2.986 (3.041)		−3.748 (2.759)		−1.269 (3.066)
PES Excess heat		−16.673*** (6.261)				−14.704** (6.456)		−10.560** (4.891)
Prior year price index	0.944* (0.547)		2.118*** (0.458)		0.447 (0.506)		0.729 (0.475)	
External procurement	−5.038** (2.481)	−1.543 (2.035)	−10.889*** (2.285)	−8.183*** (2.141)	−5.212** (2.507)	−3.088 (2.062)	−4.886* (2.539)	−5.811** (2.259)
Heat-only plant	−5.858* (3.466)	−5.093* (2.923)	−1.284 (2.952)	−2.886 (2.687)	−5.306 (3.528)	−2.571 (2.884)	−2.305 (2.851)	0.837 (2.359)
Steam	−6.762 (5.509)	−5.215 (5.021)	−3.855 (3.908)	−4.005 (3.828)	−6.468 (5.625)	−6.020 (5.176)	0.411 (5.920)	4.967 (4.783)
160 kW	−2.235 (2.552)	−2.007 (1.979)	−2.846 (2.122)	−2.849 (1.830)	−2.066 (2.544)	−1.922 (1.999)	−2.381 (2.172)	−2.148 (1.740)
600 kW	−3.282 (2.586)	−3.100 (1.998)	−4.107* (2.163)	−4.343** (1.858)	−3.075 (2.576)	−2.998 (2.018)	−3.666* (2.200)	−3.413* (1.760)
Heat sales							−0.00004*** (0.00002)	−0.00004*** (0.00001)
Total thermal power	−0.005*** (0.001)	−0.005*** (0.001)						
Maximum heat load			−0.010*** (0.002)	−0.010*** (0.002)				
Heat network supply					−0.003*** (0.001)	−0.003*** (0.001)		
Intercepts	−19.642 (52.536)	71.511*** (3.246)	−130.671*** (44.073)	73.468*** (2.862)	27.874 (48.408)	69.884** *(3.308)	4.668 (45.389)	75.508*** (4.087)
Observations	234	321	165	210	246	336	246	338
R^2	0.129	0.153	0.345	0.322	0.086	0.105	0.076	0.149
Adjusted R^2	0.094	0.111	0.307	0.274	0.051	0.063	0.041	0.109
Residual Std. Error	16.037 (df = 224)	14.541 (df = 305)	11.225 (df = 155)	10.901 (df = 195)	16.386 (df = 236)	15.023 (df = 320)	13.987 (df = 236)	13.132 (df = 322)
F Statistic	3.675*** (df = 9; 224)	3.677*** (df = 15; 305)	9.062*** (df = 9; 155)	6.624*** (df = 14; 195)	2.455** (df = 9; 236)	2.491*** (df = 15; 320)	2.155** (df = 9; 236)	3.744*** (df = 15; 322)

(Note: Table shows coefficient (error); p < 0.01 ***, p < 0.05 **, p < 0.1 *).

Table A3
OLS on variable prices with robust standard errors (cross-sectional dataset, 2021)

Variable	Model							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ownership public	−16.923*** (3.268)	−14.612*** (2.650)	−23.001*** (4.004)	−19.862*** (3.522)	−9.781*** (2.910)	−9.717*** (2.546)	−13.898*** (4.548)	−16.026*** (3.124)
Ownership regional	−3.390 (2.165)	−4.653** (1.834)	−5.682*** (2.129)	−6.750*** (2.025)	−3.810* (2.173)	−3.890** (1.912)	−9.407*** (3.377)	−11.212*** (2.818)
PES Biogas		−0.397 (2.117)		−1.736 (2.810)		−2.132 (2.083)		−3.592* (2.032)
PES Biomass		−3.961 (2.719)		−7.623* (3.993)		−0.011 (2.555)		4.456* (2.447)
PES Hard coal		−6.938*** (2.554)		−0.808 (2.190)		−1.298 (2.283)		2.635 (2.577)
PES Lignite		5.152** (2.559)		14.867*** (2.729)		3.130 (2.655)		7.571*** (2.047)
PES Other		−7.652** (3.238)		−6.942** (3.100)		−6.966** (3.087)		−1.652 (2.425)
PES Waste		−4.547* (2.532)		2.986 (3.323)		−3.748 (2.503)		−1.269 (2.408)
PES Excess heat		−16.673** (7.301)				−14.704** (7.222)		−10.560** (4.600)
Prior year price index	0.944*** (0.309)		2.118*** (0.341)		0.447 (0.295)		0.729*** (0.255)	
External procurement	−5.038* (2.802)	−1.543 (2.427)	−10.889*** (1.972)	−8.183*** (2.089)	−5.212* (2.771)	−3.088 (2.351)	−4.886** (2.392)	−5.811*** (1.842)
Heat-only plant	−5.858** (2.779)	−5.093** (2.530)	−1.284 (3.250)	−2.886 (2.961)	−5.306* (2.758)	−2.571 (2.410)	−2.305 (2.629)	0.837 (2.271)
Steam	−6.762* (3.819)	−5.215 (3.936)	−3.855 (3.206)	−4.005 (2.491)	−6.468* (3.791)	−6.020 (3.710)	0.411 (4.896)	4.967 (3.286)
160 kW	−2.235 (2.635)	−2.007 (2.037)	−2.846 (2.065)	−2.849 (1.801)	−2.066 (2.548)	−1.922 (1.976)	−2.381 (2.231)	−2.148 (1.744)
600 kW	−3.282 (2.741)	−3.100 (2.128)	−4.107* (2.169)	−4.343** (1.892)	−3.075 (2.646)	−2.998 (2.060)	−3.666 (2.335)	−3.413* (1.837)
Heat sales							−0.00004*** (0.00001)	−0.00004*** (0.00001)
Total thermal power	−0.005*** (0.001)	−0.005*** (0.001)						
Maximum heat load			−0.010*** (0.001)	−0.010*** (0.001)				
Heat network supply					−0.003*** (0.0004)	−0.003*** (0.0004)		
Intercepts	−19.642 (29.661)	71.511*** (2.344)	−130.671*** (32.701)	73.468*** (2.309)	27.874 (27.994)	69.884*** (2.366)	4.668 (24.279)	75.508*** (3.170)
Observations	234	321	165	210	246	336	246	338
Adjusted R^2	0.094	0.111	0.307	0.274	0.051	0.063	0.041	0.109

(Note: Table shows coefficient (error); $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *).

Table A4
Pooled OLS model without robust standard errors (panel dataset, 2017–2021)

Variable	Model			
	(1)	(2)	(3)	(4)
Ownership public	−3.943*** (1.033)	−6.686*** (1.415)	−3.621*** (1.204)	−4.714*** (1.566)
Ownership regional	−1.355* (0.757)	−3.870*** (1.203)	−2.111** (0.841)	−3.850*** (1.281)
Heating Degree Days	0.005*** (0.002)	0.004** (0.002)	0.007*** (0.002)	0.007*** (0.002)
PES Biogas	3.056* (1.617)	7.083** (2.932)		
PES Biomass	−0.559 (1.014)	1.391 (1.349)		
PES Geothermal energy	6.743*** (1.975)	6.520 (5.942)		
PES Hard coal	0.410 (0.744)	−0.964 (0.813)		
PES Light heating oil	4.096* (2.208)	−4.087 (2.698)		
PES Lignite	3.312*** (1.130)	8.682*** (1.344)		
PES Other	1.695* (0.875)	1.092 (1.023)		
PES Waste	−5.114*** (1.026)	−5.281*** (1.189)		
PES Excess heat	−3.081 (2.559)	−4.002 (2.476)		
PES Wood	0.446 (1.774)	5.277** (2.354)		
Prior year price index			0.034* (0.020)	−0.003 (0.022)
External procurement	−1.692*** (0.553)	−0.780 (0.666)	−2.701*** (0.609)	−1.815** (0.724)
Heat-only plant	−0.094 (0.685)	−0.947 (0.884)	−0.755 (0.743)	−1.623* (0.953)
Steam	−3.059*** (1.011)	−2.321* (1.216)	−3.565*** (1.103)	−3.069** (1.395)
160 kW	−2.508*** (0.511)	−1.888*** (0.596)	−2.137*** (0.581)	−1.548** (0.679)
600 kW	−4.251*** (0.516)	−3.534*** (0.603)	−3.896*** (0.588)	−3.289*** (0.688)
Heat sales		0.00001 (0.00000)		0.00001 (0.00000)
Year	1.593*** (0.159)	1.669*** (0.186)	1.574*** (0.176)	1.810*** (0.205)

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Table A4 (*continued*)

Variable	Model			
	(1)	(2)	(3)	(4)
Intercepts	62.325*** (4.475)	65.780*** (5.286)	54.702*** (5.845)	59.374*** (6.952)
Observations	2,542	1,695	2,015	1,374
R^2	0.104	0.136	0.090	0.101
Adjusted R^2	0.097	0.125	0.085	0.093
F Statistic	15.393*** (df = 19; 2522)	13.126*** (df = 20; 1674)	19.771*** (df = 10; 2004)	13.865*** (df = 11; 1362)

(Note: Table shows coefficient (error); $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *).

Table A5
Results of the pooled OLS model with robust standard errors (panel dataset, 2017–2021)

Variable	Model			
	(1)	(2)	(3)	(4)
Ownership public	−3.943 (2.713)	−6.686** (3.024)	−3.621 (3.219)	−4.714 (3.699)
Ownership regional	−1.355 (1.811)	−3.870 (2.360)	−2.111 (1.923)	−3.850 (2.460)
Heating Degree Days	0.005** (0.002)	0.004* (0.003)	0.007*** (0.003)	0.007** (0.003)
PES Biogas	3.056 (2.267)	7.083*** (2.050)		
PES Biomass	−0.559 (2.452)	1.391 (3.075)		
PES Geothermal energy	6.743*** (1.698)	6.520** (3.134)		
PES Hard coal	0.410 (1.526)	−0.964 (1.728)		
PES Light heating oil	4.096 (5.147)	−4.087 (2.675)		
PES Lignite	3.312 (3.429)	8.682*** (2.160)		
PES Other	1.695 (1.747)	1.092 (2.211)		
PES Waste	−5.114** (2.001)	−5.281** (2.500)		
PES Excess heat	−3.081 (2.751)	−4.002 (2.698)		
PES Wood	0.446 (3.935)	5.277 (6.229)		
Prior year price index			0.034 (0.031)	−0.003 (0.033)
External procurement	−1.692 (1.457)	−0.780 (1.480)	−2.701* (1.478)	−1.815 (1.540)
Heat-only plant	−0.094 (1.675)	−0.947 (2.442)	−0.755 (1.818)	−1.623 (2.559)
Steam	−3.059* (1.563)	−2.321 (1.847)	−3.565** (1.731)	−3.069 (2.142)
160 kW	−2.508*** (0.459)	−1.888*** (0.575)	−2.137*** (0.502)	−1.548** (0.645)
600 kW	−4.251*** (0.513)	−3.534*** (0.633)	−3.896*** (0.556)	−3.289*** (0.712)
Heat sales		0.00001 (0.00001)		0.00001 (0.00001)
Year	1.593*** (0.190)	1.669*** (0.218)	1.574*** (0.201)	1.810*** (0.239)
Intercepts	62.325*** (6.450)	65.780*** (7.663)	54.702*** (8.964)	59.374*** (11.076)
Observations	2,542	1,695	2,015	1,374
Adjusted R^2	0.097	0.125	0.085	0.093

(Note: Table shows coefficient (error); $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *).

Table A6
Random effects model without robust standard errors (panel dataset, 2017–2021)

Variable	Model			
	(1)	(2)	(3)	(4)
Ownership public	−3.784 (2.702)	−4.923 (3.343)	−3.498 (3.045)	−2.707 (3.670)
Ownership regional	−0.727 (1.879)	−2.349 (2.569)	−1.071 (1.978)	−1.645 (2.632)
Heating Degree Days	0.006*** (0.001)	0.006*** (0.001)	0.008*** (0.001)	0.008*** (0.001)
PES Biogas	0.985 (1.409)	1.572 (2.592)		
PES Biomass	−1.636 (1.103)	−2.597* (1.465)		
PES Geothermal energy	1.319 (2.277)	2.363 (5.123)		
PES Hard coal	1.316 (0.989)	−1.584 (1.141)		
PES Light heating oil	3.110 (1.894)	0.695 (2.427)		
PES Lignite	2.708 (2.509)	5.446** (2.765)		
PES Other	0.246 (0.970)	−1.547 (1.232)		
PES Waste	−0.238 (1.119)	−1.347 (1.304)		
PES Excess heat	−1.577 (2.448)	−2.983 (2.327)		
PES Wood	0.876 (1.581)	−0.172 (2.127)		
Prior year price index			0.066*** (0.018)	0.045** (0.018)
External procurement	−0.663 (0.840)	1.814* (1.035)	−0.582 (0.939)	1.826 (1.138)
Heat-only plant	0.698 (0.908)	3.390*** (1.214)	0.085 (1.025)	2.966** (1.347)
Steam	−1.426 (1.515)	−0.174 (1.566)	−1.052 (1.761)	−0.215 (1.774)
160 kW	−2.526*** (0.330)	−2.036*** (0.378)	−2.143*** (0.384)	−1.711*** (0.434)
600 kW	−4.109*** (0.335)	−3.745*** (0.384)	−3.679*** (0.391)	−3.402*** (0.441)
Heat sales		0.00001** (0.00001)		0.00001* (0.00001)
Year	1.441*** (0.111)	1.492*** (0.128)	1.476*** (0.124)	1.606*** (0.140)
Intercepts	58.769*** (3.456)	60.914*** (4.273)	46.569*** (4.703)	48.396*** (5.684)
Observations	2,542	1,695	2,015	1,374
R^2	0.318	0.330	0.356	0.362
Adjusted R^2	0.313	0.322	0.353	0.357
F Statistic	440.096***	344.505***	340.352***	276.270***

(Note: Table shows coefficient (error); $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *).

Table A7
Random effects with robust standard errors (panel dataset, 2017–2021)

Variable	Model			
	(1)	(2)	(3)	(4)
Ownership public	−3.784 (2.502)	−4.923** (2.355)	−3.498 (2.995)	−2.707 (3.237)
Ownership regional	−0.727 (1.717)	−2.349* (1.422)	−1.071 (1.510)	−1.645 (1.523)
Heating Degree Days	0.006*** (0.002)	0.006*** (0.002)	0.008*** (0.003)	0.008*** (0.003)
PES *Biogas*	0.985 (0.794)	1.572* (0.701)		
PES *Biomass*	−1.636 (1.165)	−2.597* (1.546)		
PES *Excess heat*	−1.577 (3.972)	−2.983 (3.150)		
PES *Geothermal energy*	1.319 (1.964)	2.363 (1.574)		
PES *Hard coal*	1.316 (1.476)	−1.584* (0.887)		
PES *Lignite*	2.708 (2.295)	5.446** (1.606)		
PES *Other*	0.246 (1.157)	−1.547 (1.475)		
PES *Waste*	−0.238 (1.470)	−1.347 (1.537)		
PES *Wood*	0.876 (1.474)	−0.172 (2.289)		
Prior year price index			0.066*** (0.019)	0.045** (0.019)
External procurement	−0.663 (1.399)	1.814* (1.049)	−0.582 (1.541)	1.826 (1.159)
Heat-only plant	0.698 (1.273)	3.390*** (1.998)	0.085 (1.475)	2.966** (2.310)
Steam	−1.426 (1.289)	−0.174 (1.254)	−1.052 (1.348)	−0.215 (1.415)
160 kW	−2.526*** (0.450)	−2.036*** (0.560)	−2.143*** (0.492)	−1.711*** (0.627)
600 kW	−4.109*** (0.495)	−3.745*** (0.600)	−3.679*** (0.545)	−3.402*** (0.694)
Heat sales		0.00001*** (0.00000)		0.00001** (0.00001)
Year	1.441*** (0.149)	1.492*** (0.180)	1.476*** (0.170)	1.606*** (0.202)
Intercepts	58.769*** (6.235)	60.914*** (6.582)	46.569*** (9.128)	48.396*** (10.105)
Observations	2,542	1,695	2,015	1,374
Adjusted R^2	0.313	0.322	0.353	0.357

((Note: Table shows coefficient (error); $p < 0.01$ ***, $p < 0.05$ **, $p < 0.1$ *).

Data availability

The authors do not have permission to share data.

References

Åberg, M., Fälting, L., Forssell, A., 2016. Is Swedish district heating operating on an integrated market? – Differences in pricing, price convergence, and marketing strategy between public and private district heating companies. Energy Policy (90), 222–232. https://doi.org/10.1016/j.enpol.2015.12.030.

AG Energiebilanzen, 2022. Heizwerte der Energieträger und Faktoren für die Umrechnung von natürlichen Einheiten in Energieeinheiten zur Energiebilanz 2020. https://ag-energiebilanzen.de/wp-content/uploads/2022/04/Heizwerte2005bis2020.pdf.

AGFW, 2022. Hauptbericht 2021. https://www.agfw.de/zahlen-und-statistiken/agfw-hauptbericht.

AGFW, 2023. Preisübersicht 2023-04. https://www.agfw.de/energiewirtschaft-recht-politik/wirtschaft-und-markt/markt-preise/preisanpassung.

Andersson, Werner, 2003. Fjärrvärme I sverige 2001 - en analys av ägande, jämställdhet, priser och lönsamhet I svenska fjärrvärmeföretag med vissa internationella utblickar. District Heating in Sweden 2001 – an Analysis of Ownership, Equality, Prices, and Profitability in Swedish District Heating Companies with Some International Aspects Considered).

Andersson, Werner, 2005. Fjärrvärme I sverige 2003 - en analys av råvaarukostnader, ägande, jämställdhet, priser och lönsamhet I svenska fjärrvärmeföretag. District Heating in Sweden 2003 – an Analysis of Raw Material Costs, Ownership, Equality, Prices, and Profitability in Swedish District Heating Companies).

Bacquet, A., Galindo Fernández, M., Oger, A., Themessl, N., Fallahnejad, M., Kranzl, L., Bürger, V., Köhler, B., Braungardt, S., Popovski, E., Steinbach, J., Billerbeck, A., Breitschopf, B., Winkler, J., 2022. Overview of District Heating and Cooling Markets and Regulatory Frameworks under the Revised Renewable Energy Directive. Publications Office of the European Union. https://data.europa.eu/doi/10.2833/962525.

Biggar, D., Söderberg, M., 2020. Empirical analysis of how political ideology and ownership influence price stability in the Swedish district heating market. Energy Policy 145, 111759. https://doi.org/10.1016/j.enpol.2020.111759.

Biggerson, B.O., 2004. Skäligt pris på fjärrvärme (SOU 2004: 136). https://www.regeringen.se/rattsliga-dokument/statens-offentliga-utredningar/2005/01/sou-2004136/.

Billerbeck, A., Breitschopf, B., Preuß, S., Winkler, J., Ragwitz, M., Keles, D., 2024. Perception of district heating in Europe: a deep dive into influencing factors and the role of regulation. Energy Policy 184, 113860. https://doi.org/10.1016/j.enpol.2023.113860.

Billerbeck, A., Breitschopf, B., Winkler, J., Bürger, V., Köhler, B., Bacquet, A., Popovski, E., Fallahnejad, M., Kranzl, L., Ragwitz, M., 2023. Policy frameworks for district heating: a comprehensive overview and analysis of regulations and support measures across Europe. Energy Policy 173, 113377. https://doi.org/10.1016/j.enpol.2022.113377.

Blömer, R., Billerbeck, A., Winkler, J., 2022. Setting the Scene for Auctions in the Heating Sector. Policy Brief. AURES II. http://aures2project.eu/wp-content/uploads/2022/04/AURES_II_Policy_Brief_heating_auctions.pdf.

Breitschopf, B., Billerbeck, A., 2023. Overview of heating and cooling Perceptions, markets and regulatory frameworks for decarbonisation. Deliverable 1, Meta-Study on Factors Governing Decisions in H&C (Task 1). Publications Office of the European Union. https://data.europa.eu/doi/10.2833/66699.

Bundeskartellamt, 2012. Sektoruntersuchung Fernwaerme: Abschlussbericht gemäß § 32e GWB - August 2012. https://www.bundeskartellamt.de/SharedDocs/Publikation/DE/Sektoruntersuchungen/Sektoruntersuchung%20Fernwaerme%20-%20Abschlussbericht.pdf?__blob=publicationFile&v=3.

Bundesregierung, 2024a. Anteil der Erneuerbaren Energien steigt weiter. https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/faq-energiewende-2067498#:~:text=Deutschland%20soll%20bis%202045%20klimaneutral,Wind%2D%20und%20Solarenergie%20zu%20decken.

Bundesregierung, 2024b. Kommunale Wärmeplanung für ganz Deutschland. https://www.bundesregierung.de/breg-de/aktuelles/waermeplanungsgesetz-2213692#:~:text=Klimaneutrale%20Fernw%C3%A4rme%20bis%202045&text=Die%20W%C3%A4rmeversorgung%20soll%20klimaneutral%20werden,Prozent%20Erneuerbare%20Energie%20eingeleitet%20werden.

Chittum, A., Østergaard, P.A., 2014. How Danish communal heat planning empowers municipalities and benefits individual consumers. Energy Policy (74), 465–474. https://doi.org/10.1016/j.enpol.2014.08.001.

Climate Change Laws. Heat Supply Act no 772/2000, amended by Act no 345/2005 and no 622/2010. Denmark. https://climate-laws.org/document/heat-supply-act-no-772-2000-amended-by-act-no-345-2005-and-no-622-2010_43fe.

Colnerud Granström. EI R2011:08. Analys av fjärrvärmeföretagens intäkts-och kostnadsutveckling. Swedish Energy Markets Inspectorate (Energimarknadsinspektionen). https://ei.se/download/18.d4c49f01764cbd6062189cf/1608302879528/Analys-av-fj%C3%A4rrv%C3%A4rmef%C3%B6retagens-int%C3%A4kts-och-kostnadsutveckling-Ei-R2011-08.pdf.

Croissant, Y., Millo, G., 2008. Panel data econometrics in R the plm package. J. Stat. Software (27). https://doi.org/10.18637/jss.v027.i02.

Djørup, S., Odgaard, O., Sperling, K., Lund, H., 2021. Consumer ownership of natural monopolies and its relevance for the green transition: the case of district heating. Danish Utility Regulator's Anthology Project Series on Better Regulation in the Energy Sector (1). https://doi.org/10.51138/JBBO9030.

Egüez, A., 2021. District heating network ownership and prices: the case of an unregulated natural monopoly. Util. Policy (72), 101252. https://doi.org/10.1016/j.jup.2021.101252.

Eurostat, 2023. Cooling and heating degree days by country - annual data. https://ec.europa.eu/eurostat/databrowser/view/nrg_chdd_a/default/table.

Fraunhofer, I.S.I., Consentec, ifeu, T.B., 2022. Langfristszenarien für die Transformation des Energiesystems in Deutschland (Langfristszenarien 3): T45-Szenarien. https://langfristszenarien.de.

Hvelplund, F., Djørup, S., 2019. Consumer ownership, natural monopolies and transition to 100% renewable energy systems. Energy 181, 440–449. https://doi.org/10.1016/j.energy.2019.05.058.

Johansen, K., Werner, S., 2022. Something is sustainable in the state of Denmark: a review of the Danish district heating sector. Renew. Sustain. Energy Rev. 158, 112117. https://doi.org/10.1016/j.rser.2022.112117.

Krog, L., Sperling, K., Svangren, M.K., Hvelplund, F., 2020. Consumer involvement in the transition to 4th generation district heating. International Journal of Sustainable Energy Planning and Management (29), 141–152. https://doi.org/10.5278/ijsepm.4627.

Linden, M., Peltola-Ojala, P., 2010. The deregulation effects of Finnish electricity markets on district heating prices. Energy Econ. (32), 1191–1198. https://doi.org/10.1016/j.eneco.2010.03.002.

Lund, H., Østergaard, P.A., Chang, M., Werner, S., Svendsen, S., Sorknæs, P., Thorsen, J. E., Hvelplund, F., Mortensen, B.O.G., Mathiesen, B.V., Bojesen, C., Duic, N., Zhang, X., Möller, B., 2018. The status of 4th generation district heating: research and results. Energy 164, 147–159. https://doi.org/10.1016/j.energy.2018.08.206.

Muren, A., 2011. Exploatering eller reglering av naturliga monopol? Exemplet fjärrvärme. Stockholm: Finansdepartementet, Regeringskansliet; Fritze [distributör] http://www.ems.expertgrupp.se/Uploads/Documents/EMS-2011_2-till-webben.pdf.

Mohl, A., 2024. Keine Quersubventionierung durch Fernwärme. ZfK News. https://news.zfk.de/i/_nghndNBqQ3nNHoRV1ut5RNCcocq6S-k.

Odgaard, O., Djørup, S., 2020. Review and experiences of price regulation regimes for district heating. International Journal of Sustainable Energy Planning and Management (29), 127–140. https://doi.org/10.5278/IJSEPM.3824.

R Core Team, 2023. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Statista, 2023. Preis für Fernwärme nach Anschlusswert in Deutschland in den Jahren 1991 bis 2022: (in Euro pro Megawattstunde). https://de.statista.com/statistik/daten/studie/250114/umfrage/preis-fuer-fernwaerme-nach-anschlusswert-in-deutschland/.

Statistisches Bundesamt (Destatis), 2023. Daten zur Energiepreisentwicklung - Lange Reihe. https://www.destatis.de/DE/Themen/Wirtschaft/Preise/Publikationen/Energiepreise/energiepreisentwicklung-xlsx-5619001.html.

Werner, S., 2013. District heating and cooling. Reference Module in Earth Systems and Environmental Sciences. https://doi.org/10.1016/B978-0-12-409548-9.01094-0.

Zaunbrecher, B.S., Arning, K., Falke, T., Ziefle, M., 2016. No pipes in my backyard? Energy Res. Social Sci. (14), 90–101. https://doi.org/10.1016/j.erss.2016.01.008.