RESIDENTIAL DISTRICT HEATING DEMAND IN DENMARK: EMPIRICAL EVIDENCE USING DYNAMIC AND STATIC PANEL APPROACHES

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Overview

Denmark has one of the most developed district heating networks worldwide, which provides heat (both for space heating and hot water consumption) to almost two thirds of its households. In 2019, district heating consumption in the residential sector alone represented 11% of Danish final energy consumption (Danish Energy Agency, 2019). In the near future, a higher demand for district heating coupled with higher shares of renewable energy in the power sector is expected. This creates both opportunities and challenges for the district heating sector and policymakers, amplifying the role of the residential sector in the energy transition. Reducing residential district heating demand while accelerating the transition towards clean energies is therefore crucial for meeting Denmark's climate and energy goals. Whether this will happen largely depends on the nature of the policy response.

Knowledge of the households' responsiveness to district heating price changes and drivers of consumption is relevant for the design of energy and climate policy such as taxation and for the assessment of the welfare consequences of such measures. Furthermore, insights into price elasticities and determinants of energy consumption can inform future needs and trends in energy demand and supply and improve the design of targeted energy-efficiency policies. In this context, this study contributes to the scarce literature on district heating demand by providing empirical evidence using a large-scale data set.

Methods

We investigate the demand for district heating in Danish households over the period 2015-2019. The data encompasses annual district heating consumption of households living in single-family detached houses and price information from 299 utilities provided by the Building and Housing Register. Consumption and price data are combined with households and dwelling information from Statistics Denmark. Moreover, we add heating degree days to the date, which are derived from daily average temperature data provided by the Danish Meteorological Institute on the municipality level. The final unbalanced panel data consists of 115,502 Danish households.

For our analysis, we employ the two-step system generalized method of moments (GMM) estimator developed for dynamic models of panel data by Blundell and Bond (1998), which is particularly suitable for panel data with large units of observation and small time periods. The main advantage of this estimator over a static model lies in its ability to account for the interdependence of consumption decisions over time (captured by the lagged dependent variable in the right-hand side of the demand equation) and to deal with endogeneity issues. The change in actual energy demand between two periods (*t-1* and *t*) is some fraction of the difference between the logarithm of actual energy demand in period *t−1* and the logarithm of the long-run equilibrium demand in period *t*. Also, the flexible GMM framework accommodates more than one endogenous variable, which in our case are the lagged district heating consumption and the price variables. Therefore, the district heating demand function is specified as follows:

$$\begin{aligned} lnDH_{i,t} = a_0 + a_{DH} lnDH_{i,t-1} + a_P lnP_{i,t} + a_{HI} lnHI_{i,t} + a_{Hs} lnHs_{i,t} + a_{DY} DY_{i,t} \\ + a_{LA} lnLA_{i,t} + a_{HA} HA_{i,t} + a_{GO} GO_{i,t} + a_{HDD} lnHDD_{i,t} + a_T T_t + \varepsilon_{i,t} \qquad (1) \end{aligned}$$

where $DH_{i,t}$ is the district heating consumption (kWh) of household i in year t and $DH_{i,t-1}$ is the lagged district heating consumption. $P_{i,t}$ is the average price of district heating. $HI_{i,t}$ and $HS_{i,t}$ denote household characteristics such as household disposable income and household size, respectively. $DY_{i,t}$ and $LA_{i,t}$ are vectors of dwelling characteristics such as dwelling year and living area square footage. $HA_{i,t}$ is a dummy variable indicating whether a household received heating allowance. $GO_{i,t}$ indicates the government office regions, while $HDD_{i,t}$ captures the heating degree days , thus controlling for differences in geography and weather. T_t represents the year dummy variables and $\varepsilon_{i,t}$ is the disturbance term. For comparison purposes only, we report the results of other dynamic models (Blundell-Bond one-step system GMM, Arellano-Bond one-step difference GMM) and static models (pooled OLS, random effect, fixed effect).

Results

Table 1 shows selected estimation results of the dynamic and static models.

Table 1. Selected estimation results of dynamic and static models of district heating demand (2015-2019).

	Dynamic models			Static models		
Variables	**Blundell-Bond Two-step system GMM**	**Blundell-Bond One-step system GMM**	**Arellano-Bond One-step difference GMM**	**Fixed effect**	**Random effect**	**Pooled OLS**
Lagged ln(DH consumption)	0.254***	0.243***	0.184***	-	-	-
Ln(DH price)	-0.489***	-0.545***	-0.367***	-0.913***	-0.815***	-0.797***
Ln(household income)	0.0303***	0.0290***	0.0146	0.00902	0.0229***	0.0257***
Ln(household size)	0.0155***	0.0145***	0.0356	0.0250*	0.0190***	0.0186***
Ln(living area square footage)	0.308***	0.304***	0.338**	0.323***	0.396***	0.395***
Ln(HDD)	0.682***	0.730***	0.253	0.457***	0.680***	0.788***
Dwelling year	Yes	Yes	No	No	Yes	Yes
Gov. regions	Yes	Yes	No	No	Yes	Yes
Heating allow.	0.0340***	0.0332***	No	No	0.0477***	0.0503***
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.795***	3.822***	-	6.614***	5.966***	5.706***
Number of observations	12,662	12,662	1,209	134,162	133,938	133,938
Number of instruments	25	25	14			
Arellano-Bond test for AR(1)	$z = -2.5$; $p = 0.012$	$z = -2.45$; $p = 0.014$	$z = -2.24$; $p = 0.025$			
Arellano-Bond test for AR(2)	$z = -1$; $p = 0.316$	$z = -1.02$; $p = 0.308$	$z = -1.09$; $p = 0.277$			
Hansen test of overid. restrictions	$\chi^2(5) = 8.28$; $p = 0.141$	$\chi^2(5) = 8.28$; $p = 0.141$	$\chi^2(5) = 5.07$; $p = 0.407$			
Long-run price elasticity	-0.66***	-0.72***	-0.45***			

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors omitted.

Based on our preferred method – the Blundell-Bond two-step system GMM, we find that the short-run price elasticity is -0.489, while the long-run price elasticity is -0.66. Moreover, district heating consumption increases by 3% as household disposable income increases by 10%. In addition, consumption increases by about 31% and 3% for a 10% increase in living area square footage and heating degree days, respectively (*ceteris paribus*). The Arellano-Bond test for AR(2) indicates the absence of second-order serial correlation in the error term, while the Hansen test confirms the validity of the instruments.

Conclusions

This study uses household-level longitudinal data and employs both dynamic and static models to estimate residential district heating demand in Denmark spanning the period 2015-2019. Our analysis shows that the price elasticity ranges between -0.49 and -0.66. Moreover, we reveal how socioeconomic and dwelling attributes influence district heating consumption. From an energy and climate policy perspective, these findings suggest that increasing the carbon taxes can reduce district heating consumption and encourage residential energy efficiency investments. However, such measures require the consideration of distributional impacts.

References

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