Heterogeneity in price responsiveness of electricity: contract choice and the role of media coverage

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Abstract

In this paper, I estimate the price elasticity of electricity as a function of contract choice. Further, I explore how the media coverage of electricity prices affects electricity demand, both by augmenting price responsiveness and as a direct effect of media coverage on electricity demand, independent of prices. The parameters in the model are estimated using a unique and detailed Swedish panel data on monthly household-level electricity consumption. I find that price elasticities range between -0.025 and -0.07 at the mean level of media coverage, depending on contract choice, and that households with monthly variation in electricity prices respond more to prices when media coverage of electricity prices is extensive. When media coverage is high, for example 840 news articles per month (which corresponds to the mean plus two standard deviations), the price elasticity is -0.12, or 1.7 times the elasticity at the mean media coverage. Similarly, media coverage is also found to have a direct effect on electricity demand.
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1 Introduction

In this paper, I propose an empirical model of residential electricity demand where households face different prices (and price variation) depending on their choice of electricity contract, which may be endogenous to electricity usage. The parameters in the model are estimated using unique and detailed data on the monthly residential electricity demand of roughly 54000 Swedish households. Two important topics in residential electricity demand regarding differences in price responsiveness across contract types are explored.

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First, households on electricity contracts with prices varying by month (variable-price contracts) are exposed to more price variation than households on contracts where prices are fixed for a year or longer (fixed-price contracts). The former are therefore expected to be more price elastic in the short run. Failing to consider that households on fixed-price contracts presumably have a short-run price elasticity of demand close to or equal to zero (because they face little or no short-run price variation) could potentially underestimate the demand elasticity. In particular, households may be more price sensitive than previously thought, conditional on contract choice.

Second, households on variable-price contracts are assumed to lack perfect information about electricity prices, which limits their behavioral response to price fluctuations. For example, it can be costly to stay informed of a price that varies by month, and billing information can be difficult to understand. Ex-post billing adds to this effect. This might lead to a potential welfare loss: people consume too much or too little electricity, compared to what would be the case if they had perfect information about the price. However, most Swedish households are assumed to read the newspaper (http://www.tns-sifo.se), where the electricity price typically is a hot topic, with up to 1200 news articles per month in printed media containing the word *elpris*, which is the Swedish word for electricity price (see Section 3). Further, it might be the case that news articles about electricity prices are easier to understand than billing information, which often is perceived as complicated (e.g., Borenstein (2009), Ito (2014) and Kažukauskas and Broberg (2015)). Households on variable-price contracts are therefore more exposed to price information when the media coverage of electricity prices is extensive, and media coverage of electricity prices can be thought of as reinforcing price signals. Consequently, households on variable-price contracts are expected to respond more to prices when the media coverage is substantial.

In comparison, it should be much easier for households on fixed-price contracts to keep track of the price, since it is constant over time. Further, media coverage typically reports about short-run variation in prices, and is therefore correlated with the variable price, but not with the fixed price (within a contract period). In particular, one of the reasons for choosing fixed-price contracts is to not have to worry when reading about high electricity prices in the news. For example, a popular Swedish website with comparisons of electricity contracts explains that "The benefit of a fixed electricity price is that you do not need to worry about fluctuations in the electricity price on the electricity exchange during your contract period"; see http://www.elskling.se/fragor-och-svar/. In fact, it would make little sense for a household on a fixed-price contract to decrease its usage in response to (media coverage of) high variable prices. The short-run price responsiveness for households on fixed-price contracts is therefore assumed to be independent of the media coverage.

The media coverage of electricity prices might, however, affect these households in other ways. For example, recent literature has illustrated how non-monetary measures such as information have a significant effect on electricity demand; see for example Allcott (2011c), Delmas et al. (2013), Delmas and

Lessem (2014) and Kažukauskas and Broberg (2015).

The law of demand assumes that consumers know prices, an assumption that is not necessarily satisfied in markets where households have imperfect information about prices, such as the retail market for electricity where households face ex-post billing. Recent literature on electricity demand has indeed questioned the idea that households are perfectly informed and can easily respond to changes in the electricity price; see, for example, Shin (1985), Borenstein (2009), Allcott (2011a), Ito (2014), Sexton (2015) and Kažukauskas and Broberg (2015).[1] The general findings in this literature are that households lack perfect information about prices as well as usage levels and the cost of using specific appliances. This should be the case in particular for households with electricity contracts where prices vary by month, where it may be difficult and costly to keep track of prices.

If households lack perfect information about, or are inattentive to, variation in electricity prices, we would expect price elasticities to be close to zero. For example, previous empirical literature typically finds price elasticities of residential electricity demand to be negative but close to zero, in many cases around -0.1; see, for example, Nesbakken (1999), Brännlund et al. (2007), Fell et al. (2014) and Krishnamurthy and Kriström (2015). Further, previous literature suggests that increasing information about prices and usage has a significant effect on economic behavior and price responsiveness in general and on energy and water demand in particular. For example, Parti and Parti (1980) find that the price elasticity varies across months and argue that months when households are more price sensitive are associated with extensive media coverage of electricity prices (but do not explicitly model the role of media). Ek and Söderholm (2008) find that the probability of switching to another electricity supplier is higher for households that follow the Swedish media debate about the electricity price. Allcott (2011b) explores the response to real-time pricing, and finds that reducing the cost of observing and responding to energy prices can substantially affect households' behavior. Jessoe and Rapson (2012) present experimental evidence that information feedback dramatically increases the price elasticity of electricity in a setting where signals about quantity consumed are coarse and infrequent. Li et al. (2012) illustrate how consumers respond more to tax-induced price changes in gasoline than to corresponding producer price increases, and argue that this effect is related to media coverage. Sexton (2015) studies salience effects of automatic electricity bills and finds that automatic bill payments increase electricity consumption, suggesting that households have a downward-biased perception of electricity prices. See also, for example, DellaVigna (2009) for a review on empirical behavioral economics in general.

Given that previous studies have found price elasticities to be close to zero, the findings that information augments price responsiveness are clearly of interest to policy makers trying to affect behavior through price-driven policies.

[1] Recent literature on the so-called energy efficiency gap also suggests that households have incomplete information about energy consumption behavior, which may cause inefficiencies on energy markets; see, for example, Sanstad and Howarth (1994), Allcott and Greenstone (2012) and Gillingham and Palmer (2014).

However, none of the papers above explicitly models the role of media and how it affects price responsiveness, even if media very well might be one important channel through which households receive information about electricity prices. In particular, information through media is easily available, extends to large masses of people and provides information to the public on various topics, including information about electricity prices. Further, differences in price responsiveness across the types of contracts described above have never been studied before, as far as I am aware. One explanation might be that such analysis requires detailed household-level information about both electricity prices and electricity contracts, which is rarely available. This paper is therefore an important contribution to the literature on residential electricity demand. This paper also adds to the previous literature by providing more recent estimates of residential price elasticities for Sweden, using panel data with a substantially larger sample size than most other studies using Swedish data. Finally, I address the endogeneity of electricity contract choice by using predicted probabilities from a probit model of contract choice as an instrumental variable for the endogenous variable, as suggested by, e.g., Wooldridge (2010).

The rest of this paper is structured as follows. Section 2 outlines the empirical model of price responsiveness as a function of contract type and media coverage. Section 3 describes the data, followed by estimation and results in Section 4. Section 5 concludes.

2 Empirical model

Since the deregulation of the Swedish electricity market in 1996, households are free to choose between more than 100 different electricity retailers, each offering various types of electricity contracts (or tariffs). The most common is either have a contract where the price is fixed for a year or more, or a contract with prices varying by month. Households on variable-price contracts are assumed to have imperfect information about electricity prices, in the sense that they have a biased perception about prices and therefore use a level of electricity that differs from how much they would use if they had perfect information about electricity prices (similar to Kažukauskas and Broberg (2015) and Sexton (2015)). However, it seems reasonable to assume that most households read the newspaper, where variation in electricity prices is a frequent topic (see Section 3). Typical headlines have included "Second winter in a row with large electricity expenditure" (Dagens Nyheter 2010-12-17) as well as "historically low electricity prices" (Dagens Nyheter 2011-12-31). In this paper, media coverage is defined as the number of news articles per month in Swedish printed media containing the Swedish word *elpris*. As such, it does not contain information about the price level and should be thought of as mainly reinforcing the price signal, irrespective of what the price might be. Obviously, there are other sources of information where households learn about electricity prices. However, printed media is readily available to all households, whereas access to other sources of information, for example social media, most likely differs across households.

Therefore, this paper focuses solely on the role of printed media.

Media coverage is expected to affect demand in two separate ways. First, for households on variable-price contracts, it is assumed to augment the price by providing comprehensive and noticeable information about variations in electricity prices. In particular, these households are assumed to learn about the price in media and therefore respond more to prices when media coverage of electricity prices is extensive. Throughout the rest of the paper, I refer to this effect of media as the augmenting effect of media. Because households on fixed-price contracts are never exposed to short-run fluctuations in price, it is assumed that the media coverage does not augment their price responsiveness.

Secondly, media coverage may also have a direct effect on electricity usage, which is independent of prices and therefore also independent of contract choice. As mentioned in the introduction, several papers have recently shown that non-monetary measures such as information and nudges about electricity prices, or about how much a household is consuming in comparison to other households, have a significant effect on demand; see, for example, Allcott (2011c), Delmas et al. (2013), Delmas and Lessem (2014) and Kažukauskas and Broberg (2015). In the current context, it could be the case that news reports about electricity increase awareness of electricity usage in general. This effect is referred to as the direct effect of media. However, as discussed above, note that, because media coverage is defined as the number of articles containing the word *elpris*, irrespective of whether the price was high or low, any direct effect of media coverage can be either positive and negative.

By ignoring heterogeneity across contract types for now and focusing solely on the augmenting and direct effects of media coverage on electricity demand, these effects can be modeled in a straightforward way by including the interaction between price and media, together with separate effects of these two variables, in a demand function for electricity,

$$q_{it} = f\left(p_t, m_t, p_t \times m_t\right) \tag{1}$$

where i indexes household and t indexes time, q_{it} is the quantity of electricity demanded, p_t is the electricity price and m_t is media coverage. $\partial^2 q_{it}/\partial p_t \partial m_t$ is the augmenting effect of media and $\partial q_{it}/\partial m_t$ is the direct effect of media coverage. Separate identification of these two effects of media is then relatively straight-forward using, for example, a linear specification for the demand function. To allow price responsiveness to differ across contract types, Equation 1 can be extended by the inclusion of a dummy variable describing contract choice interacted with both the variable price and media.

Consider the demand function which includes both contract choice and media coverage,

$$q_{it} = \zeta p_t^v c_{it} + \theta p_t^f \left(1 - c_{it}\right) + \alpha p_t^v m_t c_{it} + \xi m_t + \mathbf{x}_{it}'\eta + \vartheta_i + \varepsilon_{it} \tag{2}$$

where p_t^v is the variable price and p_t^f is the fixed price. Which of these two prices household i faces depends on the household's choice of contract. c_{it} is a dummy variable taking the value one if household i has a variable-price contract

at time t and zero otherwise. m_t is the number of articles in printed Swedish media containing the word *elpris*. $\mathbf{x}_{it}$ is a vector of household characteristics and time dummy variables. ϑ_i is a household-specific effect. $\zeta, \theta, \alpha, \xi$ and η are parameters that can be estimated using, for example, a fixed-effects estimator. However, note that the within-household variation in many economically relevant variables typically is small or even zero; examples include housing type, heating system, living area size and other household characteristics. Similarly, the within-household variation in prices for households on fixed-price contracts is small for obvious reasons (the price is fixed during the contract period but may vary across contract periods). An obvious alternative is using a random effects estimator, but the assumption that unobserved heterogeneity is independent of observables is typically a strong assumption.

For households with variable prices ($c_{it} = 1$), the partial derivative of electricity usage with respect to the variable price is

$$\frac{\partial q_{it}}{\partial p_t^v} = \alpha m_t + \zeta \tag{3}$$

so that, the price responsiveness is a function of media coverage for $\alpha \neq 0$. The augmenting effect of media coverage on price responsiveness for these households is

$$\frac{\partial^2 q_{it}}{\partial p_t^v \partial m_t} = \alpha \tag{4}$$

so that for $\alpha < 0$, households on variable-price contracts are more price responsive when media coverage is high. For households on fixed-price contracts ($c_{it} = 0$), the derivative of electricity usage with respect to the fixed price is θ, which is expected to be non-positive and may be different from zero if households respond to price changes across contract periods. Further, since households on variable-price contracts are exposed to more price variation than households with fixed-price contracts, I expect $\alpha m_t + \zeta < \theta$, i.e., that the price responsiveness for households on fixed-price contracts is closer to zero than for households on variable-price contracts. The direct effect of media is

$$\frac{\partial q_{it}}{\partial m_t} = \alpha p_t^v c_{it} + \xi \tag{5}$$

which differs across contract types.

Electricity contract choice is assumed to be endogenous. In particular, electricity usage is assumed to be a determinant of the electricity contract type, because households with high electricity usage might feel more vulnerable to variations in the price and are therefore more likely to choose fixed-price contracts; see, e.g., Ericson (2011), SCB (2014) and Vesterberg (2017). For example, consider two households with similar characteristics such as income, family size and location, but with one household using more electricity. This could be the case if one household has electric heating and the other household has district heating. The household with high electricity usage will then face larger increases in electricity expenditure in case of price peaks. Assuming they have

similar risk preferences, we would expect this household to be more likely to choose a fixed-price contract. This implies that any electricity demand function with electricity contract choice as a right-hand side variable suffers from simultaneity bias. Further, all interaction terms in Equation 2 that involve c_{it} are endogenous.[2]

If instrumental variables for contract choice exist, a 2SLS approach can be used to get unbiased estimates of the parameters in Equation 2. To find such instrumental variables, consider possible determinants of contract choice. For example, one determinant for contract choice that is correlated with contract choice but exogenous to electricity usage is previous contract choice. As illustrated in Vesterberg (2017) (see also SCB (2014)), there is substantial state dependence in contract choice, which can be explained by, for example, transaction costs. Previous contract choice is therefore assumed to be correlated with current contract choice, but there are no reasons to believe that previous contract choice affects current electricity usage except via the current choice of contract.

Another instrumental variable that fulfills the exclusion criteria is previous variable prices, e.g., the maximum variable price during the last 12 months. For example, if the variable price was very high during the previous 12 months, ceteris paribus, the household might believe that the price is going to remain high, and is assumed to be more likely to choose a fixed-price contract. However, the variable prices during the last 12 months should not affect current consumption, so previous price is exogenous to current electricity usage. Obviously, this hinges on the assumption that households do not substitute electricity across months, which appears to be a reasonable assumption. These two instrumental variables can then be used as instruments for the endogenous variables in a 2SLS model. As explained in, for example, Heckman et al. (1978) and Wooldridge (2010), there are no special considerations in estimating Equation 2 by 2SLS when the endogenous variable is binary. However, Wooldridge (2010) show that using a three-stage approach improves efficiency (Chap. 24.1, pp 937 in 2^{nd} ed.). First, a probit model is estimated for the choice of electricity contract using the instrumental variables as regressors in addition to the exogenous variables in $\mathbf{x}_{it}$. The predicted probabilities from this model, interacted with price and media, can then be used as instruments in a 2SLS model. This approach is similar to the one used in the seminal paper by Dubin and McFadden (1984) when model-

[2]Note that the current paper considers electricity demand conditional on electricity contract choice, which is endogenous, and does not consider electricity demand and contract choice as simultaneous decisions. This approach is plausible when there is substantial state dependence in contract choice and households tend to stick to one type of contract irrespective of price variation, as illustrated in Vesterberg (2017). An alternative approach would be to model the choice of contract and the demand for electricity as joint decisions, but such analysis is outside the scope of this paper for two main reasons. First, with price responsiveness of contract choice being very small and households only switching infrequently between contracts, such analysis would most likely not change the qualitative results in the current paper. Second, there are no straightforward applications of joint discrete-continous choice frameworks for panel data when households base their decisions on imperfect information, and where the discrete choice is dynamic, as far as I am aware.

ing heating system choice and electricity demand as joint decisions. The 2SLS standard errors are asymptotically valid (Wooldridge (2010)).

Since the endogenous variable is a choice variable, it is tempting to consider the probit model as a representation of the contract decision. However, note that, in the 2SLS framework, the instruments do not need any reasonable economic interpretation. In particular, the reduced-form equation in the first stage of the 2SLS is just a linear projection of the endogenous variable on the exogenous variable, even when the endogenous variable is a binary choice variable, and need not necessarily have a structural interpretation. The same is true if using instruments generated from the probit stage in the current framework; the main purpose of using a probit stage is to improve the efficiency of the estimator. Even if ignoring the probit stage, the 2SLS estimator will be consistent, albeit less efficient than it could be if we were to take into account the non-linear nature of the endogenous variable (Wooldridge (2010)). The approach outlined above should not be confused with the typical 3SLS as in, e.g., Zellner and Theil (1962).

The probit model is defined as

$$f_{it}\left(y_{it}|y_{it-1},\mathbf{z}_{it}\right)=\Phi\left(\beta\tilde{p}_{t}^{v}+\rho y_{it-1}+\mathbf{x}_{it}^{\prime}\theta\right) \tag{6}$$

where $y_{it}=1$ if household i has a variable-price contract at time t, y_{it-1} is the lagged dependent variable and $\tilde{p}_t^v$ is the maximum variable price during the last 12 months.[3] As in Equation 2, $\mathbf{x}_{it}$ is a vector of household characteristics and time dummy variables, and includes housing type and heating system, income, education, age, outside temperature, postal area and month and year dummy variables. Note that, even if time-invariant variables in $\mathbf{x}_{it}$ drop out from Equation 2 when using a fixed effects framework, they may still be included in the probit stage. The predicted probability of choosing a variable-price contract, denoting this probability by $\hat{c}_{it}$, can then be used to generate $p_{it}^{v}\hat{c}_{it}$, $p_{it}^{f}\left(1-\hat{c}_{it}\right)$ and $p_{it}^{v}m_{t}\hat{c}_{it}$ which, together with the exogenous variables in $\mathbf{x}_{it}$, are then used as instrumental variables for $p_{it}^{v}c_{it}$, $p_{it}^{f}\left(1-c_{it}\right)$ and $p_{it}^{v}m_{t}c_{it}$ in a 2SLS estimation of Equation 2. A more elaborate analysis of electricity contract choice is presented in Vesterberg (2017). As illustrated in Wooldridge (2010), the probit stage is robust to misspecification.

Returning to the demand function in Equation 2, prices are assumed to be exogenous to the individual household, conditional on contract choice. In Sweden, households typically face constant marginal prices as compared to the more common increasing-block pricing structure found in, e.g., the US. Further, a household buying electricity on the Nordic market is assumed too small to be able to affect the equilibrium electricity price determined by aggregate demand and supply. Therefore, the price is assumed to be exogenous, in line with previous literature on residential electricity demand in the Nordic market (e.g., Nesbakken (1999) and Krishnamurthy and Kriström (2015)).

[3]Other specifications of previous prices, such as lagged prices, give very similar results. Results are also similar if only using previous contract choice in the probit model.

In addition to prices, contract choice and media coverage, electricity usage is typically assumed to depend positively on income, family size and age. Similarly, villas with electric heating are assumed to use more electricity than villas without electric heating, and flats are assumed to use even less electricity. Further, electricity usage is expected to depend negatively on outdoor temperature. In addition, I include month and year dummy variables to control for seasonal and year-specific effects. Note that the inclusion of monthly dummies may capture some of the seasonal variation in media coverage and prices, so estimates may be on the conservative side.

3 Data

The parameters in the demand function and the probit model outlined above are estimated using unique monthly data from the customer database from Skellefteå Kraft, one of the biggest electricity retailers in Sweden, with a sample size of 54548 households observed between July 2010 and June 2014. The source material has been anonymized and identification of unique households is not possible. Of the households in the data, 12029 live in flats and the remaining households live in villas. 22641 households have had a variable-price contract during the period, and the corresponding figure for fixed-price contracts is 37549. The data only include households on these types of contracts, and for example, no households on contracts with prices varying by hour. Only 11 percent of the households in the data have switched between the two contract types during the period.

With only data on households from one supplier out of many in Sweden, there is the obvious risk that the data used in this paper is not representative of the Swedish population, and that the results cannot readily be generalized to households buying electricity from other suppliers. However, I argue that electricity demand as well as the choice of electricity contracts for customers of Skellefteå Kraft are similar in most aspects to the corresponding choices from other retailers. Most importantly, the electricity retail market in Sweden is a competitive market, and retailers are expected to be similar in terms of prices and other contract attributes. Electricity demand and the choice between different contract types from this particular retailer are therefore expected to be comparable to electricity demand and the choice between contracts from other retailers, and the qualitative results from this study are expected to hold for most of Sweden.

As illustrated in Figure 1, most of the households in the data are located in the northern part of Sweden, whereas the Swedish population is concentrated in the middle and south of Sweden. In particular, more than 70 percent of the households in the data are located in the same postal area as the supplier. This is expected, since one important determinant of supplier choice is assumed to be geographical location and closeness to the supplier. For example, Goett et al. (2000) and Revelt and Train (2000) demonstrate that households prefer their local company to any other supplier. I explore regional differences in terms of

price responsiveness in Section 4. Apart from variations in temperature, household characteristics that may differ across regions, such as building standards and heating systems, are typically fixed in the short run and are accounted for by the household-specific effect in Equation 2. Further, regional differences in the choice of electricity contract are explored in Vesterberg (2017). In general, both the choice of electricity contract and the demand for electricity (including the effect of media coverage) appear to be similar across regions. Still, some caution is appropriate when generalizing the result to the whole Swedish population, and this paper should be thought of as establishing a first baseline for further investigation of different aspects of heterogeneity in price responsiveness across contract types and how media coverage affect price responsiveness.

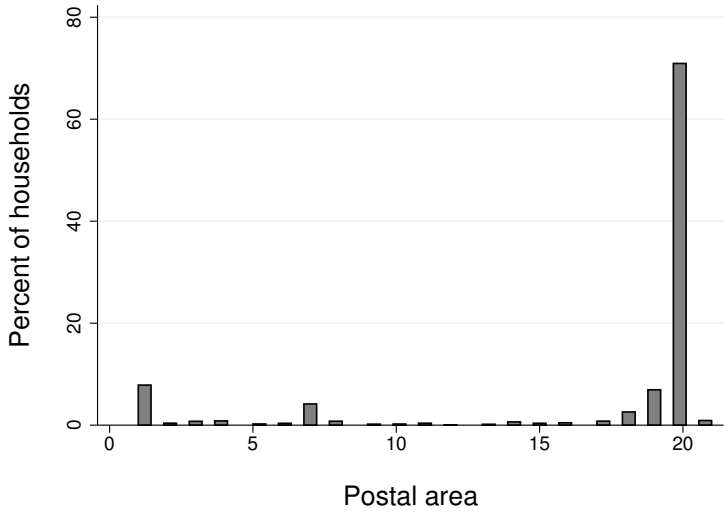


Figure 1: *Location of households. Postal area 1 is Stockholm, postal area 7 is Gothenburg, postal area 19 is Umeå and postal area 20 is Luleå (which includes Skellefteå, the location of the supplier).*

In addition to contract choice, electricity usage and prices, the data includes information about housing type (villa or flat) and heating system (electric heating or not). Unfortunately, the customer database lacks any household-level information about income and other household characteristics and only includes socio-economic information at the zip-code level using census data with figures from 2014 for annual per-capita income, family size, age and education level. Matching individual- or household-level data with zip code-level data is frequently used in economics, and examples include most notably residential electricity demand (Borenstein (2012) and Ito (2014)). The lack of variation over time for the zip-code level variables is an obvious shortcoming of the data, but to a large extent is a reflection of reality. Note that, for example, family

size and education levels typically are relatively constant in the short run. Similarly, housing type and heating system are also fixed, and variation in income - especially at the zip-code level - is expected to be small. Further, although income typically increases slightly over time, the variation in income over time is often common to all households and is easily accounted for by yearly dummy variables. Similarly, region-specific variation over time can be accounted for by including year-by-region fixed effects. Obviously, this accounts for all region-specific attributes and not only income. Further, one may argue that what matters to electricity demand is income levels. High-income households may use more electricity than low-income households (e.g., Vesterberg (2016)), and it might also be the case that households differ in behavior across income levels. For example, low-income households may be more attentive to prices and therefore expected to be more price responsive even in the absence of media coverage. If one is willing to assume that income levels are constant in the short run, heterogeneity in electricity demand across income levels can be explored by estimating separate models for each income group. While this is different from exploring how electricity usage is affected by income variation, it allows for exploration of heterogeneity across income levels in, for example, price responsiveness. Because income is measured at the zip-code level, such division of the data might also capture other zip-code specific characteristics. All these different approaches to account for possible effects of income are explored and discussed in Section 4. Finally, note that matching the customer database with survey data would only solve the problem of time-invariant characteristics if repeated surveys were collected for each year, and variation would still be expected to be limited. The same would be the case if using yearly zip-code level averages of household characteristics.

Monthly average postal-area temperature is available from SMHI (the Swedish Meteorological and Hydrological Institute; see http://opendata-download-metobs.smhi.se/explore/#) and is used to account for region-specific temperature variation. The media variable is acquired from the Retriever database (www.web.retriever-info.com). This variable is defined as the number of newspaper articles per month containing the word *elpris* or inflexions of this word in printed Swedish media. The newspapers included are the most popular newspapers in Sweden: Aftonbladet, Dagens Nyheter, Svenska Dagbladet and Expressen, all of which are available throughout the country (see http://www.tns-sifo.se). All of these newspapers are available online in addition to the printed edition, but some articles might require a subscription in order to access them.

Summary statistics are illustrated in Table 1. Since differences across contract types are of interest in the paper, descriptive statistics are illustrated for all households and also separately for households with fixed-price contracts and households with variable-price contracts.

The average price for variable-price contracts is 0.443 SEK/kWh[4], and for fixed-price contracts is 0.487 SEK/kWh. Also note the larger standard deviation for variable-price contracts than for fixed-price contracts. The prices in Table

[4]One SEK is approximately 0.11 Euro.

Table 1: *Descriptive statistics for all households and by contract type*

	All households		Fixed-price contracts		Variable-price contracts	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Media coverage	400.520	220.874				
Price (SEK/kWh)	0.484	0.088	0.487	0.073	0.443	0.118
Temperature (Celsius)	4.686	8.200	4.302	8.104	5.381	8.333
kWh, villas (electric heating)	1495.543	991.292	1525.435	996.524	1419.720	973.791
kWh, villas (non-electric heating)	1091.308	890.178	1117.141	900.070	1040.751	868.273
kWh, flats	364.183	498.633	411.579	562.305	308.243	403.888
Income (1000 SEK)	273.932	51.451	269.378	44.122	282.575	62.151
Age	49.339	4.581	49.589	4.393	48.866	5.064
	Share		Share		Share	
Family size	0.37		0.37		0.38	
Education	0.18		0.14		0.24	
Electrically heated villa	0.32		0.35		0.28	
Non-electrically heated villa	0.46		0.47		0.45	
Flat	0.22		0.18		0.27	
No. of households	54548		37549		22641	

Notes: i) Media coverage is identical for all contract types. ii) Temperature can differ across contract types if there is correlation between location and contract choice. iii) Family size is the share of households with more than two persons living in the household. iv) Education is the share of households with a university degree as the highest education. v) Electrically heated villa is the share of households living in a villa where electric heating is the main heating system, Non-electrically heated villa is the share of households living in a villa where electric heating is not the main heating system. Flat is the share of households living in a flat.

1 are prices excluding taxes, transmission fees and certificate fees (roughly 0.6 SEK/kWh in total) that are common to both types of contracts, and typically do not change very frequently. See Vesterberg (2017) for a brief description of the total cost of electricity. The average number of articles per month in Swedish printed media containing the word *elpris* is 400 but with substantial variation across months, as illustrated by a standard deviation of 221. To understand how media coverage is associated with prices, Figure 2 illustrates media coverage and the variable price over time. Although the data period starts in July 2010, prices and media coverage are available before the data period.

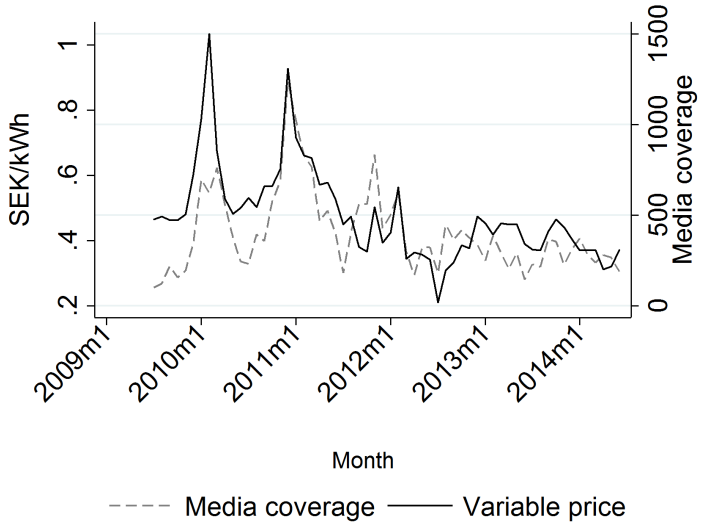


Figure 2: *Price and media coverage by month*
Notes: i) The variable price is the wholesale price, excluding taxes, transmission fees and certificate fees. ii) Media coverage is the number of articles per month containing the word elpris, the Swedish word for electricity price, or inflexions of this word.

During the first part of the data period, there is a distinct seasonal pattern in both media coverage and prices, with high prices and high media coverage during winter months. The variable price was very high during early 2010 and during the winter of 2010/2011. This was due both to cold temperatures and to disruption in some of the nuclear reactors in Sweden (Energimarknadsinspektionen (2012)). These periods were also associated with high media coverage, with roughly 700 to 1200 news articles about electricity prices. However, there are also periods with low prices but high media coverage. For example, media coverage was relatively high during late 2011 even though prices were low. Note that the relatively substantial media coverage during this period might be explained either by media writing about the unusually low price, or by expectations of

high prices after two cold winters in a row, or a combination of the two. After this period, both prices and media coverage have been relatively low. During the data period, the correlation between the variable price and the number of news articles per month about electricity prices is 0.7. Comparing with a given fixed-price contract, where prices are fixed for, e.g., a year, the correlation with media coverage is obviously zero within the contract period.

Average monthly electricity usage is 1495 kWh for electrically heated villas, 1091 kWh for non-electrically heated villas and 364 kWh for flats. Further, for all housing types, usage is somewhat smaller for households on variable-price contracts than for households on fixed-price contracts. The large standard deviation in usage illustrates both variation across households (e.g., floor area) and variation across months. For example, average usage in February for a villa with electric heating is 2306 kWh, whereas the corresponding figure for June is 729 kWh. Also note that the outside temperature, which is expected to be negatively correlated with electricity usage, is higher for households with variable-price contracts. Since the average temperature varies across location, this suggests that households on variable-price contracts live in relatively warmer places.

The average annual per capita income is 274000 SEK, to be compared with figures from Statistics Sweden for the whole population of roughly 300000 SEK for the year 2014 (see www.scb.se). Since income is a zip-code level average and most households in the sample are located in the northern part of Sweden, this difference only illustrates geographical differences in income, where income typically is higher in southern Sweden. Also note that households on variable-price contracts on average have higher income than households on fixed-price contracts. Age is similar across contract types and somewhat higher than the population average of 41.2 years. While family size is similar across contract types, the education level is higher for households on variable-price contracts. Both family size and education level correspond roughly to population figures. Finally, a large majority of the sample live in villas, and only 22 percent live in flats, which is likely explained by a large part of the sample living in relatively sparsely populated northern Sweden, where villas are more common.

4 Results

The parameters in the probit model in Equation 6 are estimated using the `probit` command in Stata, and the resulting predicted probabilities are used to generate the instruments $p_{it}^v \hat{c}_{it}$, $p_{it}^f (1 - \hat{c}_{it})$ and $p_{it}^v m_t \hat{c}_{it}$. These instruments are then used to estimate the parameters in Equation 2 using a fixed-effects 2SLS with bootstrapped standard errors (`xtivreg` in Stata). The results from the probit model can be found in the Appendix. The F-value for the first stage of the 2SLS is very large for all three instruments. Results from the first stage estimation of the 2SLS are available upon request, and the results from the second stage (i.e., estimates of the parameters in the demand function in Equation 2) are presented in Table 2. For comparison, Table 2 also includes results

from a second specification where contract choice is assumed to be exogenous. The specification where contract choice is assumed endogenous is referred to as Model 1, and the specification where contract choice is assumed exogenous is referred to as Model 2.

Table 2: *Estimation results for residential electricity demand*

	Model 1		Model 2	
	Coef.	Std. Err.	Coef.	Std. Err.
Variable price × Media ($p_t^v m_t c_{it}$)	-0.266	0.007	-0.274	0.007
Variable price ($p_t^v c_{it}$)	-41.962	12.310	-44.713	12.209
Fixed price ($p_t^f (1 - c_{it})$)	-59.882	10.225	-79.095	9.935
Media	0.131	0.004	0.135	0.004
Temperature	-49.570	0.162	-47.540	0.179
Constant	1562.876	8.715	1554.735	9.307
Month fixed effects	Yes		Yes	
Year fixed effects	Yes		Yes	
No. of observations	1676467		1676467	
No. of households	54548		54548	
Avg. time periods	33.7		33.7	
R^2- within	0.484		0.489	
R^2- between	0.027		0.019	
R^2- overall	0.230		0.231	

Notes: The parameters are estimated by 2SLS (`xtivreg` *in Stata 14) using predicted probabilities to generate the excluded instrumental variables.*

First, the results are very similar between the fixed-effects estimator and a random-effects estimator (results available upon request). Using a Hausman test, the null hypothesis that the individual-level effects are adequately modeled by a random-effects model is rejected. Similarly, the results are similar if assuming exogeneity of contract choice as in Model 2. In the discussion below, I refer to the results from Model 1 (the estimates from the 2SLS model).

Overall, the estimated price coefficients for households on variable-price contracts are similar to the estimates in previous literature, and correspond to a price elasticity equal to -0.07 (at the mean level of the variable price, electricity usage and media coverage). The price elasticity for a household on a fixed-price contract is smaller: -0.025. The estimate for Variable price × Media is an estimate of α in Equation 2, and the fact that it is negative shows that households on variable-price contracts respond more to prices when media is extensive. When media coverage is high, for example 840 news articles per month (which corresponds to the mean plus two standard deviations), the price

elasticity is -0.12, or 1.7 times the elasticity at the mean media coverage. This augmenting effect of media coverage on price responsiveness is comparable in magnitude to previous literature that explores how information augments price responsiveness; see for example Jessoe and Rapson (2012).

The direct effect of media should be interpreted with some caution. Because the main focus is on the augmenting effect of media, the direct effect of media should be thought of more as a control variable. In particular, note that the direct effect of media coverage may lead to both higher and lower levels of electricity usage. For example, even if households are informed about the price, they may still be inattentive to electricity usage, and may pay more attention to electricity consumption in general when media coverage is extensive. Whether these households increase or decrease their electricity usage depends both on whether households under- or over-estimate their usage, and most notably on the content of the news articles. Further, note that the marginal effect of an increase in the media coverage for households on variable-price contracts ($c_{it} = 1$) is a function of price, $dq/dm = \alpha p_t^v + \xi$ (see Equation 2). For these households, the total effect of an increase in media is positive when the variable price is low, and negative when the price is high. From the estimated parameters, this derivative is negative for prices above the average price. One interpretation of this result is that, if the price is higher than average, the content of the media coverage is most likely focusing on, e.g., energy conservation behavior, and households therefore reduce their consumption. The intuition for the estimated direct effect of media for households with fixed-price contracts is less obvious. One explanation might be that households on fixed-price contracts perceive their own (fixed) price as relatively low when they read about high variable prices in the newspaper, and therefore increase their consumption. Finally, temperature has a negative effect on electricity usage, as expected.

To account for possible effects of income in the estimation of electricity demand, several approaches are explored, as discussed above. First, the variation in income that is common to all households is already accounted for by the yearly dummy variables in the main specification. Heterogeneity across regions, including heterogeneity across income levels, can be accounted for by including year-by-region dummy variables, and results are very similar to those in the main specification (results available upon request). Most notably, the estimated effects of prices as well as the effects of media are very similar to the main specification. Further, heterogeneity in price responsiveness across income groups is explored by estimating the fixed-effects model separately for different income groups, using the zip-code level averages to define income groups, where group one has the lowest income and group ten has the highest income. Per-capita income by income group can be found in Table 4 in the Appendix.

Figures 3 and 4 illustrate price elasticities across income groups for fixed-price contracts and variable-price contracts, respectively. In general, results are similar across income groups, although high-income households on variable-price contracts are slightly less price elastic than low-income households. A reasonable explanation of these results is that high-income households can more easily afford high prices without adjusting their electricity usage and therefore

are less responsive to price variation.

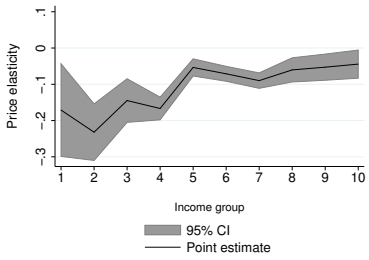


Figure 3: *Price elasticity for households with variable-price contracts, by income level at the mean level of media coverage and electricity usage (using the averages within each income group). Both point estimates and a 95% confidence interval are illustrated*

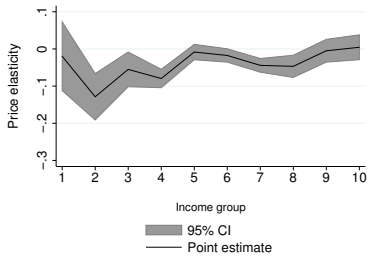


Figure 4: *Price elasticity for households with fixed-price contracts at the mean level of electricity usage and price, by income level (using the averages within each income group). Both point estimates and a 95% confidence interval are illustrated*

The estimates of the augmenting effect of media coverage across income groups (not illustrated but available upon request) are very similar across these income groups, except for the low-income group, where it is not statistically different from zero. One explanation of this interesting result might be that low-income households are more attentive to prices than high-income households.

Furthermore, price elasticities and the effects of media coverage might differ across seasons. In particular, residential electricity demand in Sweden is highly seasonal, with cold and dark winters and warm and bright summers. To explore heterogeneity across seasons, I have estimated the model separately for winter months (December, January and February) and summer months (June, July and August), excluding the monthly dummy variables. The estimated coefficients suggest that households are substantially more price elastic during winter months, with the price elasticity for households on variable-price contracts, at the mean levels of media, price and electricity usage for these months, equal to -0.25. The corresponding price elasticity for summer months is -0.03. A plausible explanation is that electricity usage is much higher during winter, and that households therefore are more responsive to prices in order to avoid large increases in expenditure when prices are high. Interestingly, the augmenting effect of media coverage is closer to zero for winter months than for summer months, which might suggest that households are more attentive to price information on the bill during winter, when prices are expected to be high. If households already are informed about electricity prices, media coverage should have little effect on price responsiveness.

I have also explored heterogeneity across housing types by estimating sepa-

rate models for electrically heated villas, non-electrically heated villas and flats. I find that different housing types are similar in price responsiveness at the mean level of media coverage, but that both the augmenting effect and the direct effect of media coverage are closer to zero for flats than for the other housing types. For example, the estimated coefficient for the direct effects of media (ξ in Equation 2) is 0.132 for electrically heated villas, 0.14 for non-electrically heated villas and 0.019 for flats. One reasonable explanation is that households living in flats might have lower income and therefore are more attentive to prices and electricity usage in general, i.e., similar to the results illustrated in Figure 3.

Overall, a plausible explanation for the heterogeneity across seasons, income levels and housing types is that households are more attentive to prices and for this reason less responsive to media coverage when electricity is a relatively large share of the budget.

Finally, I explore heterogeneity in price responsiveness and effects of media across geographical locations. Given the fact that most of the households are located in Skellefteå, it is of interest to explore regional differences in price responsiveness. To do this, I estimate separate elasticities for Skellefteå (where the supplier is located), Stockholm (roughly in the middle of Sweden) and Gothenburg (in the south-west of Sweden). The price elasticity in Skellefteå (42231 households) is -0.036 for households with fixed-price contracts and -0.095 for households with variable-price contracts at the mean value of media. For Stockholm (4925 households), corresponding figures are insignificantly different from zero for households with fixed-price contracts and -0.097 for households with variable-price contracts, and, for Gothenburg (2805 households), -0.036 and -0.107. Even though elasticities differ slightly in levels across regions, price elasticities are higher for variable-price contracts than for fixed-price contracts for all regions, and the price elasticity for the former type of contract is an increasing function of media coverage for all postal areas. This suggests that the augmenting effect of media on price responsiveness is rather homogenous across regions.

In addition to the results presented so far, several alternative specifications and estimation frameworks are explored to test the robustness of the results. Robustness checks of particular interest are discussed below, and results from these models are available upon request. First, recall that households on variable-price contracts have ex-post billing, and that the price in time t is revealed to the household only at the end of time-period t. It might therefore be the case that households respond to lagged prices rather than current prices. However, using lagged prices (and lagged contract choice) does not change the main result.

Second, remember that the panel data is unbalanced, with some attrition to other suppliers. It might be the case, for example, that households that are very price sensitive also are more likely to switch between different retailers (i.e., sample attrition). As a robustness check, I have estimated the parameters in the model using a balanced sub-set of the data. This sub-set of the data includes only households that are observed every month from July 2010 to June 2014 (9300 households). Results are very similar to the estimates using all data. For

example, the price elasticity for households on variable-price contracts at the mean values of price, electricity usage and media coverage is -0.092, and the price elasticity for households on fixed-price contracts is -0.026.

Third, it might be the case that households switching between contracts are more price responsive compared to households that remain on one type of contract. However, it also could be the case that households use the possibility of switching between contracts as a substitute for adjusting electricity usage, and that these households therefore are less price responsive. To explore this, I estimate the model separately for switchers (i.e., households that have switched contracts during the data period) and non-switchers (households that have not switched between contracts). Results are very similar, including comparable estimates of price responsiveness and augmenting and direct effects of media, suggesting that households that switch between contracts are no different from households that remain on one type of contract in terms of price responsiveness of electricity demand.

5 Conclusions

In this paper, I explore how the price responsiveness of electricity varies across contract types, and, in the case of variable-price contracts, depends on media coverage of electricity prices. The hypothesis is that, because households on fixed-price contracts face little or no price variation, estimates of price elasticities for these households should therefore be close to zero. Furthermore, households on variable-price contracts are assumed to lack perfect information about electricity prices. For example, households may find it costly to stay informed about prices that vary by month, or households may for some reason be inattentive to prices. These households are assumed to learn about the price in media and therefore respond more to prices when media coverage of electricity prices is extensive. I propose an empirical model of household demand of electricity where price responsiveness differs across contract types, and where the price responsiveness for households on variable-price contracts depends in part on media coverage. The parameters in this model are estimated using a unique and large monthly panel dataset with roughly 54000 Swedish households. Because contract choice is endogenous, an instrumental variable approach is used, where the predicted probabilities from a probit model are used as instrument in a 2SLS model. As far as I am aware, this is the first paper in the very large literature on electricity demand to have the data required to explore these topics.

I find that households are responsive to prices, and that the price elasticity is substantially higher for households with variable-price contracts than for households with fixed-price contracts. The estimated price elasticity of the variable price at the mean value of media coverage is roughly -0.07, which is in line with previous literature. The corresponding figure for fixed-price contracts is -0.025. Further, I find that media coverage augments price responsiveness. When media coverage is high, for example 840 news articles per month (which corresponds to

the mean plus two standard deviations), the price elasticity for households on variable-price contracts is -0.12, or 1.7 times the elasticity at the mean media coverage. As the results in this paper suggest, availability of comprehensive information about prices substantially increases price responsiveness.

Further, I find that low-income households are more price responsive than high-income households and that the augmenting effect of media is smaller for the former type of households. Further, a similar pattern is found when exploring heterogeneity in price responsiveness across housing types, where households in flats respond more to prices but less to media, compared to other housing types. On a similar note, I find that price responsiveness is larger, and that the augmenting effect of media is smaller, during winter, when electricity typically is a larger share of the budget compared to summer.

The results in this paper, while novel and plausible, suffer from a few data-related drawbacks which call for caution in interpretation. In particular, the limited geographic variation of the households in the data calls for some caution when extrapolating the results to the entire Swedish population. Similarly, the lack of household-level short-run variation in income and other household characteristics is a shortcoming of the data, although a reflection of the reality for many of these variables. Several different specifications are explored to account for possible income effects, and the results are robust to different specifications. This study may be viewed as a first exploration of heterogeneity in price responsiveness across contract types and also the first to look at how price responsiveness depends on media coverage.

The finding that price responsiveness differs substantially across contract types is intuitive and plausible, but nonetheless an important result. In particular, it suggest that (understanding) households' choice of contract can play an important role in the success of any price-driven policy. In particular, if households switch from variable-price contracts to fixed-price contracts, for example in response to more volatile prices as the share of intermittent production increases, the aggregate price elasticity will decrease substantially. Further, if information increases price responsiveness, this suggests that policy makers should provide information in addition to increasing prices (e.g., taxation) if energy conservation is a policy goal. In particular, providing information appears to be a low-cost measure to increase price responsiveness. This paper only explores the effect of printed media, but there might be other relevant sources of information that could affect electricity consumption and price responsiveness, such as social media and direct information through emails and text messages. For example, one potential policy measure could be to regulate the information available on electricity bills, making sure that this information (in particular price information) is easy to understand. However, credibility and households' attention to information might differ across media sources, and households might value information differently depending on the source.

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Appendix

Table 3: *Probit model of electricity contract choice, with variable contract coded as the positive outcome*

	Coef.	Std. Err.
y_{t-1}	5.838	0.013
Moving average variable price	-1.037	0.200
Temperature	0.026	0.001
Month dummies	Yes	
Year dummies	Yes	
Constant	-2.966	0.344
Log-likelihood	-34886.284	

Table 4: *Mean per-capita annual income by income group*

	Mean income (in SEK)	Number of households
Income group 1	165000	577
Income group 2	203000	1895
Income group 3	222000	2169
Income group 4	238000	8864
Income group 5	254000	11640
Income group 6	269000	12614
Income group 7	288000	10222
Income group 8	312000	2974
Income group 9	351000	2206
Income group 10	467000	1387