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Temperature Effects on Firms' Electricity Demand: An
Analysis of Sectorial Differences in Spain



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TEMPERATURE EFFECTS ON FIRMS' ELECTRICITY DEMAND: AN ANALYSIS OF SECTORIAL DIFFERENCES IN SPAIN

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Abstract

Global warming, intermittent production, and efficient use of energy require adequate demand response policies. The price inelasticity of electricity demand represents the main obstacle for developing adequate measures. A potential source of demand inelasticity is the temperature effect - the reaction of electricity demand to variations in temperature. Studies using aggregate data show that temperature-driven electricity demand is growing in most countries. Using disaggregated data by sectors, we analyze the sectorial breakdown of temperature effects on firms' electricity demand. In-depth knowledge of sectorial demand responses to temperature changes is fundamental for improved energy planning. If electricity consumption in a sector heavily reacts to temperature, "flattening" electricity demand will eventually become infeasible. Our findings indicate that in Spain firms' aggregate electricity demand is rather insensitive to temperature. However, there are marked differences among sectors, with the highest sensitivity found for firms in the service sector.

JEL Q4, L, L5, L94

Keywords: sectorial electricity demand, temperature effect, "cooling" and "heating", electricity demand.

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1. INTRODUCTION

The effect of climate variables, temperature mainly, on electricity demand is widely known. Some examples of recent works include Pardo et al. (2002), Sailor and Pavlova (2003), Moral-Carcedo and Vicens Otero (2005), Mirasgedis et al. (2006, 2007), Bessec and Fouquau (2008), Hekkenberg et al. (2009), Apadula et al. (2012), Hong et al. (2013), and Blazquez et al. (2013). Temperature, usually represented by heating (HDD) and cooling degree-days¹ (CDD), has a direct impact on aggregate electricity consumption.² Variations in outside temperature require adjusting inside temperatures to the comfort temperature. High temperatures also increases energy requirements of refrigeration appliances (Hekkenberg et al. 2009). In addition, temperatures are highly correlated with solar radiation, and hence the use of lighting electricity is negatively correlated with temperature.

The effect of temperature on electricity demand depends on the main uses of electricity, which in turn depend on climate characteristics. As pointed out by Sailor and Pavlova (2003), electric appliances and uses of electricity are climate-region-specific. For the European Union (EU), Almeida et al. (2011) report that main uses of electricity in the residential sector are refrigeration (28% of total electricity consumption), lighting (18%), washing and drying (16%), and office equipment (12%), with a limited importance of air conditioning (2%). However, the authors point to noticeable differences among countries. In warm climate regions - like Mediterranean countries - a much more extended use of air-conditioning reflects a higher, and in certain cases increasing, contribution of cooling degree days to electricity demand, also pointed out by Bessec and Fouquau (2008), Moral-Carcedo and Vicens-Otero (2005), and Zachariadis and Pashourtidou (2007). Hekkenberg et al. (2009) also find evidence of increasing cooling degree days in the Netherlands, a country with a relatively temperate climate. Observed cross-country differences in electricity demand are mainly attributed to the diversity of alternative energy sources for heating. In the case of cooling on the other hand, consumers rely entirely on electricity. An alternative explanation for cross-country differences focuses on different patterns of electricity usage by residential, commercial, and industrial customers. It is widely known that the sensitivity of electricity demand to high temperatures is higher in commercial and residential sectors (Bessec and Fouquau, 2008). In warm climate countries, these sectors tend to be the main drivers behind demand peaks during hot months. For instance, Tang et al. (2008) find that the substantial growth of energy use in Hong-Kong (subtropical climate) is due to higher electricity consumption for air-conditioning in residential and commercial sectors. Bessec and Fouquau (2008) explain a higher sensitivity of electricity consumption in summer months by an increase in the trend temperature

¹For monthly data, $CDD = \sum_{i=1}^{nd} \max(0, t_i - T^*)$, $HDD = \sum_{i=1}^{nd} \max(0, T^* - t_i)$, where t_i is the observed daily temperature, nd is the number of days in a month, and T^* is the threshold comfort temperature.

² Other weather variables, such as solar radiation, humidity, cloudiness, rainfall, and wind speed for instance also have some explanatory power for predicting short-term electricity demand changes. However, given the higher explanatory power of temperature, we exclusively focus on the effect of temperature on electricity consumption. Using only temperature variables also avoids potential collinearity problems when simultaneously employing several weather variables (HDD is highly correlated with cloudiness and solar radiation, for instance).

over the last two decades. Similarly, Moral-Carcedo and Vicéns-Otero (2005) and Zachariadis and Pashourtidou (2007) attribute the higher sensitivity of electricity consumption to high temperatures to a secular increasing trend in temperatures, higher household income, and cheaper air conditioning equipment.

The current paper focuses on temperature-driven electricity consumption. This potential source of price inelasticity in electricity demand is the main obstacle for the design of adequate demand response programs (Torriti et al 2009). Our focus is motivated by three main interrelated challenges that condition energy planning: Global warming and increasing climate instability, increasing concerns about energy use efficiency, and adequate demand response policy design.

Distinct responses of electricity demand to temperatures by residential, industrial, and service sectors also affect the long term trend of energy demand, as pointed out by Vassileva et al. (2012). The authors find that between 1990 and 2004, growth in electricity consumption in EU-25 countries was mainly driven by the service sector, followed by households. On the other hand, the literature usually assumes electricity demand by industrial activities to not be affected by temperature. This generally accepted view stands in stark contrast to the scarcity of available studies on this topic, mainly due to problems of data availability. A deeper understanding of how sector electricity demand reacts to weather variables can help to disentangle sources of demand variability and demand price inelasticity. Advances in our knowledge about consumer behavior in electricity markets allow for designing more adequately oriented measures of short and long term energy planning. Electricity demand behavior by sectors can help to understand how demand response actions - like “time of day pricing schemes” or “interruptible tariffs” - affect aggregate and sectorial electricity demand. An in-depth knowledge regarding which sectors contribute to demand peaks is key for better managing the system load and for improved long term planning of network capacity. The latter is especially important if, as in the case of Spain, sectors tend to be geographically concentrated.

Only recently has data on electricity consumption by sectors become available for Spain; thanks to improvements in the data collected by the Spanish system operator (Red Eléctrica de España, S.A., REE hereafter, <http://www.ree.es>). This newly available data allows for an in-depth study of the relationship between electricity consumption, economic activity, and temperature. In our study we analyze the sectorial breakdown of electricity consumption in electricity intensive firms in Spain. In particular we study how electricity demand by economic sectors (NACE rev.2 at two digits) changes with temperature. Our data only includes firms with electricity consumption above 450Kw. Despite this restriction, firms in our sample accounted for nearly 40,5% of total electricity consumption in Spain in 2012, and for over half of total firms’ electricity demand. The remainder of the paper is organized as follows. In the next section we describe our data. In Section 3 we present our estimation strategy. Section 4 discusses our results and in Section 5 we present our conclusions.

2. SECTORIAL ELECTRICITY DEMAND

The deregulation and re-regulation of the electricity market in Spain since 1998 has had a secondary but relevant side effect: the availability of data about its main actors (consumers,

producers, distributors, and retailers) has improved significantly. The new regulation distinguishes between two types of consumers: (i) those who can choose a regulated price (regulated tariffs, called “tariffs of last resort” since 2008) and (ii) those who can choose a non-regulated tariff or market tariff. In the first years, after the initial deregulation only few consumers opted for the non-regulated tariff regime. Moreover, some returned to the regulated tariff after a short period; initially there was no obligation to remain in the “market price” regime. From July 2009 onwards the regulation changed radically. Nowadays, all consumers with contracted power supply above 10 Kw have to acquire electricity directly or indirectly in the electric power market (RD 871/ 2007). The regulation even foresees penalties for consumers who do not switch to the liberalized market. This new legal framework also implied an improved availability of data about electricity consumption in Spain. Since 2009, REE - the system operator of the Spanish electricity market- has collected individualized data on power consumption of qualified consumers (contracted power supply above 450 kW)

Consumer types, or consumption point types are defined by their contracted power supply. The new regulation of the electricity market (Article 7 RD 1110/2007) establishes the following classification, displayed in Table 1.

Table 1- Consumer classification

Type	Contracted Power Supply
1	$P_c > 10 \text{ MW}$
2	$P_c > 450 \text{ kW}$
3	$P_c \leq 450 \text{ kW}$ y $> 50 \text{ kW}$
4	$P_c \leq 50 \text{ kW}$ y $> 15 \text{ kW}$
5	$P_c \leq 15 \text{ kW}$

Our period of analysis runs from January 2009 to October 2013. Our data includes “local consumption points”, or technically speaking Universal Supply Point Code (USPC hereafter) of type 1 and 2, i.e. consumers with a contracted power supply above 10 MW or with an annual consumption exceeding 5 GW (type 1), and those with more than 450 kW contracted power supply or with an annual consumption exceeding 750 MW. For these particular consumers we have detailed information about their economic activity. For all other consumers (types 3 to 5) only aggregates are available, and we cannot differentiate between commercial and residential consumers. Despite the exclusion of types 3 to 5, demand by consumers in our data still represents 40.5% of total electricity consumption in Spain (2012 data). Taking into account that households accounts for around 25% of total electricity consumption³, USPC types 1 and 2 account for about 54% of firms’ electricity consumption. Our data on firms’ economic activity is specified as two-digit NACE rev2 sectors. We exclude⁴ from our analysis sectors with no USPC data (sectors 95: “Repair of computers”, 78: “Employment activities”, 75: “Veterinary activities” and 50: “Water transport”).

³ Institute for Energy Diversification and Saving, IDAE, project SECH-SPAHOUSEC.

⁴ We also exclude sector 7- Mining of metal ores, because of unexplained variations in the data.

On September 30th 2011, the total number of USPC types 1 and 2 was 20,348, belonging to 12,723 firms. Hence, on average there were 1.6 USPC per company. Table 2 represents the sectorial distribution of companies. Around 57% of all companies in our sample engage in industrial activities, followed by service sector firms (35%). A sectorial breakdown according to electricity consumption indicates an overrepresentation of industrial activities. In 2012, industrial activity accounted for 73.1% of total electricity consumption while it only accounted for 15.9% of total GDP. On the other hand, electricity demand in the service sector represented 24.7% of total electricity consumption, while the contribution of the service sector to GDP was 65.7%.

Table 2. Sectorial consumption breakdown (USPC types 1 and 2). Comparison with sectorial GDP.

		GDP (%)	Electricity Consumption (%)
A	Agriculture, forestry and fishing	2.3%	1.2%
B,C,D, E	Mining ; Manufacturing ,Energy and Water Supply, , sewerage, waste management and remediation	15.9%	73.1%
F	Construction	7.9%	1.0%
	Service Sector	65.7%	
G,H,I	Wholesale and retail trade; transport, Accommodation and food service activities	23.2%	14.3%
J	Information and Telecommunications	3.9%	1.6%
K	Financial and insurance activities	4.0%	0.7%
L	Real estate activities	7.6%	0.9%
M,N	Professional, scientific and technical activities	7.1%	1.0%
O,P,Q	Public administration and defense, Education and Health	16.6%	5.2%
R,S,TU	Arts, entertainment and recreation, Other services	3.4%	1.0%

Note: Net taxes (8.2% of GDP) are not included in the table.

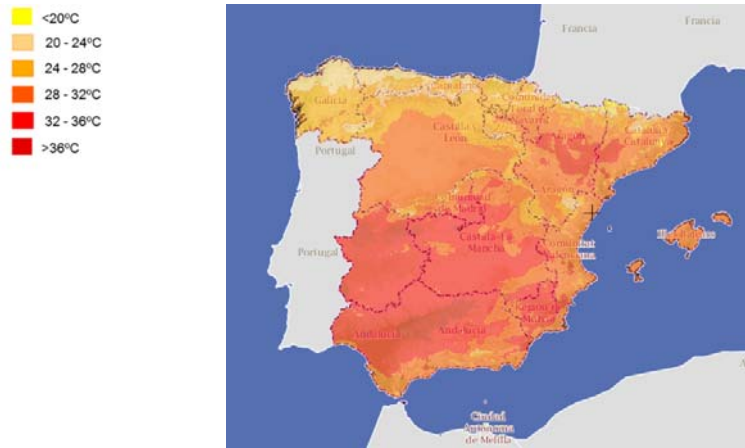
Source: Spanish National Statistics Institute (INE) and REE.

2.1 Temperature data

In general, economic activity is not identically distributed across a country. The Spanish economy is not an exception. Certain economic activities are highly concentrated in certain regions and

absent in others. As a consequence, sectorial electricity consumption displays a non-homogeneous regional distribution. Apart from the geographic variability in economic activities, in Spain there is also a high inter-regional variability in temperatures (see Figure 1). To deal with both features, we compute sectorial temperature indicators. To this end, we use the daily maximum temperature at the regional level which we weight by the regional breakdown of electricity consumption of a given activity (NACE rev2 at two digits). The regional temperature is obtained as an electricity consumption weighted average of the maximum temperature registered in the province capitals (NUTS3) of a certain region (NUTS2). Temperature at regional levels turns out to be much more homogenous than at the national level. This procedure thus provides us with a much more accurate measure of effective temperature. It would be desirable to further disaggregate the temperature data to the local level. However due to data confidentiality we do not dispose of sectorial electricity consumption at the local level.

Figure 1- Territorial distribution of maximum temperatures and administrative bounds (NUTS2) in Spain in the hottest month (Cº)



Note: Canary Island are not included in this map. Temperature data 1960-1996.

Source: Spanish Ministry of Agriculture and Environment. <http://sig.magrama.es/geoportail/>

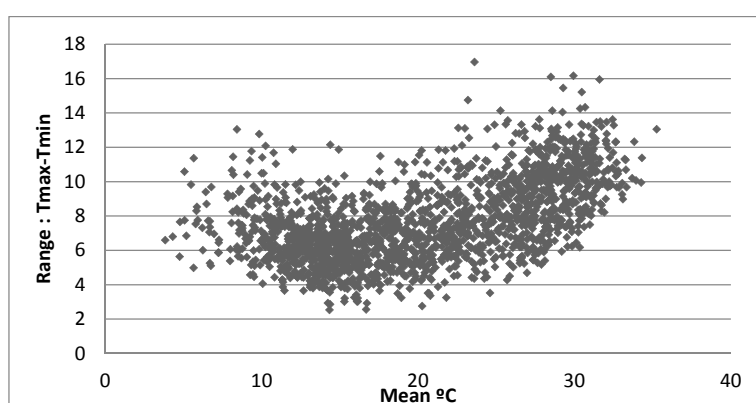
For sectors $i=1,...,85$, temperature indicators of day t are obtained as ,

$$T_{i,t} = \sum_{j=1}^{15} w_{i,j,m} \sum_{p=1}^{n_j} \frac{1}{n_j} T \max_{p,t} ,$$

where $T \max_{p,t}$ is the maximum temperature on day t recorded in the capital of province p (NUTS3) belonging to region j , n_j is the number of provinces included in region j (NUTS2). The weight $w_{i,j,m}$ denotes the share of electricity consumption of NACE rev 2 activity i in region j in month m relative to total consumption by activity i . Weights are updated monthly because regionally disaggregated sectorial electricity consumption is only available on a monthly basis.

This procedure provides us with 82 temperature indicators, one for each sector of activity. Our indicator measures temperature more appropriately, both from a sectorial as well as a territorial perspective. If we were to use a simple temperature indicator, the observed response of electricity consumption could lead to wrong conclusions; in particular when differences between indicators vary with temperature. In the period 2009-2013, the mean range - measuring the difference between the highest and the lowest temperature of sectorial indicators- was equal to 7.7°C (see Figure 2). However, this range was clearly increasing with higher and lower temperatures. Hence, an un-weighted temperature indicator - a single temperature indicator for all sectors - would induce a bias into the estimated response of sectorial electricity consumption to temperature changes.

Figure 2- Differences between sectorial temperature indicators. (Maximum temperature indicator minus minimum temperature indicator for a given day). 2009-2013.



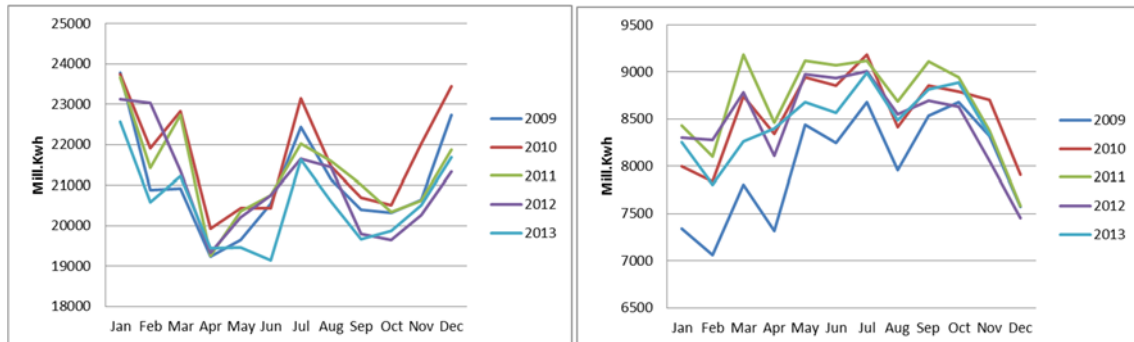
3. MODELLING TEMPERATURE EFFECTS

A first look at firms' monthly pattern of electricity demand (USPC 1 and 2) shows remarkable differences with respect to total electricity demand, see Figure 3. Total electricity demand exhibits a "W" shaped seasonal pattern with a sharp decline during summer holidays, coherent with traditional explanations based on CDD and HDD variables. Firms' electricity demand on the other hand looks much more like an inverted "W" shape. On the aggregate, electricity demand by firms seems rather insensitive to high temperatures, but directly related to low temperatures. As can be observed in Figure 3, electricity consumption by firms is lower during winter months. This aggregate firm behavior seems to be inconsistent with traditional explanations based on nonlinear effects of temperatures. Furthermore, such an insensitiveness of firms' electricity demand to temperature could imply that residential demand is more intensely affected by temperatures than suggested by estimations using aggregated data.

In this section we analyze firm behavior in more detail to see how each sector contributes to the observed pattern. From an energy planning perspective it is important to know if all sectors share the same demand profile, or if there are differences among sectors. For instance, a "time-of-day

tariff” for all consumers would penalize firms with a flatter demand curve. The situation would be even worse if firms’ electricity demand were completely symmetric to total electricity demand. Another potential problem emerges when electricity demand is price inelastic and driven by temperature variations. In this case, higher prices caused by increased electricity consumption by firms could be translated to final consumers without any effect on total electricity consumption.

Figure 3.-Spanish total electricity demand (left) and total electricity consumption by USPC types 1 and 2, monthly profile.



Source: REE

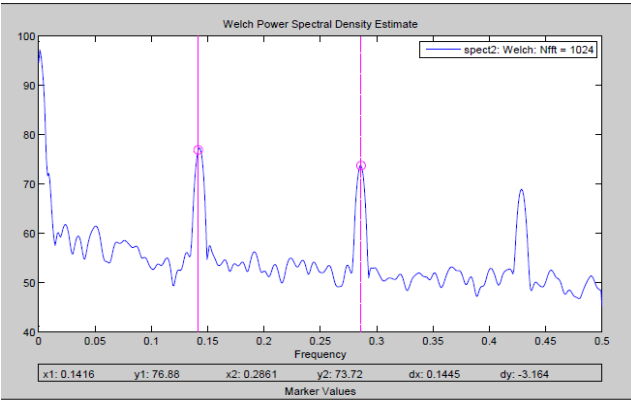
To better disentangle sectorial responses to temperatures we consider daily data. This, on the other hand, requires adjusting for calendar effects. During the analyzed period (2009-2013), the Spanish economy experienced a deep economic recession and many firms ceased their activities. On the other hand, the process of incorporating all companies into the market price system has not been fully completed. Both aspects cause sudden jumps in electricity demand by some sectors. However, such jumps are more frequent in the first years of the series. To avoid that sudden changes affect our estimates of the temperature effect, we work with data on daily average consumption of electricity (Kw consumption per USPC unit). Then, in order to obtain results for total sector electricity demand we have to account for the number of firms in a given sector. Given that results reported at the firm level (mean USPC effect) will differ from those at the sector level (total effect), in our discussion of results we will indicate clearly to which of the two we are referring.

3.1.-Working day effect

Daily electricity demand is strongly affected by calendar effects, as pointed out by Pardo et al. (2002), Moral-Carcedo and Vicens (2005), Hekkenberg et al. (2009) Apadula et al. (2012). The repeated succession of working days and weekends creates an underlying periodic 7-day behavior. Superimposed on this cycle are the effects of holidays and other deterministic events (national strikes, etc.). Such weekly cycles are the main drivers of short-term variations in sectorial electricity consumption. Figure 4 displays the spectral density of daily sectorial consumption data. The spectral peaks are located around the 0.1416 frequency ($1/0.1416 = 7.06$ days period) and their harmonics around the 0.2832 and 0.4248 frequencies. This periodic pattern, with higher electricity demand in central week days (Tuesday to Friday), is common to all sectors. However,

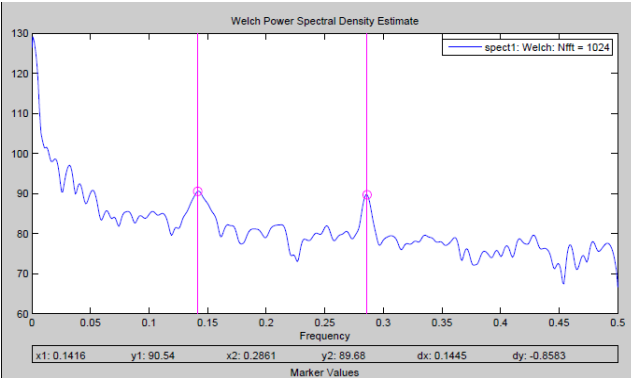
in some cases it is dampened by sector-specific factors, like adjustment costs for changes in production, unstoppable activities, or anomalies in the cycle due to the particular nature of the economic activity; for instance, higher activity on weekends instead of central week days. The first sector-specific factors affect for instance “manufacturing of coke and refined petroleum products”, “manufacturing of chemicals and chemical products”, or “manufacturing of basic metals” (see Figure 5). Other sectors which display unusual patterns of weekly electricity consumption are: “Crop and animal production”; “hunting and related service activities”, “electricity”; “gas”; “steam and air conditioning supply”, “sewerage”, “accommodation”, “motion picture”, “video and television program production”, “sound recording and music publishing activities”, “services to buildings and landscape activities”, “gambling and betting activities”, “sports activities and amusement and recreation activities”, and “activities of extraterritorial organizations”.

Figure 4- Typical spectral density estimate in daily electricity consumption data. (USPC mean)



Note: Spectral density estimate of daily electricity consumption data for sector 79: “Travel agency, tour operator and other reservation service and related activities”

Figure 5. - Atypical spectral density estimate in daily electricity consumption data. (USPC mean)



Note: Spectral density estimate of daily electricity consumption data for sector 24: “Manufacturing of basic metals “

Figure 6.-Symmetric (centered) moving average: Filter gain (logs).

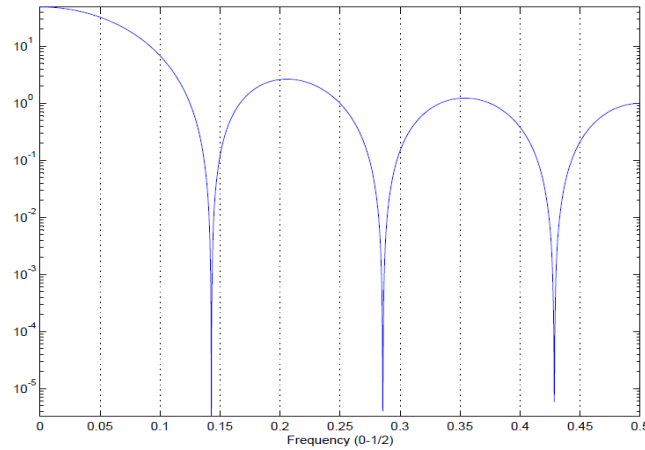
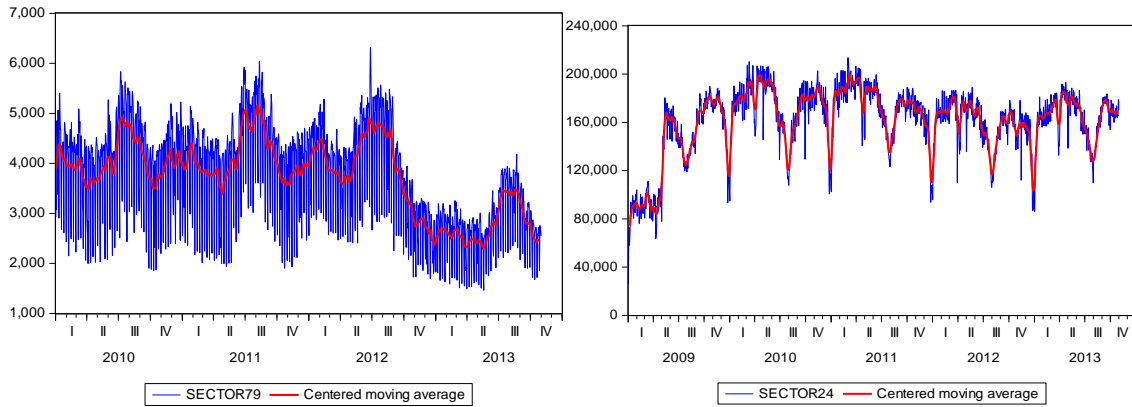


Figure 7. –Daily sectorial consumption (USPC mean). Raw data (blue line) and Centered moving average (red line).



Sector 24: "Manufacturing of basic metals" and Sector 79: "Travel agency, tour operator and other reservation service and related activities"

In order to deal with working day effects we filter-out the effects of the weekly cycle by applying a centered moving average filter to the original series of sectorial electricity demand,

$$\bar{y}_{i,t} = \frac{1}{14} S(B)S(B^{-1})y_{it} = \frac{1}{14} (1 + B + B^2 + \dots + B^6)(1 + B^{-1} + B^{-2} + \dots + B^{-6})y_{i,t},$$

where B is the lag/forward operator, $B^k y_t = y_{t-k}$. This treatment filters-out all 7-day periodic components. Simultaneously, it also partially de-noises our original series due to the characteristics of the filter gain function. This function is depicted in Figure 6. The centered moving average lacks any intra-week variation but it preserves the remaining characteristics of the original series. In particular, it tracks the sudden drops in electricity consumption linked to holidays. This can be observed in Figure 7, where as an example we have plotted the original and

the filtered series for two sectors. To deal with the effect of holidays we consider two alternative methods. In one case, we directly exclude data from these periods (see Table 3 for a detailed description of the days excluded). As an alternative approach, we use dummy variables for each weekday and for holidays, as proposed by Moral-Carcedo and Vicens (2005) or Apadula et al. (2012). Such a procedure would allow us to simultaneously estimate a day-effect together with all other factors (temperature and underlying trend linked to economic factors). In any case, the estimated temperature elasticity of electricity demand from both methods is very similar.

Table 3.- Holidays .

Non working days	National and regional Holidays	16 days in a typical year.
	Local holidays	8 local Holidays (major cities) : Madrid, Barcelona. Valencia, Sevilla, and Zaragoza
	Easter period	Holy Monday- Easter Tuesday
	Christmas	December, 24 th - January, 7 th

Note: Each year, government and regional authorities approve the national, regional, and local holidays calendar. If holidays coincide we consider only one dummy; for example, December 25th is a national holiday but also lies in the Christmas period. In this case we consider December 25th as the latter only.

3.2. - Demand sensitivity to temperature variations: temperature effect estimation

Temperature affects electricity demand in a nonlinear way, due to different energy usage patterns when temperatures are low (demand for *heating*) or high (demand for *cooling*). Because of this nonlinearity we have to estimate both, the effect of temperature on electricity demand, as well as the threshold temperature where we observe a change of direction in energy demand. When temperatures are below this threshold we expect demand to decrease with higher temperatures (“heating”). If temperatures lie above the threshold electricity demand and temperature are expected to move together in the same direction (“cooling”). Therefore, demand sensitivity to temperature has two dimensions: First, temperature modifies the direction of electricity consumption or the “demand state”. Second, conditional on the “demand state”, changes in temperature affect electricity demand, i.e. “demand temperature-elasticity”. The first dimension requires an estimation of the threshold temperature for each sector, i.e. the temperature at which demand switches. This temperature is related to different usages of electrical appliances (cooling or heating). For the second dimension we analyze the relative elasticity of a sector’s electricity demand to temperatures in every “demand state.” This analysis

will enable us to understand for which sectors electricity demand reacts more strongly to variations in temperature.

For our analysis of sectorial temperature thresholds we employ a smooth transition model (STR) similar to the one by Moral-Carcedo and Vices-Otero (2005) and Bessec and Fouquau (2008). We estimate the following logistic smooth transition regression model

$$\bar{y}_{i,t} = \sum_{j=1}^3 \phi_{i,j} t_t^j + (\phi_{4,i} + \phi_{5,i} T_{it}) [1 - \Phi(T_{it}, \gamma_i, \tau_i)] + (\phi_{6,i} + \phi_{7,i} T_{it}) \Phi(T_{it}, \gamma_i, \tau_i) + \phi_{8,i} A_t + \xi_{i,t} \quad [1]$$

where, $\bar{y}_{i,t} = \frac{1}{15} \left(\sum_{j=-7}^7 y_{i,t-j} \right)$ is the filtered electricity consumption (USPC mean) of sector i on

day t , $\sum_{j=1}^3 \phi_{i,j} t_t^j$ is a third order trend polynomial used to capture business cycle economic factors

that influence electricity demand⁵, T_{it} is the sectorial temperature indicator described in section

2.1, $\Phi(T_{it}, \gamma_i, \tau_i) = \frac{1}{1 + \exp[-\gamma_i (T_{it} - \tau_i)]}$ is the logistic transition term, with parameters τ_i ,

the sectorial temperature threshold, and γ_i which modulates the speed of transition. Finally, A_t

is a dummy variable that takes on value 1 in August and 0 in any other month, and $\xi_{i,t}$ is the i.i.d

stochastic term. In this model, sector-specific characteristics of the temperature effect on the

“demand state” are reflected by terms τ_i and γ_i . Demand elasticity to temperature can be

measured by parameters $\phi_{5,i}$ and $\phi_{7,i}$. However, due to the presence of the $\Phi(T_{it}, \gamma_i, \tau_i)$ term,

this method will only provide “point” elasticity estimates which depend on a particular

temperature value. To better measure sectorial demand elasticity to temperature we will use a

closely related model instead. Following Hansen (2000) we propose the following model,

$$\bar{y}_{i,t} = \sum_{j=1}^3 \beta_{i,j} t_t^j + (\beta_{4,i} + \beta_{5,i} T_{it}) (T_{it} \leq \tau_i) + (\beta_{6,i} + \beta_{7,i} T_{it}) (T_{it} > \tau_i) + \beta_{8,i} A_t + \varepsilon_{i,t}, \quad [2]$$

Conditional on “demand state” ($T_{it} \leq \tau_i$) or ($T_{it} > \tau_i$), the relative elasticity of sectorial demand

to temperature is captured accurately by parameters $\beta_{5,i}$ and $\beta_{7,i}$. As an alternative, we

estimate model [2] using unfiltered sectorial electricity consumption (raw data). To deal with the

calendar effect we include a set of dummy variables to characterize all holidays and working days

(we consider a set of 47 dummies⁶). To this end, we group all dummies with estimated coefficients

which are not statistically different from each other. We apply an iterative procedure of

⁵ In the analyzed period the Spanish economy experienced a double-dip recession, with troughs in 2009 and 2012. We have decided to include a third order polynomial to capture a common trend, even though in the case of some sectors a lower/higher order provides a better adjustment.

⁶ We specify holidays as detailed in Table 3 as well as seven working days with an additional August effect (for each working day an additional dummy is included in August). National and regional holidays have a differentiated dummy for each week day (i.e., national holiday on Monday, national holiday on Tuesday...). For national and regional holidays we also include a dummy for the day after to account for a “post- holiday effect”.

estimation. In each step we group coefficients which are more similar in value and test if they are statistically different from each other by means of a Wald test.

The procedure terminates if the test is rejected, leading to G_i sector-specific groups of day-effects denoted by,

$$\sum_{j=4}^{G_i} \beta'_{i,j} D_t^j$$

where G_i is the number of day-effects identified and is the effect of type D. In particular, D is a dummy variable that takes on value 1 if observation $\beta'_{i,j}$ t is of type D. After applying this grouping procedure the final model is expressed as follows:

$$y_{i,t} = \sum_{j=1}^3 \beta'_{i,j} t_t^j + (\beta'_{4,i} + \beta'_{5,i} T_{it})(T_{it} \leq \tau_i) + \beta'_{6,i} T_{it}(T_{it} > \tau_i) + \sum_{j=4}^{G_i} \beta'_{i,j} D_t^j + \varepsilon'_{i,t}. \quad [3]$$

Models described by Equations [2] and [3] are estimated with daily data for 2009-2013. The model of Equation [2] is estimated for two alternative cases: In the first case, holiday data are excluded from the sample. In the second case we use the complete sample. Following Hansen (2000), models [2] and [3] are estimated by taking values from the interval $\tau_i \in [T_{\min,i}, T_{\max,i}]$. For the temperature threshold we keep the lowest estimated value according to the AIC criteria. Note that in general, the AIC criteria decreases very smoothly near the optimal threshold. Therefore, slight changes in the optimal temperature threshold (minimum AIC) do not have any significant impact on our estimations. Furthermore, optimal thresholds do not vary much for different model specifications. In particular, we obtain the same value for the optimal sectorial temperature threshold for any of our three specifications (the two alternative specifications for Equation [2] and the specification for Equation [3]).

For both specifications [2] and [3] we correct the standard errors by applying the Newey-West coefficient covariance estimator. This estimator is consistent in the presence of both residual autocorrelation and heteroskedasticity of any unknown form. This correction enables us to test for significance of the estimated coefficients, even when facing problems of omitted variables.

4. RESULTS

4.1. Switching behavior in sectorial electricity demand

Temperatures do not change abruptly. They display substantial inertia (i.e. autocorrelation). Moreover, clear responses in electricity demand are only observed whenever indoor temperatures differ significantly from comfort levels (around 20°C in most studies). Both aspects imply that changes in the response of electricity demand to temperatures are expected to be quite smooth. A convenient way to capture such smooth behavior is to characterize this transition by functions like the logistic transition function:

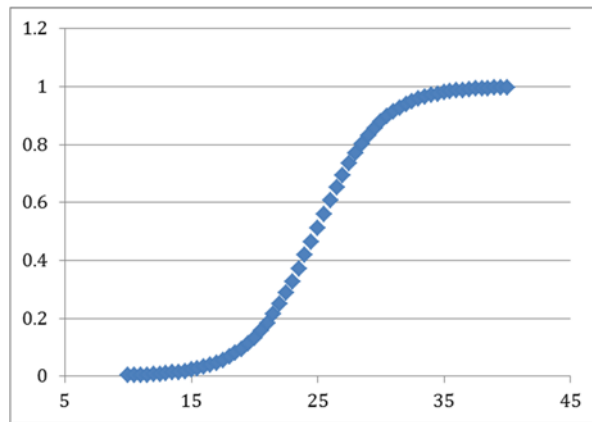
$$\Phi(T_{it}, \gamma_i, \tau_i) = \frac{1}{1 + \exp[-\gamma_i(T_{it} - \tau_i)]}.$$

The parameter τ_i , the sectorial temperature threshold, and the parameter γ_i , which modulates the speed of transition, characterize the speed and symmetry of the transition between states. The sectorial parameter estimates, presented in Table A.1 of the Appendix, convey valuable information about the demand response to temperatures and the speed of transition. In some cases we do not observe any response, for instance when the estimated τ_i is abnormally high or low, or has a large standard deviation. For 35 of the 82 sectors in our data we do not find any significant values for the transition parameters τ_i and γ_i . In these cases we find rather atypical responses, with unexpected falls in electricity demand to low or high temperatures, as well as asymmetric responses. In particular, our extreme results range from almost rigid electricity demand in some sectors, (sector 49: “Land transport”) to asymmetric responses to temperature variations, i.e. demand only reacting to high temperatures (in sectors 73: “Advertising and market research” and 80: “Security and investigation activities”).

Only considering those sectors for which both parameters are statistically significant at least at the 10% level, most temperature thresholds (maximum daily temperature) are located in the 20°C-30°C range. This is the case for 34 of the 47 sectors which satisfy the significance criteria. The speed of transition is, as expected due to smooth transition between states, relatively low. For 78.7% of all cases, estimates for parameter γ_i lie in the range of [0.2-0.5]. For certain peculiar sectors with higher estimated values for the speed of transition (sectors 5: “Mining of coal”, 20: “Manufacturing of chemicals”, 24: “Manufacturing of basic metals” and 37: “Sewerage”) we also find atypical responses of electricity consumption to temperatures – lower consumption on warmer days.

Figure 8. - Typical estimated transition. (γ_i median =0.3846 , τ_i median =24.86)

$$\Phi(T_{it}, \gamma_i, \tau_i) = \frac{1}{1 + \exp[-\gamma_i(T_{it} - \tau_i)]}$$



4.2.-Sectorial electricity demand sensitivity to temperature.

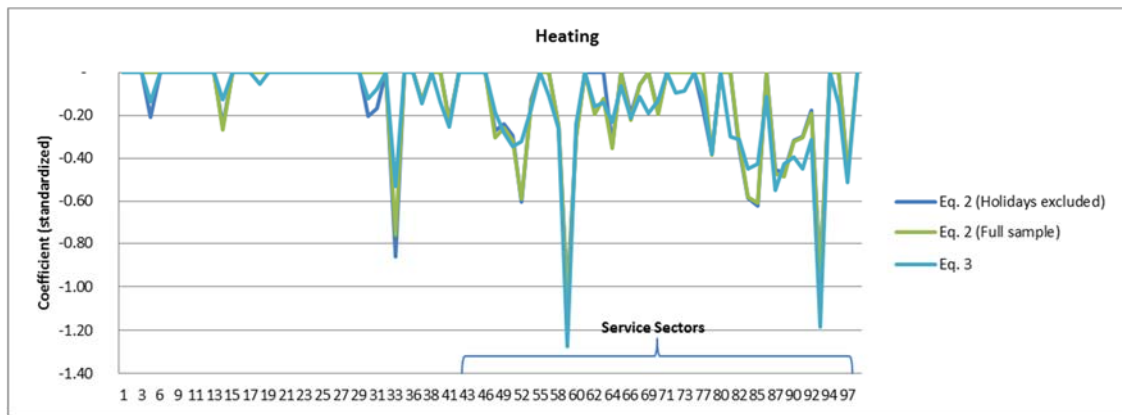
Our results show that aggregate firms' electricity demand is in general insensitive to temperature variations. Sectors that represent around 81% of firms' electricity consumption in our data (USPC types 1 and 2) do not display remarkable "heating needs". Therefore their electricity demand is relatively insensitive to low temperatures. With respect to the "cooling effect", we find a higher sensitivity. Sectors which show a significant effect of high temperatures on demand represent around 44% of total firms' electricity consumption in our data. Most significant temperature effects are found in the service sector. In this sector it is most likely that electricity consumption is linked to final usages of heating and cooling.

In the Appendix, we present the estimated graphical response to temperature variations using our model [2]. An overall analysis of sectorial estimated temperature effects (see Table 4) shows that heating induced electricity demand has a low impact on total demand. Most remarkable effects are found in sectors with a reduced weight in total electricity consumption, i.e. for instance sectors 59: "Motion picture, video and television program production," 9: "Sports activities and amusement activities," or 33:"Other manufacturing".

Demand for cooling on the other hand, is much more pronounced in sectors 87:"Residential care activities," 93: "Sports activities and amusement," 59: "Motion picture, video and television program production", 94: "Activities of membership organizations", 86: "Human health activities", 96: "Other personal service activities", and 47: "Retail trade". Apart from being more significant, the "cooling effect" also shows a higher potential impact on total electricity demand. Our estimates reflect that significant "cooling effects" exist in sectors that individually represent more than 2% of total firms' electricity demand in our data, see Figure 11.

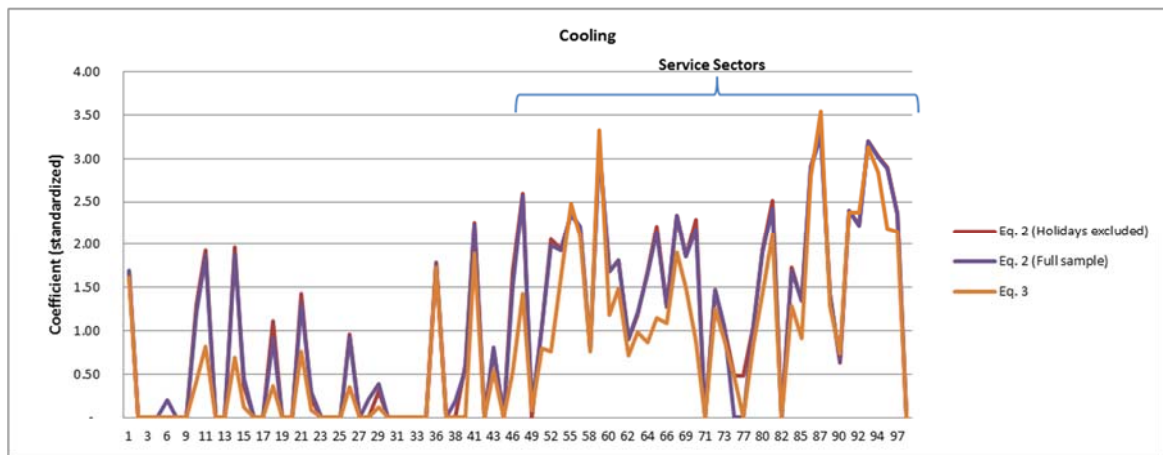
The pattern of electricity demand by sector 24: "Manufacturing of basic metals" deserves a separate comment. This sector is the main electricity consumer in Spain, accounting for 21.5% of total consumption of USPC types 1 and 2. As detailed in the Appendix, this sector does not display any significant "heating" effect. Moreover, and maybe more striking, electricity demand by this sector displays a significant but negative response to high temperatures. This phenomenon might be linked to the fact that some firms in this sector participate in so-called "interruptible programs of demand response management". Thus it seems natural to explain the behavior of the "cooling" effect in this sector by firms' production strategies - planning lower production when prices are expected to be high or when the "interruptible program" is more likely to be "switched on." However, there does not seem to exist any direct evidence that firms behave this way. Requested demand reductions have been rather infrequent; between 0 and 4 days per year (Torriti et al., 2010). This makes it hard to believe that interruption risks are driving the pattern of electricity demand in this sector. Moreover, as Torriti et al. (2009) point out, for Spanish industrial consumers reducing production in order to save electricity costs does not seem to be a profitable strategy. It is hence much more likely that the observed pattern is due to seasonal factors, i.e. general reduction of economic activity during summer holidays and fewer construction activities in winter times, both lowering the demand for basic metals.

Figure 9. - “Heating” effect (USPC mean). Standardized coefficient estimates.



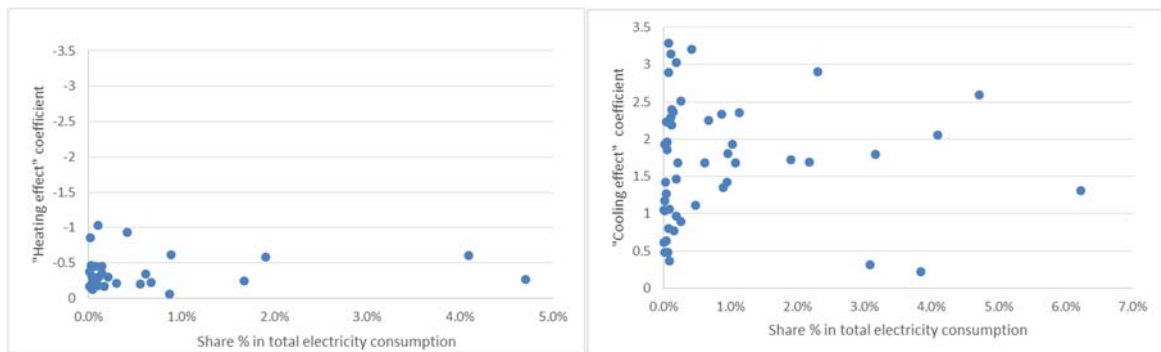
Note: Only significantly negative coefficients - we expect electricity demand to increase when temperature decreases- are plotted. The Appendix includes the full set of results.

Figure 10. - “Cooling” effect. (USPC mean) Standardized coefficient estimates.



Note: Only significantly positive coefficients - we expects electricity demand to increase with higher temperatures - are plotted. The Appendix includes the full set of results.

Figure 11. - USPC mean “Cooling and Heating effects” (Standardized coefficient estimates) versus Sectorial share (%) in total firm’s electricity consumption (USPC types 1 and 2).



Note: Only significant coefficients with the correct expected sign (+, as electricity demand increases with higher temperatures, and – as demand decreases with lower temperature) are plotted.

Table 4.- Summary of sectorial temperature effects - Standardized coefficients.

Temperature effect	NACE rev 2 code	Share (%) of total firms' electricity consumption
Heating effect [-1.3 - 0]		
No effect		81.40%
Stand. Coefficient < abs(-.6)	84, 88, 87, 97, 79, 82, 64, 90, 91, 60, 51, 47, 14, 58, 49, 41, 5, 30, 66, 70, 92, 77, 31, 37, 53, 68	12.9%
Stand. Coefficient > abs(-.6)	59, 93, 33, 85, 52	5.7%
Cooling effect [0 - 3.4]		
No effect		56.1%
Stand. Coefficient < .6	77, 74, 15, 29, 22	7.2%
	72, 21, 88, 85, 10, 66, 63, 18, 51, 79, 73, 26, 62, 58, 43, 90, 39	
.6 < Stand. Coefficient < 1.5		9.8%
	87, 93, 59, 94, 86, 96, 47, 81, 91, 97, 55, 68, 70, 41, 92, 65, 56, 52, 14, 53, 11, 80,	
Stand. Coefficient > 1.5	69, 61, 36, 84, 46, 64, 60, 1	26.9%

Note: Sectorial codes are detailed in the Appendix.

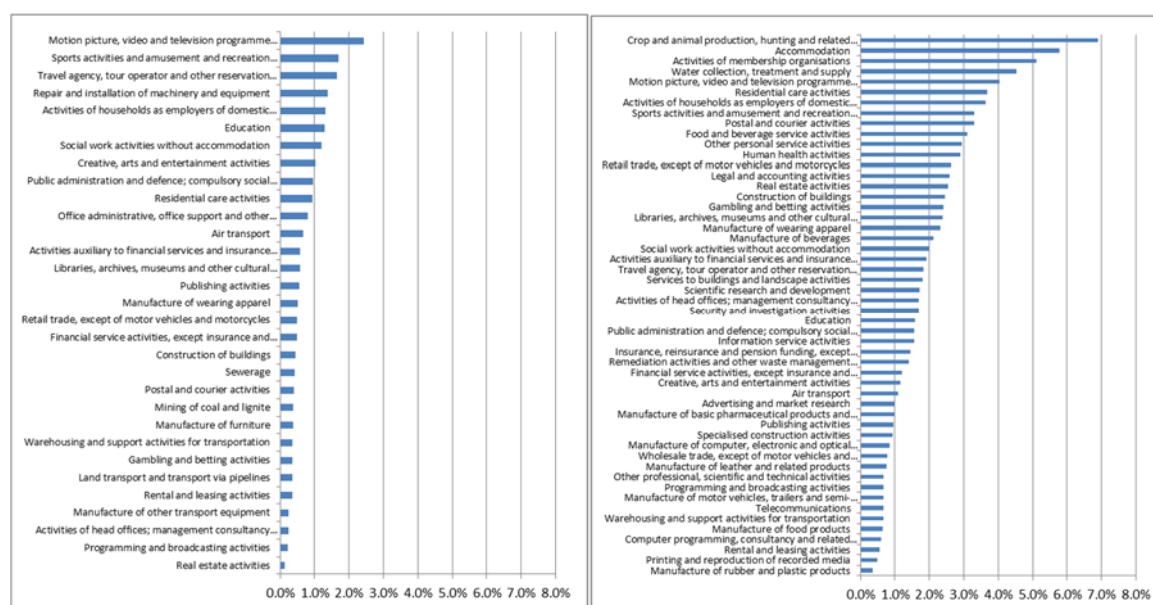
In order to provide more insight into the quantitative effect of temperatures, we analyze the elasticity of sectorial electricity demand. In particular, we consider by how much demand changes when the sectorial indicator temperature varies by 1°C. As a reference for the “basic electricity demand” we use the mean of daily sectorial electricity demand⁷ when temperatures lie around the threshold temperature estimated by our model [2]. More precisely, we consider the following temperature range $[\tau_i - 2^\circ\text{C}, \tau_i + 2^\circ\text{C}]$. As two complementary measures, we define the “maximum variation in electricity demand”. This measure is calculated as the ratio of the sectorial electricity consumption when the sectorial indicator of temperature lies in its maximum range $[t_{\max_i} - 6^\circ\text{C}, t_{\max_i}]$ to the basic sectorial electricity demand defined before. The second alternative measure is the “minimum” variation in electricity demand. Similarly, this measure is calculated as the ratio of the sectorial electricity consumption when temperatures lie in the minimum range $[t_{\min_i}, t_{\min_i} + 6^\circ\text{C}]$ to the basic sectorial electricity demand. Both measures reflect the maximum observed impact of temperatures on sectorial electricity demand. They combine the elasticity effect (sensitivity to unitary increases in temperature) and the temperature range variation effect (how extreme the temperature variation is). We present detailed sectorial results for these measures in the Appendix.

⁷ Electricity consumption varies with each day of the week. This is why we use average electricity consumption for several days to dampen the working day effect.

We find that heating effects are quantitatively less relevant than cooling effects in terms of variations in demand. Our estimates show that total firms' daily electricity consumption (USPC types 1 and 2) increases in mean by 0.1%⁸ due to the "heating" effect and by 0.7% due to the "cooling" effect, per 1°C variation in temperature (below and above the threshold temperature in each case). This translates into estimated increases in electricity demand of 276 Mw and 2,001 Mw respectively. The latter figure is particularly important taking into account predictions about secular temperature increases due to global warming. Furthermore, in Spain, during the period June to September average temperature easily climbs to 10 °C above threshold temperature⁹. In any case, demand by large firms (USPC 1 and 2) does not seem to be the main driver behind the progressive increase in the sensitivity of the aggregate Spanish electricity demand to temperatures.

Figure 12-a (USPC mean) Demand elasticity to temperature. "Heating" (left) and "cooling" (right) effect and sectorial detail.

Relative increase (%) in daily basic demand per 1°C variation (below and above threshold temperature respectively)

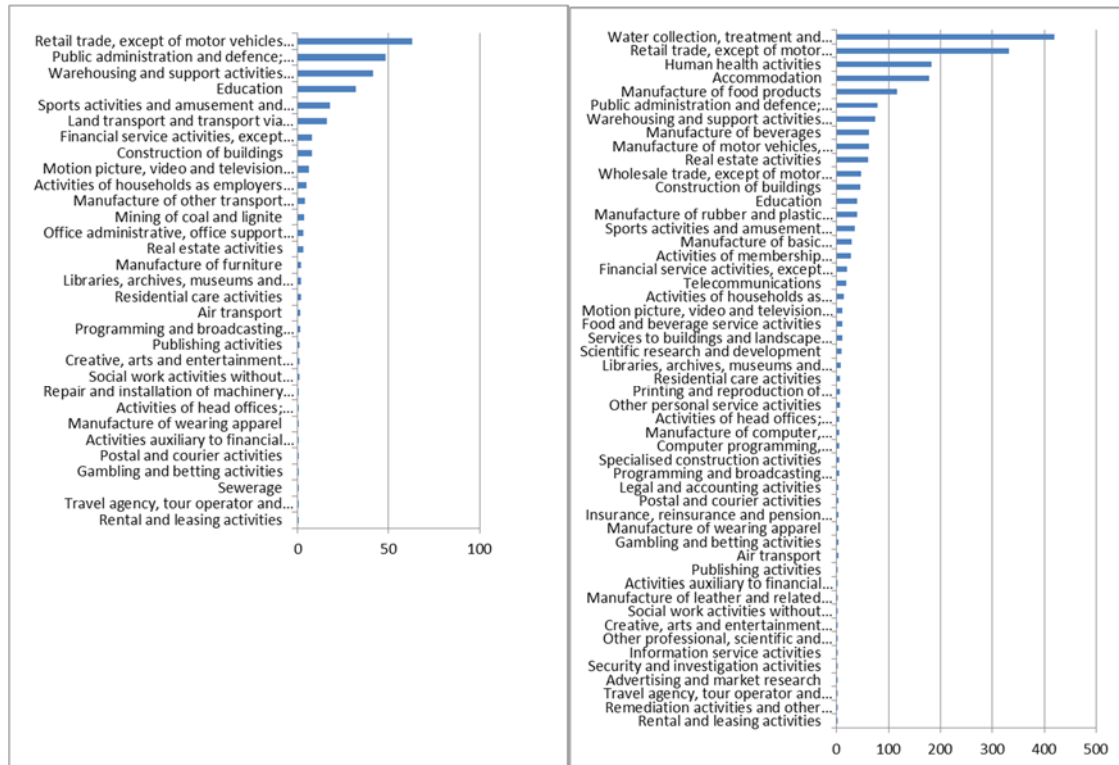


⁸ We apply the estimated sectorial elasticities to the mean daily sectorial electricity consumption in May 2012. This provides us with an estimation of sectorial consumption increases per 1°C variation. We then sum these values over all sectors to obtain the total increase in consumption. We choose May because average temperatures in this month lie near the mean estimated threshold temperature of 20.2°C.

⁹ See the Appendix for a detailed range of variation of sectorial temperature indicators.

Figure 12b- (Total sector) Demand elasticity to temperature. “Heating” (left) and “cooling” (right) effect and sectorial detail.

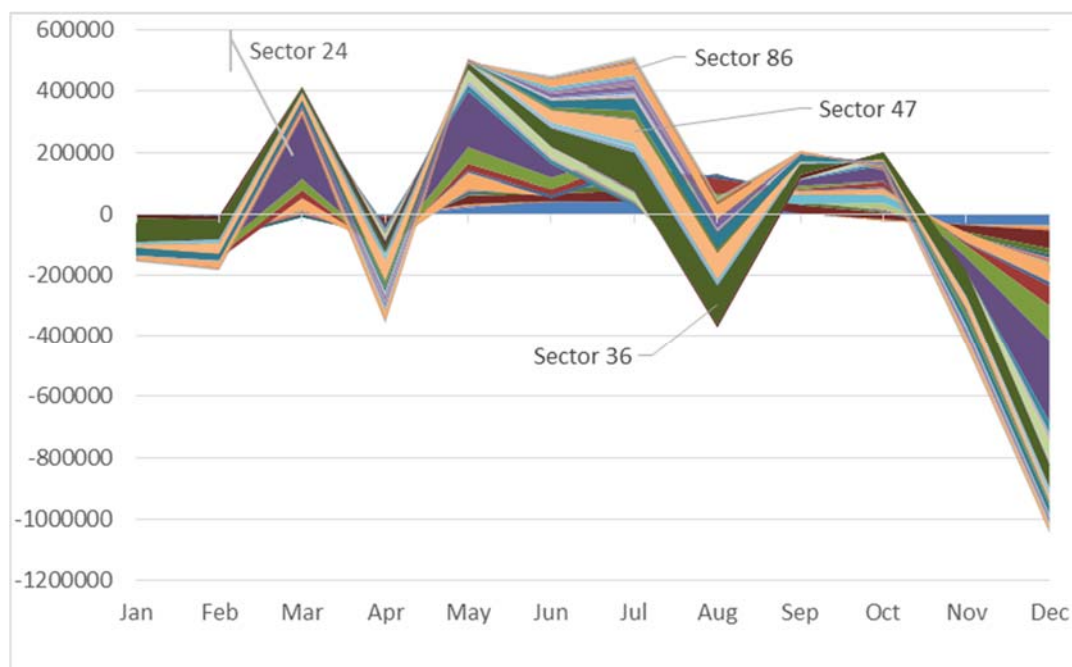
Absolute increase (Mw) in daily basis demand per 1°C variation (below and above threshold temperature respectively)



Once we have analyzed how sectorial electricity demand reacts to temperature changes, it is important to consider the aggregate demand response. As mentioned before, the inverted “W” shape of monthly firms’ electricity demand seems to be inconsistent with traditional explanations based on temperature effects. Figure 13 depicts the differences between monthly sectorial electricity demand and average annual demand for 2012 for all sectors. There are remarkable differences both in monthly sectorial demand patterns and in their final impact on total electricity demand. Three episodes of relatively low demand are found in April (Easter effect), August (summer holidays) and during the winter months. High demand episodes are located between May and July. One can observe that the demand composition is the main driver behind the exhibited aggregate pattern. Sectors do not behave in the same way and they do not share a common demand profile. In particular, electricity consumption by sector 24: “Manufacturing of basic metals” takes on a predominant role. While the “heating” effect is negligible in total firms’ electricity demand, the “cooling” effect becomes particularly evident during June and July. Even though there are only small differences in total consumption between May and July, we observe notable changes in the demand composition. While the weight of sector 24 decreases, we observe notable increases in electricity demand of sectors 36: “Water collection, treatment and supply”, 47: “Retail trade”, 55: “Accommodation,” and 86: “Human health activities”. Consumption by these four sector alone increased by over 250.000 Mw between May and July,

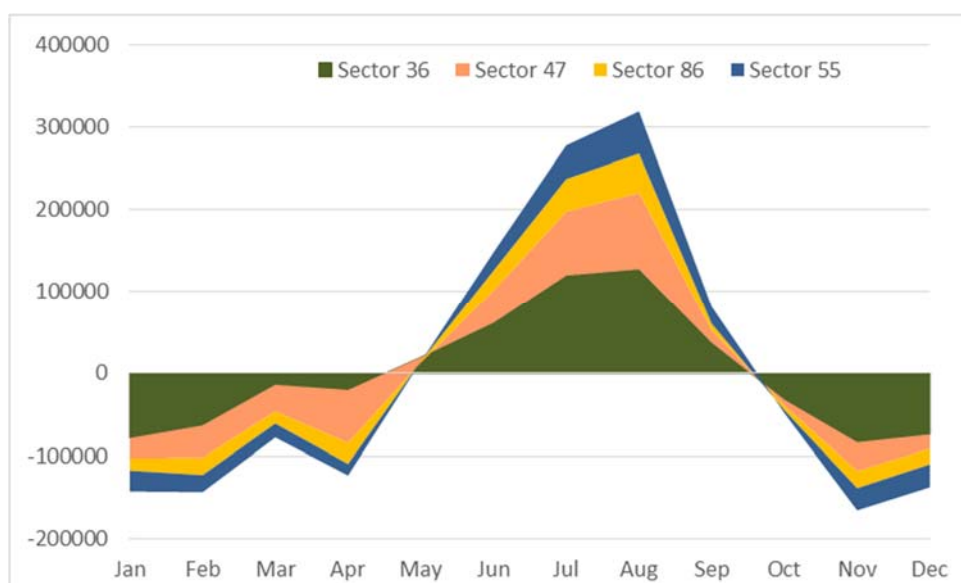
see Figure 14. This increase is mainly due to temperature effect that were high enough to compensate for the reduction in electricity consumption by sector 24.

Figure 13. - Sectorial breakdown of monthly electricity demand. Differences between sectorial electricity consumption and annual mean value. Mw. 2012.



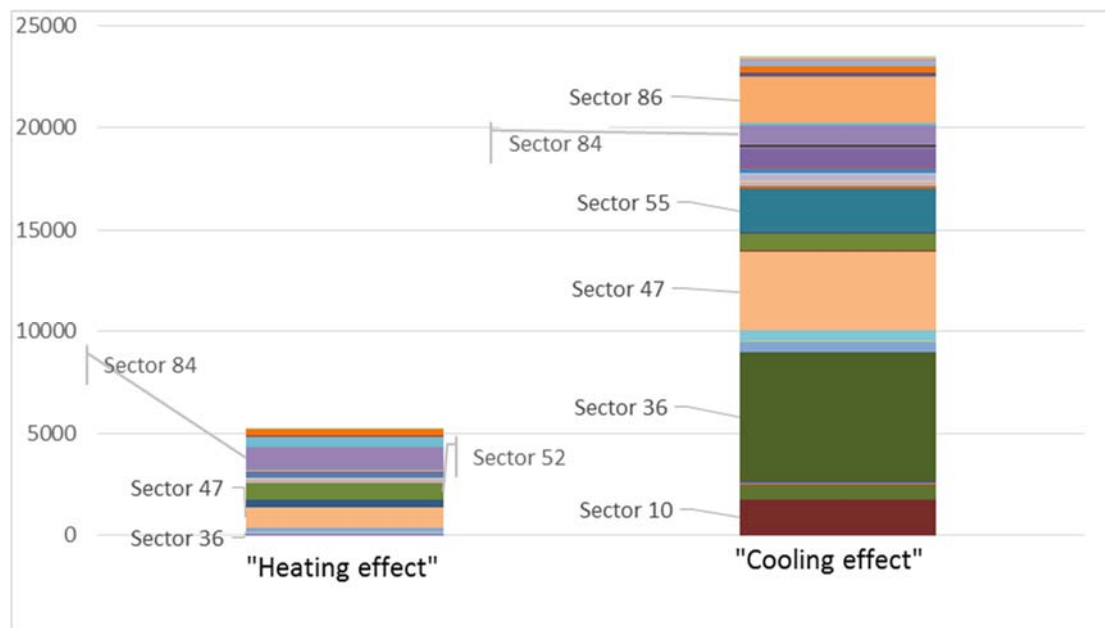
Note: Sectors 36 “Water collection”, 24 “Manufacturing of basic metals”, 86 “Human health activities”, 47 “Retail trade”, and 55 “Accommodation”.

Figure 14 Monthly electricity demand: differences between sectorial electricity consumption and annual mean value. Mw. 2012. Details for sectors 36, 47, 86, and 55.



Note: Sectors 36 “Water collection”, 24 “Manufacturing of basic metals”, 86 “Human health activities”, 47 “Retail trade”, and 55 “Accommodation”.

Figure 15. - Estimates of “Max” and “Min” daily variation in electricity demand due to temperature variation (reference consumption: April 2012). Mw



Note: Sectors 10: “Manufacturing of food products”, 36: “Water collection”, 47: “Retail trade”, and 55: “Accommodation”, 84: “Public administration” and 86: “Human health activities”.

Aggregate demand variability depends not only on how sectors individually react to changes in temperature. It also matters how all other sectors behave. A well-known result on the properties of the variance can be extended to the analysis of the intra-year variability of electricity demand. The aggregate variability is the combination of individual variability and the covariance of sectorial electricity demand. Ideally, it is possible to reach a fully smooth aggregate demand by simply combining sectors, if they exist, with similar but inversely related demand profiles. However, such ideal coordination will have a potentially negative counterparts. An aggregate lower variability is highly dependent on how sectorial demands are coupled. This makes the scenario highly unstable as there is an inherent problem of coordination. Any sector-specific shock that alters a sector’s temporal demand profile – by postponing consumption for instance - could generate an amplified aggregate effect. This is similar to what happens when two out-of-phase waves that cancel each other out are amplified when they are synchronized.

5. CONCLUSIONS

Energy planning is key for reaching better long-term economic outcomes, particularly in a global environment that poses significant challenges (global warming, increasing costs of fossil fuels, unreliable supply sources, etc.). Certain peculiarities characterize the electricity market: no storage, risk of congestion, intermittent production from renewable sources, diversity in marginal generation costs, unfeasibility of on-demand availability in some cases, etc. To guarantee an efficient electricity supply in terms of production and costs, and with a minimal environmental

impact, it is necessary to better understand the behavior of electricity demand. A sound knowledge of demand characteristics – like its sensitivity to energy prices or its dependence on economic activity - allow for better forecasts of future energy needs. However, is also important to comprehend how demand reacts to other short term variables like working days or temperature. Such analysis are key for understanding the effectiveness of optimal demand management policies. They are also useful for anticipating policy limits and potential externalities that may arise from measures of “flattening” demand like “time of day pricing”, “interruptible consumption”, etc. Ultimately, an improved knowledge of demand characteristics can help to better evaluate demand-based energy planning measures as well as the potential need to combine these with support measures to the supply side.

In this paper, we analyze the change in sectorial electricity demand driven by temperature variations. While electricity demand by households, as well as by some service sectors (e.g. the commercial sector), has been analyzed in detail, to the best of our knowledge this is the first work that provides detailed results by sectors; an analysis that we could carry out thanks to the availability of detailed data provided by REE.

Our results are in line with the generally accepted view regarding a higher sensitivity to temperatures in electricity demand of the service sector, and the absence of any significant response in industrial activities. Our estimates show that daily total firms’ electricity consumption increases in mean by 0.1% due to the "heating" effect and by 0.7% as consequence of the "cooling effect," per 1°C variation in temperature (below and above threshold temperature in each case). This is equivalent to increases in electricity demand of 276 Mw and 2,001 Mw, per 1°C variation respectively. This overall effect is rather low. However, according to our results there are significant differences in both the average sensitivity and total sensitivity at the sectorial level. The latter measure includes both, the average effect at the USPC level and the number of USPCs in a particular economic activity, i.e., it takes into account the effective weight of a sector in aggregate electricity demand.

In the Spanish case, six economic sectors turn out to be especially noteworthy (four in the service sector, and two in the industrial sector). The following sectors display high demand sensitivity to temperatures: *Retail trade, Public Administration, Accommodation, Human health activities, Water collection, and Manufacturing of food products*. In these sectors, the use of refrigeration and air conditioning appliances accounts for the increased sensitivity of electricity consumption to variation in temperatures. Of particularly importance for the Spanish economy is the “*Accommodation*” sector, linked to the tourism industry. This sector is characterized by marked seasonal effects - increased activity during warmer months.

A high demand sensitivity to temperatures leads to a higher price inelasticity of electricity demand. This is why in-depth knowledge of sectorial demand responses to temperature changes is fundamental. Once sectorial differences in temperature effects have been assessed, the potential effects of energy planning measures can be addressed more adequately. In this paper we also highlight the relevance of the sectorial composition effect when analyzing the demand variability of electricity throughout the year.

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ANNEX

Table A.1.- Smooth transition regression model estimation result. $\bar{y}_{i,t} = \sum_{j=1}^3 \phi_{i,j} t_i^j + (\phi_{4,i} + \phi_{5,i} T_{it}) [1 - \Phi(T_{it}, \gamma_i, \tau_i)] + (\phi_{6,i} + \phi_{7,i} T_{it}) \Phi(T_{it}, \gamma_i, \tau_i) + \phi_{8,i} A_i + \xi_{i,t}$

Nace rev2	Description	$\phi_{4,i}$	$\phi_{5,i}$	$\phi_{6,i}$	$\phi_{7,i}$	γ_i	τ_i	
1	Crop and animal production, hunting and related service activities	6029.487 (1158.445)	8.756438 ** (86.98674)	3280.134 (1644.914)	195.8612 ** (44.48707)	0.287537 ** (0.190426)	16.80046 (3.401662)	**
2	Forestry and logging	5540.125 (1067.391)	91.62075 ** (6.374935)	7165.754 ** (1571.029)	19.57654 ** (36.54761)	24.4638 (100.623)	28.04089 (0.199989)	**
3	Fishing and aquaculture	9667.422 (195.6897)	61.40035 ** (4.292435)	11375.18 ** (481.6541)	-2.894132 ** (16.21228)	1.227601 (1.009997)	24.15702 (0.97272)	**
5	Mining of coal and lignite	29513.44 (1105.097)	-8.135671 ** (24.62297)	28076.45 (1422.286)	-14.93548 ** (34.47364)	1.061995 (0.487562)	18.70775 ** (0.546628)	**
6	Extraction of crude petroleum and natural gas	3538.556 (321.6757)	93.07311 ** (31.40426)	4210.89 ** (255.8751)	3.028952 ** (3.345025)	67.77743 (899.001)	10.79538 (0.485089)	**
8	Other mining and quarrying	5715.451 (295.2966)	27.9741 ** (17.51782)	7417.233 (1523.851)	-44.9048 ** (52.7484)	0.399611 (0.634332)	24.32307 (6.848888)	**
9	Mining support service activities	6727.061 (436.1911)	11.32511 ** (3.83589)	5882.219 ** (2355.201)	35.08616 ** (77.2091)	2.468904 (6.080402)	27.44929 (1.392915)	**
10	Manufacture of food products	12347.81 (356.5424)	2.933963 ** (20.73043)	16837.53 (3232.431)	-89.04053 ** (99.32569)	0.35609 (0.106254)	24.42183 ** (1.813413)	**
11	Manufacture of beverages	14141.55 (858.5728)	-63.27118 ** (98.37171)	38502.81 (25554.39)	-578.296 (719.1241)	0.236033 (0.072126)	26.70789 ** (3.814696)	**
12	Manufacture of tobacco products	30965.54 (1587.903)	-5.550393 ** (35.06703)	30694.97 (1818.759)	-37.72248 ** (26.87473)	4.851707 (11.76648)	19.05578 (0.496467)	**

Nace rev2	Description	φ4,i	φ5,i	φ6,i	φ7,i	Υi	τi	
13	Manufacture of textiles	11884.49 (678.4897)	** 24.93118 (16.23073)	11518.38 (5199.055)	** 12.16631 (156.3383)	0.722153 (0.813694)	27.04275 (3.936028)	**
14	Manufacture of wearing apparel	4267.141 (318.3258)	** -24.90897 (8.494564)	** 8112.369 (2008.635)	** -91.73695 (57.38604)	0.426911 (0.072243)	26.85846 (0.877805)	**
15	Manufacture of leather and related products	1911.481 (7292.642)	648.4208 (1305.54)	5002.714 (398.5793)	44.13068 (9.85428)	** 0.62462 (0.270333)	7.400367 (4.596434)	**
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	13693.41 (1457.729)	** -163.5816 (302.0336)	19458.66 (6846.56)	** -232.3621 (208.4294)	0.26248 (0.257346)	17.48078 (4.42282)	**
17	Manufacture of paper and paper products	65718.51 (1948.027)	** -349.4401 (95.08739)	** 62700.44 (2194.146)	** 4.493707 (53.13668)	2.125235 (1.337613)	14.33962 (0.377331)	**
18	Printing and reproduction of recorded media	8076.657 (256.4167)	** -0.209474 (4.161907)	7477.153 (545.8002)	** 35.09928 (16.79594)	** 1.826364 (2.914222)	24.1298 (1.096901)	**
19	Manufacture of coke and refined petroleum products	14904.93 (9873.54)	-41.98084 (104.4593)	12867.21 (12733.73)	325.6255 (259.9867)	855.3267 (4800000000)	26.76932 (159820.5)	
20	Manufacture of chemicals and chemical products	26920.79 (1483.639)	** -147.9802 (73.45497)	** 28468.92 (2033.117)	** -29.6077 (57.17029)	0.984718 (0.301696)	17.03588 (0.400994)	**
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	18975.84 (836.5382)	** 20.08951 (40.26397)	22579.02 (4197.285)	** -13.34445 (122.0294)	0.39269 (0.172739)	24.25837 (2.158393)	**
22	Manufacture of rubber and plastic products	30956.98 (1005.798)	** 188.9486 (91.93815)	** 30864.42 (996.2672)	** 112.5993 (14.57481)	** 12.55707 (33.66492)	10.6678 (0.323302)	**
23	Manufacture of other non-metallic mineral products	13320.23 (824.7061)	** 72.92254 (53.05604)	18971.11 (2379.035)	** -101.0078 (82.52554)	0.538815 (0.242523)	18.1577 (1.259396)	**
24	Manufacture of basic metals	190203.7 (14681.4)	** -515.3584 (698.4252)	228286.2 (14763.84)	** -1784.954 (269.9147)	** 1.242793 (0.602455)	16.04058 (0.540988)	**

Nace rev2	Description	φ4,i	φ5,i	φ6,i	φ7,i	Υi	τi	
25	Manufacture of fabricated metal products, except machinery and equipment	8197.386 (681.1933)	-96.06224 ** (105.0502)	10685.52 (4416.321)	-104.8188 ** (130.9102)	0.263407 (0.228517)	19.37899 (3.971766)	**
26	Manufacture of computer, electronic and optical products	11625.05 (407.116)	-15.63933 ** (10.44211)	10356.35 (726.3852)	64.42342 ** (22.19983)	1.225796 ** (1.477815)	20.40827 (1.211472)	**
27	Manufacture of electrical equipment	25686.06 (2052.228)	88.18618 ** (188.4149)	25240.9 (1676.177)	19.97004 ** (15.90706)	314.5827 (1985.181)	10.49034 (0.037183)	**
28	Manufacture of machinery and equipment n.e.c.	9182.464 (478.8392)	-7.588387 ** (44.68218)	8524.117 (482.3421)	17.60242 ** (4.762244)	6.427882 ** (11.58175)	10.00661 (0.514324)	**
29	Manufacture of motor vehicles, trailers and semi-trailers	27545.49 (2967.513)	-382.6462 ** (117.5832)	21703.74 ** (2953.174)	161.0561 ** (30.66689)	281.3814 ** (3090.58)	13.54012 (0.12207)	**
30	Manufacture of other transport equipment	38398.59 (927.8091)	-134.1683 ** (20.8826)	44568.93 ** (4012.276)	-243.2773 ** (120.5317)	0.694135 ** (0.22159)	26.00878 ** (0.815406)	**
31	Manufacture of furniture	4228.67 (271.9821)	-12.37958 ** (5.215741)	3951.351 ** (780.5607)	8.134166 ** (24.12021)	1.562416 (2.421815)	25.3642 (1.159913)	**
32	Other manufacturing	11051.64 (804.7276)	61.12319 ** (14.15518)	12376.56 ** (1481.603)	17.86409 ** (41.29476)	1.529309 (5.416179)	24.17784 (2.995889)	**
33	Repair and installation of machinery and equipment	7551.924 (505.3199)	-104.915 ** (9.197892)	6865.721 ** (1731.039)	-33.95411 ** (54.75776)	1.058402 (0.452548)	24.86451 ** (0.641369)	**
35	Electricity, gas, steam and air conditioning supply	2907.465 (336.3032)	-43.34167 ** (41.74358)	2941.626 (888.808)	0.158402 ** (26.10444)	0.282447 (0.163679)	17.47844 * (2.446673)	**
36	Water collection, treatment and supply	13337.5 (938.847)	-18.94636 ** (32.75013)	8413.153 (924.9749)	293.626 ** (5.857986)	8.229727 ** (54.42319)	15.37069 (1.034325)	**
37	Sewerage	6297.975 (540.1475)	-8.697684 ** (7.200507)	7916.655 (722.3756)	-41.97852 ** (14.74135)	3.948012 ** (1.266096)	22.1239 ** (0.108782)	**

Nace rev2	Description	φ4,i	φ5,i	φ6,i	φ7,i	Υi	τi	
38	Waste collection, treatment and disposal activities; materials recovery	6515.089 (207.0474)	** 13.5097 (2.659184)	** 7870.813 (2104.285)	** -37.77254 (67.97088)	3.701566 (10.26899)	28.7794 (1.177696)	**
39	Remediation activities and other waste management services	2789.709 (83.25955)	** -19.02455 (3.377032)	** 2619.635 (235.3726)	** -3.050131 (7.769289)	0.641771 (0.329541)	* 20.66556 (1.271346)	**
41	Construction of buildings	4833.241 (168.9477)	** -28.69352 (6.620006)	** 10333.17 (4368.974)	** -134.0621 (124.8898)	0.322568 (0.040217)	** 28.36008 (1.843618)	**
42	Civil engineering	4373.096 (303.1253)	** -3.767115 (8.012632)	3714.41 (1231.538)	** 15.38506 (37.8017)	0.500051 (0.815248)	25.80001 (5.354011)	**
43	Specialised construction activities	25.42876 (266.6128)	-19.65326 (7.55423)	** 30.54241 (1673.338)	3.101445 (51.25034)	0.484456 (0.230357)	** 24.71459 (2.71234)	**
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	9670.749 (580.013)	** -55.90517 (11.53289)	** 9170.366 (978.3723)	** -18.21814 (27.65371)	2.266113 (5.517126)	22.62308 (1.357945)	**
46	Wholesale trade, except of motor vehicles and motorcycles	5249.239 (171.8703)	** 11.21711 (4.391637)	** 4542.96 (339.9818)	** 53.16667 (10.68594)	** 0.833981 (0.689488)	20.94964 (1.438272)	**
47	Retail trade, except of motor vehicles and motorcycles	5067.354 (345.2751)	** -29.83852 (10.09801)	** 3250.177 (782.1633)	** 96.98276 (21.19457)	** 0.479772 (0.08946)	** 22.86629 (0.644966)	**
49	Land transport and transport via pipelines	19427.88 (261.7578)	** -2.401087 (18.65479)	** 18452.26 (264.1104)	** 19.59922 (3.566017)	** 0.730978 (0.184779)	** 14.73063 (0.587522)	**
51	Air transport	-941.0833 (1140.254)	-254.6688 (19.77216)	** -3646.699 (5421.987)	36.64928 (148.5233)	0.446988 (0.10337)	26.17125 (1.296532)	**
52	Warehousing and support activities for transportation	17697.38 (241.3359)	** -61.71472 (7.83444)	** 19647.13 (2715.725)	** -59.64947 (80.18546)	0.401292 (0.075045)	26.02112 (1.507193)	**
53	Postal and courier activities	6711.514 (366.6185)	** -41.904 (12.59346)	** 16604.7 (6313.642)	** -239.9195 (174.1974)	0.31191 (0.042587)	28.89386 (1.678757)	**

Nace rev2	Description	φ4,i	φ5,i	φ6,i	φ7,i	Υi	τi	
55	Accommodation	3659.481 (519.9694)	-14.68867 ** (36.50346)	1511.206 (1831.94)	161.9039 (52.16539)	0.305168 ** (0.089319)	20.61632 ** (1.916586)	**
56	Food and beverage service activities	4502.07 (231.0919)	-6.579906 ** (10.66595)	5133.446 (1143.983)	26.51025 ** (33.99356)	0.346097 (0.065672)	23.63598 ** (1.148814)	**
58	Publishing activities	9305.175 (217.1038)	-37.68395 ** (3.306992)	7301.173 ** (260.3264)	61.92339 ** (6.511089)	1.611506 ** (2.057501)	21.75829 (1.103874)	**
59	Motion picture, video and television programme production, sound recording and music publishing activities	4777.603 (185.753)	-69.99553 ** (5.523283)	6443.637 ** (2593.745)	-50.97164 ** (74.96206)	0.362437 (0.042504)	26.88611 ** (1.399135)	**
60	Programming and broadcasting activities	13949.83 (273.1475)	-26.48023 ** (7.668424)	11345.55 ** (309.1793)	92.6715 ** (5.310324)	0.607025 ** (0.259562)	20.83345 ** (1.379456)	**
61	Telecommunications	14436.89 (219.3718)	7.371386 ** (11.58539)	14213.48 (629.9785)	56.61336 ** (17.73261)	0.309754 ** (0.085561)	21.28379 ** (1.378478)	**
62	Computer programming, consultancy and related activities	7471.136 (338.8597)	-46.62534 ** (21.00374)	8010.129 ** (4208.396)	15.50732 * (106.8722)	0.232979 (0.072825)	25.01953 ** (4.875387)	**
63	Information service activities	7321.762 (211.2889)	-24.70573 ** (8.723856)	7578.933 ** (621.261)	5.809531 ** (19.46589)	0.456963 (0.093513)	21.5484 ** (0.710335)	**
64	Financial service activities, except insurance and pension funding	8668.425 (191.1115)	-45.26798 ** (9.16844)	12257.54 ** (3196.743)	-83.31954 ** (86.11937)	0.271128 (0.043167)	27.33599 ** (2.084593)	**
65	Insurance, reinsurance and pension funding, except compulsory social security	7769.742 (234.9182)	-23.35154 ** (7.962869)	18740.47 ** (9363.927)	-263.3683 ** (247.5003)	0.275391 (0.040671)	31.64002 ** (2.970724)	**
66	Activities auxiliary to financial services and insurance activities	7062.145 (194.5906)	-44.83607 ** (4.712653)	6941.058 ** (1213.071)	15.44233 ** (34.63768)	0.38432 (0.05298)	25.32518 ** (1.092491)	**
68	Real estate activities	6416.139 (326.4759)	-11.6089 ** (9.889505)	5670.153 (856.9931)	74.94748 ** (23.58215)	0.384665 ** (0.075484)	23.353 ** (0.833349)	**

Nace rev2	Description	φ4,i		φ5,i		φ6,i		φ7,i		Υi		τi	
69	Legal and accounting activities	5280.325 (348.1607)	**	-50.17835 (29.66815)	*	27917.38 (29651.03)		-545.8887 (769.628)		0.205937 (0.044778)	**	32.13141 (6.188192)	**
70	Activities of head offices; management consultancy activities	3094.451 (266.4089)	**	-19.27163 (9.342378)	**	4286.441 (1699.731)	**	-10.6358 (48.05328)	**	0.369291 (0.089444)	**	25.41717 (1.527842)	**
71	Architectural and engineering activities; technical testing and analysis	9750.701 (251.7093)	**	-29.03529 (3.149023)	**	8899.939 (466.005)	**	15.51771 (12.99101)	**	1.366912 (0.950578)		25.3347 (0.716472)	**
72	Scientific research and development	7968.452 (169.7124)	**	-39.60025 (17.20908)	**	31549.56 (39208.66)	**	-639.084 (1098.097)		0.222738 (0.044436)	**	32.11648 (7.775002)	**
73	Advertising and market research	7124.113 (211.8481)	**	0.260393 (8.827671)		5988.75 (236.6605)	**	54.75325 (3.91437)	**	0.412159 (0.165776)	**	18.54791 (2.849307)	**
74	Other professional, scientific and technical activities	12060.26 (358.2027)	**	8.046125 (12.82377)		12355.61 (1671.119)	**	44.60847 (48.3158)	**	0.385199 (0.142764)	**	24.08584 (1.901544)	**
77	Rental and leasing activities	6692.284 (186.347)	**	-12.46592 (4.255466)	**	8290.185 (2694.353)	**	-42.29234 (77.77686)	**	0.399487 (0.134121)	**	27.65774 (3.20161)	**
79	Travel agency, tour operator and other reservation service and related activities	7462.352 (266.0015)	**	-47.24064 (9.932964)	**	11969.7 (4794.483)	**	-99.7752 (122.3599)	**	0.238296 (0.040601)	**	29.16533 (3.051549)	**
80	Security and investigation activities	5036.212 (246.3071)	**	-28.49429 (10.63136)	**	21856.44 (11333.07)	*	-416.6222 (287.393)		0.220952 (0.032623)	**	33.76284 (3.318601)	**
81	Services to buildings and landscape activities	2761.054 (778.1365)	**	-21.12399 (14.84701)		-1021.811 (852.4481)		139.22 (17.97391)	**	3.900609 (3.913969)	**	21.51562 (0.317746)	**
82	Office administrative, office support and other business support activities	13697.48 (695.9193)	**	-77.32774 (16.56729)	**	15609.22 (1521.572)	**	-110.6527 (49.48757)	**	0.738609 (0.412147)	*	22.00474 (1.080703)	**
84	Public administration and defence; compulsory social security	6530.148 (155.4183)	**	-54.61265 (3.719602)	**	7613.254 (1469.784)	**	-36.95678 (42.13994)	**	0.422191 (0.053428)	**	26.84845 (0.96816)	**

Nace rev2	Description	$\phi 4,i$	$\phi 5,i$	$\phi 6,i$	$\phi 7,i$	Υi	τi	
85	Education	10796.79 (372.3748)	** -87.19154 (8.397073)	** 7018.963 (632.0423)	** 113.2251 (17.65987)	** 0.974535 (0.734566)	20.84573 (1.014216)	**
86	Human health activities	12363.8 (864.6474)	** -13.13245 (45.81471)	4567.481 (1165.4)	** 364.9361 (29.81299)	** 0.370626 (0.083663)	19.92274 (1.795384)	**
87	Residential care activities	3067.308 (238.4434)	** -22.20253 (4.496106)	** 1534.027 (388.9273)	** 60.38003 (9.34326)	** 0.572706 (0.124272)	24.24996 (0.571977)	**
88	Social work activities without accommodation	4374.793 (196.8074)	** -42.70078 (4.144589)	** 6151.019 (1690.362)	** -50.08903 (45.79534)	0.369087 (0.05055)	27.91851 (1.227927)	**
90	Creative, arts and entertainment activities	7875.364 (282.5326)	** -51.22257 (6.288707)	** 6074.63 (335.3079)	** 45.57604 (6.844835)	** 1.03077 (1.216641)	19.17282 (1.807158)	**
91	Libraries, archives, museums and other cultural activities	8531.23 (467.2708)	** -46.17935 (15.1674)	** 9896.703 (2094.407)	** -0.413389 (61.9094)	0.379432 (0.068574)	24.17045 (1.004751)	**
92	Gambling and betting activities	4289.655 (252.8896)	** -48.16051 (21.87554)	** 13535.19 (14542.94)	-204.9555 (370.0053)	0.206473 (0.046275)	30.60658 (6.019358)	**
93	Sports activities and amusement and recreation activities	3687.856 (255.3649)	** 8.492479 (24.26896)	296.9595 (305.8988)	126.1238 (6.730983)	** 0.483416 (0.070628)	16.52389 (0.59617)	**
94	Activities of membership organisations	6720.808 (612.9918)	** 19.7443 (13.6761)	3542.226 (1472.43)	188.21 (38.80169)	** 0.442311 (0.123799)	23.5671 (1.647196)	**
96	Other personal service activities	8251.038 (276.4313)	** -15.0741 (9.666999)	15028.33 (6479.044)	** -147.3092 (179.9466)	0.326257 (0.054655)	29.35031 (2.332647)	**
97	Activities of households as employers of domestic personnel	6838.278 (416.75)	** -78.66355 (16.55301)	** 12188.61 (4338.386)	** -120.6321 (117.8579)	0.307816 (0.043493)	27.44607 (1.376457)	**
99	Activities of extraterritorial organisations and bodies	8747.165 (1226.062)	** 18.09417 (41.0147)	5926.344 (1123.441)	** 134.1786 (12.32808)	** 2.095604 (1.231017)	15.72276 (0.347101)	**

Note: *, coefficient significant at 10% confidence level, **. Coefficient significant at 5% confidence level. Estimated coefficients for August month dummy and for third-order time trend polynomial not included in the table.

Table A.2.- Sectorial “heating” and “cooling effect” estimation results . Standardized coefficients

Nace rev2	Description	Model Eq .2 Exc. Holidays				Model Eq. 2 Holidays included				Model Eq. 3			
		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$	
		Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.
1	Crop and animal production, hunting and related service activities	0.058206	*	1.680392	**	0.069007	*	1.689765	**	0.084683	**	1.609976	**
2	Forestry and logging	0.787652	**	-0.449128	*	0.785174	**	-0.47395	*	0.599154	**	-0.449912	*
3	Fishing and aquaculture	1.129975	**	0.144648		1.122612	**	0.206239		0.949142	**	0.169527	
5	Mining of coal and lignite	-0.207743	**	-0.197224		-0.167597	*	-0.220366		-0.135241	**	-0.24666	
6	Extraction of crude petroleum and natural gas	0.38817	**	0.076398		0.316838		0.197607	**	0.043734		0.008251	
8	Other mining and quarrying	0.403596	**	-1.209627	**	0.467992	**	-1.0596	**	0.15289	**	-0.587075	**
9	Mining support service activities	0.026758		0.267572		0.05867	*	0.280084	*	0.009986		0.149815	
10	Manufacture of food products	0.386083	**	1.310364	**	0.34982	**	1.218289	**	0.095751	**	0.419595	**
11	Manufacture of beverages	0.311635	**	1.928879	**	0.296959	**	1.863496	**	0.110067	**	0.824008	**
12	Manufacture of tobacco products	-0.044108		-0.367764	**	-0.075207		-0.258413	*	-0.051186		-0.141331	*
13	Manufacture of textiles	0.064368		-0.744995		0.144808	**	-0.893666		0.025212		-0.560492	
14	Manufacture of wearing apparel	-0.246975	**	1.960144	**	-0.266716	**	1.883944	**	-0.124297	**	0.685573	**
15	Manufacture of leather and related products	0.056813		0.364212	**	-0.005695		0.460215	**	-0.08527	*	0.11436	**
													Threshold

Nace rev2	Description	Model Eq .2 Exc. Holidays				Model Eq. 2 Holidays included				Model Eq. 3				Threshold
		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		
		Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.075981		-0.17301		0.173553	**	-0.227695		0.027673		-0.453982		28
17	Manufacture of paper and paper products	0.275711	**	0.028766		0.230377	*	0.137888		0.020679		-0.061763	*	16.6
18	Printing and reproduction of recorded media	-0.029881		1.108492	**	0.071444		0.914666	**	-0.05302	**	0.361365	**	24.6
19	Manufacture of coke and refined petroleum products	0.09088	**	-0.182013		0.09211	**	-0.178856		0.099701	**	-0.17283		26.8
20	Manufacture of chemicals and chemical products	0.156858		-0.179155	*	0.148878		-0.132833		0.135784		-0.170555	*	18
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.098523		1.424295	**	0.111897		1.312122	**	0.051282		0.759768	**	21
22	Manufacture of rubber and plastic products	0.240122		0.216685	**	0.17129		0.294999	**	0.026913		0.081064	**	10.6
23	Manufacture of other non-metallic mineral products	0.779611	**	-0.863116	**	0.813863	**	-0.757323	**	0.635394	**	-0.735514	**	20.8
24	Manufacture of basic metals	0.02722		-0.78519	**	0.065276		-0.638453	**	0.074614		-0.647048	**	16.8
25	Manufacture of fabricated metal	0.031584		-0.957192	**	0.134642		-0.907906	**	0.000452		-0.544668	**	24.4

Nace rev2	Description	Model Eq. 2 Exc. Holidays				Model Eq. 2 Holidays included				Model Eq. 3				Threshold
		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		
		Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	
	products, except machinery and equipment													
	Manufacture of computer, electronic and optical products	-0.134462		0.963528 **		-0.110605		0.927684 **		-0.039935		0.356877 **		20.2
26	Manufacture of electrical equipment	0.177494		0.028024		0.186926		0.141767 *		0.013747		-0.01168		10.4
27	Manufacture of machinery and equipment n.e.c.	0.04841		0.09012		0.068618		0.207651 **		-0.04293		0.027647		10.4
28	Manufacture of motor vehicles, trailers and semi-trailers	0.184895 *		0.30992 **		0.122861		0.386958 **		0.030746		0.118799 **		16
29	Manufacture of other transport equipment	-0.202152 **		-0.434091		-0.10278		-0.366894		-0.12182 **		-0.149633		25.4
30	Manufacture of furniture	-0.167012 **		-0.142115		-0.065981		-0.199295		-0.078014 **		-0.144278		25
31	Other manufacturing	0.278062 **		-0.329943		0.338195 **		-0.312426		0.113195 **		-0.225463		25.4
32	Repair and installation of machinery and equipment	-0.86106 **		0.401609		-0.763066 **		0.354582		-0.52909 **		0.186519		22.6
33	Electricity, gas, steam and air conditioning supply	0.343034 **		-0.120466		0.341428 **		-0.166823		0.298561 **		-0.123038		27.6
34	Water collection, treatment and supply	-0.064207		1.79265 **		-0.058328		1.764459 **		-0.037949		1.73039 **		15.8
35	Sewerage	-0.135207 **		0.048295		-0.130198 **		0.03632		-0.146864 **		0.051883		22.4
36	Waste collection, treatment and disposal activities; materials	0.545189 **		0.078856		0.451752 **		0.189957 **		0.092754		0.000114		27.8
37														
38														

Nace rev2	Description	Model Eq. 2 Exc. Holidays				Model Eq. 2 Holidays included				Model Eq. 3				Threshold
		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		
		Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	
	recovery													
	Remediation activities and other waste management services	-0.142687		0.609424	**	-0.125067		0.551217	**	-0.140657	**	0.286574		21.8
39	Construction of buildings	-0.220595	**	2.253645	**	-0.230589	**	2.22773	**	-0.254147	**	1.896341	**	19.8
41	Civil engineering	0.093951	**	0.015304		0.117548	**	0.030736		0.090758	**	0.071814		25.8
42	Specialised construction activities	0.03845		0.768009	**	-0.069157		0.81132	**	-0.099425		0.537793	**	15
43	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.179428		-0.094699		0.167254		0.006431		0.021353		-0.050239	*	22.8
45	Wholesale trade, except of motor vehicles and motorcycles	0.278277	**	1.688001	**	0.258109	**	1.507506	**	0.072504	**	0.525561	**	20.8
46	Retail trade, except of motor vehicles and motorcycles	-0.2697	**	2.59013	**	-0.304731	**	2.569696	**	-0.187238	**	1.423099	**	19.4
47	Land transport and transport via pipelines	-0.239388	**	0.086551		-0.259165	**	0.121439	**	-0.279776	**	0.085571	**	14.8
49	Air transport	-0.293387	**	1.057677	**	-0.31713	**	1.057881	**	-0.345078	**	0.797467	**	19.2
51	Warehousing and support activities for transportation	-0.604071	**	2.05223	**	-0.590573	**	1.981495	**	-0.321742	**	0.756309	**	18.8
52	Postal and courier activities	-0.128526	**	1.941647	**	-0.145379	**	1.927731	**	-0.166418	**	1.629902	**	20.6
53	Accommodation	0.124485	**	2.359772	**	0.163085	**	2.356511	**	0.083839	**	2.479669	**	18.4
55	Food and beverage	-0.055755		2.185737	**	-0.062353		2.206234	**	-0.110189	**	2.090752	**	17
56														

Nace rev2	Description	Model Eq. 2 Exc. Holidays				Model Eq. 2 Holidays included				Model Eq. 3				Threshold
		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		
		Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	
	service activities													
58	Publishing activities	-0.246782	**	0.797991	**	-0.250737	**	0.788126	**	-0.263022	**	0.761032	**	21.2
	Motion picture, video and television programme production, sound recording and music													
59	publishing activities	-1.03638	**	3.143816	**	-1.065567	**	3.124657	**	-1.271942	**	3.330885	**	21
	Programming and													
60	broadcasting activities	-0.295787	**	1.681555	**	-0.301338	**	1.678824	**	-0.240075	**	1.181851	**	20
61	Telecommunications	0.186554	**	1.80626	**	0.177169	**	1.810853	**	0.146854	**	1.488564	**	17
	Computer programming, consultancy and related													
62	activities	-0.155686		0.895647	**	-0.196473	**	0.908909	**	-0.156988	**	0.708269	**	17
	Information service													
63	activities	-0.104179	*	1.175169	**	-0.122516	**	1.204619	**	-0.138331	**	0.986328	**	15
	Financial service activities, except insurance and pension													
64	funding	-0.339313	**	1.683968	**	-0.351411	**	1.663542	**	-0.229802	**	0.862177	**	18.4
	Insurance, reinsurance and pension funding, except compulsory social													
65	security	-0.059313		2.212825	**	-0.057506		2.141954	**	-0.064625	**	1.143017	**	22.8
	Activities auxiliary to financial services and													
66	insurance activities	-0.195643	**	1.270038	**	-0.22197	**	1.279952	**	-0.213315	**	1.090542	**	19.8
68	Real estate activities	-0.06012	**	2.336361	**	-0.060121	**	2.330997	**	-0.111515	**	1.901219	**	19.2
	Legal and accounting													
69	activities	-0.142824	*	1.856415	**	-0.137689	*	1.857901	**	-0.188158	**	1.495824	**	16.2

Nace rev2	Description	Model Eq. 2 Exc. Holidays				Model Eq. 2 Holidays included				Model Eq. 3				Sign.	Threshold
		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$			
		Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.		
70	Activities of head offices; management consultancy activities	-0.179457	**	2.294769	**	-0.194249	**	2.170137	**	-0.133212	**	0.879668	**		20.4
71	Architectural and engineering activities; technical testing and analysis	-0.124995	*	0.157284		-0.088236		0.140367		-0.079123	*	0.212911			26.4
72	Scientific research and development	-0.035866		1.464912	**	-0.029138		1.467533	**	-0.094442	**	1.253492	**		17.8
73	Advertising and market research	-0.057841		1.043018	**	-0.065944		1.052575	**	-0.085348	**	0.898973	**		19.8
74	Other professional, scientific and technical activities	0.506974	**	0.477167	**	0.526706	**	0.426156	*	0.356002	**	0.473875	**		25.8
77	Rental and leasing activities	-0.169934	**	0.478364	**	-0.163342	*	0.464184	*	-0.116104	**	0.212736			22.8
79	Travel agency, tour operator and other reservation service and related activities	-0.374678	**	1.052084	**	-0.386263	**	1.055026	**	-0.379959	**	0.847166	**		14.8
80	Security and investigation activities	-0.004914		1.926468	**	-0.02004		1.908622	**	-0.065496	*	1.426512	**		20.2
81	Services to buildings and landscape activities	-0.206782		2.514691	**	-0.195984		2.419408	**	-0.300487	**	2.109827	**		22.2
82	Office administrative, office support and other business support activities	-0.355256	**	-0.985282	**	-0.329003	**	-0.977851	**	-0.313853	**	-0.679524	**		22.2

Nace rev2	Description	Model Eq .2 Exc. Holidays				Model Eq. 2 Holidays included				Model Eq. 3				Sign.	Threshold
		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$		$T_{it}(T_{it} \leq \tau_i)$		$T_{it}(T_{it} > \tau_i)$			
		Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.	Heating effect	Sign.	Cooling effect	Sign.		
	Public administration and defence; compulsory														
84	social security	-0.582641	**	1.725737	**	-0.58053	**	1.693673	**	-0.448117	**	1.284264	**		21.2
85	Education	-0.620878	**	1.350103	**	-0.607186	**	1.343268	**	-0.426671	**	0.909445	**		20.4
86	Human health activities	-0.036462		2.90581	**	-0.053775	*	2.883431	**	-0.111919	**	2.795257	**		20.4
87	Residential care activities	-0.451174	**	3.292068	**	-0.470554	**	3.271716	**	-0.548763	**	3.542218	**		22
	Social work activities														
88	without accommodation	-0.465684	**	1.420816	**	-0.485641	**	1.414827	**	-0.426346	**	1.281133	**		21.8
	Creative, arts and														
90	entertainment activities	-0.314753	**	0.636324	**	-0.319305	**	0.652953	**	-0.393732	**	0.74121	**		19.6
	Libraries, archives, museums and other														
91	cultural activities	-0.299292	**	2.394337	**	-0.301423	**	2.394409	**	-0.447027	**	2.368386	**		18
	Gambling and betting														
92	activities	-0.177313	**	2.233212	**	-0.19186	**	2.222872	**	-0.310193	**	2.366859	**		18.8
	Sports activities and amusement and														
93	recreation activities	-0.93609	**	3.204478	**	-0.954774	**	3.205995	**	-1.182952	**	3.133613	**		20.4
	Activities of membership														
94	organisations	0.164392	**	3.023912	**	0.153484	**	3.010347	**	0.087952	**	2.84427	**		21
	Other personal service														
96	activities	-0.098504	*	2.893647	**	-0.099413	*	2.887079	**	-0.150028	**	2.182592	**		21
	Activities of households as employers of domestic														
97	personnel	-0.447275	**	2.364874	**	-0.46648	**	2.360788	**	-0.511008	**	2.146561	**		19.8
	Activities of extraterritorial														
99	Organisations and bodies	-0.024198		0.145281	*	-0.039276		0.145177	*	0.013685		0.130434	*		16.2

Note: *, coefficient significant at 10% confidence level, **. Coefficient significant al 5% confidence level. Table Cells shaded if the estimated coefficient has the wrong expected sign.

Table A.3.- Estimated sectorial demand elasticities for “heating” and “cooling” effect.

Nace rev2	Description	Heating effect			Cooling effect			Basis Reference Consumption		
		Elasticity	Min/Basis Consumption ratio	Range Min ¹ (°C)	Elasticity	Max/Basis Consumption ratio	Range Max ² (°C)	Daily Consumption per CUPS unit (Kwh)	Total Sector Monthly Consumption Mwh (May 2012)	% share in total consumption CUPS 1 & 2 (May 2012)
1	Crop and animal production, hunting and related service activities				6.9%	122.0%	21.9	3,062.6	111,778	1.3%
2	Forestry and logging							3,427.2	543	0.0%
3	Fishing and aquaculture							8,193.8	11,940	0.1%
5	Mining of coal and lignite	0.4%	5.3%	19.1				15,536.3	29,834	0.3%
6	Extraction of crude petroleum and natural gas							2,798.0	1,850	0.0%
8	Other mining and quarrying							6,626.5	88,599	1.0%
9	Mining support service activities							4,339.2	6,281	0.1%
10	Manufacture of food products				0.7%	9.9%	13.8	12,333.7	553,744	6.2%
11	Manufacture of beverages				2.1%	24.0%	13.8	12,560.9	90,616	1.0%
12	Manufacture of tobacco products							13,074.2	4,359	0.0%
13	Manufacture of textiles							8,585.2	72,201	0.8%
14	Manufacture of wearing apparel	0.5%	6.3%	16.9	2.3%	17.4%	14.9	3,723.4	4,140	0.0%

Nace rev2	Description	Heating effect			Cooling effect			Basis Reference Consumption		
		Elasticity	Min/Basis Consumption ratio	Range Min ¹ (°C)	Elasticity	Max/Basis Consumption ratio	Range Max ² (°C)	Daily Consumption per CUPS unit (Kwh)	Total Sector Monthly Consumption Mwh (May 2012)	% share in total consumption CUPS 1 & 2 (May 2012)
15	Manufacture of leather and related products				0.7%	-5.4%	19.0	4,635.3	8,037	0.1%
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials							12,765.3	92,943	1.0%
17	Manufacture of paper and paper products							60,456.4	455,936	5.1%
18	Printing and reproduction of recorded media				0.5%	3.4%	11.5	7,368.0	40,448	0.5%
19	Manufacture of coke and refined petroleum products							156,098.8	215,822	2.4%
20	Manufacture of chemicals and chemical products							49,609.9	768,555	8.6%
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations				1.0%	2.2%	14.8	17,115.3	87,066	1.0%
22	Manufacture of rubber and plastic products				0.3%	-6.6%	24.7	16,811.8	346,718	3.9%
23	Manufacture of other non-metallic mineral products							19,311.7	513,514	5.8%
24	Manufacture of basic metals							162,771.2	1,996,851	22.4%

Nace rev2	Description	Heating effect			Cooling effect			Basis Reference Consumption		
		Elasticity	Min/Basis Consumption ratio	Range Min ¹ (°C)	Elasticity	Max/Basis Consumption ratio	Range Max ² (°C)	Daily Consumption per CUPS unit (Kwh)	Total Sector Monthly Consumption Mwh (May 2012)	% share in total consumption CUPS 1 & 2 (May 2012)
25	Manufacture of fabricated metal products, except machinery and equipment							8,659.4	181,889	2.0%
26	Manufacture of computer, electronic and optical products				0.8%	2.4%	13.4	7,571.8	17,426	0.2%
27	Manufacture of electrical equipment							23,425.6	131,596	1.5%
28	Manufacture of machinery and equipment n.e.c.							6,582.8	44,435	0.5%
29	Manufacture of motor vehicles, trailers and semi-trailers				0.7%	-2.7%	18.3	26,962.2	288,137	3.2%
30	Manufacture of other transport equipment	0.3%	2.2%	21.1				20,371.4	50,760	0.6%
31	Manufacture of furniture	0.4%	11.1%	20.8				3,780.0	15,738	0.2%
32	Other manufacturing							9,202.2	11,474	0.1%
33	Repair and installation of machinery and equipment	1.4%	16.5%	17.5				6,398.8	1,871	0.0%
35	Electricity, gas, steam and air conditioning supply							6,481.2	167,558	1.9%
36	Water collection, treatment and supply				4.5%	68.8%	19.2	6,847.9	287,001	3.2%
37	Sewerage	0.4%	3.3%	17.5				7,137.9	2,707	0.0%

Nace rev2	Description	Heating effect			Cooling effect			Basis Reference Consumption		
		Elasticity	Min/Basis Consumption ratio	Range Min ¹ (°C)	Elasticity	Max/Basis Consumption ratio	Range Max ² (°C)	Daily Consumption per CUPS unit (Kwh)	Total Sector Monthly Consumption Mwh (May 2012)	% share in total consumption CUPS 1 & 2 (May 2012)
38	Waste collection, treatment and disposal activities; materials recovery							5,455.4	27,301	0.3%
39	Remediation activities and other waste management services				1.4%	13.3%	12.6	1,577.2	553	0.0%
41	Construction of buildings	0.4%	11.0%	16.0	2.5%	28.9%	15.3	3,822.6	56,596	0.6%
42	Civil engineering							5,073.0	16,222	0.2%
43	Specialised construction activities				0.9%	11.2%	20.7	3,807.1	13,168	0.1%
45	Wholesale and retail trade and repair of motor vehicles and motorcycles							8,935.1	21,110	0.2%
46	Wholesale trade, except of motor vehicles and motorcycles				0.8%	8.0%	14.2	5,982.3	189,751	2.1%
47	Retail trade, except of motor vehicles and motorcycles	0.5%	7.9%	15.2	2.6%	31.0%	15.4	5,703.9	390,983	4.4%
49	Land transport and transport via pipelines	0.3%	7.8%	11.5			21.7	14,650.0	142,495	1.6%
51	Air transport	0.7%	9.4%	18.9	1.1%	24.5%	21.6	21,559.1	7,107	0.1%
52	Warehousing and support activities for transportation	0.4%	7.5%	15.0	0.7%	7.2%	16.4	13,897.5	350,106	3.9%
53	Postal and courier activities	0.4%	11.1%	17.4	3.3%	39.0%	15.4	5,079.6	3,416	0.0%
55	Accommodation				5.8%	70.4%	16.1	3,794.1	95,397	1.1%

Nace rev2	Description	Heating effect			Cooling effect			Basis Reference Consumption		
		Elasticity	Min/Basis Consumption ratio	Range Min ¹ (°C)	Elasticity	Max/Basis Consumption ratio	Range Max ² (°C)	Daily Consumption per CUPS unit (Kwh)	Total Sector Monthly Consumption Mwh (May 2012)	% share in total consumption CUPS 1 & 2 (May 2012)
56	Food and beverage service activities				3.1%	41.7%	17.6	3,051.3	10,440	0.1%
58	Publishing activities	0.5%	17.8%	18.8	1.0%	13.2%	16.0	6,647.6	6,977	0.1%
59	Motion picture, video and television programme production, sound recording and music publishing activities	2.4%	42.3%	17.7	4.0%	47.6%	15.4	2,543.0	8,180	0.1%
60	Programming and broadcasting activities	0.2%	7.1%	17.8	0.7%	9.2%	18.2	12,638.0	18,162	0.2%
61	Telecommunications				0.7%	11.8%	20.7	13,411.6	83,017	0.9%
62	Computer programming, consultancy and related activities				0.6%	10.5%	21.8	12,121.8	22,599	0.3%
63	Information service activities				1.6%	24.4%	19.1	4,536.6	1,714	0.0%
64	Financial service activities, except insurance and pension funding	0.5%	11.0%	15.5	1.2%	16.3%	18.4	6,706.9	52,307	0.6%
65	Insurance, reinsurance and pension funding, except compulsory social security				1.5%	16.1%	15.1	6,519.3	7,721	0.1%
66	Activities auxiliary to financial services and insurance activities	0.6%	20.8%	17.9	1.9%	28.7%	17.4	4,873.5	3,296	0.0%
68	Real estate activities	0.1%	5.4%	16.4	2.6%	34.5%	17.4	5,336.1	74,280	0.8%

Nace rev2	Description	Heating effect			Cooling effect			Basis Reference Consumption		
		Elasticity	Min/Basis Consumption ratio	Range Min ¹ (°C)	Elasticity	Max/Basis Consumption ratio	Range Max ² (°C)	Daily Consumption per CUPS unit (Kwh)	Total Sector Monthly Consumption Mwh (May 2012)	% share in total consumption CUPS 1 & 2 (May 2012)
69	Legal and accounting activities			12.1	2.6%	41.2%	19.8	5,320.3	4,616	0.1%
70	Activities of head offices; management consultancy activities	0.2%	7.8%	17.1	1.7%	18.3%	16.8	4,891.6	8,759	0.1%
71	Architectural and engineering activities; technical testing and analysis							3,834.6	10,031	0.1%
72	Scientific research and development				1.7%	20.1%	15.1	6,249.3	16,563	0.2%
73	Advertising and market research				1.0%	17.7%	18.5	4,713.1	1,377	0.0%
74	Other professional, scientific and technical activities				0.7%	0.4%	10.2	5,052.9	5,762	0.1%
77	Rental and leasing activities	0.3%	7.0%	20.3	0.6%	6.7%	12.1	2,814.6	1,168	0.0%
79	Travel agency, tour operator and other reservation service and related activities	1.7%	37.7%	14.9	1.8%	35.9%	22.8	3,430.2	642	0.0%
80	Security and investigation activities				1.7%	20.2%	18.2	4,338.3	1,286	0.0%
81	Services to buildings and landscape activities				1.8%	7.2%	10.3	9,597.9	17,299	0.2%
82	Office administrative, office support and other business support activities	0.8%	11.5%	18.4				7,515.2	12,365	0.1%
84	Public administration and defence; compulsory social security	1.0%	22.1%	18.2	1.6%	17.7%	15.5	4,682.3	154,344	1.7%
85	Education	1.3%	20.4%	15.9	1.6%	5.2%	14.0	7,051.9	77,592	0.9%
86	Human health activities				2.9%	35.3%	15.5	13,057.3	195,498	2.2%

Nace rev2	Description	Heating effect			Cooling effect			Basis Reference Consumption		
		Elasticity	Min/Basis Consumption ratio	Range Min ¹ (°C)	Elasticity	Max/Basis Consumption ratio	Range Max ² (°C)	Daily Consumption per CUPS unit (Kwh)	Total Sector Monthly Consumption Mwh (May 2012)	% share in total consumption CUPS 1 & 2 (May 2012)
87	Residential care activities	0.9%	17.9%	19.8	3.7%	45.9%	15.8	2,341.5	5,740	0.1%
88	Social work activities without accommodation	1.2%	24.2%	19.7	2.0%	24.4%	15.6	3,047.1	2,555	0.0%
90	Creative, arts and entertainment activities	1.0%	17.3%	15.0	1.2%	-3.4%	13.4	4,220.0	3,611	0.0%
91	Libraries, archives, museums and other cultural activities	0.6%	9.5%	14.8	2.4%	30.3%	16.9	6,754.6	9,630	0.1%
92	Gambling and betting activities	0.4%	6.0%	14.8	2.4%	31.4%	16.8	4,200.5	3,276	0.0%
93	Sports activities and amusement and recreation activities	1.7%	26.9%	16.2	3.3%	31.2%	13.8	3,843.9	32,506	0.4%
94	Activities of membership organisations				5.1%	45.8%	14.0	4,173.3	16,543	0.2%
96	Other personal service activities				3.0%	33.5%	15.8	4,598.0	6,743	0.1%
97	Activities of households as employers of domestic personnel	1.3%	23.4%	16.6	3.6%	49.4%	17.7	4,546.5	11,414	0.1%
99	Activities of extraterritorial organisations and bodies							11,030.3	2,102	0.0%

Notes: Lower temperature range (Estimated sectorial threshold temperature minus minimum sectorial temperature 2009-2013). 2.- Upper temperature range (Maximum sectorial temperature 2009-2013 minus threshold temperature). Elasticities are only calculated for sectors with significant coefficients for “Heating” and “cooling” effects , and with the right expected sign. Elasticities measure the estimated increase in mean electricity consumption given by an 1°C change in temperature. If elasticities are multiplied by the temperature range (min and max) we obtain the estimated demand driven by temperature variations. This estimated demand is related with the Max/basis and Min/basis consumption ratios. The

differences between estimated demand and these ratios are due to the effect of factors affecting demand, others than temperature variation, like holiday summer, Christmas, variations in sectorial activity, etc.

ANNEX

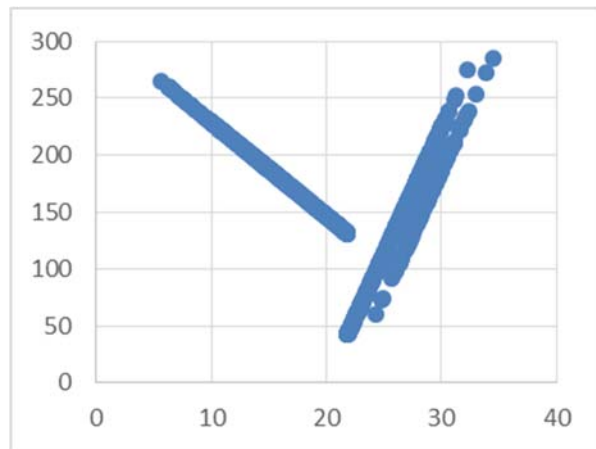
Figure.- Estimated mean sectorial electricity demand (Kw day) response to temperature. In Model eq. [2] with sample 1-1-2009/ 10-31-2013 excluding holidays

$$\bar{y}_{i,t} = \sum_{j=1}^3 \beta_{i,j} t_t^j + (\beta_{4,i} + \beta_{5,i} T_{it})(T_{it} \leq \tau_i) + (\beta_{6,i} + \beta_{7,i} T_{it})(T_{it} > \tau_i) + \beta_{8,i} A_t + \varepsilon_{i,t}$$

Demand response is calculated as (where ^ denotes estimated coefficient)

$$DR_{i,t} = (\hat{\beta}_{4,i} + \hat{\beta}_{5,i} T_{it})(T_{it} \leq \tau_i) + (\hat{\beta}_{6,i} + \hat{\beta}_{7,i} T_{it})(T_{it} > \tau_i) + \hat{\beta}_{8,i} A_t$$

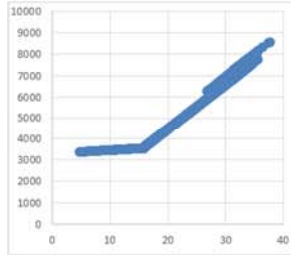
Example.- Sector 39.- Remediation activities and other waste management services



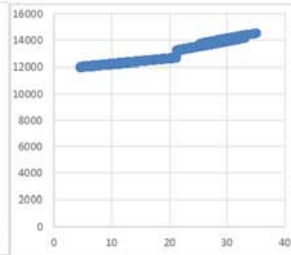
Variable	Coefficient	Std. Error
TEMP.<=21.8	311.3656 **	113.9978
TEMP.>21.8	-441.6581	237.1906
TEMP.*(TEMP<=21.8)	-8.249238 **	5.501841
TEMP.*(TEMP.>21.8)	22.18948	8.641205
August	-36.80641	62.04358
t	5.989751 **	0.350756
t^2	-0.007143 **	0.000465
t^3	2.59E-06 **	1.81E-07
R-squared	0.732773	
S.E. of regression	251.8567	
Sum squared resid	97558081	
Log likelihood	-10737.29	
Durbin-Watson stat	0.023039	

$$DR_{i,t} = (311.4 - 8.25T_{it})(T_{it} \leq 21.8) + (-441.7 + 22.19T_{it})(T_{it} > 21.8) - 36.81A_t$$

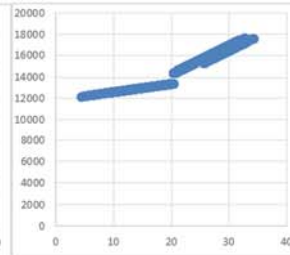
A.- Sector 1



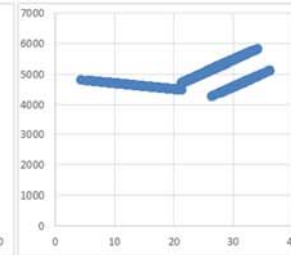
Sector 10



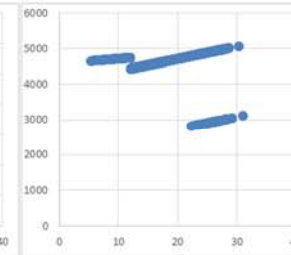
Sector 11



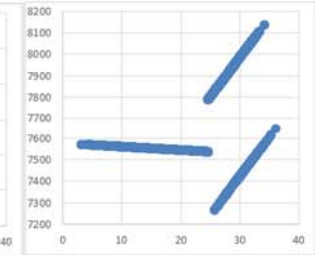
Sector 14



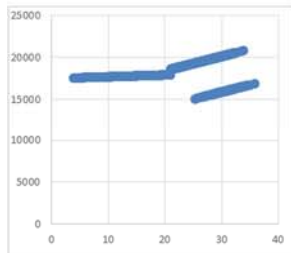
Sector 15



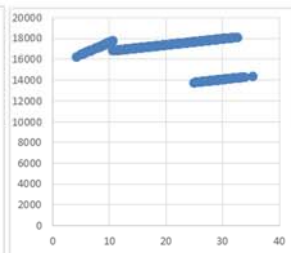
Sector 18



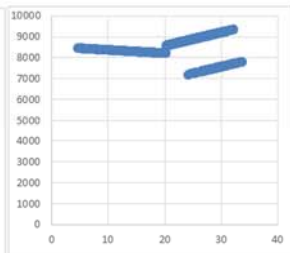
B- Sector 21



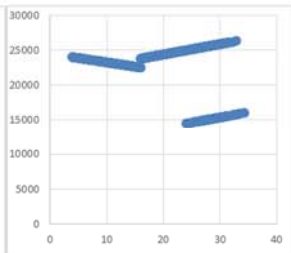
Sector 22



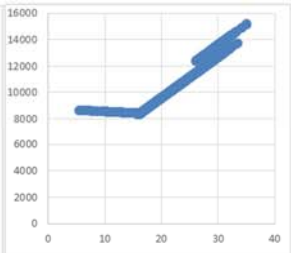
Sector 26



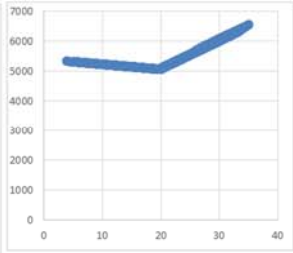
Sector 29



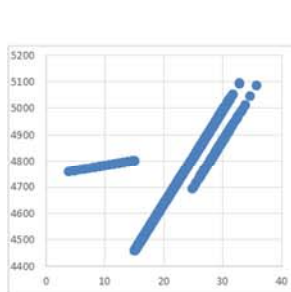
Sector 36



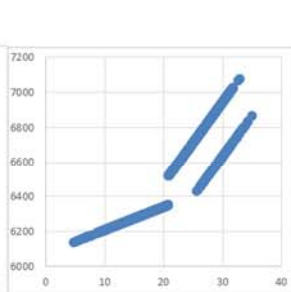
Sector 41



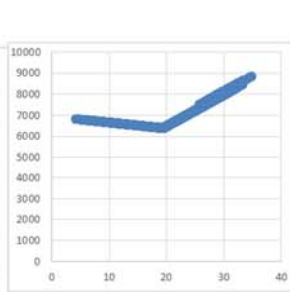
C.- Sector 43



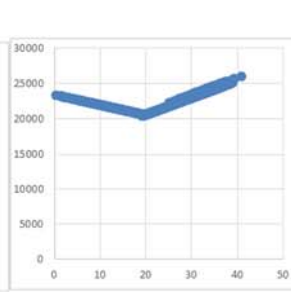
Sector 46



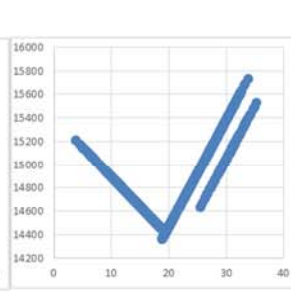
Sector 47



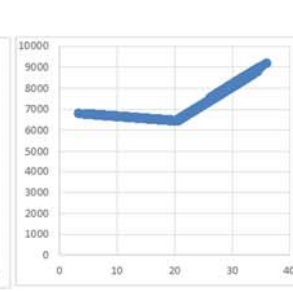
Sector 51



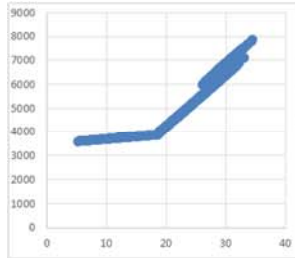
Sector 52



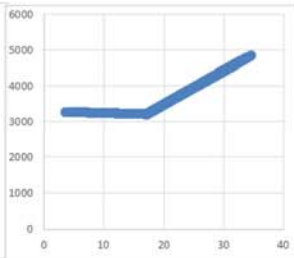
Sector 53



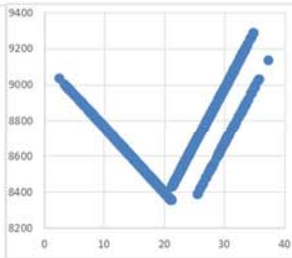
D.- Sector 55



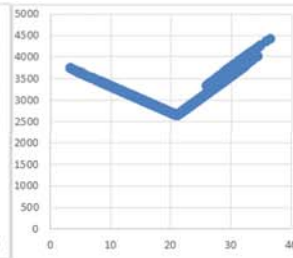
Sector 56



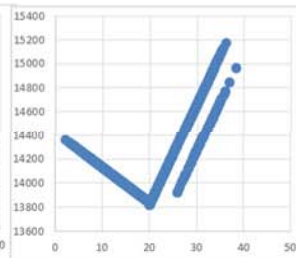
Sector 58



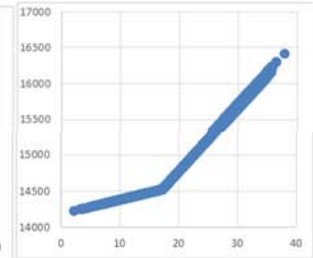
Sector 59



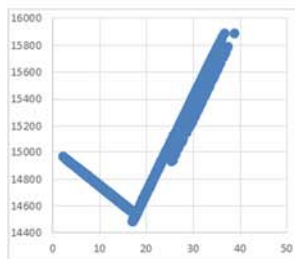
Sector 60



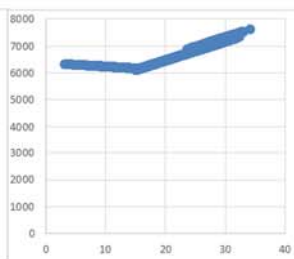
Sector 61



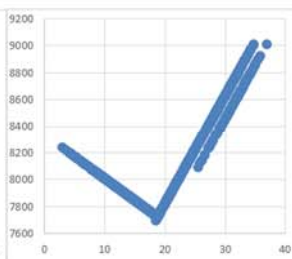
E.- Sector 62



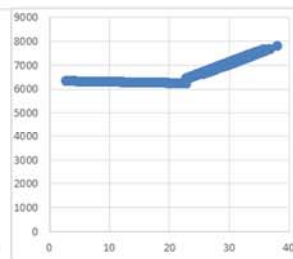
Sector 63



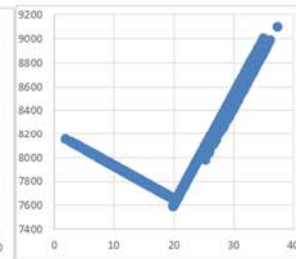
Sector 64



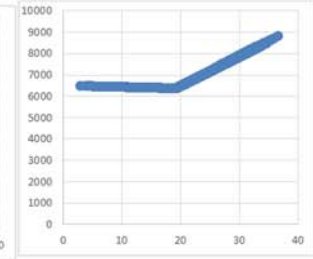
Sector 65



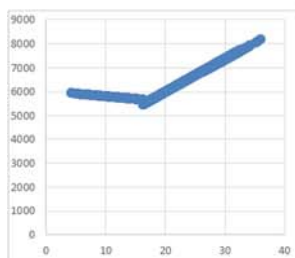
Sector 66



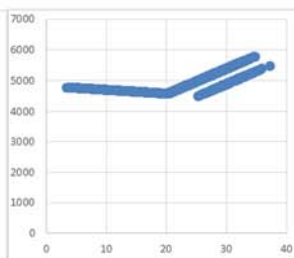
Sector 68



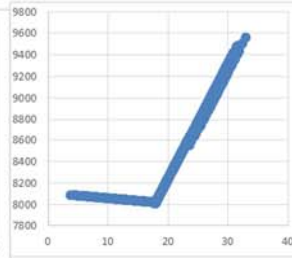
F.- Sector 69



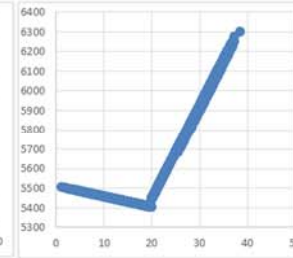
Sector 70



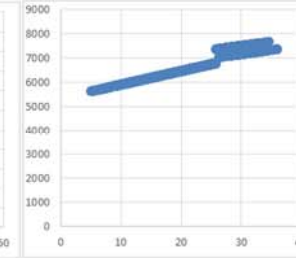
Sector 72



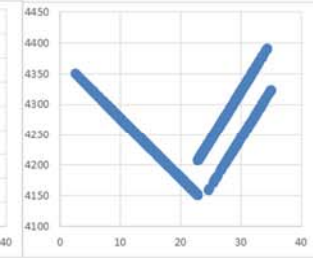
Sector 73



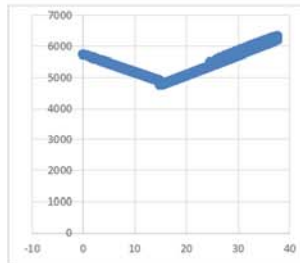
Sector 74



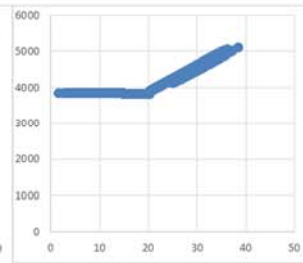
Sector 77



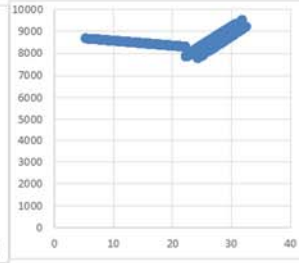
G.- Sector 79



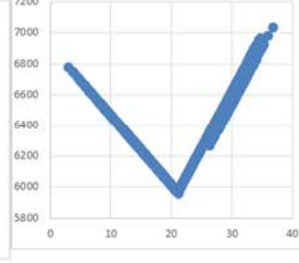
Sector 80



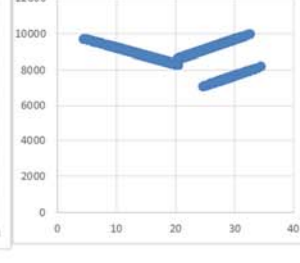
Sector 81



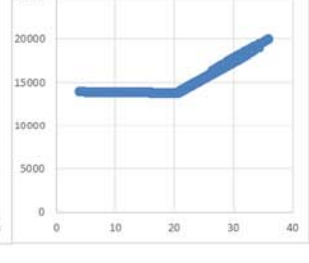
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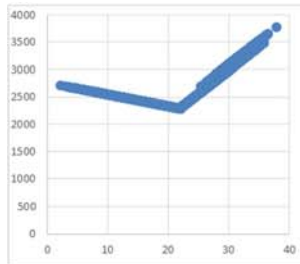
Sector 85



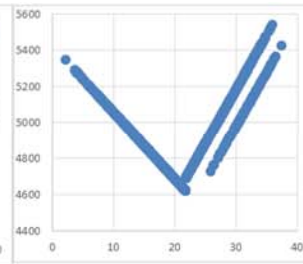
Sector 86



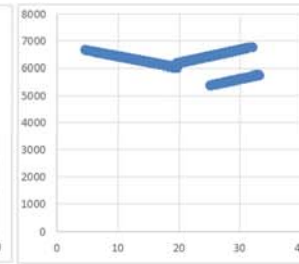
H.- Sector 87



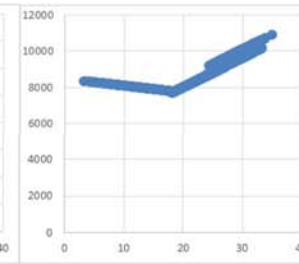
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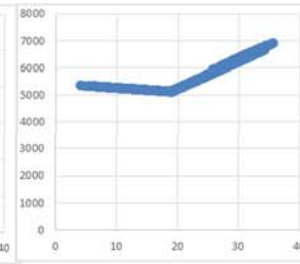
Sector 90



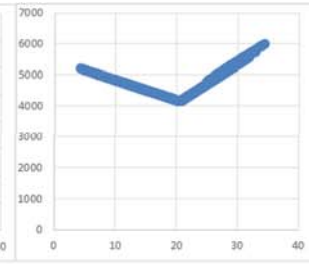
Sector 91



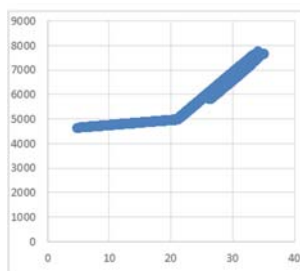
Sector 92



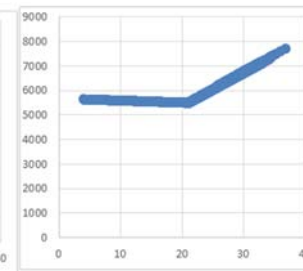
Sector 93



I.- Sector 94



Sector 96



Sector 97

