2017-07

The effect of climate change on electricity expenditures in Massachusetts

Online Appendix for "The effect of climate change on electricity expenditures in Massachusetts"

Section 1 Background on High-Resolution Climate Output. In order to provide future projections of CDD and HDD we incorporate climate model output from a selection of global climate models (GCMs) from the Coupled Model Intercomparison Project Phase 5 (CMIP5). GCM output is generally at too coarse of a scale to use for localized impact assessments, therefore we apply a technique called statistical downscaling to translate the GCM output to a spatial scale representative of the climate divisions and bias correct the output to account for errors due to the coarseness of the large-scale models.

High-resolution average daily temperature projections are produced for three climate divisions in Massachusetts for 1950-2100 for nine GCMs corresponding to the high future pathway for human activities and resulting greenhouse gas emissions. This scenario is defined by Representative Concentration Pathways (RCP; Moss et al., 2010) of 8.5 and cover a range of plausible futures in terms of human emissions and their resulting impacts on climate. Under this scenario, atmospheric CO2 levels approximately double by mid-century and triple by late-century relative to pre-industrial levels. The reason for choosing the highest pathway of emissions is to illustrate the worst-case scenario, which we are currently on track to follow, and to emphasize the importance of adhering to the United Nations Framework Convention On Climate Change (UNFCCC) Paris agreement of staying below 1.5°C of global mean warming.

The nine GCMs, listed in Table A.1, are selected to represent a broad range of future global climate projections with respect to the models' sensitivity to a doubling in atmospheric CO2 relative to preindustrial levels, known as the equilibrium climate sensitivity, i.e. the equilibrium global mean temperature change reached from a doubling in CO2 relative to preindustrial levels (Flato et al., 2013). The statistical Asynchronous Regional Regression Model (ARRM; Stoner et al., 2012) is then used to translate the global climate model output into high-resolution projections directly relevant to and reflective of historical conditions of the three climate divisions in Massachusetts.

The same GCMs and RCP pathway are used to identify the years that thresholds of increases in global mean temperature, in incremental steps of 0.1°C, will be reached. These years are calculated relative to the 1976-2005 global mean temperature and a given year corresponds to the average increase in global temperature centered on a 21-year window, reducing the effect of natural cycles affecting the global mean temperature. The 1976-2005 base period is chosen since it is the last 30 years of the historical CMIP5 GCM simulations and is the closest representation of the current climate. It is also the base period that is being used in the upcoming fourth U.S. National Climate Assessment. The years that the median threshold reaches 2°C for each of the 9 GCMs are displayed in Table A.1.

Section 2 Error Correction Model. To evaluate the degree to which the cointegrating relation can be interpreted as a relation for electricity consumption, we estimate an error correction model (ECM) that is given by:

$$\Delta \ln E_{y,m} = \alpha + \rho\varepsilon_{y,m-1} + \sum_{i=1}^{s} \theta_i \, \Delta \ln E_{y,m-i} + \sum_{i=1}^{s} \kappa_i \, \Delta CDH_{y,m-i} + \sum_{i=1}^{s} \omega_i \, \Delta HDH_{y,m-i} + \sum_{i=1}^{s} \chi_i \, \Delta I_{y,m-i} + \zeta_{y,m} \tag{A.1}$$

in which the lag length s is chosen with the Akaike Information Criterion, AIC [47], ε is the residual from the cointegrating relation ($\varepsilon_{y,m} = E_{y,m} - (\hat{\beta}_0 + \hat{\beta}_1 CDH_{y,m} + \hat{\beta}_2 HDH_{y,m} + \hat{\beta}_3 \ln I_{y,m})$), and ρ represents the rate at which electricity consumption responds to disequilibrium in the cointegrating relationship. A value -1£ *r*£0 indicates that disequilibrium moves electricity consumption E_{t}y,m toward the equilibrium value that is implied by the cointegrating relation. The point estimate $\hat{\rho} = -0.53$ indicates that about half of the disequilibrium is eliminated each month (Table A.4). Although this rapid rate of adjustment is unimportant for the long term forecast, this statistical result confirms that electricity consumption adjusts to weather.

Section 3. Cooling degree days ($CDD_{y,m}$) and heating degree days ($HDD_{y,m}$) are constructed with the same set points that are used to estimate equation (1) by assuming that all days in any given month have the same average temperature. We use the following expressions to compute $CDD_{y,m}$ and $HDD_{y,m}$:

$$CDD_{y,m} = I_{+} \left(T_{y,m} - j\right) \times \ N_{m} \qquad (A.2)$$

$I_{+} = 1$ if $T_{y,m} > j$, and zero otherwise.

$$HDD_{y,m} = I_{+} \left(j - T_{y,m}\right) \times \ N_{m} \qquad (A.3)$$

$I_{+} = 1$ if $j > T_{y,m}$, and zero otherwise.

in which $T_{y,m}$ is the monthly temperature forecast for month m of year y, j is the set point of each end-use sector and N_{m} is the number of days in a given month.

For both the base and climate change scenarios, we translate forecasts for dry bulb temperature into wet bulb temperature with the following equation:

$$T_{wet,h} = \alpha + \beta \, T_{dry,h} + \mu_{h} \qquad (A.4)$$

in which $T_{wet,h}$ is hourly wet bulb temperature, $T_{dry,h}$ is hourly dry bulb temperature and μ is the regression error (Table A.6).

Section 4. State-wide electricity consumption forecast for each month ($\bar{E}'_m$). We compute the monthly average of total electricity consumption in Massachusetts for each month $\bar{E}_m$ in the 2004-2012 sample period, as the sum of the electricity consumption by all zones in month m. This value is used to compute monthly consumption in the climate change scenario ($\bar{E}'_m$) as follows:

$$\bar{E}'_m = (1 + \delta_m)\bar{E}_m \tag{A.5}$$

Section 5. State-wide day- and night-time electricity consumption forecast for each month ($\bar{E}'^{night}_m$ and $\bar{E}'^{day}_m$). To account for a reduction in the diurnal temperature change (DTR) that is simulated by the climate model, we decompose the forecast for monthly consumption into monthly values for day- ($\bar{E}'^{day}_m$) and night-time ($\bar{E}'^{night}_m$). This decomposition is based on the assumption that the ratio of changes in night-time consumption to day-time consumption equals $\frac{\hat{\bar{E}}^{min}_m}{\hat{\bar{E}}^{max}_m}$:

$$\frac{\bar{E}'^{night}_m / \bar{E}^{night}_m}{\bar{E}'^{day}_m / \bar{E}^{day}_m} = \frac{\hat{\bar{E}}^{min}_m}{\hat{\bar{E}}^{max}_m} \tag{A.6}$$

in which $\bar{E}'^{night}_m$ and $\bar{E}^{night}_m$ are the average monthly consumption during night-time hours (from 21:00 hrs to 08:00 hrs) for the climate change and base case scenarios, respectively. $\bar{E}^{night}_m$ equals $\sum_h E_h \,/\, 12 \times N_m$ if h is within the night-time period. $\bar{E}'^{day}_m$ and $\bar{E}^{day}_m$ are the average monthly consumption during day-time hours (all hours not included in the night-time period) for the climate change and base case scenarios, respectively. $\bar{E}^{day}_m$ equals $\sum_h E_h \,/\, 12 \times N_m$ if h is within the day-time period. $\hat{\bar{E}}^{min}_m$ is the average monthly consumption (1990-2010) computed with semi-elasticities estimated from equation (4) and degree hours variables constructed with T^{min}_h. T^{min}_h equals $T_h + \Delta\bar{T}^{min}_m$ if h is within the night-time period, and T_h otherwise. $\Delta\overline{T}_m^{min}$ corresponds to the decadal change by season in minimum temperature in the Northern Hemisphere between 1950 and 2004[25] (Table A.7). $\overline{\overline{E}}_m^{max}$ is the average monthly consumption (1990-2010) computed with semi-elasticities from equation (4) and degree hours variables constructed with T_h^{max}. T_h^{max} equals $T_h + \Delta\overline{T}_m^{max}$ if h is within the day-time period, and T_h otherwise. $\Delta\overline{T}_m^{max}$ corresponds to the decadal change by season in maximum temperature (Table A.7).

We solve for $\overline{E}'^{night}_m$ and $\overline{E}'^{day}_m$ by using equation (10) and (11) and substituting $\overline{E}_m$ for $(\overline{E}_m^{night} + \overline{E}_m^{day})/2$ in equation (10). This generates the following expressions:

$$\overline{E}'^{night}_m = \frac{\phi_m(1+\delta_m)(\overline{E}_m^{night}+\overline{E}_m^{day})\overline{E}_m^{night}}{\phi_m\overline{E}_m^{night}+\overline{E}_m^{day}} \qquad (A.7)$$

$$\overline{E}'^{day}_m = \frac{(1+\delta_m)(\overline{E}_m^{night}+\overline{E}_m^{day})\overline{E}_m^{day}}{\phi_m\overline{E}_m^{night}+\overline{E}_m^{day}} \qquad (A.8)$$

in which ϕ_m is the ratio between $\overline{\overline{E}}_m^{min}$ and $\overline{\overline{E}}_m^{max}$.

Section 6. Hourly day- and night-time electricity consumption forecast by zone. Hourly values for state-wide consumption ($E'^{t}_{m,h}$, with t = {night, day}) area are allocated among the three ISO-NE load zones based on the hourly share of consumption in each zone ($E'^{t}_{z,m,h} = E'^{t}_{m,h} \times \frac{E^t_{z,h}}{E^t_{m,h}}$). We average the 8,760 annual hourly changes in consumption and then across the one hundred iterations to generate a single value for the change in consumption by zone (Table 1). The 90 percent confidence intervals are computed as the average value ± 1.645 × the standard deviation. These values correspond to the 5th and 95th percentiles associated with consumption changes.

Section 7. Hourly day- and night-time electricity consumption forecast by sector (residential and commercial). We construct hourly time series for consumption by the residential and commercial sectors between 2004 and 2012 by multiplying the state-wide hourly consumption by the hourly share of consumption by sector. We obtain these sectoral shares from the 2012 hourly load profiles for an average residential, commercial and industrial customer (rate R-1 for residential, G-1 for commercial, and G-3 for industrial) [48], which are rescaled such that on average the share of each end-use sector matches the monthly average consumption between 1990 and 2010 (35 percent for residential, 44 percent for commercial, and 21 percent for industrial). To simulate hourly values for residential and commercial consumption ($E^{r\prime}_{h,z}$ and $E^{c\prime}_{h,z}$) we follow the temporal downscaling procedure that use Monte Carlo techniques.

Table A.1. Global climate models used in the study along with their sensitivity to a doubling in atmospheric CO_2 relative to preindustrial levels (Flato et al., 2013) and the median year with global mean temperature (GMT) increase of 2°C relative to 1976-2005.

Model acronym	Host institution	Equilibrium climate sensitivity (°C)	Median year with GMT increase of 2°C
CCSM4	National Center for Atmospheric Research, USA	2.9	2056
CNRM-CM5	Centre National de Recherches Meteorologiques, France	3.3	2057
CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organization, Australia	4.1	2054
HadGEM2-CC	Met Office Hadley Centre, United Kingdom	N/A	2044
INM-CM4	Institute for Numerical Mathematics, Russia	2.1	2070
IPSL-CM5A-LR	Institut Pierre-Simon Laplace, France	4.1	2047
MIROC5	University of Tokyo Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan	2.7	2057
MPI-ESM-LR	Max Planck Institute for Meteorology, Germany	3.6	2057
MRI-CGCM3	Meteorological Research Institute, Japan Meteorological Agency, Japan	2.6	2061

Table A.2 | Monthly electricity consumption: MHEGY test.

Variable:	Test Statistics
ln residential electricity sales	-2.82
ln commercial electricity sales	-1.24
ln industrial electricity sales	-0.45
ln state personal income	-2.91
ln commercial employment	-2.86
ln industrial employment	-4.04***
ln residential electricity price	-2.44
ln commercial electricity price	-2.77**
ln industrial electricity price	-3.89***
CDH (set point: 65°F; dry bulb temperature)	-0.33
HDH (set point: 65°F; dry bulb temperature)	-2.37*
CDH (set point: 55°F with 5°F set back; wet bulb	-1.92
HDH (set point: 55°F with 5°F set back; dry bulb	-2.15

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.116$. The MHEGY unit root test is performed as follows: 1) considering a constant, a seasonal dummy, and a time trend for electricity consumption and employment variables, 2) considering a constant and time trend for state personal income, and 3) considering a constant and seasonal dummy for CDH, HDH and electricity prices. Commercial and industrial employment correspond to the total full-time and part-time employment by NAICS supersectors for the Current Employment Statistics (CES-National) of the U.S. Bureau of Labor Statistics. Employment by the commercial sector includes: trade, transportation, utilities, information, financial activities, professional and business activities, educational and health services, leisure and hospitality, other services and government. Employment by the remaining NAICS industries are classified as industrial: construction, manufacturing, natural resources and mining.

Table A.3 | Monthly electricity consumption: cointegration ADF test.

Model	ADF test
Residential electricity consumption	-7.469***
Commercial electricity consumption	-1.195
Industrial electricity consumption	-2.684

Notes: *** p<0.01, ** p<0.05, * p<0.1[23]. The ADF test is performed on the residual of each cointegrating relationship without a constant and without a time trend[18].

Table A.4 | Monthly residential electricity consumption: DOLS estimation and ECM.

Dependent Variable:	Residential Consumption
$CDH_{65\ Dry}$	1.74***
	(0.21)
$HDH_{65\ Dry}$	0.45***
	(0.05)
ln Income	0.34***
	(0.02)
Observations	249
R-squared	0.84
p-value F-test	0
ε_{t-1}	-0.53***
	(0.11)

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. CDH and HDH are divided by 1,000 to obtain larger figures. Specification also include lead and lags of the first difference of CDH, HDH and Income.

Table A.5 | Monthly commercial electricity consumption: OLS estimation.

Dependent Variable:	Commercial Consumption
CDH 50 Wet Set back	0.48***
	(0.02)
HDH 50 Dry Set back	0.23***
	(0.02)
ln Price	-0.08**
	(0.03)
ln Employment	0.47**
	(0.21)
year = 1991	0.02
	(0.02)
year = 1992	0.03*
	(0.02)
year = 1993	0.04**
	(0.02)
year = 1994	0.04**
	(0.02)
year = 1995	0.08***
	(0.02)
year = 1996	0.06***
	(0.02)
year = 1997	0.09***
	(0.02)
year = 1998	0.09***
	(0.03)
year = 1999	0.02
	(0.03)
year = 2000	0.12***
	(0.04)
year = 2001	0.18***
	(0.04)
year = 2002	0.19***
	(0.04)
year = 2003	0.23***
	(0.04)
year = 2004	0.27***
	(0.03)
year = 2005	0.28***
	(0.04)
year = 2006	0.29***
	(0.04)
year = 2007	0.31***
	(0.04)
year = 2008	0.29***
	(0.04)
year = 2009	-0.11***
	(0.04)
year = 2010	-0.11***
	(0.04)
Constant	10.33***
	(1.66)
Observations	252
R-squared	0.95
p-value F-test	0

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. CDH and HDH are divided by 1,000 in order to obtain larger figures. p-value from F-test of main regressors (CDH, HDH and employment).

Table A.6 | Wet bulb temperature regression.

Dependent Variable:	Wet bulb temperature
Dry bulb temperature***	0.881***
	(0.001)
Constant***	0.685***
	(0.025)
Observations	183,638
adjusted R-squared	0.945

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.7 | Temperature trends for the Northern hemisphere (1950-2004).

Season	Maximum Temperature $\Delta\overline{T}_m^{max}$	Minimum Temperature $\Delta\overline{T}_m^{min}$	Diurnal Temperature Range (DTR)
Winter (D-J-F)	0.214	0.309	-0.099
Spring (M-A-M)	0.192	0.252	-0.063
Summer (J-J-A)	0.119	0.174	-0.057
Fall (S-O-N)	0.096	0.178	-0.085
Annual	0.155	0.228	-0.076

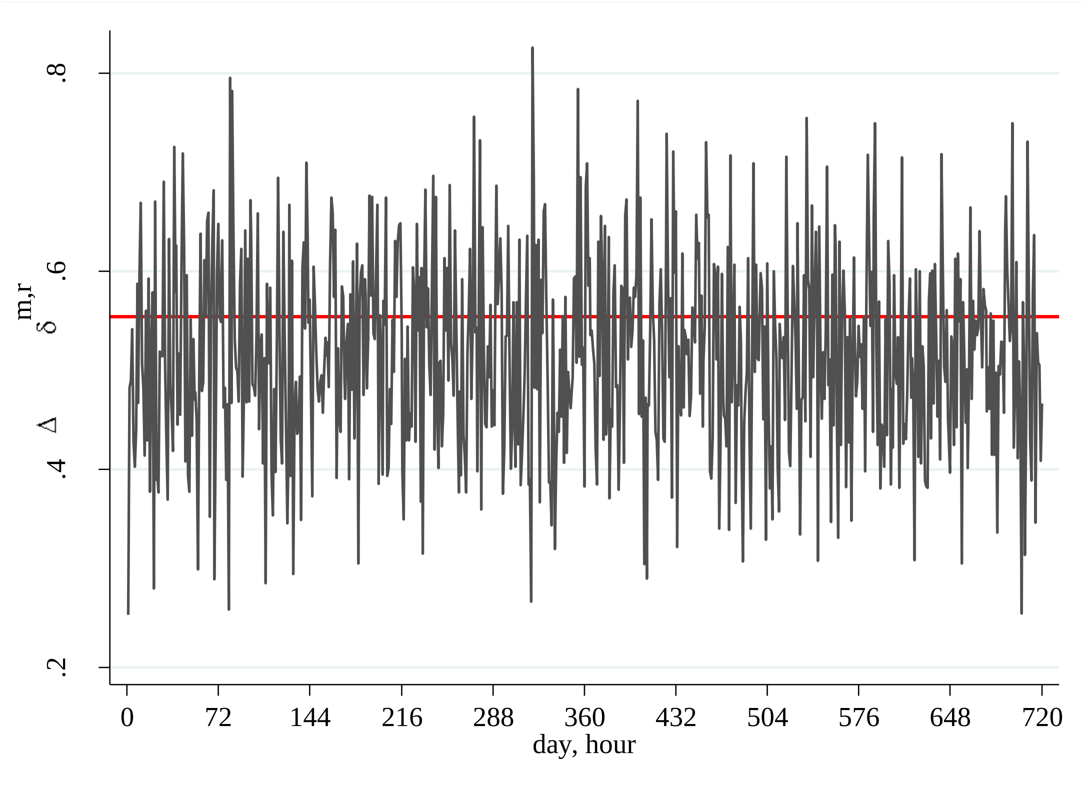
Notes: All variables are measured in °C per decade [25].

Table A.8 | Temporal downscaling of electricity consumption: normal distribution parameters.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
μ_m^{night}	0.950	0.922	0.932	0.978	1.010	1.104	1.169	1.217	1.242	1.164	0.965	0.933
μ_m^{day}	0.957	0.928	0.937	0.988	1.028	1.109	1.160	1.211	1.248	1.174	0.972	0.940
$\mu_{m,res}^{night}$	0.915	0.872	0.832	0.879	0.923	1.210	1.382	1.469	1.549	1.204	0.916	0.881
$\mu_{m,res}^{day}$	0.922	0.878	0.837	0.888	0.939	1.216	1.371	1.462	1.558	1.215	0.922	0.887
$\mu_{m,com}^{night}$	0.955	0.927	0.980	1.050	1.088	1.071	1.078	1.118	1.113	1.212	0.990	0.944
$\mu_{m,com}^{day}$	0.962	0.933	0.986	1.060	1.108	1.076	1.070	1.113	1.119	1.223	0.996	0.951

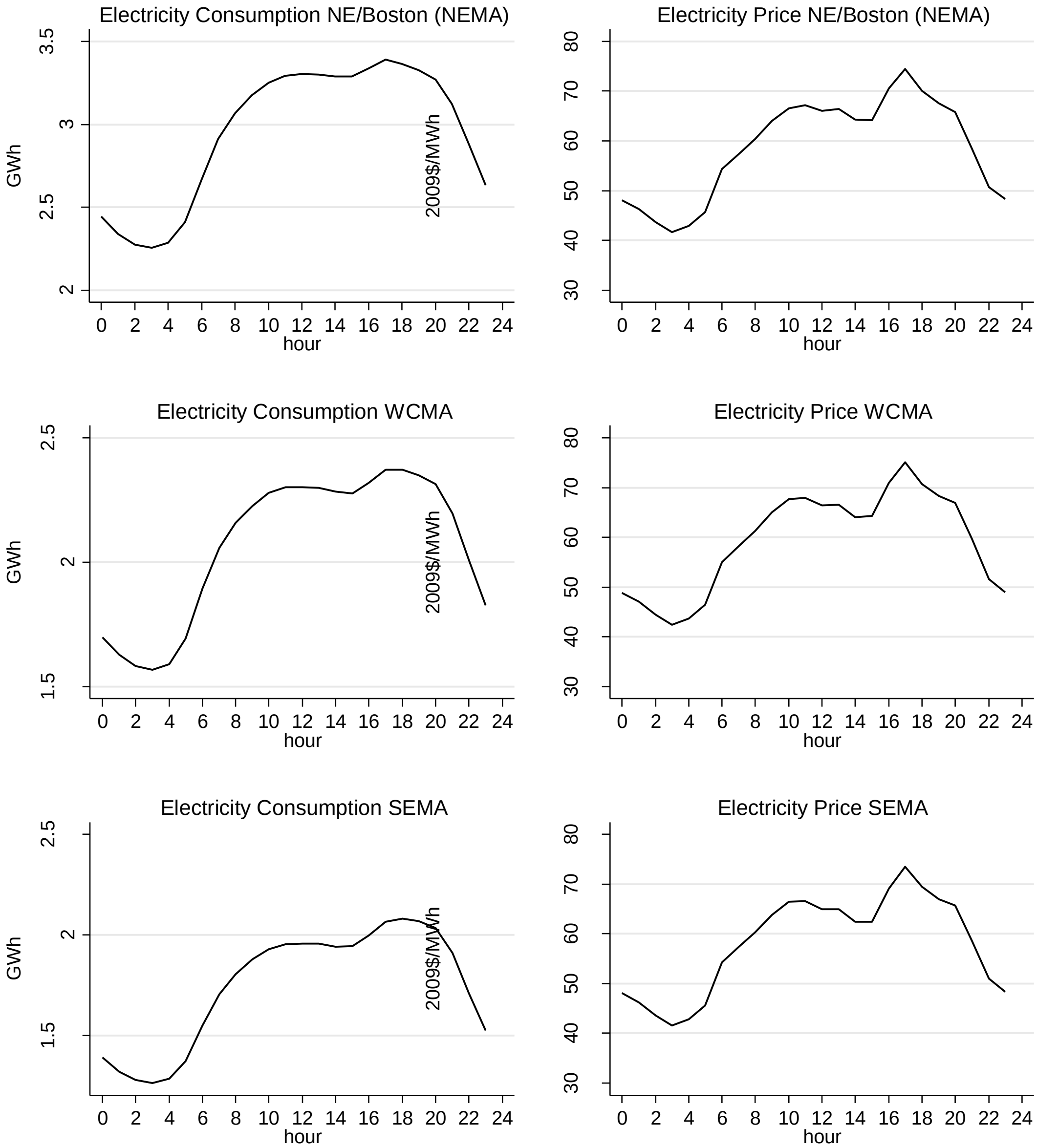
Notes: Results are based on procedure explained in the Monte Carlo procedure explained in the electricity demand forecasts section of the “Methodology”.

Figure A.1. Example of the downscaling monthly forecasts to hourly values for the residential sector in the Boston load zone



Notes: The black line shows the hourly values for a single iteration in the Boston load zone in September for the MRI-CGCM3 CGM model. The red line shows the estimated change in monthly consumption for the residential sector, Δ% 2°C $\delta_{m,r}$, in September as indicated in Table 1 in the paper.

Figure A.2. Hourly electricity consumption and price by load zone.



Source: Own construction based on data from ISO-NE. Further details about the characteristics of these data are explained in the data section of the "Methodology".

Table A.9 | Summary statistics of hourly electricity price and hourly consumption.

Variable	Label	Mean	Std. Deviation	Minimum	Maximum	Obs.
Electricity consumption (GWh)	E					
NE/Boston		3.0	0.6	1.8	5.7	78,903
WCMA		2.1	0.4	0.7	3.8	78,903
SEMA		1.8	0.4	0.9	3.7	78,903
Electricity price ($/MWh)	P					
NE/Boston		59.0	36.0	0.0	1,275	78,903
WCMA		59.0	33.0	0.0	1,076	78,903
SEMA		58.0	32.0	0.0	1,063	78,903

Source: Own construction based on dataset characteristics explained in the data section of the “Methodology”.

Table A.10 | Price change forecast and hourly price estimation: price effect of consumption beyond individual load zones.

	NEBoston	WCMA	SEMA
$\Delta\widehat{P}$	28.8% (28.5, 29.2)	21.9% (21.7, 22.0)	-15.0% (15.3, 14.8)
$\widehat{P}$	61.5	62.5	61.4
mean $\widehat{P}'$	79.3	76.2	52.2
sd $\widehat{P}'$	0.14	0.06	0.09
$\Delta\widehat{E}$	5.5% (5.5, 5.6)	5.3% (5.3, 5.4)	5.7% (5.7, 5.8)
Dependent variable:		Hourly electricity price	
E	312.434***	-227.229***	560.312***
	(39.203)	(65.898)	(118.796)
E^2	-90.318***	123.596***	-263.976***
	(12.685)	(33.744)	(60.984)
E^3	8.628***	-16.528***	39.593***
	(1.335)	(5.523)	(10.083)
E_{ISO-z}	-13.805	68.118***	-67.676***
	(10.46)	(15.072)	(17.345)
E^2_{ISO-z}	0.506	-5.572***	4.159***
	(0.916)	(1.203)	(1.215)
E^3_{ISO-z}	0.014	0.139***	-0.070**
	(0.026)	(0.031)	(0.028)
year==2005	22.339***	21.740***	21.047***
	(0.466)	(0.416)	(0.402)
year==2006	4.970***	4.718***	4.195***
	(0.472)	(0.32)	(0.32)
year==2007	7.104***	9.430***	9.701***
	(0.354)	(0.31)	(0.297)
year==2008	21.064***	22.997***	24.325***
	(0.431)	(0.386)	(0.375)
year==2009	-14.519***	-11.982***	-12.297***
	(0.359)	(0.29)	(0.271)
year==2010	-11.188***	-8.762***	-8.682***
	(0.412)	(0.323)	(0.316)
year==2011	-13.444***	-11.038***	-11.336***
	(0.405)	(0.322)	(0.318)
year==2012	-23.614***	-20.439***	-21.604***
	(0.393)	(0.337)	(0.334)
month==2	-7.089***	-7.787***	-6.811***
	(0.436)	(0.432)	(0.433)
month==3	-7.643***	-7.763***	-7.288***
	(0.412)	(0.411)	(0.413)
month==4	-1.469***	-0.777*	-1.503***
	(0.434)	(0.426)	(0.427)
month==5	1.952***	1.841***	-0.234
	(0.644)	(0.488)	(0.471)
month==6	-9.801***	-7.724***	-10.100***
	(0.481)	(0.487)	(0.481)
month==7	-18.994***	-12.208***	-16.270***
	(0.645)	(0.641)	(0.579)
month==8	-16.775***	-11.257***	-15.345***
	(0.511)	(0.506)	(0.53)
month==9	-7.937***	-4.799***	-8.714***
	(0.454)	(0.479)	(0.477)
month==10	-1.273***	0.751	-2.136***
	(0.48)	(0.497)	(0.485)
month==11	-4.626***	-3.069***	-4.165***
	(0.435)	(0.444)	(0.441)
month==12	-1.613***	-0.265	-0.953*
	(0.481)	(0.488)	(0.489)
dayofweek==1	-3.197***	-5.659***	-3.661***
	(0.319)	(0.315)	(0.297)
dayofweek==2	-4.559***	-8.800***	-5.582***
	(0.396)	(0.341)	(0.31)
dayofweek==3	-3.783***	-7.812***	-4.465***
	(0.348)	(0.396)	(0.345)
dayofweek==4	-4.239***	-7.895***	-4.744***
	(0.293)	(0.334)	(0.288)
dayofweek==5	-3.527***	-6.699***	-3.990***
	(0.293)	(0.309)	(0.277)
dayofweek==6	1.041***	0.491*	1.297***
	(0.274)	(0.279)	(0.273)
observations	78,903	78,903	78,903
adjusted R-squared	0.456	0.522	0.516

Notes: $\Delta\widehat{E}$ lower bound and $\Delta\widehat{E}$ upper bound show 90 percent confidence intervals, which are the 5th and 95th percentiles associated with electricity consumption changes. $\Delta\widehat{P}$ lower bound and $\Delta\widehat{P}$ upper bound are the analogous values for price changes. Robust standards errors in parenthesis. *** p<0.001, ** p<0.05, * p<0.1. All specifications include month and day of week fixed effects. Electricity price is measured in $/MWh. Regressions include a constant term. For NEBoston E_{ISO-z} variables are not significant. Therefore we compute $\Delta\widehat{P}$, mean $\widehat{P}'$, and sd $\widehat{P}'$ with estimates shown in Table 1.

Table A.11 | Residential consumer's typical monthly bill.

Item	Rate (2013 $/kWh)	Cost (2013 $)	% of Basic Service Cost
(1) Basic service charge	0.1003	60	
(2) Delivery service charge:		45	75*
Customer charge	4.0000**	4	7
Distribution charge - first 600 kWh	0.0354	21	35
Distribution charge - in excess of 600 kWh	0.0420	0	0
Transition charge	0.0016	1	2
Transmission charge	0.0213	13	21
Energy efficiency charge	0.0094	6	9
Renewables charge	0.0005	0	0

Notes: This bill represents the typical amount paid for basic service and delivery service charge by a residential consumer with rate R -1 and 600 kWh of monthly consumption [27]. *This figure corresponds to $\alpha^{ds,r}$. ** The customer service charge is measured in 2013 $.

Table A.12 | Commercial consumer's typical monthly bill.

Item	Rate (2013 $/kWh)	Cost (2013 $)	% of Basic Service Cost
(1) Basic service charge	0.110	16,473	
(2) Delivery service charge		7,743	47*
Transition energy peak charge	0.015	1,245	8**
Transition energy off-peak charge	0.008	510	3***
Distribution demand charge	3.920****	2,352	14
Transition demand charge	0.002	243	1
Transmission charge	0.016	2,474	15
Energy efficiency charge	0.006	845	5
Renewables charge	0.001	75	0

Notes: This bill represents the typical amount paid for basic service and delivery service, transition energy, and delivery service charge by a commercial consumer with rate G-3, 600kW of power, 150,000 kWh of monthly consumption, and 55 percent of the consumption within the peak period [27]. $\alpha^{ds,c}$ is computed as the difference between the delivery service share of the basic service (*) and $\alpha^{tp,c} + \alpha^{to,c}$. **This figure corresponds to $\alpha^{tp,c}$. ***This figure corresponds to $\alpha^{to,c}$. ****The distribution and transition demand charge are measured in 2013 $/kW.

Table A.13 | Expenditure forecast: all residential consumers with smart meters.

	Δ Price and Δ Consumption		Δ Consumption only		Δ Price only	
	cost 2°C	NPV	cost 2°C	NPV	cost 2°C	NPV
NEBoston	111,400,000	1,011,000,000	62,289,456	602,200,000	31,987,419	310,100,000
WCMA	81,419,981	735,000,000	43,189,234	417,500,000	24,634,159	238,800,000
SEMA	79,117,637	718,800,000	44,542,492	431,000,000	22,412,607	217,400,000
MA	271,900,000	2,465,000,000	150,000,000	1,451,000,000	79,034,186	766,300,000
MA/N	102	926	56	545	30	288
Annualized MA/N_r		39		23		12

Notes: Figures are measured in 2009 dollars. Expenditure forecasts for residential consumers are computed for the following 2°C scenarios: i) change in consumption only; ii) change in price only; iii) change in both consumption and price. The change in price in scenarios ii) and iii) are due to changes in the basic service charge. All present value calculations use a 3 percent discount rate.

Table A.14 | Expenditure forecast: all commercial consumers with smart meters.

	Δ Price and Δ Consumption		Δ Consumption only		Δ Price only	
	cost 2°C	NPV	cost 2°C	NPV	cost 2°C	NPV
NEBoston	214,033,390	1,882,710,800	80,511,301	778,946,540	84,470,970	819,580,750
WCMA	144,144,266	1,268,733,600	54,937,946	531,427,880	56,397,125	547,105,665
SEMA	118,776,354	1,056,765,000	52,734,896	510,451,375	41,852,762	406,118,910
MA	476,935,195	4,208,309,400	188,173,550	1,820,975,800	182,720,853	1,772,805,350
MA/N	179	1,581	71	684	69	666
Annualized MA/N_c		67		29		28

Notes: Figures are measured in 2009 dollars. Expenditure forecasts for commercial consumers are computed for the following 2°C scenarios: i) change in consumption only; ii) change in price only; iii) change in both consumption and price. The change in price in scenarios ii and iii are due to changes in the basic service charge, transition energy peak charge, and transition energy off-peak charge. All present value calculations use a 3 percent discount rate.

Table A.15 | Expenditure forecast: half of residential consumers with smart meters.

	Δ Price and Δ Consumption		Δ Consumption only		Δ Price only	
	cost 2°C	NPV	cost 2°C	NPV	cost 2°C	NPV
NEBoston	63,165,421	631,200,000	18,401,531	186,600,000	40,838,354	420,600,000
WCMA	48,198,705	481,500,000	13,688,564	138,800,000	31,471,044	324,100,000
SEMA	45,556,430	456,000,000	14,766,981	150,000,000	28,012,578	289,000,000
MA	156,900,000	1,569,000,000	46,857,076	475,300,000	100,300,000	1,034,000,000
MA/N	418	4,178	125	1,266	267	2,753
Annualized MA/N_r		176		53		116

Notes: See footnotes of Table A.13.

Table A.16 | Expenditure forecast: half of commercial consumers with smart meters.

	Δ Price and Δ Consumption		Δ Consumption only		Δ Price only	
	cost 2°C	NPV	cost 2°C	NPV	cost 2°C	NPV
NEBoston	152,582,711	1,512,600,000	31,200,766	318,300,000	106,419,177	1,100,800,000
WCMA	103,099,353	1,020,750,000	21,844,282	223,900,000	71,235,522	734,050,000
SEMA	79,278,215	785,500,000	20,383,491	208,000,000	51,506,289	534,000,000
MA	334,950,000	3,319,000,000	73,928,538	749,650,000	229,150,000	2,369,500,000
MA/N	892	8,838	196	1,997	610	6,309
Annualized MA/N_c		373		84		266

Notes: See footnotes of Table A.14.