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POWERING WORK FROM HOME

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ABSTRACT

This paper documents an increase in residential electricity consumption while industrial and commercial consumption has fallen during the COVID-19 pandemic in the United States. Hourly smart meter data from Texas reveals how daily routines changed during the pandemic, with usage during weekdays closely resembling those of weekends. The 16% residential increase during work hours offsets the declines from commercial and industrial customers. Using monthly data from electric utilities nationwide, I find a 10% increase in residential consumption, and a 12% and 14% reduction in commercial and industrial usage, respectively, during the second quarter of 2020. This contrasts with the financial crisis of 2008, which also witnessed a rapid decline in industrial electricity consumption, but left residential usage unaffected. The increase in residential consumption is found to be positively associated with the share of the labor force that may work from home. From April through July of 2020, total excess expenditure on residential electricity was nearly $6B.

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1 Introduction

This paper estimates how electricity consumption has changed in the United States during the COVID-19 pandemic. Accompanying the public health crisis has been a major economic shock—one that has affected both the level and composition of economic activity. The reduction in economic activity is clear in patterns of industrial and commercial electricity consumption, while there has been a striking shift towards using more residential usage.

To reduce the risk of exposure to the SARS-CoV-2 virus, roughly one-third of the American labor force has been working from home (Bick et al. (2020); Brynjolfsson et al. (2020); Dingel and Neiman (2020)). Household expenditures have also changed dramatically, reflecting both the loss of income and consumption opportunities, and a shift toward household production (Baker et al. (2020); Cox et al. (2020)). Whether under government order to shelter-in-place, working remotely, or out of work and school, people are spending an inordinate amount of time at home (Chetty et al. (2020)). Additional time and consumption at home requires significant increases in electricity consumption. This represents an additional and essential expense at a time that many households are also experiencing severe economic hardship.

I measure changes in electricity consumption during the COVID-19 pandemic using two distinct data sources. The first is an hourly dataset from Innowatts, a Houston-based utility analytics company. It reports the total hourly residential consumption from 2019-May 2020 in Texas. When including adjustments for weather (heating and cooling are important determinants of electricity demand), these data reveal how usage has changed over the work week. I find that the patterns that used to distinguish work days from weekends have largely disappeared—residential consumption rises later in the morning, and is 16% higher during work hours than during normal times.

The second dataset comes from the Energy Information Administration (EIA), and reports monthly electricity consumption by customer class (residential, commercial, and industrial) for most U.S. utilities. The broader coverage and longer reporting horizon of the EIA data allow me to evaluate correlates of consumption changes, and to compare the COVID-19 pandemic to prior economic shocks. I find that residential consumption rose by 10% on average during the second quarter of 2020, while commercial and industrial usage fell by 12% and 14%, respectively.

I find that the increase in residential consumption is associated with the share of the labor force that may work from home according to the measure developed by Dingel and Neiman (2020). While rising unemployment is strongly associated with commercial and industrial electricity declines, it is more weakly associated with residential increases. Non-essential business closures do not have statistically significant impacts on usage beyond the direct potential employment effects. I also show the increase in residential consumption is not a general feature of economic downturns—it did not occur during the Great Recession.

From April to July, 2020, American households spent nearly $6B in excess residential electricity consumption. Electricity bills were over $20/month higher on average for utilities serving one fifth of U.S. households. This increased expenditure reduces the net benefits of working from home associated with less commuting (Barrero et al. (2020); Brodeur et al. (2020)) and improved environmental quality (Cicala et al. (2020); Gillingham et al. (2020); Quéré et al. (2020)). As industrial and commercial activity recovers, working from home has the potential to increase emissions from the power sector on net. In the same way that dense cities are more energy efficient than suburbs (Glaeser and Kahn (2010)), it requires more energy to heat and cool entire homes than the offices and schools in which people usually congregate during the day. A mixed work format based on part-time work from home entails higher power demand, as both offices and homes will be simultaneous drawing additional power. This is especially important given that more than one third of firms that have adopted remote work believe it will continue beyond the COVID-19 pandemic (Bartik et al. (2020)).

This paper also has important implications for the emergent literature that uses real-time electricity consumption to proxy for economic activity during the COVID-19 pandemic (Cicala (2020), Benedikt and Radulescu (2020); Buechler et al. (2020); Chen et al. (2020); Fezzi and Fanghella (2020); Figer et al. (2020); International Association for Energy Economists (2020); Leach et al. (2020); Richter de Almeida (2020)). The appeal of electricity consumption as an economic indicator is based on its real-time availability, universal use in economic activity, and lack of substitutes. This allows one to learn about high-frequency changes in economic activity by monitoring electricity consumption—but the appropriate conversion factor between changes in electricity and economic activity is yet to be determined. This paper provides evidence that higher residential usage is masking significant declines in commercial and industrial consumption. While total U.S. electricity consumption returned to normal levels in July, 2020, industrial and commercial users were still 5% below normal on average. This deviation from normal is similar to that of the sluggish state of the economy in early 2010, following the Great Recession.

The paper is organized as follows: I first describe the data sources in section 2, then the econometric methods I employ in section 3. The fourth section presents the results, and the final section concludes. Additional results and robustness checks are presented in the Appendix.

2 Data

Monthly data on electricity consumption, revenues, and net-metered generation capacity come from the Energy Information Administration (EIA), Form EIA-861M (formerly EIA-826). These data are reported monthly by utility, state, and customer class with an approximately two month lag.[1] This form is based on a sample of utilities, but reporting is a balanced panel between 2016 and July 2020 for roughly two-thirds of consumption in the lower 48 states. Data from power marketers are not identifiable until nine months after the reporting period, making coverage in Texas in particular relatively sparse. Roughly three-quarters of residential consumption outside of Texas is reported is reported comprehensively through the study period. EIA estimates consumption for the balance of non-reported consumption, but these predictions are dropped from the analysis.

The bundled utilities reporting in EIA-861M spend roughly $250B per year on residential, commercial, and industrial electricity.[2] Appendix Figure A.1 plots the monthly consumption and expenditure totals for these individually-reported utilities since 2016. Residential electricity consumption is highly seasonal, reflecting the importance of home heating and cooling. Overall, residential consumption is responsible for about 40% of consumption and half of expenditures. Industrial power is relatively cheaper, accounting for one-quarter of quantities and one-eighth of expenditures. Commercial power accounts for the remaining third of each. With approximately 90 million of the total 135 million residential customer accounts reported in these data, the typical monthly residential bill is about $110.

[1]Delmarva Power, for example, reports its business in Delaware and Maryland separately. Only 10% of utilities report for multiple states, so I refer to a utility-state reporting unit as a utility for brevity, though all data remain at the utility-state level.

[2]A relatively small amount of electricity is also reported in an "Other" category, and represents public lighting and transportation, railroads, and irrigation. It is omitted from the analysis.

I use meteorological data from ERA5 (European Centre for Medium-Range Weather Forecasts (2019)), which combines observational data and atmospheric models to provide a high-frequency, high-resolution 'reanalysis' of the global climate. I calculate heating and cooling degrees (distance from 18C) and downward shortwave radiation flux (i.e. sunlight) at the hourly level for each US county, and then use population weights to aggregate up to utilities based on service territories reported in Form EIA-861, "Annual Electric Power Industry Report." These measures are then aggregated to the monthly level to merge with consumption data.

Data on non-essential business closures come from Goolsbee et al. (2020), who compile the dates of local policy interventions through mid-May 2020. I convert these dates to the share of each utility territory's time under business closure in a particular month.[3]

The share of the labor force that may be able to work from home is drawn from Dingel and Neiman (2020), who find that 37% of jobs could plausibly be conducted remotely based on surveys of occupation characteristics. The Dingel-Neiman data are reported by the census' core-based statistical areas (CBSAs). These are cross-walked to US counties and weighted by population up to utility service areas within states using Form EIA-861 as above with other county-level data.

Hourly residential electricity consumption data come from Innowatts, a Houston-based utility analytics company. These data are derived from smart meters, and aggregated up to the hourly level for residential customers within the footprint of Texas' asynchronous electrical grid (ERCOT). These are proprietary data, obtained under a nondisclosure agreement with the company. Combined commercial and industrial hourly consumption is calculated by subtracting residential consumption from publicly-available hourly total system load data from ERCOT. These data cover from 2019-May 2020, so I focus on the months with two years of coverage.

3 Methods

Hourly Analysis

I use hourly data to track changing patterns in electricity consumption over the day and week in Texas. I estimate equations separately by customer class of the form

$$Load_t = \tau_{hdy} + \sigma_h heating_t + \kappa_h cooling_t + \phi_h flux_t + u_t$$

Each τ_{hdy} is a dummy variable for an hour of the week (hour h and day of week d of year y) in either 2019 or 2020, starting with midnight on Sunday. The sample is a time series from April and May (or January and February for comparison). To account for heating and cooling demand, as well as behind-the-meter rooftop solar panels, I include hour of day-specific controls for each variable, respectively.[4] When the τ_{hdy} are plotted against hour of week, they trace out the mean weather-adjusted electricity consumption during the period in question.

[3]This measure would equal 0.5, for example, if half of the population-weighted counties experienced a shutdown the entire month while the remainder had no shutdown at all. It would also be 0.5 if the entire population faced a shutdown for half of the month's days. These data include planned reopenings in June that were announced in May. If no reopening plans were announced by the end of the reporting period, I assume the remainder of June was under a non-essential business closure.

[4]A heating-degree in hour t is defined as the number of degrees the ambient temperature is below 18^oC: $\max\{18 - temperature_{it}, 0\}$. It is defined analogously for cooling degrees when the ambient temperature exceeds 18^oC.

Monthly Analysis

The monthly analysis is based on a panel of bundled U.S. utilities. There is vast dispersion in the size of the utilities, from Florida Power & Light's 4.4M customers to small local cooperatives in the Dakotas serving 5,500. I estimate equations in logarithms and weight by 2019 quantities delivered. The meteorological data is collapsed from hourly to the monthly level, tabulating the total number of heating and cooling degree-hours that occurred in the territory of utility i in month m ($heating_{im} = \sum_{t \in m} heating_{it}$, for example).

There is a minor complication in the analysis due to the explosive growth of distributed rooftop solar since 2016. This introduces a time-varying sensitivity of metered residential consumption to monthly sunlight ($flux_{im}$). This can be accounted for by interacting $flux_{im}$ with the capacity of rooftop solar. In areas with relatively little solar, however, this ends up fitting spurious, highly variable trends with the monthly data. This has little impact on the overall estimates, but widens the dispersion of the utility-specific measures. I therefore only include the $flux_{im}$ measure for utilities with at least 500MW of distributed solar by 2019.

I estimate equations of the form

$$Log(Load_{im}) = \tau_{ym} + \mu_M + \Gamma_i + \sigma heating_{im} + \kappa cooling_{im} + \phi\{solar_{im} * flux_{im}\} + u_{im}$$

where μ_M and Γ_i are month of year and utility fixed effects, respectively. Some specifications estimate utility-specific month of year fixed effects and meteorological influences. The coefficients of interest, τ_{ym} track the evolution of weather-adjusted electricity consumption over time, where the period just before the shock is omitted and magnitudes are interpreted as changes in year y, month m relative to the baseline normalization.

4 Results

Hourly Data from Texas

Figure 1 shows how electricity consumption over the week has changed dramatically during the COVID-19 pandemic. The solid lines represent mean consumption by hour of week for April and May of 2020. The dashed lines represent the same for April and May of 2019. All estimates are adjusted for meteorological conditions, so the levels may be interpreted as non-heating/cooling electricity consumption.

Focusing first on residential consumption, the dashed lines for 2019 indicate that residential consumption is usually quite different between weekdays and weekends during normal times. People tend to be home during the day on weekends, and this presence is reflected in higher midday consumption on the first and last days of the week. During the work week in normal times there is a sharp uptick in the mornings as people get up, a minor drop off as many leave the house for work, followed by relatively stable levels until returning home in the evening, when consumption peaks. The peaks on Friday and Saturday evenings are smaller than other days of the week, reflecting the tendency to go out on these nights.

During the COVID-19 pandemic, in the prescient words of Morrissey and Street (1988), Everyday Is Like Sunday. The morning upticks at 7AM are gone, with residential consumption almost 2GW lower as the day begins an hour or so later. With everyone home, midday residential electricity during the work week is 3-4 GW higher than normal, with distinct peaks at 1PM, 5PM, and 9PM. Friday and Saturday evening peaks are no lower than other days of the week, as days of the week cease to have meaning.

Figure A.3 undertakes the same exercise for January and February, showing that 2019 and 2020 had essentially the same pattern pre-pandemic, though consumption was slightly lower in 2020. This suggests a difference-in-difference estimation to account for the year-to-year changes: compare the spring-winter change in 2020 to that of 2019. The results for this estimation using the natural logarithm of consumption as the dependent variable is presented in Table A.1. It finds a roughly 8% increase in residential consumption when averaged over all hours, with increases during work hours of over 16%. On average over all hours, there was a 1.25GW increase based on the double-difference estimates. This translates to about \$110M in additional monthly expenditures.[5]

Commercial and industrial electricity consumption during normal times reflects the work week: it is sharply higher Monday-Friday, 9AM-5PM. There is typically a second, smaller peak in the evening. While the daytime and evening peaks continue during the pandemic, they have been significantly muted with reduced activity in these sectors.

Again, Figure A.3 shows that January and February 2020 were unremarkable compared to 2019, though consumption was somewhat higher in 2020 across all hours of the week. Panel B of A.1 presents the difference-in-difference estimates for non-residential consumption, finding a nearly 12% reduction overall, which translates to about 3GW and \$150M in reduced electricity expenditures per month. Complementing the results with residential consumption, business hour load was down over 16% for commercial and industrial customers.

Monthly Data from U.S. Utilities

Figure 2 (a) plots the evolution of weather-adjusted electricity consumption for U.S. utilities by customer class relative to February, 2020. These figures expand upon the specification of column (5) of Table 1, which presents the average change in consumption for the second quarter of 2020 relative to February.[6] This includes utility-month of year fixed effects and utility-specific meteorological controls. The small annual declines in electricity consumption since the Great Recession are barely perceptible in these figures. Instead, the months of the second quarter of 2020 stand out for their significant and unprecedented departures from recent consumption patterns. July of 2020 saw persistently high residential usage while commercial and industrial consumption was recovering—making it appear as though total consumption was back to normal.

As summarized in Table 1, in Q2-2020 there was a 10% increase in residential consumption, a 12% decrease in commercial consumption, and a 14% reduction in industrial electricity usage. Regressing the total consumption across all sectors on the same controls, one finds only a modest 3.5% decline sustained over the quarter. Table 1 shows that these results are stable across various specifications, even when only including month of year fixed effects (Column 1). Nearly all of the variation in monthly electricity consumption is accounted for with month of year and utility fixed effects.

Is this normal for a fast-moving economic crisis? In panel (b) of Figure 2, I present the analogous results for the time surrounding the financial crisis of 2008. The plots are normalized to September,

[5]The mean residential price in Texas is \$0.12/kWh. The mean price for commercial and industrial power in 2019 was \$0.07/kWh.

[6]After Q2-2020 is omitted from the estimates for the table to keep a consistent sample with the heterogeneity analysis, which lacks locality-level data on business closures over the summer of 2020.

2008 (i.e. the bankruptcy of Lehman Brothers). Industrial production responded quite swiftly during the financial crisis, falling 10-15% within a couple of months of the initial shock. On the other hand, reductions in commercial consumption accumulated much more gradually, not reaching -10% until over a year after the crisis began. It is interesting that the magnitudes of the commercial and industrial shocks are similar to that of COVID-19, even if on a different time scale—because the similarities end there. In contrast to the sharp increase in residential usage during the COVID-19 pandemic, it is difficult to discern any significant change in residential usage from the noise during the 2008 financial crisis.

There have, of course, been significant differences in experience across jurisdictions during the COVID-19 pandemic. To get a better sense of the heterogeneity in how consumers have been affected, Figure 3 maps the results by utility by interacting utility indicators with a post-April, 2020 dummy in a pooled regression with utility-specific month of year and meteorological controls. Pacific Gas & Electric led the nation, with residential consumption estimated to have been over 40% above weather-adjusted normal levels. New England, Illinois, and California have seen some of the largest increases overall. While virtually all utilities saw residential consumption increases of some form,[7] the smallest increases occurred through Appalachia and South-Central states.

To explore potential determinants of this heterogeneity, I interact measures of potential explanations with the indicator for the second quarter of 2020: the share of the labor force that may be able to work from home according to Dingel and Neiman (2020), unemployment from the Bureau of Labor Statistics, non-essential business closures from Goolsbee et al. (2020), and heating/cooling measures. The last of these variables estimate the extent to which heating and cooling affected electricity demand during the pandemic more (or less) than during normal times.

Both work from home and unemployment variables are in percents, and have been normalized to have zero mean by month. This means the main coefficient on Q2-2020 can be interpreted as the average change in electricity consumption at $18^o C$, without mandatory business closures, with a workforce composition at the national average in each month of the second quarter of 2020.

The interaction terms correlate the intensity of electricity consumption changes during Q2-2020 with cross-sectional characteristics of utilities, and should be interpreted as exploratory. Each of the presented measures are likely correlated with other potential determinants of electricity consumption changes, so a fair amount of caution is warranted before making causal interpretations. The results are, however, informative for understanding where the changes in electricity consumption have been largest.

The results are presented by customer class in Table 2. Places with a larger share of the workforce potentially working from home have in fact seen larger increases in residential electricity consumption. The difference between the national average and the top ten metropolitan areas in potential to work from home is about 10 percentage points (Dingel and Neiman (2020)). This is associated with a 3 percent increase in residential consumption, which is significant relative to the overall increase in residential usage. The association of work from home with electricity consumption is much smaller for commercial and industrial users, and not significantly different from zero.

Areas that have experienced larger unemployment shocks have also seen large reductions in commercial and industrial electricity consumption. The positive association of unemployment with

[7] The exceptions were Cincinnati Gas & Electric, the City of Tupelo, MS, and the Cleveland Electric Illuminating Company.

residential usage is smaller than that of working from home, but both may be contributing to the overall increase. After controlling for unemployment, the additional impact of non-essential business closures is relatively small and not significantly different from zero for any customer class. This is not to say that shutdown policies have little impact on electricity consumption—they are likely to have direct impacts on unemployment in their own right, and the collinearity of these measures make it difficult to disentangle. It also appears that electricity consumption has become somewhat more responsive to heating and cooling degrees during the pandemic. The measures are presented as degrees sustained over the entire month, so a comparison of utilities in Florida with those in Minnesota translates to a 5^oC cooling degree-month difference, and 2.5% higher residential electricity consumption. Commercial and industrial usage also appear to have been more temperature-sensitive, which is not consistent with idling, but may also be correlated with other differences across utilities.

At prevailing prices (which were within 2% of normal on average during Q2-2020), a 10% increase in residential electricity consumption translates to monthly average of $10.59/household for the period between April and July, 2020.[8] With 137M total residential accounts in the United States, this is a total excess expenditure of $1.5B/month. Figure A.4 in the appendix presents the expenditure analog of Figure 3, mapping the heterogeneity in residential expenditures. The expenditure pattern follows the change in quantities extremely closely. Utilities with high prices (in California and New England) are also those with large increases in residential usage, driving expenditure increases that top $50/household in July, 2020. One fifth of the population is serviced by a utility whose mean bill has risen by at least $20/month.

5 Conclusion

This paper estimates changes in residential, commercial, and industrial electricity consumption during the COVID-19 pandemic. Using hourly data from Texas, I find significant disruptions to daily patterns of life as workplaces close and more time is spent at home. These changes in daily rhythms are reflected in monthly data from utilities around the country, with residential consumption rising by 10% on average, and commercial and industrial consumption falling by 12% and 14%, respectively, during the second quarter of 2020. The rise in residential consumption means that households spent nearly $6B on excess electricity from April-July, 2020.

These results highlight that initiatives to buffer the economic impact of the pandemic require special attention to the ways in which it differs from a typical economic downturn (Alon et al. (2020); Ziedan et al. (2020)). The rise in residential electricity consumption has also been working to mask the impact of the pandemic in measures that use total electricity consumption as a real-time proxy for lagging economic statistics (Lewis et al. (2020)). Finally, the relative energy intensity of heating and cooling the entire homes of employees rather than a single office suggests that the future of working from home is not as green as one might think based on reduced commuting alone.

[8] For this calculation, I use the percent conversion of the coefficient from column (5) of Table 1 as $0.099 = exp(0.094) - 1$. The implied change in electricity expenditure per household is then $\frac{0.099}{1.099}$ times the observed revenue per household. I take the customer count-weighted average of this number over U.S. utilities to arrive at the average excess monthly expenditure. It was $8.15 in April, $8.81 in May, $11.14 in June, and $14.25 in July, 2020.

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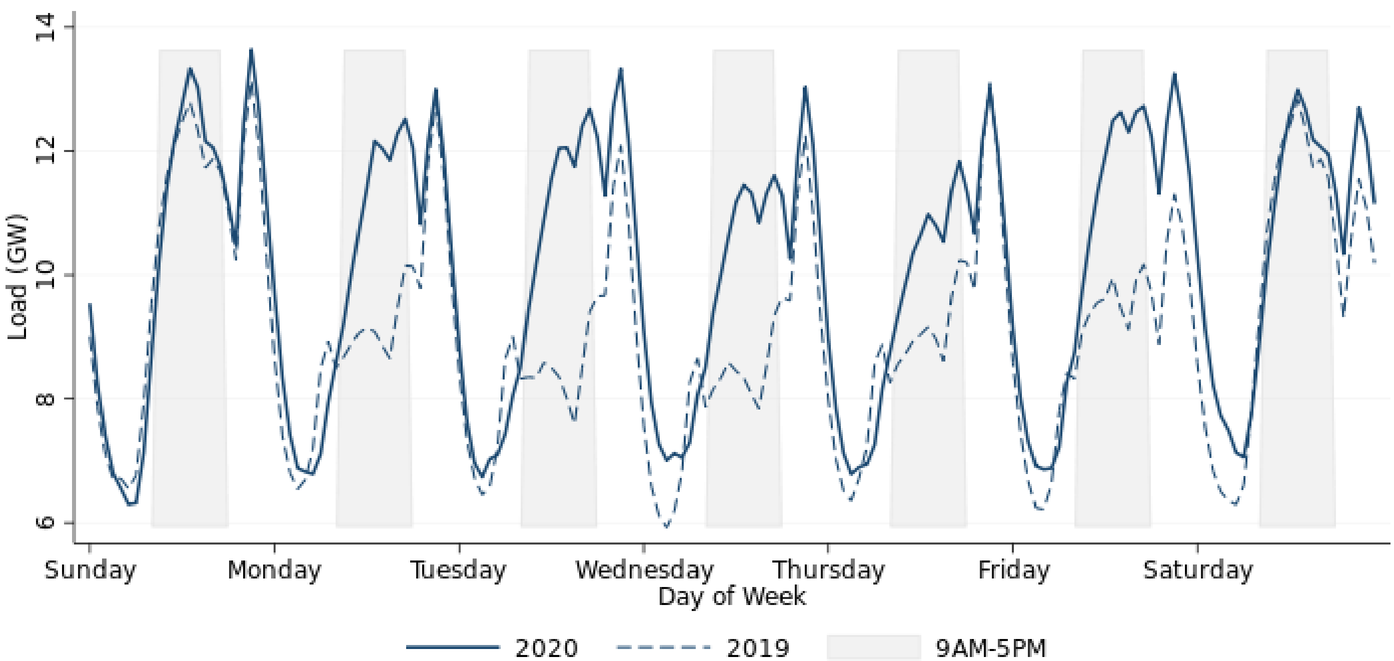
Figure 1: Temperature-Adjusted Electricity Consumption in Texas by Customer Class: April/May, 2020 versus 2019

(A) Residential



(B) Commercial and Industrial

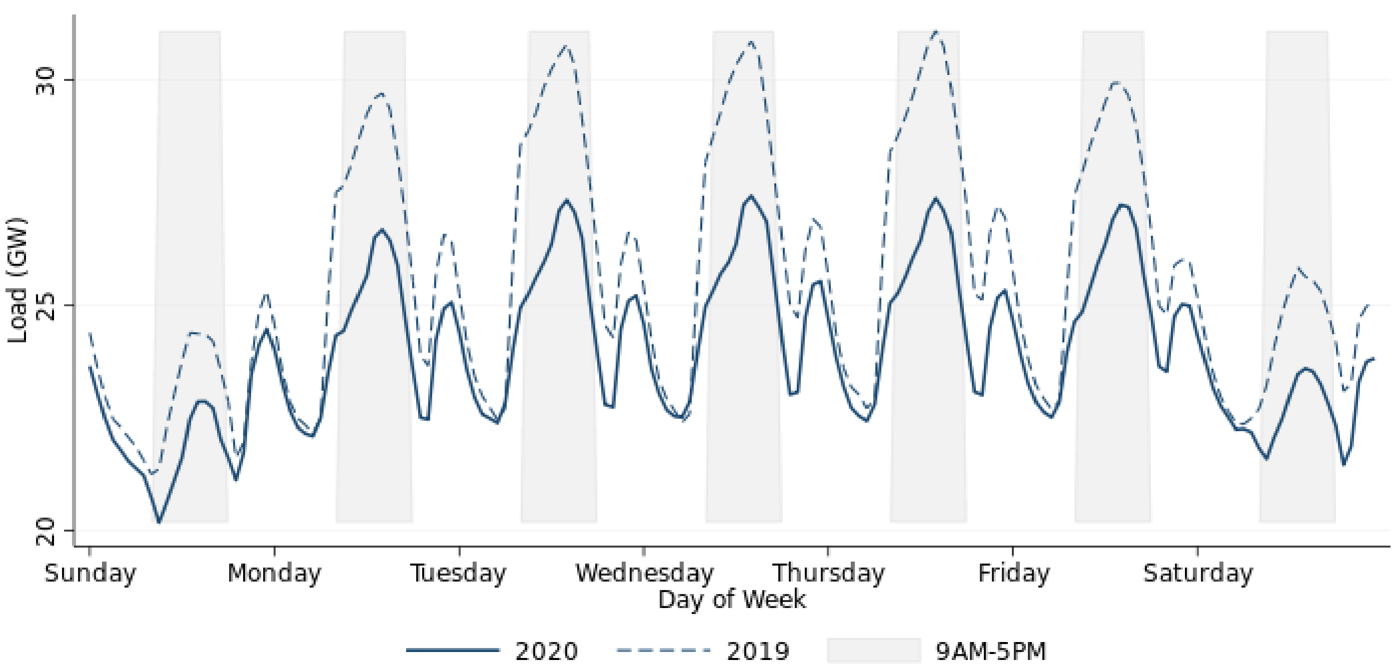
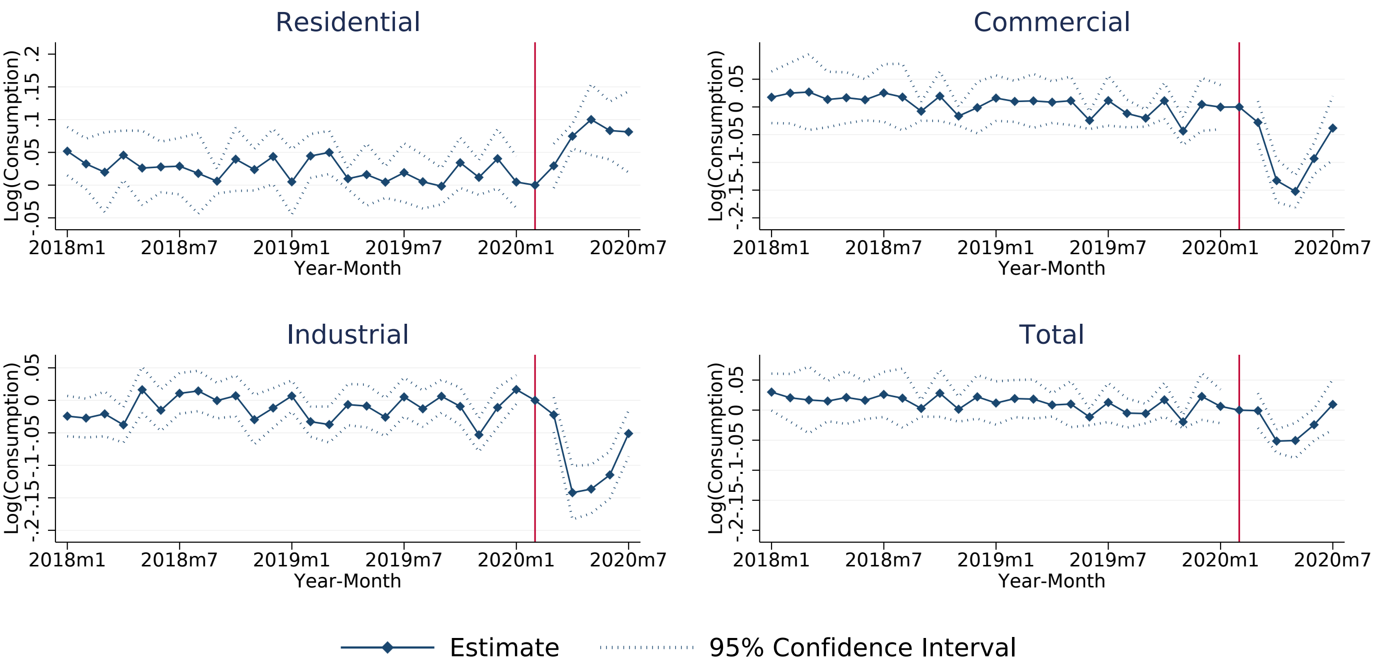
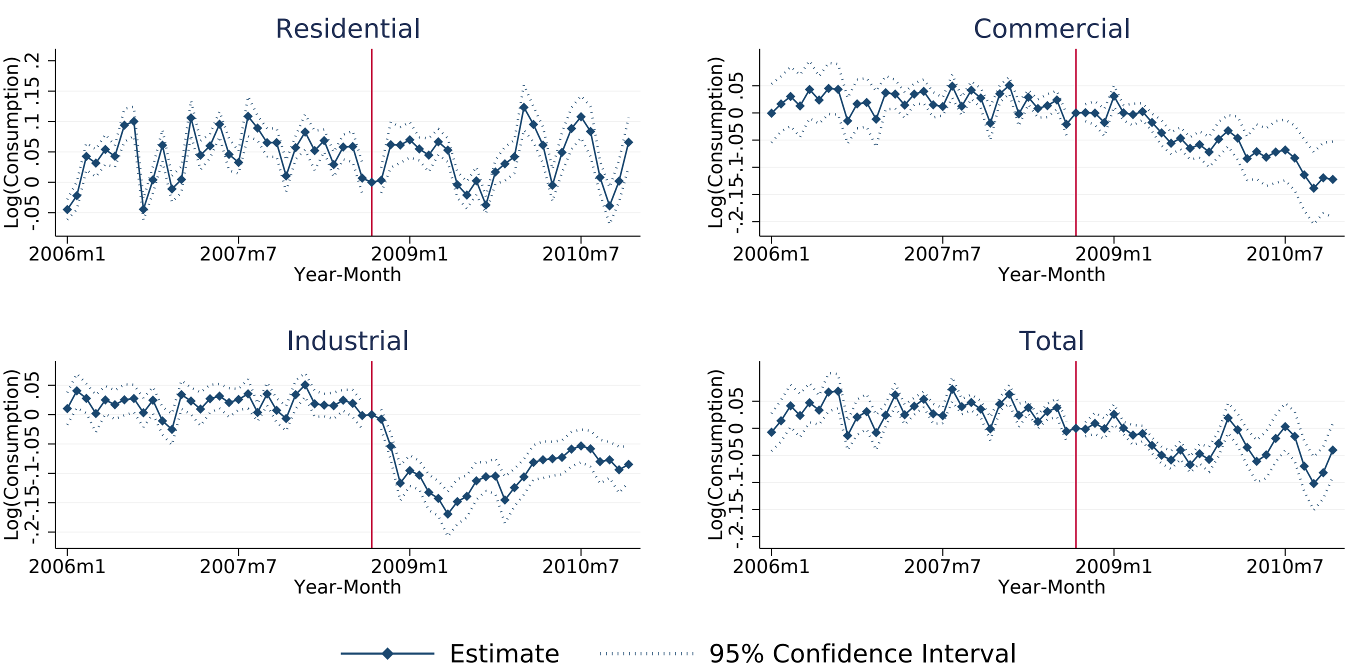


Figure 2: Electricity Consumption During Crises by Customer Class

(A) COVID-19 Pandemic

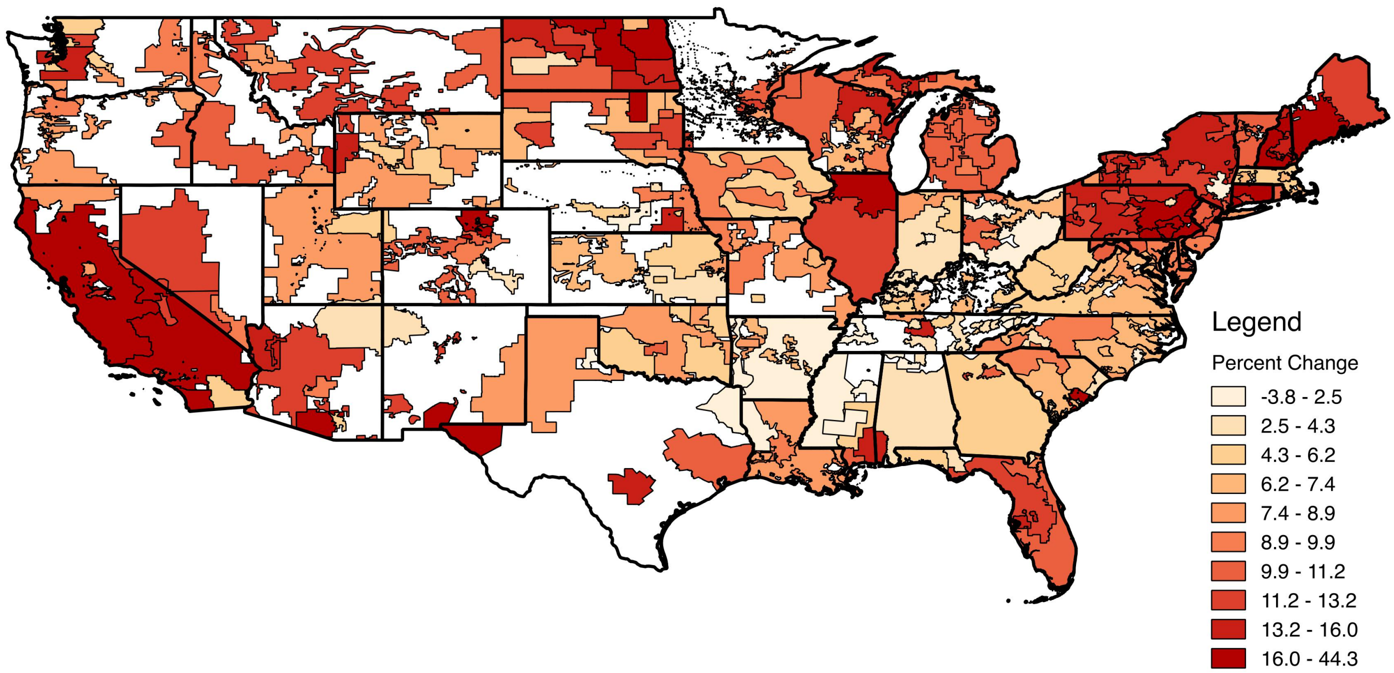


(B) 2008 Financial Crisis



Note: Estimates are based on specification (5) of Table (1), which include utility-month of year fixed effects and utility-specific meteorological controls.

Figure 3: Residential Electricity Consumption Anomaly in Percent: April-July, 2020



Note: Estimates report the interaction of utility dummies with a post-April, 2020 indicator from a pooled regression with utility-specific month of year and meteorological controls. Colors correspond to deciles of the distribution of utility-level estimates. White space on the map represents utilities that were not regular reporters in EIA-861M.

Table 1: Change in *Log*(Electricity Consumption) by Customer Class

A. Residential	(1)	(2)	(3)	(4)	(5)
2020 Second Quarter	0.062***	0.061***	0.076***	0.091***	0.094***
	(0.019)	(0.019)	(0.017)	(0.015)	(0.017)
Utility FE		Yes	Yes	Yes	
Weather			Yes		
Utility-Weather				Yes	Yes
Utility-Month FE					Yes
Clusters	284	284	284	284	284
R^2	0.017	0.981	0.989	0.995	0.998
Obs.	15330	15330	15330	15330	15330

B. Commercial	(1)	(2)	(3)	(4)	(5)
2020 Second Quarter	–0.132***	–0.133***	–0.128***	–0.126***	–0.121***
	(0.016)	(0.016)	(0.015)	(0.015)	(0.016)
Utility FE		Yes	Yes	Yes	
Weather			Yes		
Utility-Weather				Yes	Yes
Utility-Month FE					Yes
Clusters	267	267	267	267	267
R^2	0.005	0.994	0.996	0.996	0.997
Obs.	14414	14414	14414	14414	14414

C. Industrial	(1)	(2)	(3)	(4)	(5)
2020 Second Quarter	–0.155***	–0.151***	–0.148***	–0.145***	–0.142***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)
Utility FE		Yes	Yes	Yes	
Weather			Yes		
Utility-Weather				Yes	Yes
Utility-Month FE					Yes
Clusters	228	228	228	228	228
R^2	0.002	0.984	0.984	0.988	0.990
Obs.	12304	12304	12304	12304	12304

D. Total	(1)	(2)	(3)	(4)	(5)
2020 Second Quarter	–0.055***	–0.056***	–0.046***	–0.039***	–0.035**
	(0.014)	(0.014)	(0.013)	(0.013)	(0.014)
Utility FE		Yes	Yes	Yes	
Weather			Yes		
Utility-Weather				Yes	Yes
Utility-Month FE					Yes
Clusters	345	345	345	345	345
R^2	0.007	0.992	0.994	0.996	0.998
Obs.	18625	18625	18625	18625	18625

Note: All specifications include month of year fixed effects. Column (3) controls for weather with single coefficients for heating and cooing degree hours, and a measure of distributed solar. Columns (4) and (5) estimate utility-specific coefficients for these controls. Standard errors clustered by utility in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

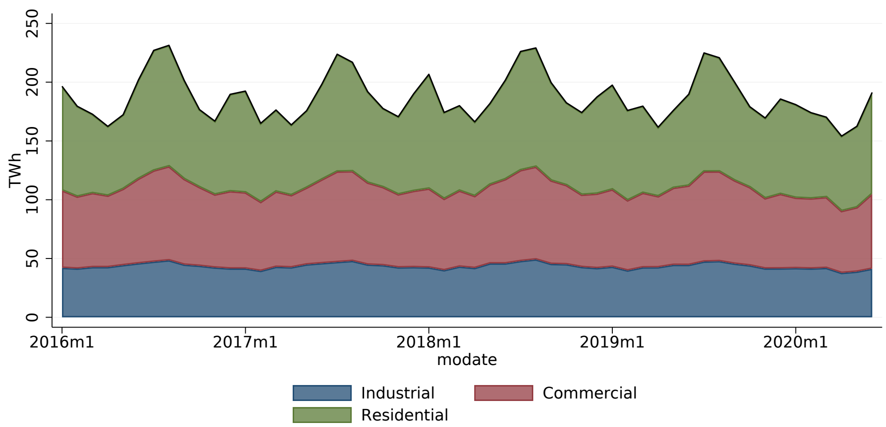
Table 2: Heterogeneity in *Log*(Electricity Consumption) Changes by Customer Class

	(1) Residential	(2) Commercial	(3) Industrial	(4) Total
2020 Second Quarter	0.063***	–0.154***	–0.191***	–0.070***
	(0.018)	(0.027)	(0.037)	(0.019)
x Percent Work from Home	0.003***	0.001	–0.001	0.004***
	(0.001)	(0.002)	(0.004)	(0.001)
x Percent Unemployed	0.002	–0.005**	–0.019***	–0.003
	(0.002)	(0.002)	(0.005)	(0.002)
x Non-essential Business Closed	0.003	–0.034	0.044	0.021
	(0.021)	(0.032)	(0.029)	(0.015)
x Cooling-Degree Months	0.005	0.009***	0.011**	0.007**
	(0.004)	(0.003)	(0.005)	(0.003)
x Heating-Degree Months	0.003*	0.004	–0.005	–0.002
	(0.002)	(0.005)	(0.004)	(0.002)
Clusters	284	267	228	345
R^2	0.995	0.996	0.988	0.997
Obs.	15241	14354	12190	18442

Note: All specifications include utility-month of year fixed effects and utility-specific weather controls. The percents of workers unemployed and potentially working from home have been normalized to be mean zero for each month of the sample. Utilities lacking work from home estimates are omitted. Standard errors clustered by utility in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Figure A.1: U.S. Monthly Electricity Consumption and Expenditures by Customer Class

(A) Consumption



(B) Expenditure

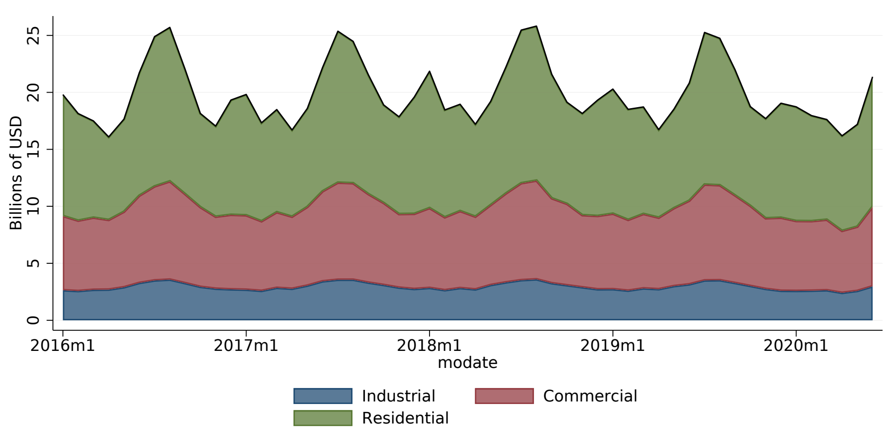
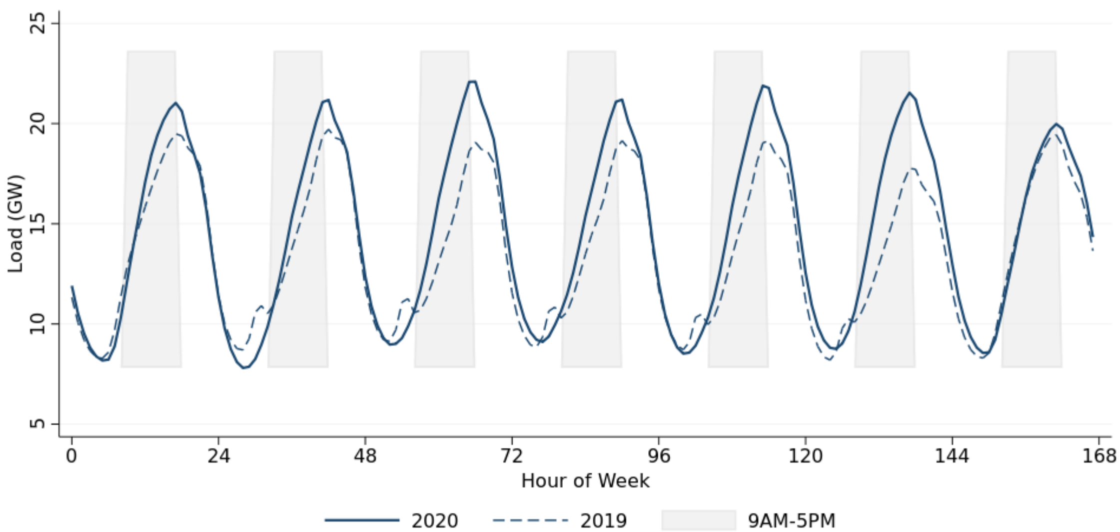


Figure A.2: Raw Hourly Electricity Consumption in Texas by Customer Class: April/May, 2020 versus 2019

(A) Residential



(B) Commercial and Industrial

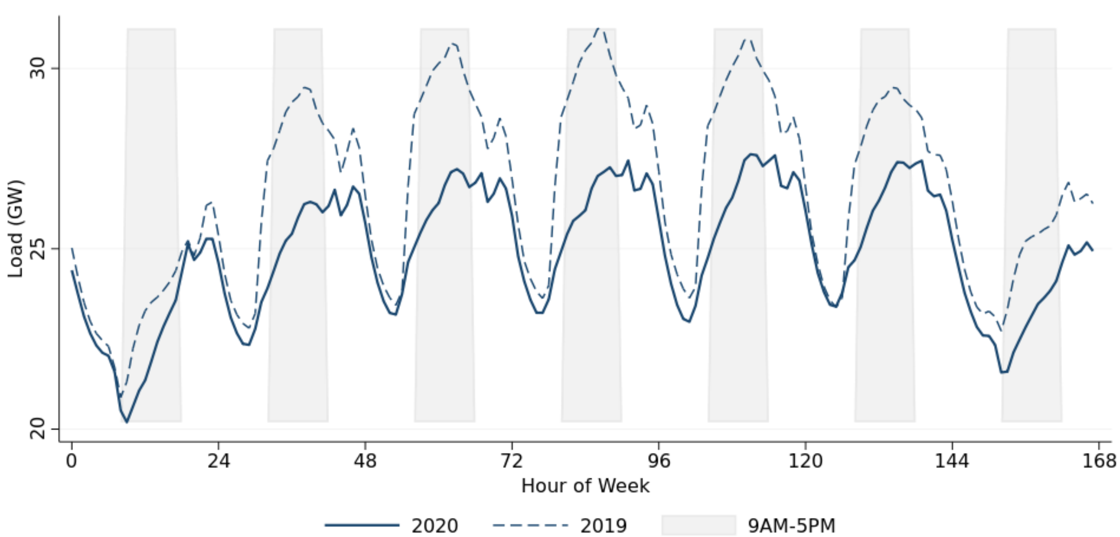
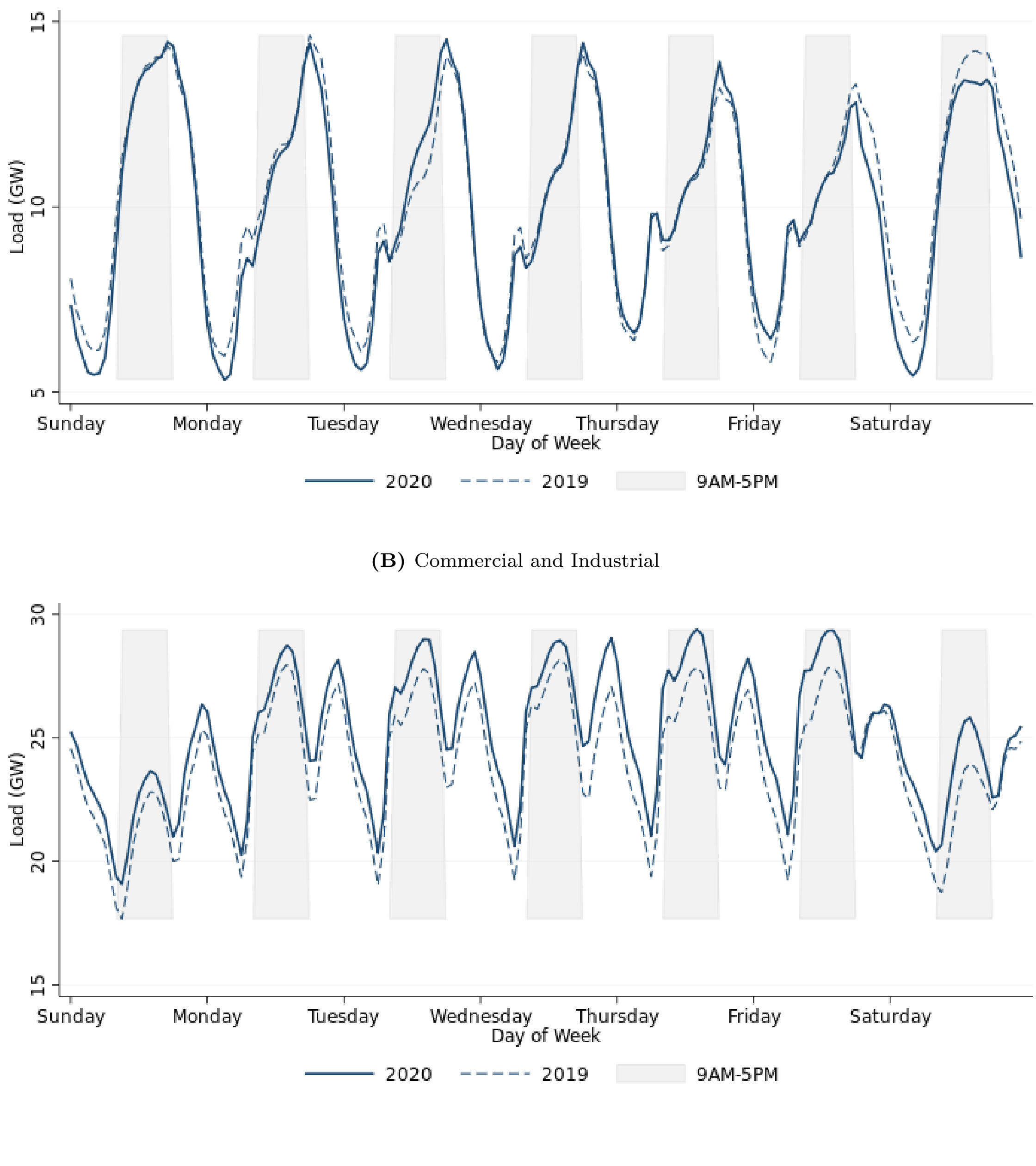


Figure A.3: Temperature-Adjusted Electricity Consumption in Texas by Customer Class: January and February 2020 versus 2019

(A) Residential



(B) Commercial and Industrial

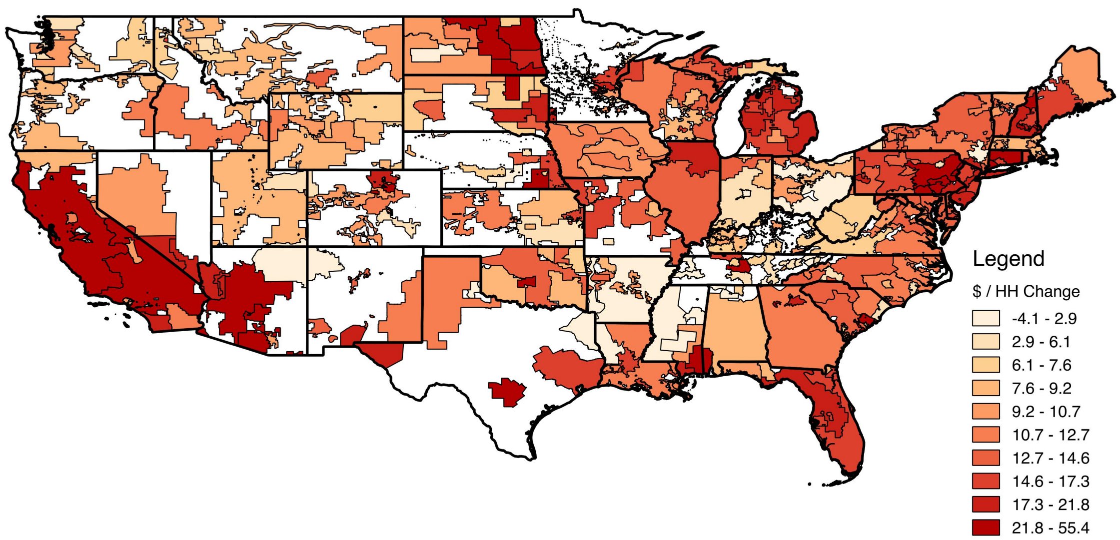
Table A.1: Texas Hourly Change in *Log*(Electricity Consumption) by Customer Class: Difference-in-Difference Estimates

A. Residential	(1)	(2)	(3)	(4)
Apr/May 2020	0.104	0.086***	0.073**	0.039
	(0.087)	(0.029)	(0.029)	(0.027)
x M-F: 9AM-5PM				0.122***
				(0.032)
Weather		Yes		
Hour-Weather			Yes	Yes
Clusters	34	34	34	34
R^2	0.012	0.589	0.777	0.788
Obs.	5712	5712	5712	5712

B. Non-Residential	(1)	(2)	(3)	(4)
Apr/May 2020	–0.112***	–0.110***	–0.116***	–0.098***
	(0.021)	(0.013)	(0.012)	(0.010)
x M-F: 9AM-5PM				–0.060***
				(0.010)
Weather		Yes		
Hour-Weather			Yes	Yes
Clusters	34	34	34	34
R^2	0.071	0.250	0.538	0.748
Obs.	5712	5712	5712	5712

Note: All specifications include year and spring fixed effects. Column (2) controls for weather with single coefficients for heating and cooling degree hours, and a measure of distributed solar. Columns (4) and (5) estimate hour-specific coefficients for these controls. Column (5) includes an indicator for work hours and its interaction during the pandemic. Standard errors clustered by sample week in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Figure A.4: Residential Electricity Expenditure per Customer Anomaly: July, 2020



Note: Quantity-based estimates from Figure 3 are applied to observed quantities and prices to calculate excess expenditure. Colors correspond to deciles of the distribution of utility-level estimates. White space on the map represents utilities that were not regular reporters in EIA-861M.