ENERGYECOLAB

The Spanish Economy, the Power Sector and the Pandemic

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COVID as a natural experiment

There is much to learn from these unique times,
also in the area of Energy and Environmental Economics

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1. **Competing Strategies for Carbon Abatement: Degrowth versus Decoupling** (with A. Lacuesta and M. Souza)
2. **Firms and Households during the Pandemic: What do we Learn from their Electricity Consumption?** (with O. Bover, S. García-Uribe, A. Lacuesta ad R. Ramos).

Firms and Households during the Pandemic

Energy Consumption during the Pandemic

Research questions:

1. Can we use electricity demand as an **indicator of economic activity** during the pandemic?
2. How have electricity consumption patterns changed due to the **lockdowns**?
3. What do electricity consumption patterns tell us about **firms' and households' work and habits** during the pandemic?

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  1. **Regulated market**: only households
  2. **Liberalized market**: households and firms
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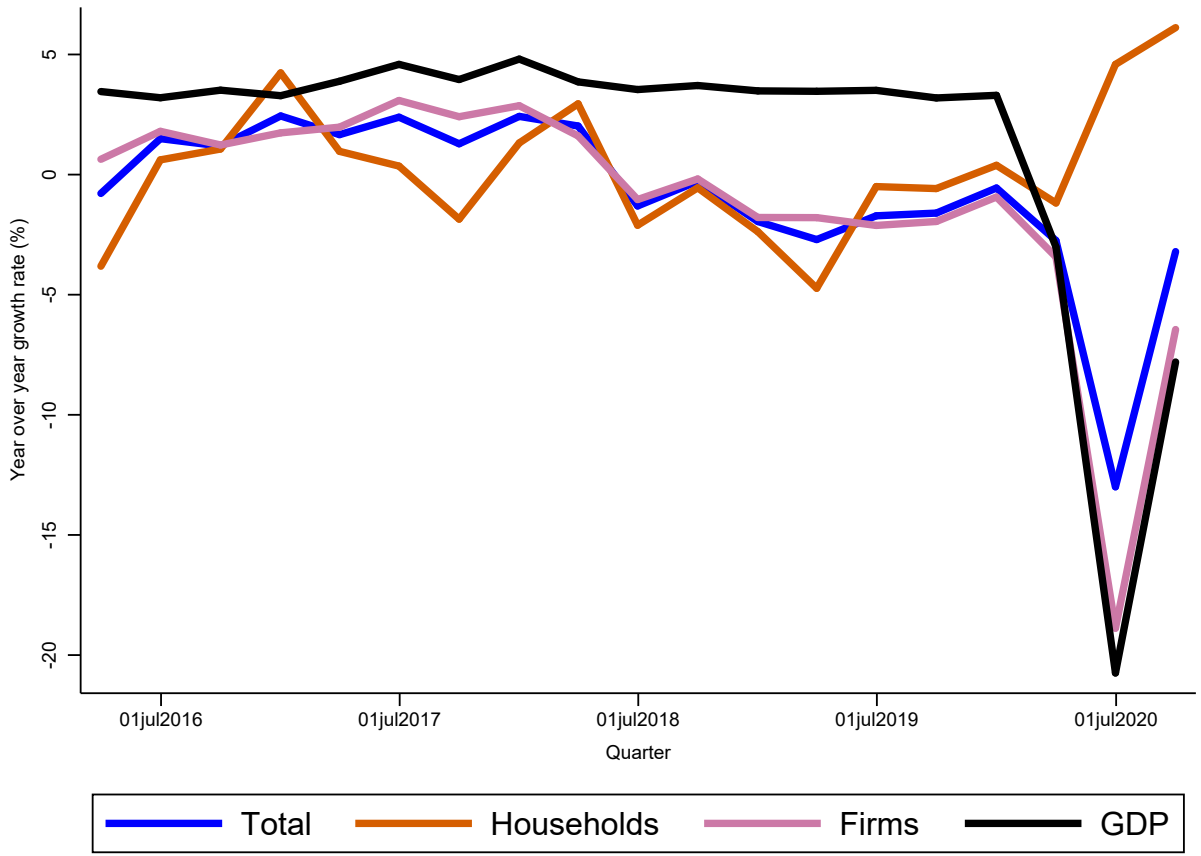
- Assumption: on average, households in the regulated or liberalized market consume the same

$\longrightarrow$ We obtain estimated series of firms' and households' electricity consumption

Electricity Demand and GDP Growth Rates



Predictive Impact of the Pandemic

- Data: daily electricity consumption 2015-2020
- **Estimating equation:**

$$\ln(q_{dt}) = \rho + \beta\tau_t + \beta_2\tau_t^2 + \gamma_t + \epsilon_{dt}$$

- Controls: temperature; time fixed effects

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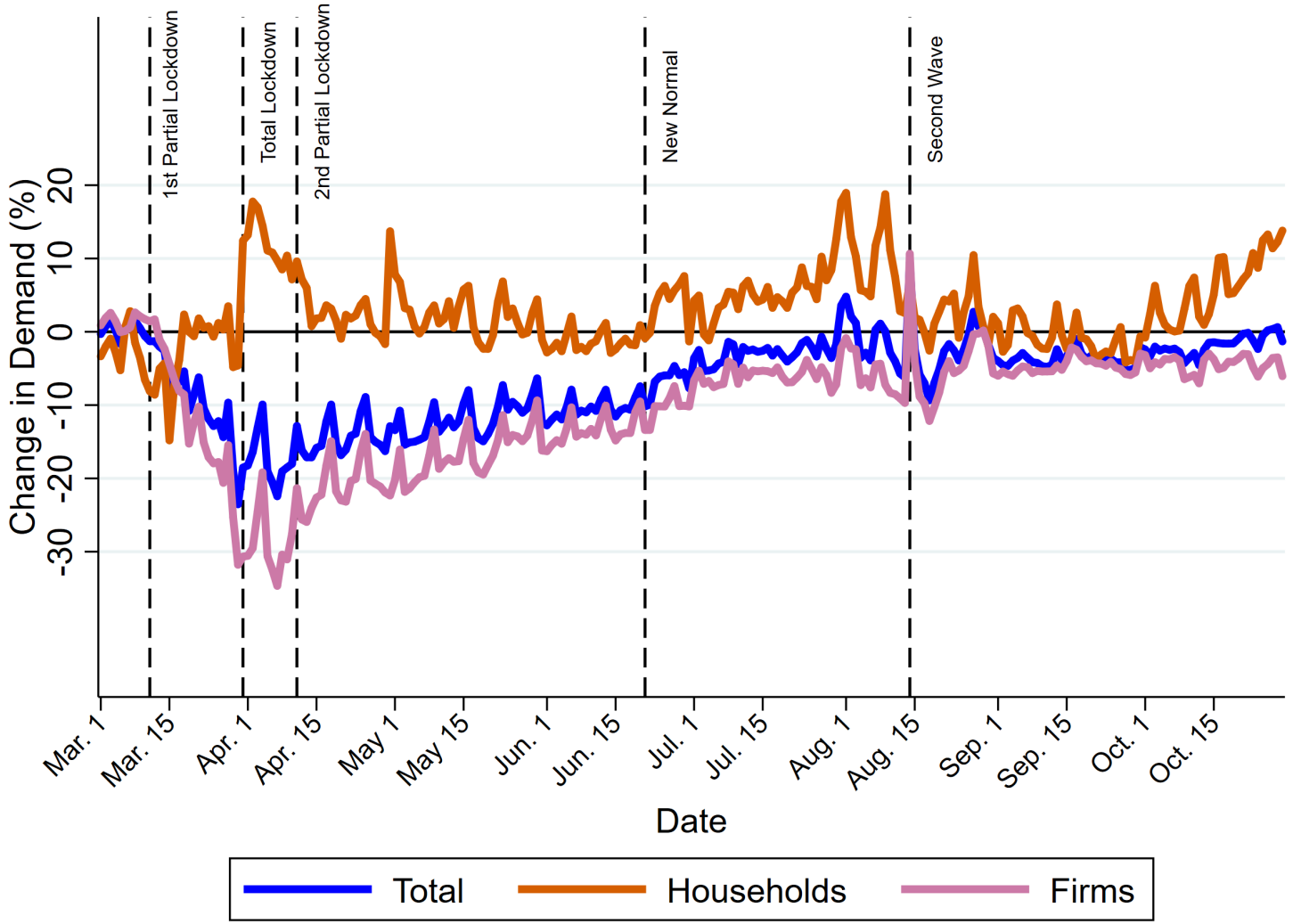
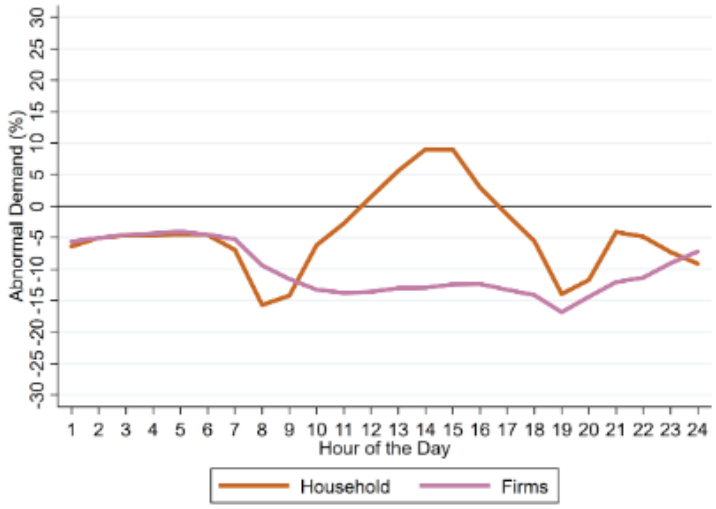
- Controls: temperature; time fixed effects
- Pre-pandemic, average of the residuals at weekday d: $\tilde{\epsilon}_d$
- During the pandemic, estimated residual $\hat{\epsilon}_{dt}$
- **Impact of the pandemic**: $\hat{\epsilon}_{dt} - \tilde{\epsilon}_d$

The Impact on Electricity Consumption

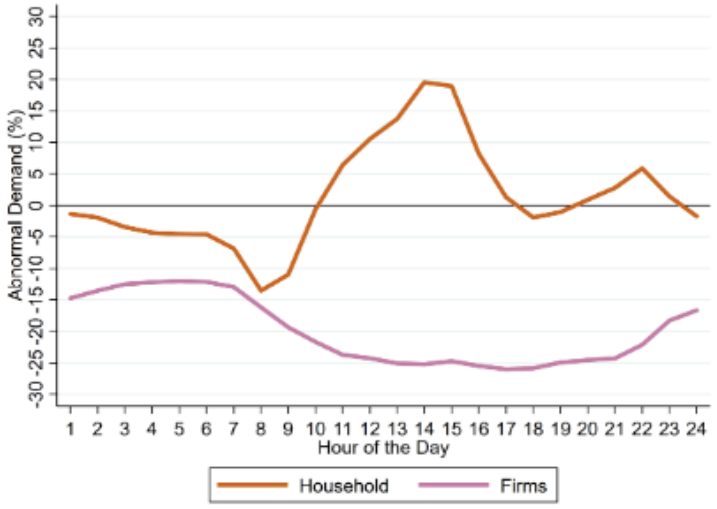


Analysis of Hourly Data

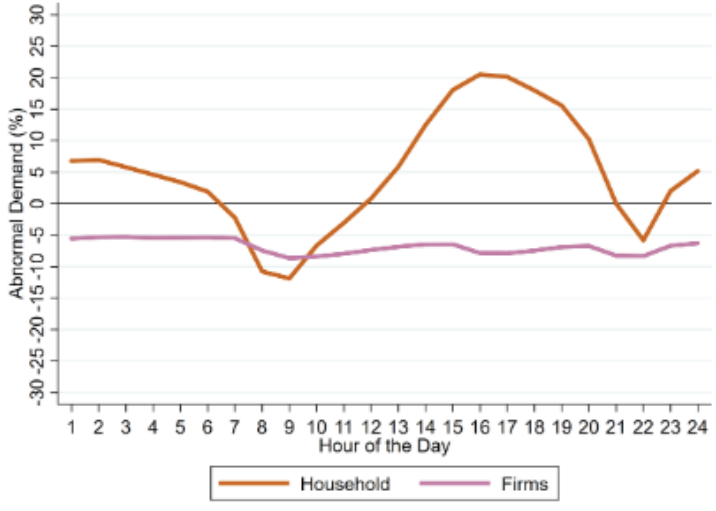
Panel A: 1st Partial Lockdown



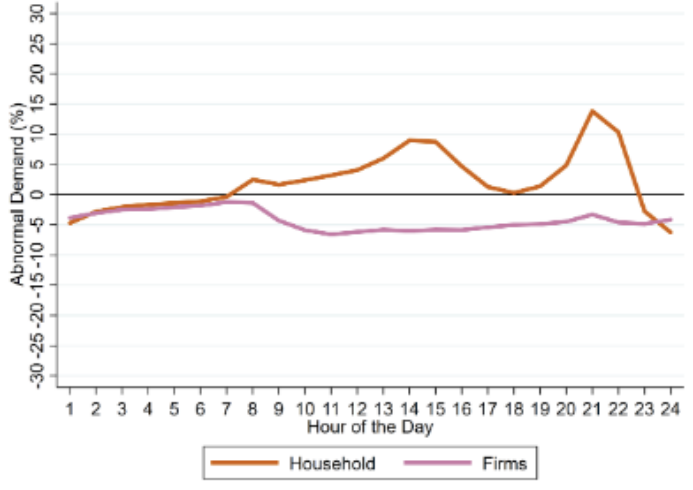
Panel B: Total and 2nd partial lockdown



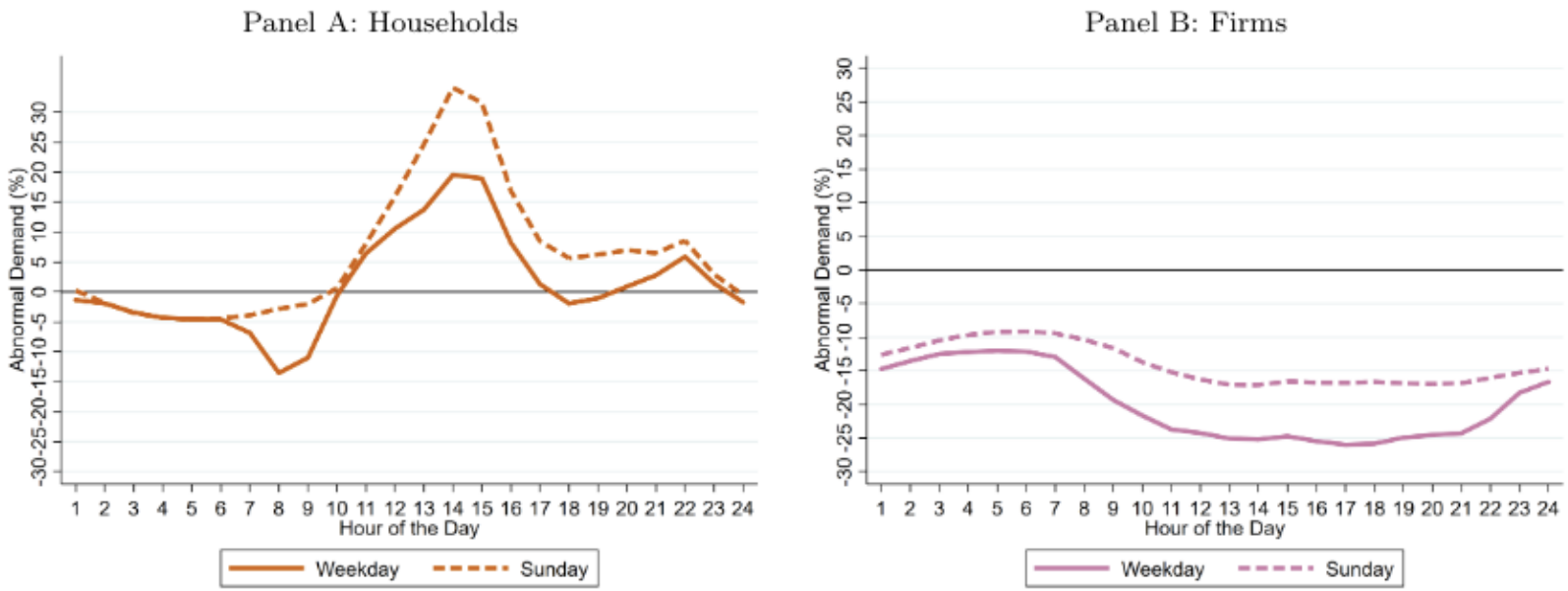
Panel C: New normal



Panel D: Second wave



The Sunday Effect



Notes: These figures show the estimated percentage change in hourly electricity consumption by firms and households as compared to what the model would have predicted with 2015-2019 data. Both weekdays and Sundays that were no holiday are considered separately.

Conclusions (so far)

Understanding the **link between electricity consumption and economic activity** is highly valuable...
Yet this link **might have changed**

1. During the pandemic, electricity consumption by firms has fallen while that of households has increased
2. Aggregate electricity consumption figures thus hide the true economic impact of the pandemic
3. Changes in hourly consumption patterns by households reflect habit changes

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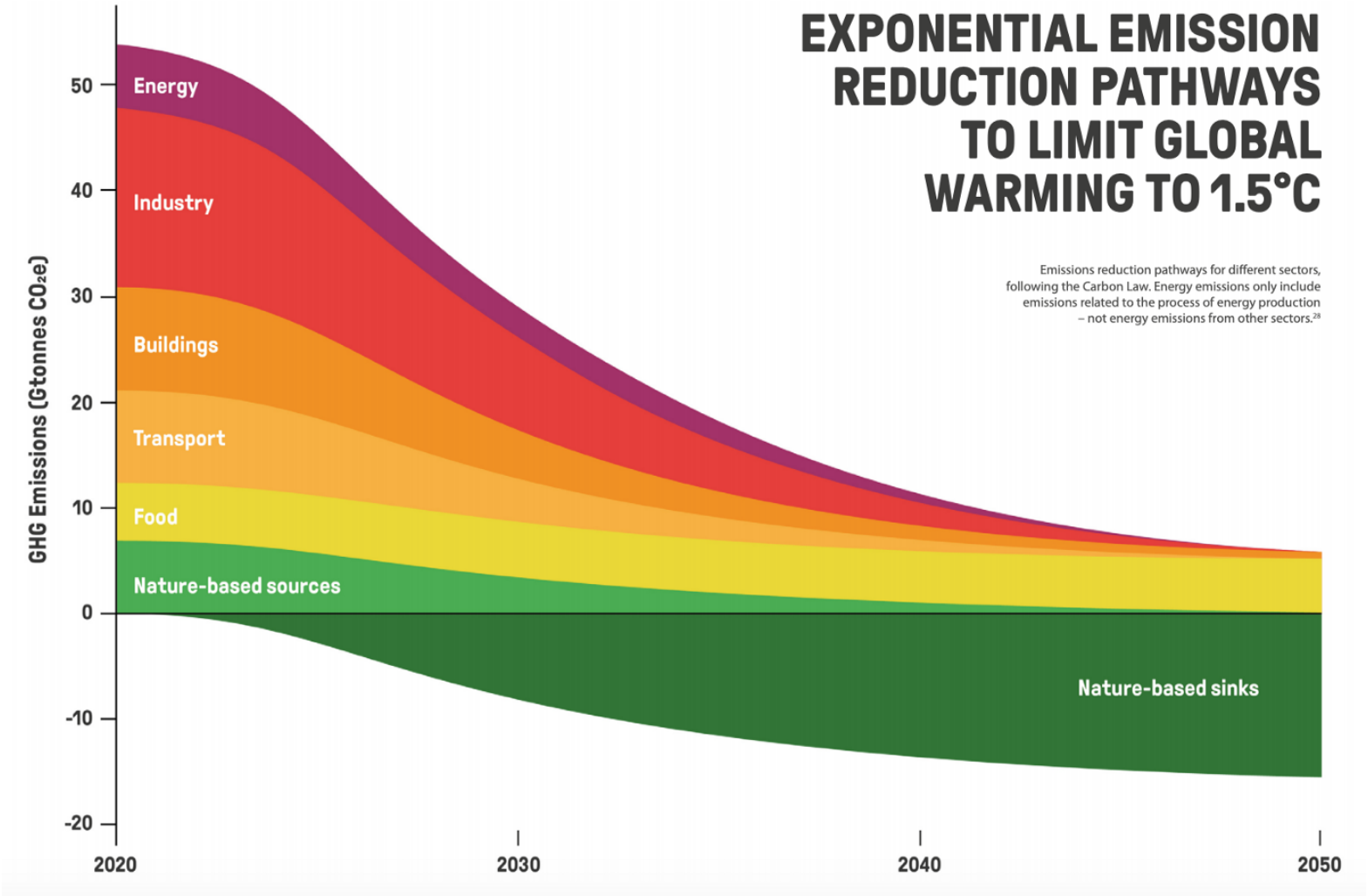
Competing Strategies for Carbon Abatement

Towards Carbon-Free Economies



How to Achieve Emissions Reductions

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1. **Degrowth strategy**:
   Stop GDP growth in order to tackle climate change
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Caveats!: these have been the results of a shock, not of optimally defined strategies

Competing Strategies for Carbon Abatement

- We leverage the **effects of COVID** on the Spanish economy.
- We measure the impact on **emissions reductions**.
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Steps of the analysis:

1. Counterfactual **emissions** in all sectors
   - Power sector
   - Other sectors
2. Counterfactual **GDP**
3. Counterfactual **investments** to achieve similar CO2 reductions
4. More detailed analysis of the **power sector**

Predicting Counterfactual Electricity Demand

- **Data:** hourly demand 2005-2020
- **Predictive machine learning model of demand:**

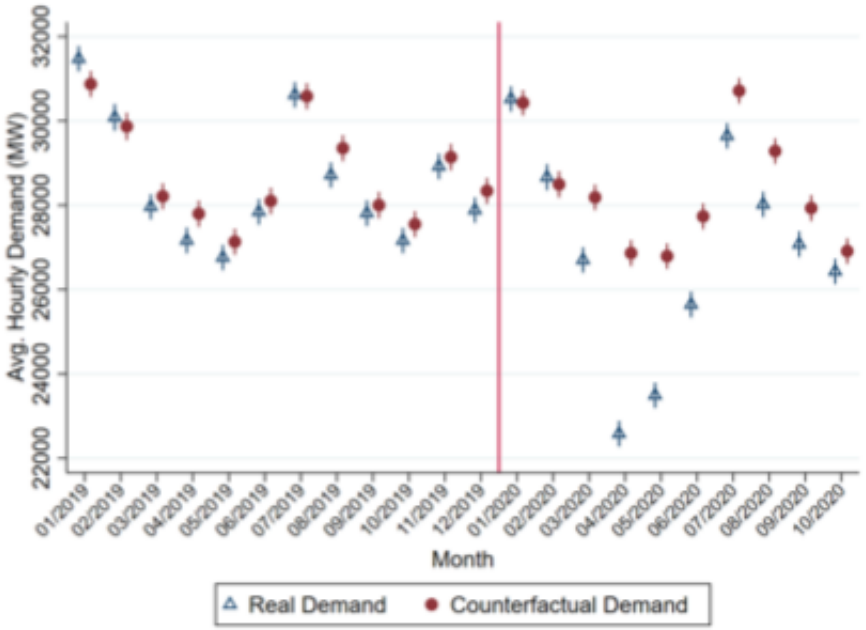
$$\hat{Y}_t(0) = g(\mathbf{X}_t) + \varepsilon_t$$

- Impact of the pandemic on electricity demand:

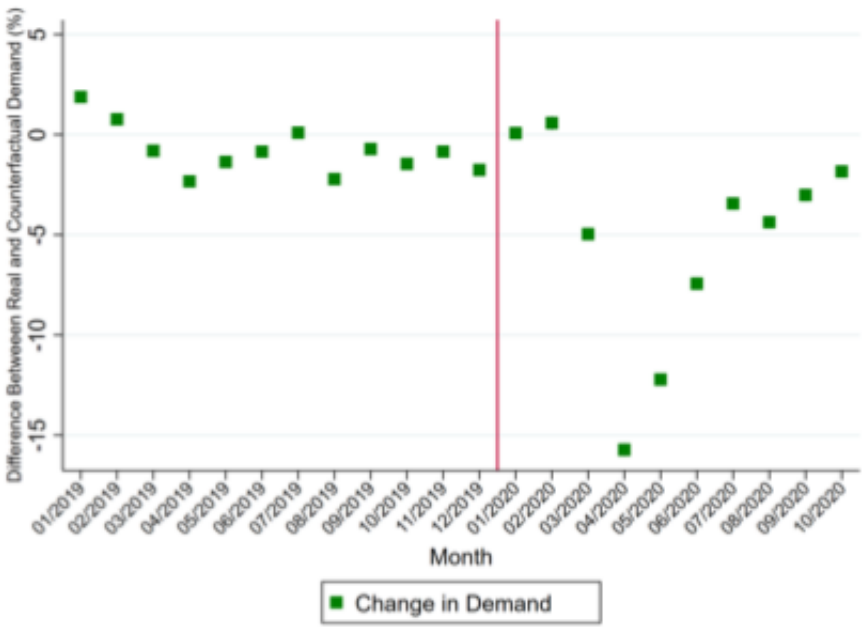
$$b_t = Y_t(1) - \hat{Y}_t(0) = Y_t(1) - g(\mathbf{X}_t) - \varepsilon_t$$

- Covariates $\mathbf{X}_t$: weather and date/time fixed effects
- $g()$: Gradient Boosted Trees (Chen and Guestrin, 2016)
- Model trained and cross-validated with past data (2015-2019)
- Counterfactual predictions for year of pandemic (2020)

Counterfactual Demand in the Power Sector



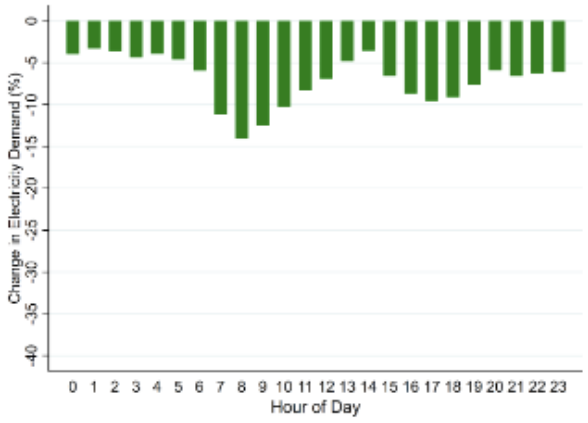
a: Realized and Counterfactual Demand



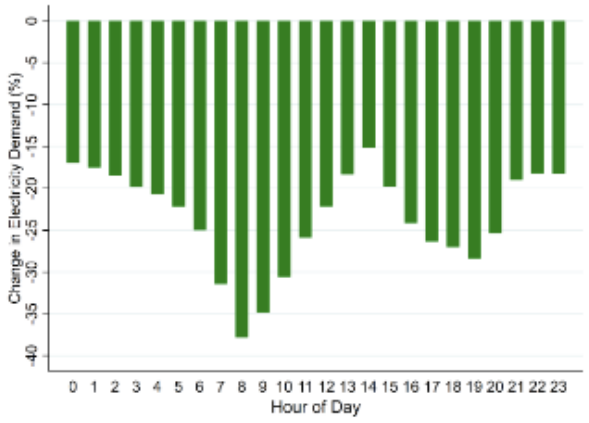
b: Percentage Difference

Figure: Realized and counterfactual electricity demand (2019-2020)

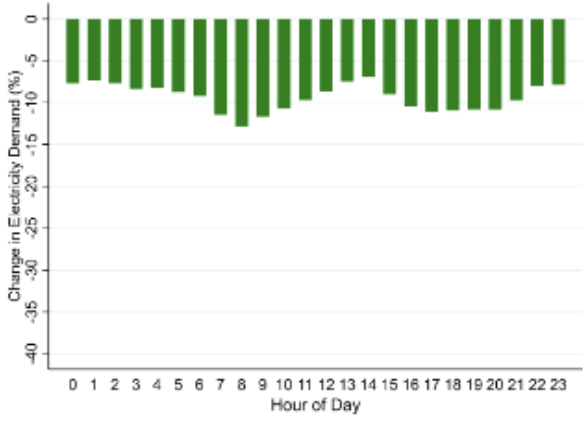
Counterfactual Demand in the Power Sector



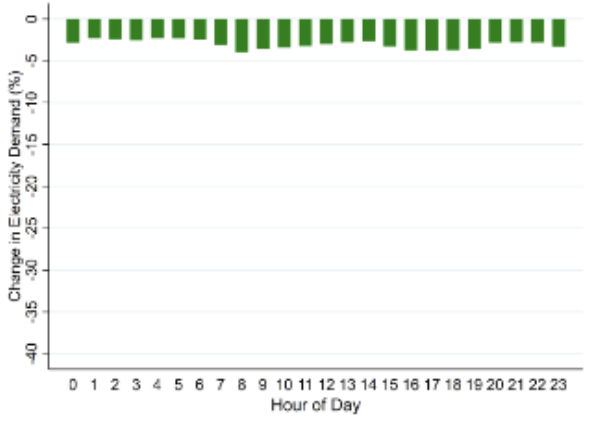
a: 1st Partial Lockdown
(March 11 - March 28)



b: Full Lockdown
(March 29 - April 10)



c: Partial Lockdowns + New Normal
(April 11 - August 14)



d: Beginning of Second Wave
(August 15 - October 31)

Counterfactual Emissions in the Power Sector

- We use the hourly demand estimates to **simulate the hourly electricity market outcomes** with and w/o the pandemic

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- We take all else as given:
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  - Existing capacity of gas/coal/nuclear plants
  - Daily prices of gas/coal/CO2
  - Caveats!: nuclear availability and gas/coal/CO2 prices

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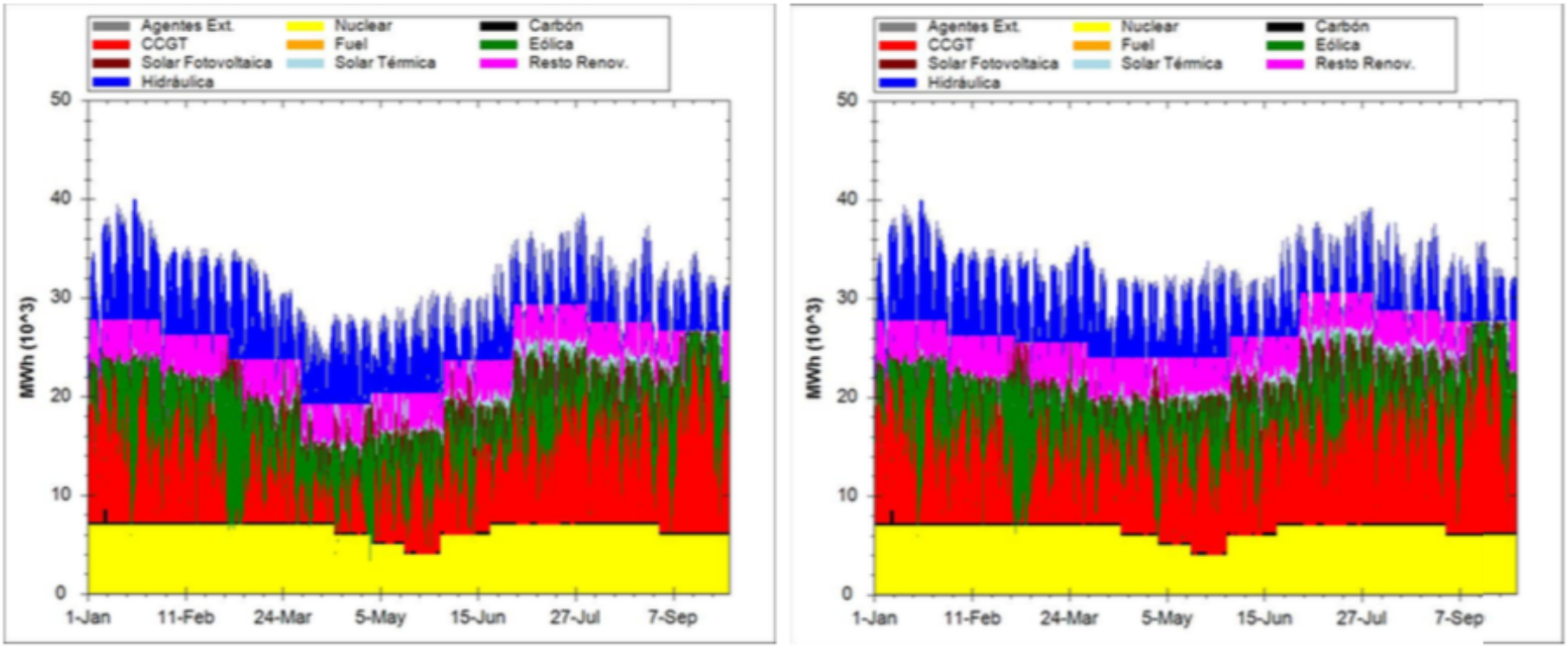
- **Simulated outcomes** (with and w/o the pandemic)
  - Electricity market prices
  - Production per technology
  - Emissions

Counterfactual Emissions in the Power Sector



a: Using realized demand

b: Using counterfactual demand

Figure: Real and simulated generation mix (Jan-Sept 2020)

Counterfactual Emissions in the Power Sector

Table: Generation Mix in Realized and Counterfactual Scenarios

	Realized Demand		Counterfactual Demand		Difference	
CO2 (M Ton)	Competitive	Strategic	Competitive	Strategic	Competitive	Strategic
Coal	0.48	0.56	0.52	0.59	0.03	0.03
Gas	13.01	12.99	16.40	16.37	3.39	3.38
Cogen + Others	9.26	9.70	9.67	9.89	0.41	0.19
Total	22.75	23.25	26.59	26.86	3.83	3.61

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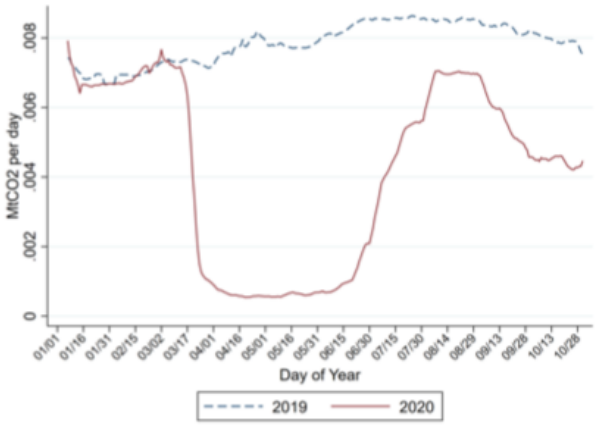
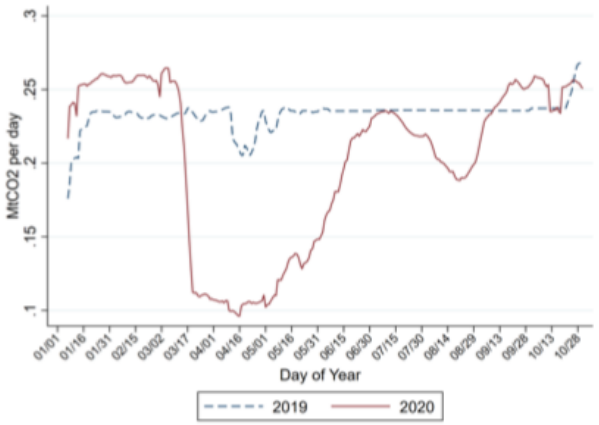
Other variables of interest (January-September 2020):

- Prices fell by 3.7% (competition) or 1.4% (strategic).
- Firms' market revenues fell by 7.6% or 6.0%.
- Generation costs fell by 12.4% or 12.2%.

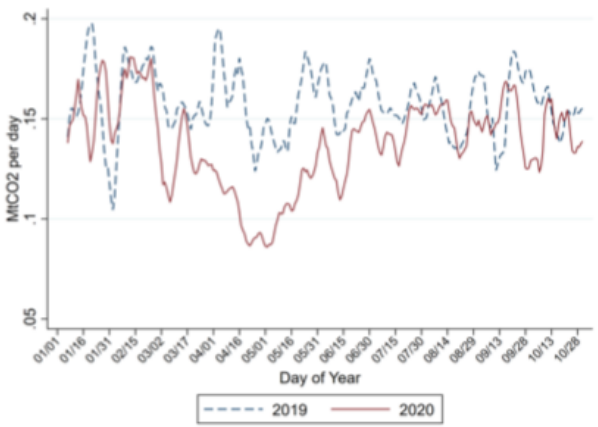
Counterfactual Emissions in Other Sectors



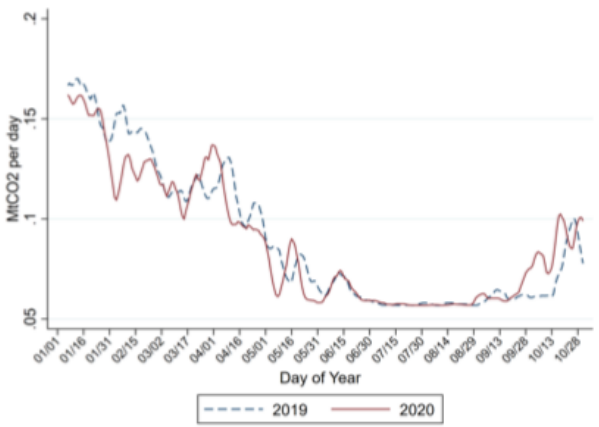
a: Domestic Aviation



b: Ground Transport



c: Industry



d: Residential

Source: Carbon Monitor

Counterfactual Emissions in Other Sectors

Table: Other Sectors' CO2 Emissions from January - September 2020

	MtCO2 Emissions			
	2019	2020	Diff.	Pct. Diff.
Domestic Aviation	2.14	1.15	-0.99	-46.30
Ground Transport	63.17	54.06	-9.11	-14.42
Industry	43.10	37.41	-5.69	-13.21
Residential	25.30	24.36	-0.94	-3.73

Notes: Data from Carbon Monitor (Liu, Ciais, Deng, Lei, et al., 2020; Liu, Ciais, Deng, Davis, et al., 2020). This table compares Spanish CO2 emissions from Jan-Sep of 2019 and 2020, and across different sectors.

Degrowth Strategy

- To construct counterfactual GDP, we rely on quarter-on-quarter growth rate forecasts.
- We apply those forecasts to the actual GDP Q4-2019.
- Total GDP loss Q1-Q3 2020: 133.34 Billion Euros

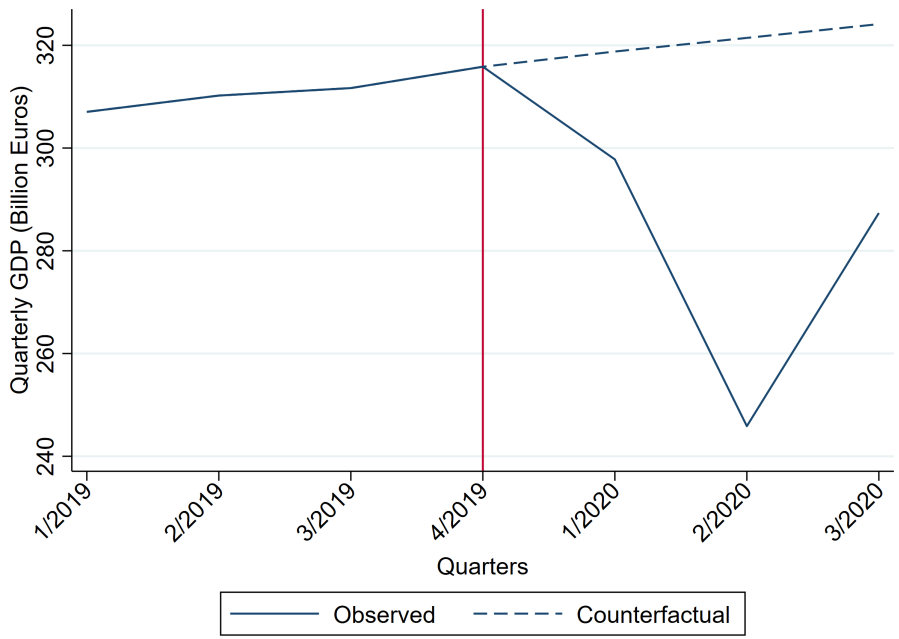


Figure: Spanish real and counterfactual Quarterly GDP

Decoupling Strategy

- We simulate the market under various renewable investments.
- We retain the ones that would have yielded the same emissions reductions in the power sector as the pandemic.
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	Emission Reductions (M Tons)		Investment Costs (M EUR)		Implicit Cost of Carbon (EUR)	
	Competitive	Strategic	Total	Investment+O&M (Q1-Q3)	Competitive	Strategic
Degrowth	3.83	3.61	-	-	-	-
Solar Investments	4.01	3.72	5,917.5	230	57.4	61.8
Wind Investments	3.80	3.45	10,486.7	482	126.9	139.6
Hybrid Investments	3.93	3.65	8,202.1	356	90.5	97.4

Figure: Investment Costs and Emissions Reductions in the Power Sector

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The implicit cost of carbon under each strategy is:

1. Degrowth: 6.510€/Ton CO2
2. Decoupling: 57.4€/Ton CO2

Conclusions

COVID has hit hard the economy and the energy sector

1. Need to revisit the link between economic activity and electricity consumption
2. The pandemic has weakened economic activity more than what is reflected in aggregate consumption data
3. Carbon abatement can be obtained through a slow down in growth and/or low-carbon investments
   - Halting growth is too costly and socially unacceptable
   - Relying in investment would bring in further economic benefits

The technology is ripe to allow for true **sustainable growth**!

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Thank You!

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Comments? Feedback? Questions?

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