Effect of COVID-19 on Power Sector Emissions

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This paper provides causal estimates of the spread of the coronavirus (COVID-19) on power sector emissions via a drastic drop in electricity demand. For 16 European economies, we find that at its peak, COVID-19 reduced hourly carbon emissions by 34%. Our results vary by country depending on the particular electricity supply mix and demand shock. Our study reveals the limits of energy efficiency policies, which may never reach the scope of COVID-19's demand reduction.

Keywords: Coronavirus; COVID-19; Electricity demand; Emissions

JEL Classification: Q41, Q54, R11

1 Introduction

Global climate policy has been struggling to reduce emissions at a large scale. During the last 30 years, our planet has experienced ever-increasing energy-related CO_2 emissions, with a one-time exemption of a 1.3% dip during the financial crisis in 2009 (IEA, 2020). This picture has changed with the recent coronavirus (COVID-19) pandemic. Most nations reacted with drastic measures, most notably social distancing, short-time work, and lockdowns of public life, leading to significant reductions in industrial activity, mobility, and energy consumption.

The popular media reports that COVID-19 has brought about a significant drop in emissions around the globe. For example, New York's carbon emissions plummeted by 50% during March 2020, when the virus spread across the city (Henriques, 2020). China's emissions fell by 25% at the start of 2020, with a significant reduction in coal-fired electricity production. Satellite images show significant reductions in air pollution in France, Germany, Italy, and Spain during March 2020 (ESA, 2020). However, many reports argue that the drop in emissions will only be temporary, giving earth's climate a short break, whereas emissions may pick up with

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their pre-crisis trend once the economy recovers from COVID-19. In contrast to an abundance of articles in the popular media, from the academic perspective we are the first to provide sound and causal evidence of the COVID-19's dampening effect on power sector emissions.

We estimate a two-stage instrumental variables model, where we use the cumulative number of infections per country as an indicator of the treatment intensity, to trace out causal effects. In the first stage, we thus estimate the exogenous effect of COVID-19 on the electricity demand. In the second stage, we estimate the effect of a COVID-19-induced reduction in electricity demand on power sector emissions. Importantly, our sample covers 16 European economies for the hourly period 2020/01/01–2020/03/23, during which COVID-19 spread across Europe and lead to significant reactions in electricity demand. We find remarkable effects, which bear policy relevance. At its peak, COVID-19 reduced electricity demand by 19%, which in turn manifested in a significant drop in carbon emissions by 34%.

2 Data and methodology

We rely on data about cumulative COVID-19 infections per country for the period 2020/01/01–2020/03/23 (Roser et al., 2020). We calculate hourly power sector CO_2 emissions as power generation by technology (ENTSO-E, 2020) multiplied by the respective emission factor, weighted by average plant vintage (Gugler et al., 2020). Hourly data on electricity demand and infeed from wind and solar power stems from ENTSO-E (2020).

We use these data to estimate a two-stage instrumental variables model. Crucially for identification, the cumulative number of reported infections represents our indicator of treatment intensity, which serves as an exogenous instrument for a demand shock (c.f. Figure 1). We acknowledge that individual countries may follow individual strategies of testing for COVID-19. For example, countries with high testing penetrations (i.e. a higher testing rate per capita) may also have a higher number of reported infected cases. Nevertheless, the variation in the time series should be unaffected unless the testing rate does not change relative to other countries.

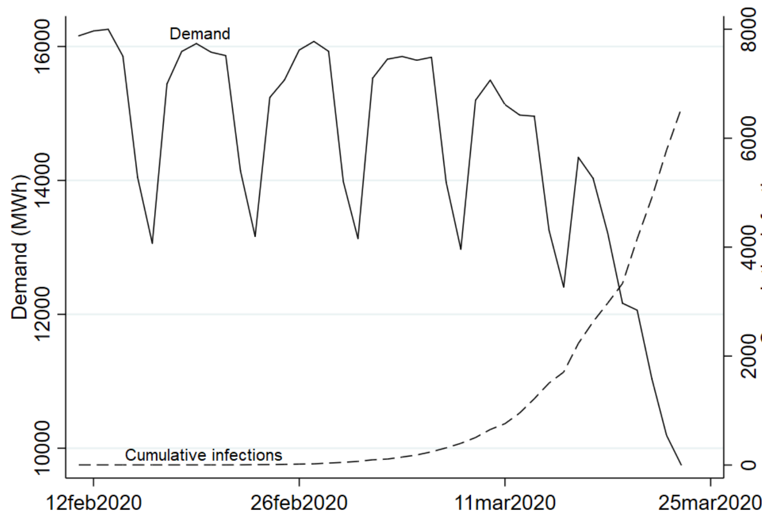
Importantly, we run individual time-series regressions for each country to avoid bias from size-effects.[1] In the first stage, we estimate the impact of cumulative infections (Inf) on electricity demand (D):

$$D_t = \alpha_{Inf} \cdot Inf_t + X_t' \alpha + \epsilon_t, \quad (1)$$

where t denotes the sample hour. X is a vector of control variables, including wind and solar electricity, hour-of-day, day-of-week, and monthly fixed effects, and a daily time trend. Importantly, the increase in Inf should identify the decrease in demand. We thus expect the

[1] A fixed-effects panel regression with all variables adjusted for population yields almost identical results (not shown for brevity).

Figure 1: Demand and infections, daily averages



estimate of α_{Inf} to be negative and statistically significant.

In stage two, we regress emissions from the power sector (E_t) on the predicted values of $\widehat{D}$ plus control variables:

$$E_t = \beta_D \cdot \widehat{D}_t + X_t' \beta + \mu_t, \tag{2}$$

which should yield an unbiased estimate of β.

Our 2SLS model allows for estimating the causal chain of infected cases on demand and further on emissions, using the first-stage estimate of α_{Inf} and the second-stage estimate of β_D (Kling, 2001). We measure the effect on emissions as $\Delta_E = Inf \cdot \widehat{\alpha}_{Inf} \cdot \widehat{\beta}_D$. As the COVID-19 infection rate seems to have peaked by 23 March 2020 (the infection rated slowed down considerably in most European countries thereafter), we may evaluate Δ_E for the maximum number of infections, $\overline{Inf}$, per country. This gives us an estimate of the maximum treatment effect on emissions. Finally, to get a feel of the percentage impact, we assess the effect for $\overline{Inf}$ relative to the average of predicted pre-treatment emissions ($\hat{E}_{pre} = \sum_t \hat{E}_t(Inf_t = 0)/t$):[2]

$$\%\Delta_E = \Delta_E(\overline{Inf})/\hat{E}_{pre} \cdot 100. \tag{3}$$

[2] In contrast to *actual* emissions, *predicted* emissions are adjusted for seasonality.

Table 1: First- and second-stage regression estimates

Country	1st stage: $\widehat{\alpha}_{Inf}$	2nd stage: $\widehat{\beta}_D$	Obs.	Kleib.-Paap F
AT	-0.3900	0.0847	1,969	208
BE	-0.5510	0.4294	1,969	196
CZ	-1.2153	0.3354	1,969	232
DE	-0.2191	1.0566	1,969	60
DK	-0.2231	0.8329	1,969	74
ES	-0.1811	0.3078	1,969	135
FI	-1.3452	0.1947	1,969	74
FR	-2.5490	0.0705	1,850	1,592
HU	-4.0437	0.3524	1,969	152
IT	-0.2049	0.2092	1,969	290
NL	-0.3829	0.5724	1,969	75
PL	-4.8862	0.7195	1,969	137
PT	-0.5050	0.2393	1,969	79
RO	-1.7356	1.0853	1,968	128
SK	-2.7495	0.2421	1,956	275
UK	-0.7720	0.4612	1,967	68
Weighted avg.	-1.2424	0.4948		

All estimates are statistically significant at the 1% level, using heteroskedasticity-robust standard errors. Missing values reduce the number of observations for some countries. Average weighted by countries' population.

3 Empirical analysis

Table 1 provides the first- and second-stage regression estimates of α_{Inf} and β_D. All estimates are statistically significant and have the expected sign. F tests suggest that infected cases are not a weak instrument for electricity demand. On average, we find that a reduction in demand by one MWh reduces emissions by 0.49 tCO_2.

Table 2 reports our main results. Most notably, we find a significant reduction in electricity demand, evaluated for the national cumulative infections cases as of the end of our sample period on 23 March 2020, of 19% on average – an economically sizable effect. However, we can see significant variations in $\%\Delta_E$ depending on the treatment intensity. Moreover, the demand-dampening effects translate into significant carbon abatement. On average, we find that COVID-19 reduced CO_2 emissions from the power sector by 34%. However, the effects vary across countries, due to their specific supply curves. In power markets, the marginal costs (mainly fuel costs) of generation technologies determine the curvature of the supply curve. In most European countries, coal- or gas-fired power plants represent the marginal (price-setting) technology. Yet, natural gas contains around only half the carbon emissions of coal per unit of electricity produced (Wilson and Staffell, 2018), and most other technologies produce little or zero emissions. Hence, depending on which technologies are mainly replaced by a

Table 2: Results

	Predicted pre-treatment values:		Treatment		Effects on demand and emissions			
country	Demand (MWh)	Emissions (tCO_2)	Max. infected	(in % of population)	Δ_D (MWh)	$\%\Delta_D$	Δ_E (tCO_2)	$\%\Delta_E$
AT	7,648	732	3,631	(0.0413%)	-1,416	-18.5%	-120	-16.4%
BE	10,154	1,013	3,401	(0.0298%)	-1,874	-18.5%	-805	-79.4%
CZ	8,452	4,497	1,165	(0.0110%)	-1,416	-16.8%	-475	-10.6%
DE	59,672	14,424	24,774	(0.0299%)	-5,428	-9.1%	-5,735	-39.8%
DK	4,245	719	1,395	(0.0263%)	-311	-7.3%	-259	-36.1%
ES	29,309	3,112	28,572	(0.0612%)	-5,174	-17.7%	-1,593	-51.2%
FI	10,224	698	626	(0.0114%)	-842	-8.2%	-164	-23.5%
FR	63,974	2,308	7,730	(0.0115%)	-19,704	-30.8%	-1,389	-60.2%
HU	5,380	937	167	(0.0017%)	-675	-12.6%	-238	-25.4%
IT	33,672	5,664	59,138	(0.0979%)	-12,117	-36.0%	-2,535	-44.8%
NL	12,003	3,053	4,204	(0.0244%)	-1,610	-13.4%	-921	-30.2%
PL	20,258	12,348	634	(0.0017%)	-3,098	-15.3%	-2,229	-18.1%
PT	6,143	701	1,600	(0.0155%)	-808	-13.2%	-193	-27.6%
RO	7,292	2,129	433	(0.0022%)	-752	-10.3%	-816	-38.3%
SK	3,603	364	185	(0.0034%)	-509	-14.1%	-123	-33.9%
UK	38,292	5,136	5,683	(0.0085%)	-4,387	-11.5%	-2,023	-39.4%
Mean	20,020	3,615			-3,758	-18.8%	-1,226	-33.9%

demand reduction and the intensity of the demand shock determine a country's emissions reduction.

This result is so pronounced that countries (e.g. Germany), which had probably failed their climate targets set for 2020 without COVID-19, may now reach them (Radowitz, 2020). In any case, the power sector is responsible for the bulk of global carbon emissions (41% in 2017; IEA, 2019). A vast temporary reduction in power sector emissions may thus buy humanity precious time to fight climate change. Nevertheless, it seems evident that emissions may rise again once the economy recovers from COVID-19.

4 Conclusion

We find a drastic reduction in power sector emissions of 16 European economies, drawn by a significant reduction in electricity demand, as induced by the spread of COVID-19. At the same time, our results demonstrate the limits of climate policy in terms of demand-side measures. COVID-19 reduced economic activity to a minimum, depressing electricity demand in a scope which energy efficiency policies, as for example propose by the European Commission (EC, 2020), may not be achieved in the coming years. From this perspective, climate policies may also focus on intensifying carbon pricing, which sets not only demand-side but especially supply-side incentives by increasing the marginal costs of carbon-intensive technologies.

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