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Measuring the Economic Impact of COVID-19 with Real-Time Electricity Indicators

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Abstract

The COVID-19 pandemic is posing unprecedented challenges, making it difficult for policy makers to design appropriate policies. In this context, real-time information can play a most valuable role for policy makers in developing countries, particularly since official economic indicators, such as the evolution of GDP and unemployment, not only are released with considerable delays, but also are not always fully reliable. This paper follows the literature by using the dependent variable electricity consumption per capita as a proxy measure of economic activity in the short run. Based on this method, it examines the short-run economic impact of the pandemic itself, as well as the public health restrictions that were adopted to control the outbreak and the macro-economic measures applied to revive the economy. The analysis confirms the significant cost of lockdown measures in terms of reduction in economic activity but finds that the spread of the disease itself had an economic impact distinct from that of the lockdown measures. The analysis shows that the use of expansionary fiscal and monetary policies also played a key role in mitigating such an impact, driving some initial recovery. Finally, the evidence points to a complete structural break in economic activity at the onset of the lockdown period.

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Measuring the Economic Impact of COVID-19 with Real-Time Electricity Indicators

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Keywords: Power sector, COVID 19, electricity demand, real time indicators

JEL: D14, E21, G51

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1. Introduction

The COVID-19 pandemic is posing unprecedented challenges, making it difficult for policy makers to design appropriate policies. The size of the economic shock triggered by the pandemic and the associated lockdown has not been fully assessed because the official economic indicators, such as evolution of GDP and unemployment, are not only released with considerable delay, but are also not always fully reliable, and often revised downwards. In this context, real-time information can play a most valuable role for policy makers in developing countries.

While theoretical work on the current COVID-19 pandemic is flourishing, still a relatively small part of the literature offers a comprehensive assessment of the economic impact. The current crisis encompasses both supply and demand shocks. Lockdowns and social distancing measures are forcing workers to stay at home, causing rationing in the consumption of some services, while consumers react to the pandemic by reducing consumption that requires interpersonal contact (Wren-Lewis, 2020). The recent paper by Guerrieri *et al.* (2020) models such impact triggered by the COVID-19 pandemic as a "Keynesian" supply shock, which ends up generating a much larger drop in aggregate demand larger than the supply shock itself. Social distancing measures and especially lockdowns have been subject to strong public debate, with many commentators claiming that the economic impact associated with them is more severe than the human cost these interventions are trying to prevent.

In this context, real-time information can play a most valuable role for policy makers in developing countries, particularly to address the questions highlighted in what follows. How has the magnitude of the economic impact been affected by the evolution of the pandemic and the stringency of lockdowns? What were the relative economic impacts of the disease versus the health policy remedy of lockdown? How effective were macroeconomic monetary and fiscal policy responses in shoring-up the economy?

As shown by recent studies (Arora and Lieskovsky, 2014; Cicala, 2020; Chen *et al.*, 2020, Demirgüç-Kunt *et al.*, 2020), electricity demand and consumption have been used as a relevant proxy for economic activity in the short run. The focus of these studies has been only on a selected number of countries, mostly the United States and developed countries in Europe (Cicala, 2020 for Europe and Janzen and Radulescu, 2020 for Switzerland), with the exception of Demirgüç-Kunt *et al.* which includes countries in Europe and Central Asia and Beyer *et al.* (2020) for India.

This paper proceeds as follows. Section 2 describes the data that we will subsequently use to provide a real-time estimation of economic activity. Section 3 provides estimates of the impact of the pandemic and lockdown evolution on activity measures. Section 4 concludes with a discussion on policy implications.

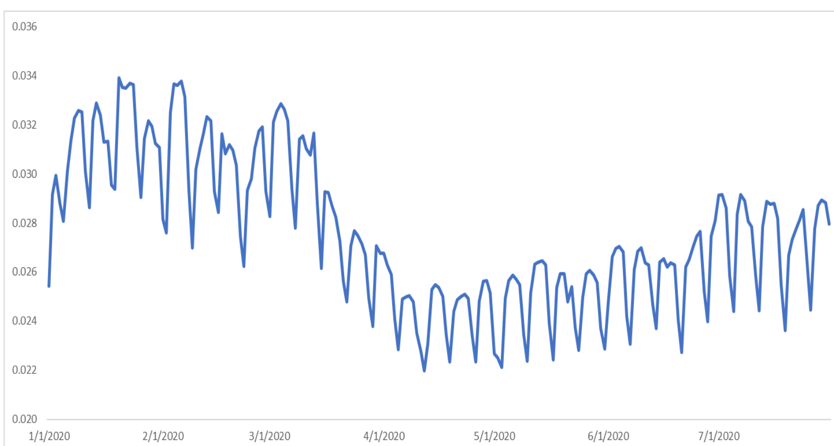
2. Empirical Approach

The purpose of this paper is to explore the short-run economic impacts of the COVID-19 pandemic and its associated public health and macroeconomic policy responses. In this section, we present the data that will be used to capture each of these elements.

2.1 Variable definitions

Several possible measures of short-term economic activity exist, including electricity consumption, stock market indices, and monthly industrial production figures. Electricity is required by most economic activities. Over longer time horizons, electricity consumption responds to the price of consuming electricity services and technological innovations affecting demand (among other drivers), making it a less useful proxy of economic activity. However, changes in productivity and the ability to substitute toward other inputs over time are unlikely to be important drivers of consumption changes over the much shorter time horizon during which economic information is unavailable due to lags in official statistics. Following the literature, in our analysis, we use as a dependent variable electricity consumption per capita as a proxy measure of economic activity. Data reported on the total daily consumption of electricity was obtained from national grid operators and then normalized by the national population to make it comparable. Data is available for 52 countries including both developed and developing countries belonging to EAP, ECA, LAC, SAR and SSA.[1] The trend over time of daily electricity consumption for the first seven months of 2020 for the overall sample is reported in Figure 1 below.

Figure 1: Average value of daily electricity consumption (KWh per capita) for the sample of countries (1st Jan to 31th July 2020)

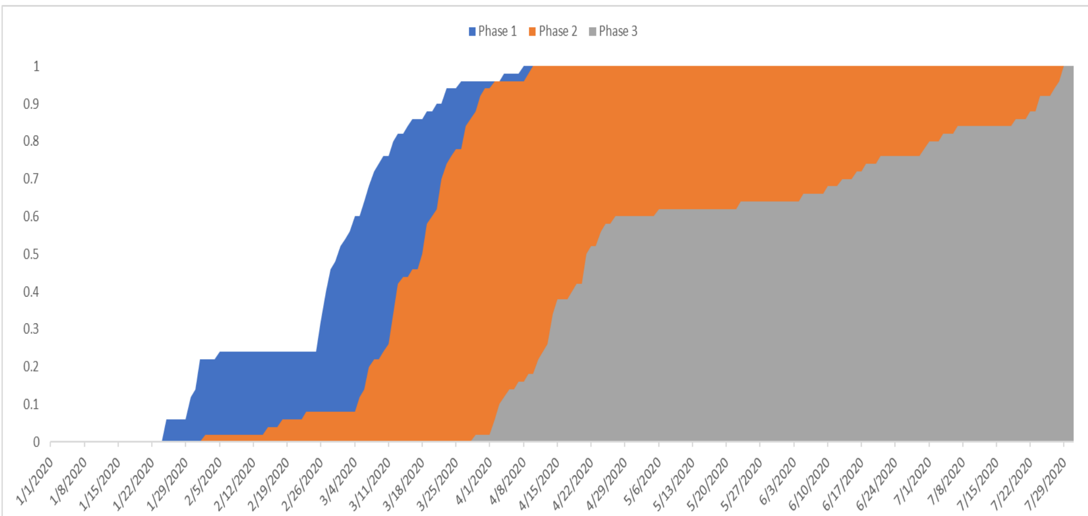


Source: Author's elaboration based on Transmission System Operators

[1] The countries included in the sample are Argentina, Austria, Bangladesh, Belgium, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Costa Rica Croatia, Czech Republic, Denmark, El Salvador, Estonia, Finland, France, Germany, Greece, Hungary, India, Ireland, Italy Latvia, Lithuania, Luxembourg, Malaysia, Mexico, Moldova, Netherlands, Nigeria, North Macedonia, Norway, Panama, Peru, Philippines, Poland, Portugal, Spain, Romania, Russian Federation, Serbia, Singapore, South Africa, Slovak Republic, Slovenia, Sweden, Switzerland, Turkey, United Kingdom, Ukraine, and Uruguay.

To represent the evolution of the pandemic, we consider the number of daily cases and deaths due to COVID-19. Figure 2 plots the share of countries in our sample in each phase of the evolution of the pandemic by date. As evident from the graphical representation, in early February 2020, most countries were in the first phase (with cases of infection reported and no death yet attributable to the pandemic) and only a handful in the second phase. By the beginning of April, all countries were in Phase 2, which includes the time range since the first case of death occurred until the peak of deaths is reached. Phase 3 started to kick in for a limited number of countries soon after the beginning of April, involving the majority of countries towards the end of April, to then reach the remaining countries towards the end of the summer.

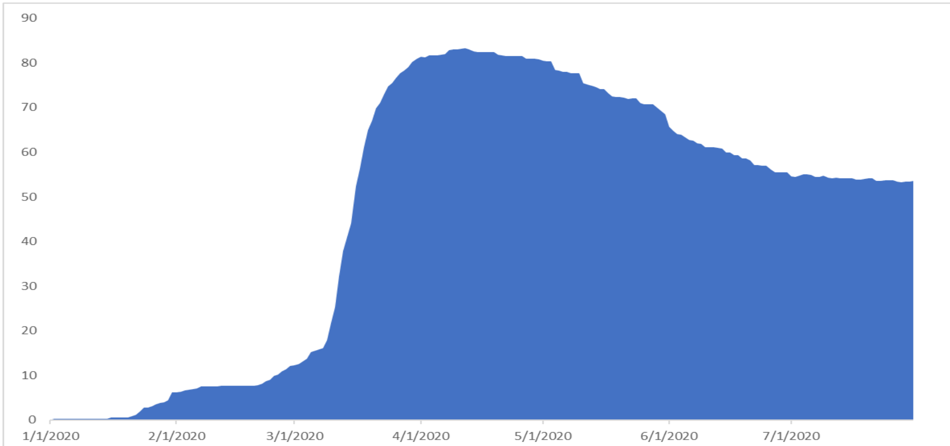
Figure 2: Distribution of countries by the different pandemic phases (1st Jan to 31th July 2020)



Source: Hale et al. (2020): Phase 1 (since 1st Covid-19 case was detected); Phase 2 (since 1st case of death occurred), Phase 3 (after the peak of COVID-19 deaths is reached)

The stringency of the national lockdown is measured using both de jure and de facto indices. The first index represents the *de jure* stringency of the lockdown, and it consists of the average value of the government response stringency index during the period when a full lockdown was in place, from the Oxford Government Response Tracker. The evolution of this index over time is depicted in Figure 3, ranging from 0 (less stringent) to 100 (most stringent) and is based on the policy decisions taken by governments across several areas: workplace restrictions, mobility restrictions, school closures, and restrictions on gatherings and public events (Hale *et al.*, 2020).

Figure 3: Average value of the stringency index (0-100) for the sample of countries (1st Jan to 31th July 31 2020)



Source: Hale *et al.* (2020)

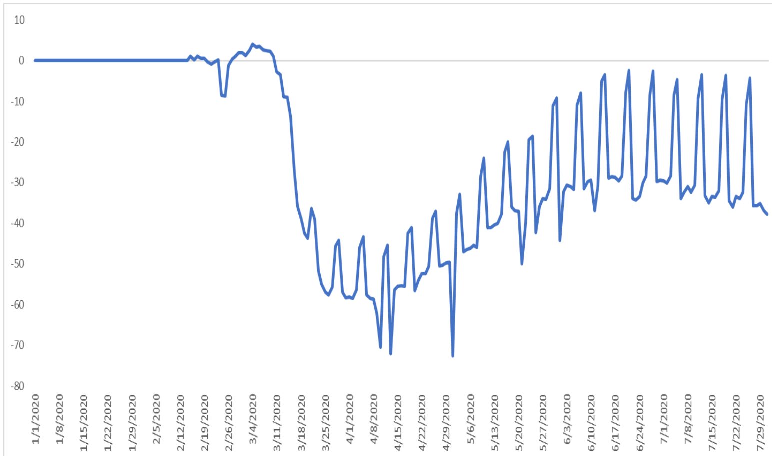
The second index capturing the *de facto* stringency of the lockdown represents the extent to which it was effectively implemented, and is derived from the Google COVID-19 Community Mobility Reports which measures how visits and length of stay at different places change compared to a baseline. The baseline is the median value, for the corresponding day of the week, during the 5-week period from January 3 to February 6, 2020. Hence, a lower value of the index reflects the decreased mobility following the lockdown. Location data derived from smartphones has become a popular way to illustrate mobility patterns by urban planners and transportation specialists.[2]

In the context of the COVID-19 outbreak, Fang, Wang, and Yang (2020) study the impact that the lockdown of the most affected Chinese provinces using mobility patterns derived from the use of the smartphone mapping application of Baidu, one of China's most popular search engines. Real-time data collected from mobile devices gives a precise picture of the extent of the social distancing measures and the effectiveness of their enforcement.

The lockdowns restrict people's movements, allowing for a limited number of essential trips to grocery shops and pharmacies. Figures 4 and 5 reports the average change in time spent respectively in workplaces and public transit compared to the selected baseline across our sample of countries in public transit.

[2] See for instance Calabrese *et al.* (2013) and Hawelka *et al.* (2014) for an example of cellphone data used to track individual mobility patterns at the urban and global levels, respectively.

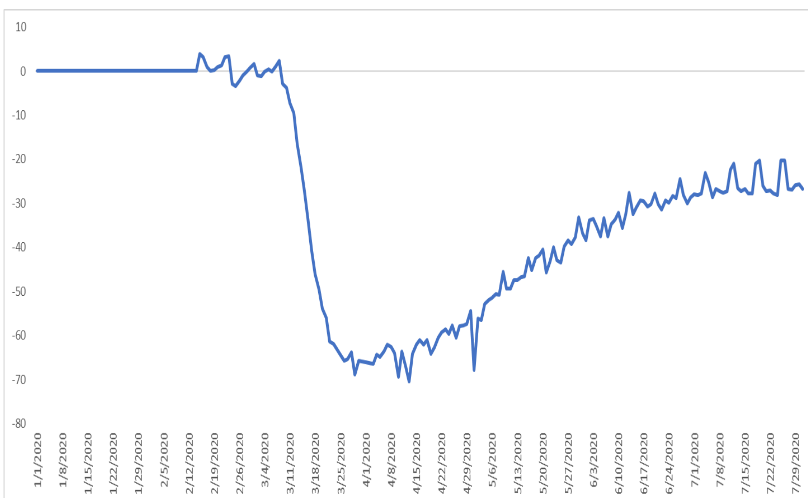
Figure 4: Average change in time spent in workplaces for the sample of countries



Source: Google Community Mobility Reports

Whereas Figure 5 displays a much lower decline during weekends, possibly due to the higher percentage of average time spent in workplaces during holidays ahead of the pandemic, Figure 4 display the opposite trend during weekends at least ahead of the summer, due to the change in leisure mobility, to avoid the spread of the disease.

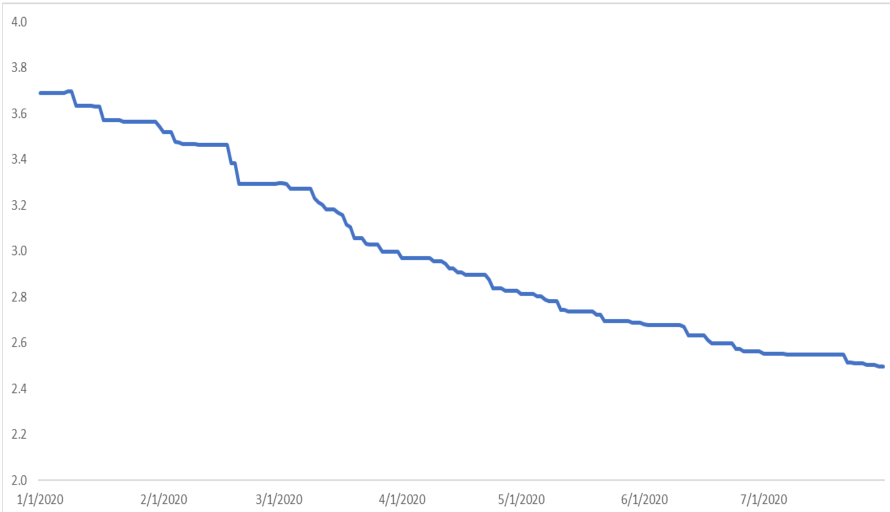
Figure 5: Average change in time spent in transit places for the sample of countries



Source: Google Community Mobility Reports

Governments' economic responses to the COVID-19 crisis are unprecedented and have been estimated to be three times as large as the response to the 2008–09 financial crisis. One widely used tool during the pandemic has been policy rate cuts, or cuts to interest rates. The theory behind rate cuts is relatively straightforward: a central bank places downward pressure on short-term interest rates, decreasing the overall cost of borrowing for households and businesses at a critical time. They are also intended to spur consumer spending and business investment when the economy emerges from the depths of the crisis. Figure 6 below shows how monetary policy becomes more accommodating, with significant reduction in policy rates across the sample, with multiple interventions by Central Banks being triggered. Once expectations of future growth prevail, then policy rates are left unchanged or start to be increased.

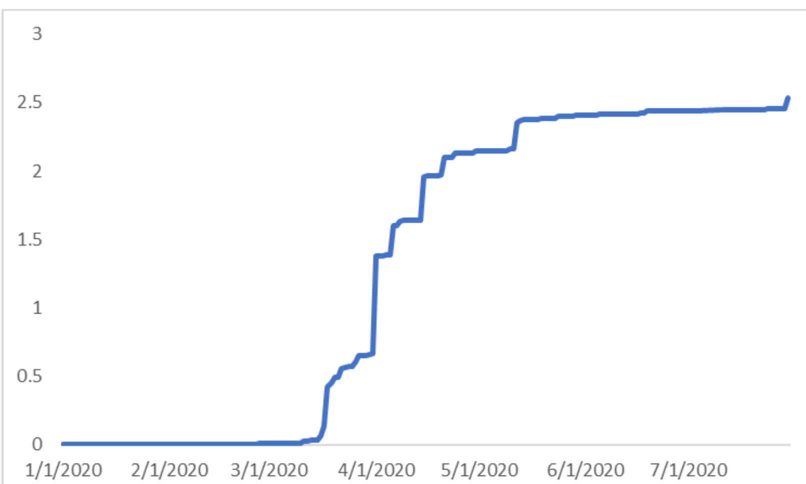
Figure 6: Average policy rate trend for the sample of countries



Source: Author elaboration based on Central Bank's information

Governments across the globe responded to the crisis by enacting a number of policies to provide fiscal stimulus to the economy and relief to those affected by this global pandemic. Figure 7 below reports the average fiscal stimulus, as a percentage of GDP, which jumps to 2.5 percent already from May 2020.

Figure 7: Average announced fiscal stimulus trend for the sample of countries (as percentage of GDP)



Source: estimates from Hale *et al.* (2020)

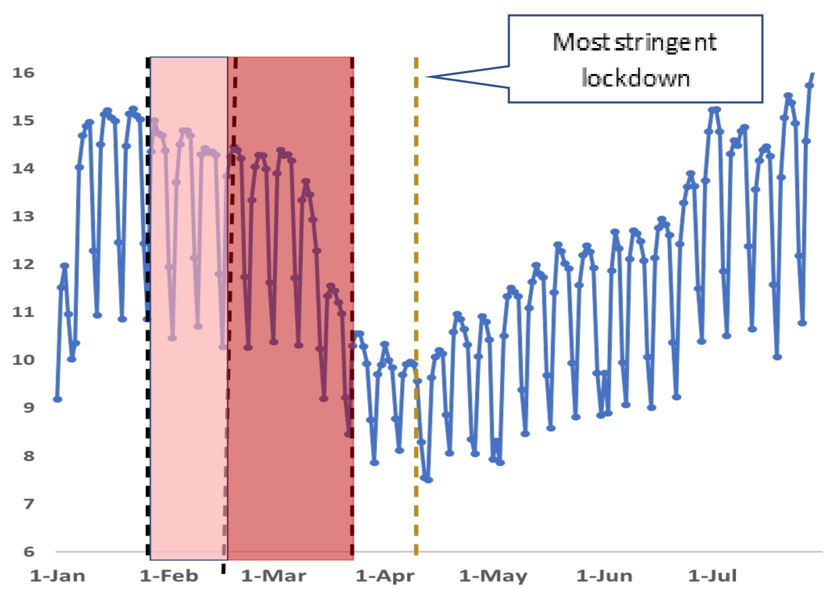
2.2 Exploratory data analysis

In what follows, before moving to the econometric analysis, we will first provide some patterns that our data show in the case of some of the countries that have applied much tougher measures to prevent the spread of the pandemic vis- à-vis those that have implemented somewhat looser preventive measures, regarded as sufficient to prevent the spread of the disease.

Figures 8 and 9 below compare Italy with Sweden, which exemplified the two different approaches followed to mitigate the impact of the pandemic. Italy was one of the first countries in Europe to be affected by the pandemic, with the first case reported on January 23, 2020 in the northern regions, and the first death recorded on February 23. Italy's response to the COVID-19 pandemic included tough measures including total lockdown with very limited possibility of movement for over 60 million individuals, scoring 92-94 on March 20, compared to 28 for Sweden according to the Oxford COVID-19 Government Response Tracker (one of the highest values of the index across the world, with values ranging from 0 to 100).

The harsh measures implemented by the Italian government arguably came too late, as shown in Figure 8, where it is evident that the most stringent lockdown measures occurred after Phases 1 and 2, highlighted in different shades of red, and did not manage to prevent a peak of death, which occurred during the severe lockdown, and heavily taxed the health care system. After months of lockdown, the situation in Italy was gradually getting under control and the country—as of July 2020 seemed to have "flattened the curve" (see Farina and Lavazza, 2020 for more details).

Figure 8 Evolution over time of daily electricity consumption in Italy (KWh per capita)



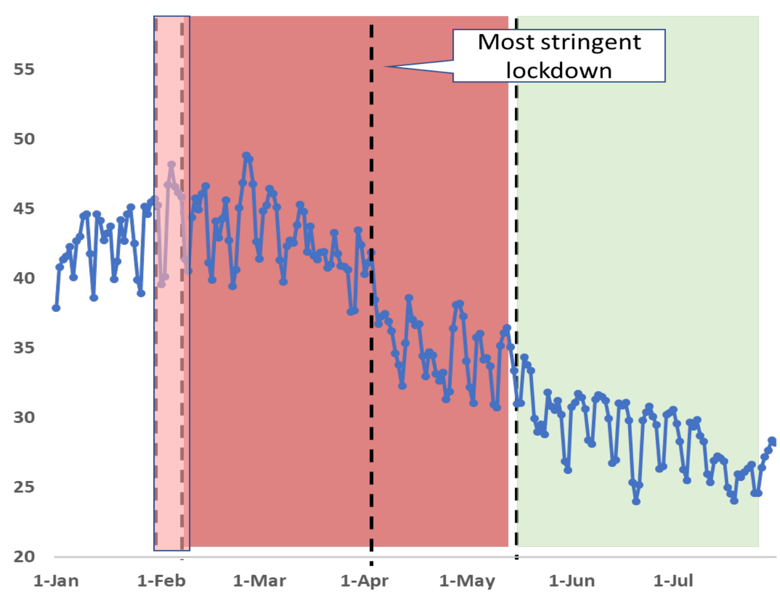
Source: Terna

Interestingly, however, Figure 10 shows also how the most drastic reduction of economic activity (as proxied by the reduction in electricity consumption) occurred indeed soon after the implementation of the most severe lockdown measures.

At the beginning of the pandemic, the Swedish government decided not to enforce lockdown or to impose strict social-distancing policies and tended to safeguard fundamental constitutional rights. It only implemented a minor set of restrictions, such as banning gatherings of more than 50 people, and trust-based measures (such as recommendations to avoid social contact or recommending work from home, particularly for the elderly) to protect and safeguard social freedoms and in line with other (economic, constitutional or sometimes even scientific) reasons. Sweden reached the peak score (46) in terms of severity of the measures taken to prevent the spread of the disease on April 5, still according to the same index and it was among the countries with the least stringent measures in the world.

The potential cost in terms of human lives of this approach, which was praised for attempting to safeguard citizens' freedom, has also been raised as more evidence emerges that the Swedish approach to curb the COVID-19 pandemic has not been as successful as first thought. Sweden also has a death toll comparable to that of Italy (581) towards the end of July but nearly five times greater than that of the other Nordic countries combined, which seems to suggest that under similar conditions the death toll could have been much lower.

Figure 9 Evolution of daily electricity consumption in Sweden (KWh per capita)

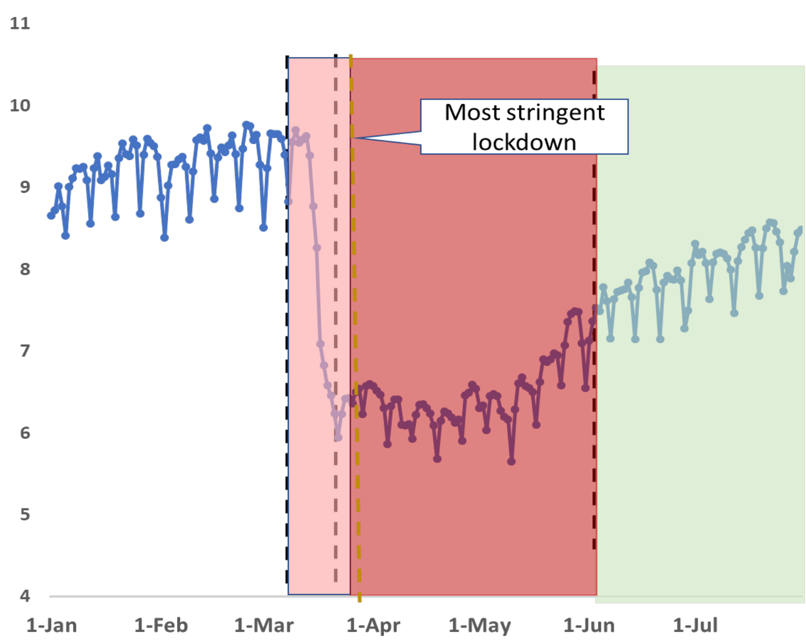


Source: Svenska kraftnät

In terms of economic impact, Figure 9 shows how in this case economic activity was initially not much affected by the lockdown measures, due to the limited severity of those, whereas a distinct impact is clearly discernible once Sweden entered Phase 3 where the number of deaths started to become significant.

In a similar vein, Figures 10 and 11 below compare Peru with Singapore, countries that took different measures to improve compliance to the regulations made to reduce the spread of COVID-19, trying to tackle specific challenges coming from the high degree of informality of the labor market in Peru and the large presence of foreign labor in Singapore, again with the first country enforcing a very strict lockdown since the beginning and the latter only much later.

Figure 10 Evolution of daily electricity consumption in Peru (KWh per capita)



Source: COES

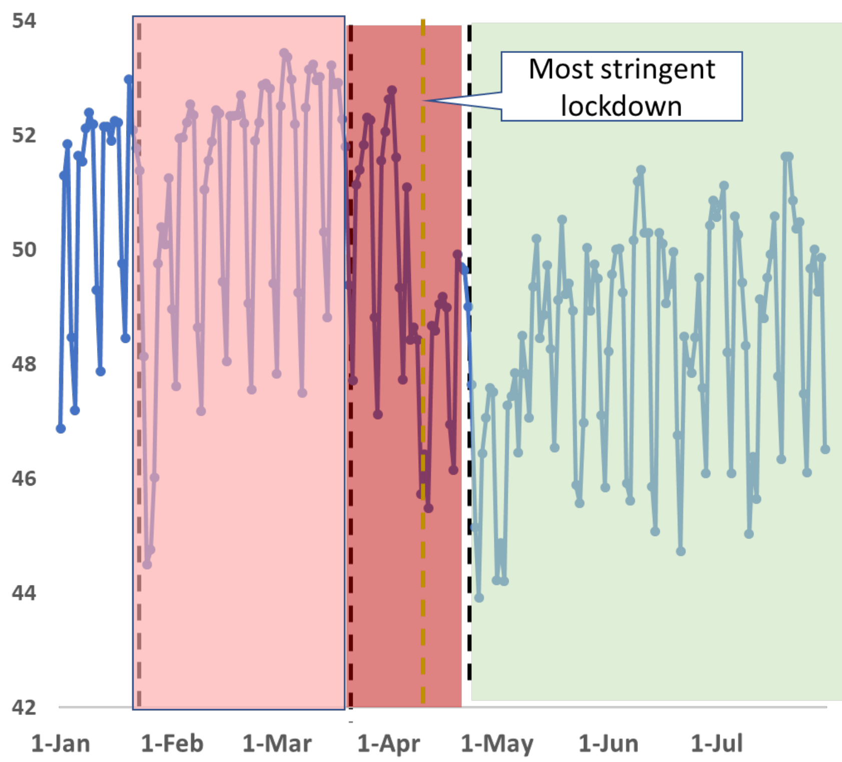
Peru began its COVID-19 lockdown on March 16, when there were only 71 reported cases of the coronavirus. Peru's leader strictly adhered to the World Health Organization's coronavirus recommendations and mobilized the police and army to enforce a stringent quarantine. Subsequently, on March 17, the president of Peru ordered a curfew to avoid nighttime socializing to prevent disease transmission (Explorer, 2020; Writing, 2020). But more than two months later, the country is one of the countries in the Latin America region's worst-hit by COVID-19 and has been unable to flatten the curve of infections, ranking second only to Brazil in Latin America. Deadly outbreaks on Peru's northern coast and Amazon regions, where social distancing was routinely broken threatened

Peru's chronically underfunded health care system. COVID-19 hit Peru's largest Amazon city, Iquitos, with deadly force before spreading to Pucallpa, on the country's eastern border with Brazil. To provide some explanation in enforcing lockdown is the informal or unregulated economy – in Peru about 40 percent are self-employed, the highest rate in the Latin America and Caribbean region.

Interestingly, very much in line with the case of Italy, Figure 10 shows also how the first most drastic reduction of economic activity (as proxied by the reduction in electricity consumption) occurred soon after the implementation of the most severe lockdown measures. However, differently from the case of Italy, the second even deeper reduction in economic activity occurred as Peru entered Phase 3, due to the reported difficulties in effectively enforcing the lockdown measures.

Outside China, Singapore, where the first symptomatic imported case was reported on January 23, 2020, has been able to maintain relatively low COVID-19 incidence levels through active case finding, tracing and strict social distancing measures.

Figure 11 Evolution of daily electricity consumption in Singapore (KWh per capita)



Source: EMA

The implementation of social distancing measures in Singapore has been progressive from March 10 with the rollout of gradually stricter recommendations and regulations leading to the implementation of a lockdown, but only at a much later stage in response to rising cases. Although Singapore's lockdown seemingly had no effect on several large outbreaks among foreign worker dormitories that started in early April, it appears to have arrested the growth of the epidemic in the general population, using school closures and workplace distancing as recognized and effective attack rate reduction measures. Schools and businesses remained initially open, while businesses have moved to encourage working from home. In addition to other precautionary measures like regular temperature checks at work and enacting business continuity plans, the World Health Organization praised Singapore for its efforts at contact tracing and its measures to limit transmission. In Singapore, they introduced legal implications for individuals who defy the health precautions. In addition, harsh legal measures were also enforced for providing false information posing a risk to public health, and made such cases liable to a hefty fine (up to US$7,000) with the possibility of 6 months imprisonment.

Nearly 4 months after recording its first case, Singapore experienced its second wave of infections, triggering a lockdown effective April 28, 2020. While Singapore has implemented more restrictive measures, it has not gone into a total lockdown, scoring at the apex “85”, again according to the index we are following. Most recently, Singapore implemented more restrictions and those who fail to follow social distancing measures (such as maintaining social distancing in public areas) would now face fines or jail. Singapore is reporting equally high levels of COVID-19 cases but accompanied by much lower mortality rates.

In terms of economic impact, Figure 11 shows how in this case economic activity was initially not much affected by the lockdown measures, due to the limited severity of those, whereas a distinct impact is clearly discernible once Singapore entered Phase 3 where the number of deaths started to become significant.

3. Results

In this section, we estimate a baseline model that relates the demand for electricity in a country, as a proxy of economic activity, to the evolution of the pandemic and the lockdowns, and a range of controls. Our model accounts for seasonality and weekly patterns in electricity consumption, as well as the changes in electricity demand during the national holidays. We also control for differences in electricity consumption related to heating and cooling degrees.[3]

3.1 Econometric model and testable hypotheses

The basic specification of the model used is as follows:

[3] To approximate the heating and cooling demand, we use the differential degrees when the daily average temperature is below 16 C and when the temperature exceeds 26 C.

(1) $$Y_{i,t} = \beta L_{i,t} + \omega P_{i,t} + +\vartheta M_{i,t} + \theta W_{i,t} + \Phi CH_{i,t} + \epsilon_{i,t}$$

where:

- $Y_{c,t}$ is the electricity consumption in country *i* at time *t*.
- $L_{i,t}$ is the indicator capturing the severity of lockdown, capturing both the de jure and de facto indices, which are introduced separately in the regressions.
- $P_{i,t}$ is the indicator capturing the evolution of the pandemic through the daily number of infected cases and deaths per million due to COVID-19.
- $M_{i,t}$ are macroeconomic policies, including the level of policy rates and the fiscal measures to capture the policy responses.
- $W_{i,t}$ is equal to one if date *t* is a working date (that is, excluding national holidays or nonworking days such as weekends).
- $CH_{i,t}$ represents two variables for the heating and cooling days.
- $\epsilon_{i,t}$ is an i.i.d. innovation term.
- $\beta, \omega, \theta, \vartheta, \ \pi, and\ \gamma$ are the estimated parameters.

This model can be used to test the following hypotheses.

Hypothesis 1: *Countries where the lockdown measures were effectively enforced were characterized by a greater decline in economic activity.*

This first hypothesis tests whether the economic impact reflects the severity of the lockdown measures is more severe depending on the evolution of the lockdown. In terms of equation (1), this translates into a coefficient value β<0. Since the stringency of the national lockdowns can be measured both using de jure and de facto indices, as noted above, the econometric model can also be used to explore which of these has the most influence on economic activity.

Hypothesis 2: *Countries where the pandemic moved from Phase 1 to Phase 2 and where loss of lives was experienced also display a greater decline in economic activity.*

The second hypothesis is that evolution of the pandemic captured by the move from Phase 1 to Phase 2, when countries start registering actual cases of death for COVID-19, also has a distinct economic impact over and above the lockdown measures themselves. In terms of equation (1), this would imply a coefficient value $\omega < 0$. It is of interest to compare the adverse economic consequences of the pandemic itself relative to the associated lockdown measures.

Hypothesis 3: *Countries adopting expansionary monetary and fiscal policy responses have been effective in shoring-up the economy.*

This third hypothesis examines whether countries that have started to implement expansionary monetary and fiscal policies have been showing sign of recovery in economic activity. We insert in the model a variable capturing implementation of reduction in policy rates by the Central Bank, the type of accommodating monetary policy as well as the announcement of fiscal stimulus packages. In terms of equation (1), this is captured by coefficient values $\vartheta > 0$.

In addition, the following specification is also estimated.

(2) $$Y_{i,t} = \beta L_{i,t} + \omega P_{i,t} + +\vartheta M_{i,t} + \theta W_{i,t} + \Phi CH_{i,t} + \pi D_t + \pi E_i + \epsilon_{i,t} \ ,$$

where the additional variables are:

- D_t is a dummy for the month where all countries in the sample entered Phase 3.
- E_t is a vector of time invariant control variables, including the previous year annual GDP per capita, the electricity price, an indicator of affordability and the latitude of country *i*.

This specification permits the testing of a fourth hypothesis.

Hypothesis 4: *The pandemic and the associated lockdown measures are associated with a structural break in economic activity across all countries that goes beyond individual countries' specific lockdown measures.*

This fourth hypothesis goes more in depth to determine whether the pandemic and associated lockdown measures caused a structural break in economic activity after a certain threshold for all countries in the sample. To test such a hypothesis, a dummy capturing the peak of the impact (towards the beginning of April, when most of the countries move from Phase 2 to Phase 3) is introduced and interacted with the right-hand side variables. This then provides an automatic test of whether the parameters differ before and after this structural break. In equation (2), this would signify a coefficient value of $\pi > 0$.

The full set of explanatory variables is presented in Table 1.

Table 1
Explanatory Variables Influencing Electricity consumption per capita (MWh/person)

Variables	Definition	Expected Sign
PANDEMIC EVOLUTION		
Covid cases	= number of (new) infected cases reported daily (per million)	-
Covid deaths	= number of (new) deaths from Covid-19 reported daily	-
LOCKDOWN EVOLUTION		
Stringency index	= average value of the government response stringency index based on the policy decisions taken, with the index ranging from 0 (less stringent) to 1 (most stringent).	-
Mobility (working time)	= time spent in work places, compared to a baseline (Google community mobility)	+
Mobility (transit time)	= time spent in workplaces, compared to a baseline (Google community mobility)	+
Lockdown (April dummy)	= time spent in public transport hubs such as subway, bus, and train stations compared to a baseline (Google community mobility)	-
MACROECONOMIC FISCAL AND MONETARY POLICIES		
Policy rate	= interest policy rates reduction implemented by the Central Banks	+
Fiscal measures	= announcement of fiscal stimulus packages	+
DAILY CONTROLS		
Working days	= 1 if working day = 0 otherwise (weekends or national holidays)	+
Cooling	= Min (temp -26C, 0), where temp is the average daily temperature	+
Heating	= Max (16-temp, 0)	+
COUNTRY CONTROLS		
GDP per capita (US$)	= GDP per capita (US$ thousand)	+
Electricity prices (US$ per MWh)	= average business and residential electricity price (US$c per MWh)	-
Affordability	= average electricity tariff (in terms of GDP)	+
Distance from equator	= distance of the capital from the equator (in miles)	-

3.2 Empirical results

Table 2 provides the results of the fixed and random effect regressions, estimating electricity consumption for the basic specification (1), which can be used to test the stated hypotheses.

Hypotheses 1 and 2 are validated as the coefficients ω, which can be interpreted as estimates of the effect of the spread of the disease, and the coefficient β, which estimates whether the effect of the lockdown measures are both negative and significant at the 1 percent confidence level. It is also worth noting that β is in absolute terms higher than ω, confirming the higher impact of the lockdown measures, but implying a distinct but lower impact associated to the spread of the disease across all specifications. Indeed, the elasticity of the marginal effect of the lockdown measures estimated at the mean is equal to -0.06, twice as much as the elasticity of the marginal effect of the spread of the disease. If we include the interacted term, it is characterized by a positive and significant sign, due to the presence of some non-linearities, smoothening the negative impact of each of the measures.

Hypothesis 3 is also confirmed across all specifications. All the coefficients ϑ capturing the policy rate interventions as well as expansionary fiscal policies are positively associated to a recovery. Namely, when Central Banks stop reducing the policy interest rates, it signals expectations of future growth and recovery, which are materialized in higher recovery in economic activity. Since this type of accommodating monetary policy is done in coordination with the announcement of fiscal stimulus packages, we can also conclude the effectiveness of such expansionary policies. The elasticity of the marginal effect of the monetary policy estimated at the mean is equal to 0.23 significantly higher than the elasticity of the marginal effect of the fiscal policy, probably due to the immediate implementation of the policy rate change vis-à-vis the announcement of the fiscal stimulus package. If we include the interacted term, it is characterized by a negative and significant sign, due to the presence of some non-linearities, smoothening the positive impact of each of the policies.

Among the other controls that are included in Table 2, it is worth noting the expected positive sign of higher electricity demand during working days, and during extreme periods (either requiring additional heating or cooling). Last but not least, the overall explanatory power both under the fixed and random effect specifications is around 40 percent.

Table 2
Regression Results of determinants of Electricity per capita consumption (Basic Model)

	(1.a) Fixed	(1.b) Random
PANDEMIC & LOCKDOWN EVOLUTION		
Covid death (per Million)	-0.0010*** (0.0008)	-0.0010*** (0.0008)
Stringency Index	-0.0046*** (0.0003)	-0.0046*** (0.0003)
MACROECONOMIC POLICIES		
Policy rate reduction	0.0021*** (0.00008)	0.0021*** (0.00008)
Fiscal Measures	0.0114*** (0.0022)	0.0114*** (0.0022)
DAILY CONTROLS		
Working days	0.0034*** (0.0016)	0.0034*** (0.0016)
Cooling	0.0008*** (0.0001)	0.0008*** (0.0001)
Heating	0.0008*** (0.0002)	0.0008*** (0.0002)
Constant	0.0222*** (0.0036)	0.0222*** (0.0052)
N	9,969	9,969
N countries	48	48
F/ Wald $\chi 2$	328.26***	2319.38***
Within R^2	0.1881	0.1980
Between R^2	0.4144	0.4137
Overall R^2	0.4033	0.4042

Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

To ascertain whether the preferred specification is the fixed or random effect, we run the Hausman test for fixed effect which slightly favors the random effect specification (see Table below).

FIXED AND RANDOM EFFECT TESTS

	(1)	(2)
HAUSMAN TEST FOR FIXED EFFECT		
Hausman $\chi2$ (7)	11.59	12.34*
PREFERRED SPECIFICATION		
Fixed effect		
Random effect	✓	✓

Table 3 expands the random effect regression by reporting additional country controls, as per specification (2). As is evident from Table 3, hypotheses 1, 2 and 3 continue to hold even after introducing additional controls, such as the previous year annual GDP per capita, the electricity price, an indicator of affordability and the latitude of the country, all time invariant variables that we could not include in the fixed effect specifications. All coefficients ω, which can be interpreted as estimates of the effect of the spread of the disease, and coefficient β estimates of the effect of the lockdown measures are negative and significant at the 1 percent confidence level, as in Table 2. Also, in this case, β is in absolute terms higher than ω, confirming the higher impact of the lockdown measures. At the same time, all the coefficients ϑ capturing the expansionary monetary and fiscal policy are positively associated to a higher level of economic activity, pointing at the effectiveness of such policies.

Last but not least, it is worth noting how the overall explanatory power, both under the random effect specification increases from a value around 40 percent to one close to 60 percent, under the second model specification. The sign associated to the previous year annual GDP per capita is positive and significant at the 1 percent confidence level, the coefficient associated to the average electricity price is negative, though significant only at 10 percent confidence level, whereas the level of affordability is positive, but not statistically significant.

Table 3
Regression Results of determinants of Electricity per capita consumption (Random Effects)

	(1.a)	(1.b)
PANDEMIC & LOCKDOWN EVOLUTION		
Covid death (per million)	-0.0012*** (0.00008)	-0.0011*** (0.00008)
Stringency Index	-0.0046*** (0.0003)	-0.0031*** (0.0003)
Monthly dummy (April)		-0.0013*** (0.0003)
MACROECONOMIC POLICIES		
Policy rate	0.0021*** (0.00008)	0.0022*** (0.00008)
Fiscal Measures	0.0012*** (0.0022)	0.0013*** (0.0022)
COUNTRY LEVEL CONTROLS		
GDP per capita (US$)	0.8581*** (0.2086)	0.8684*** (0.2096)
Electricity prices (US$ per MWh)	-0.2272* (0.1321)	-0.2224* (0.1327)
Affordability	0.2389 (0.5530)	0.2721 (0.5558)
SECTORAL CONTROLS		
Working days Cooling Heating	Yes	Yes
Constant	0.01670 (0.01782)	0.0147 (0.0179)
N	9,969	9,969
N countries	48	48
Wald $\chi2$	2348.87***	2461.12***
Within R^2	0.1881	0.1954
Between R^2	0.5296	0.5451
Overall R^2	0.5210	0.5363

Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

Robustness checks have also been undertaken, adding each macroeconomic variable separately and including additional control variables, such as the composition of consumers (residential vis-à-vis non-residential).

To start to test hypothesis 4 and identify signs of structural break in the data before and after a threshold date, we first introduce monthly dummies, and retain the month of April in column (b) of Table 3. The sign associated to the dummy variable capturing the month of April is negative and statistically significant at the 1 percent confidence level.

The dummy capturing the month of April is also reported in Table 4 where our model (1) specification is tested introducing country fixed effects. In this case the explanatory value of the regression is close to 100 percent. Whereas this result provides strong evidence on the presence of a structural break in the short term, we are not yet in a position to answer whether this structural break will persist in the long-run,

Table 4
Regression Results of determinants of Electricity per capita consumption with country fe

	(2.a)	(2.b)
PANDEMIC & LOCKDOWN EVOLUTION		
Covid death (per Million)		-0.0010*** (0.00009)
Monthly dummy (April)	-0.0048*** (0.0001)	-0.0023*** (0.0002)
MACROECONOMIC POLICIES		
Policy rate		0.0014*** (0.00006)
Fiscal measures		0.0010*** (0.0002)
CONTROLS		
Working days	0.0032*** (0.00016)	0.0033*** (0.00016)
Cooling	0.0009*** (0.00009)	0.0007*** (0.00009)
Heating	0.0012*** (0.0022)	0.0021*** (0.0002)
Distance from Equator		-0.0146*** (0.0015)
COUNTRY FE		
Country FE	Yes	Yes
Constant	0.0071*** (0.0004)	-0.0109*** (0.00092)
N	10,827	9,969
N countries	52	48
Wald $\chi 2$	426659.64***	458924.85***
Within R^2	0.1217	0.2153
Between R^2	0.9999	0.9999
Overall R^2	0.9754	0.9779

Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

To go further in identifying the structural break, Table 5 interacts all variables with a dummy for the break and interacting it with the right-hand side variables. Column (2.a) reports the coefficients associated to the right-hand side variables as in specification (2), whereas column (2.b) reports the coefficients associated to the interacted variable of the "break" dummy and the respective right-hand side variables.

As all variables and their respective interacted terms are significant and in almost all cases at the 1 percent confidence level, this means that the parameters differ significantly before and after the break, validating Hypothesis 2 and confirming the presence of a structural break.

In terms of interpreting the sign of the interacted terms, the impact of the pandemic evolution is somewhat smoothened after the structural break, and so is the impact of monetary intervention. On the other hand, the increase in the monthly production index is instead strengthened, confirming that the economy is starting to recover. Interestingly also the impact of the initial baseline in terms of GDP per capita, electricity prices and affordability are also smoothened. The smoothening impact is substantial in the case of affordability for which the overall impact is close to zero which may explain the insignificant value found in the previous regressions. As one would expect, during such a substantial recession affordability issues that may have not been so strong to affect consumption before the break, became very significant afterwards, posing significant challenges to recovery.

Table 5

Regression Results of structural break in Electricity per capita consumption (Random Effects)

	(2.a)var	(2.b)int	(2.a)var	(2.b)int
PANDEMIC & LOCKDOWN EVOLUTION				
Covid death (per Million)	-0.0064*** (0.0010)	0.0053*** (0.0010)	-0.0064*** (0.0010)	0.0059*** (0.0010)
MACROECONOMIC POLICIES				
Policy rate	0.0021*** (0.00009)	-0.0002*** (0.00003)	0.0020*** (0.00009)	-0.0002*** (0.00003)
Fiscal measures	-0.0027*** (0.0075)	0.0357** (0.0074)	-0.0029*** (0.0073)	0.0384*** (0.0072)
COUNTRY LEVEL CONTROLS				
GDP per capita (US$)			0.9110*** (0.2086)	- 0.1164*** (0.0084)
Electricity prices (US$ per MWh)			-0.2639** (0.1322)	0.0475*** (0.0040)
Affordability			0.3255 (0.5535)	-0.2482*** (0.0186)
DAILY CONTROLS				
Working days, Cooling Heating	Yes	Yes	Yes	Yes
Constant	0.0020*** (0.0047)		0.0176 (0.0178)	
N	9,970		9,970	
N countries	48		48	
Wald χ2	2271.46***		2984.08***	
Within R^2	0.1849		0.2288	
Between R^2	0.4104		0.5104	
Overall R^2	0.4006		0.5022	

Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

So far, we have been using de jure indicators of lockdowns. Tables 6 and 7 refine the analysis replacing the de jure indicators of lockdowns with *de facto* indicators of the effective implementation of the lockdowns, as captured by the Google COVID-19 Community Mobility Reports which measure how visits and length of stay at different places change compared to a baseline. Tables 6 and 7 replicate respectively Tables 2 and 3 using specifications (1) and (2).

As explained in Section 2, a lower value of the mobility index reflects the decreased mobility following the lockdown. Accordingly, we expect a positive sign associated to such indicators, which is confirmed. It is also worth noticing that the absolute value of the mobility indicators associated to the length of time spent commuting to work is higher than the one associated to public transit. All other results related to the tests of the various hypotheses are validated, so that we do not need to repeat them.

Last but not least, also the explanatory value of the regression is somewhat higher, reaching a value close to 70 percent in Table 7, but this may also be partially due to the reduction in the number of countries for which COVID-19 Community Mobility Reports are available.

Some cautionary remarks are needed as mobility itself may have a direct effect on electricity consumption and reverse causality may occur. Therefore, the estimated coefficients may be biased. We report these results for illustration purposes, as this is the best proxy of *de facto* more stringent lockdown.

Table 6
Regression Results of determinants of Electricity per capita consumption with mobility

	Fixed	Random	Fixed	Random
PANDEMIC & LOCKDOWN EVOLUTION				
Covid death (per Million)	-0.0007*** (0.00008)	-0.0010*** (0.00008)	-0.0011*** (0.00009)	-0.0011*** (0.00009)
Mobility (working time)	0.0046*** (0.0005)	0.0049*** (0.0006)		
Mobility (transit time)			0.0017*** (0.00006)	0.0017*** (0.00006)
MACROECONOMIC CONTROLS				
Policy rate	0.0027*** (0.00010)	0.0028*** (0.00010)	0.0028*** (0.00009)	0.0029*** (0.00010)
Fiscal measures	0.0096*** (0.0024)	0.0097*** (0.0024)	0.0097*** (0.0024)	0.0097*** (0.0024)
SECTORAL CONTROLS				
Working days	0.0044*** (0.0002)	0.0044*** (0.0002)	0.0038*** (0.0002)	0.0040*** (0.0002)
Cooling	0.0008*** (0.0001)	0.0009*** (0.0001)	0.0007*** (0.0001)	0.0007*** (0.0001)
Heating	0.0008** (0.0003)	0.0003 (0.0003)	0.0009*** (0.0003)	0.0009*** (0.0003)
Constant	0.0154*** (0.0010)	0.0153*** (0.0054)	0.0125*** (0.0011)	0.0122** (0.0052)
N	7,413	7,413	7,413	7,413
N countries	36	36	36	36
F/ Wald $\chi 2$	251.97 ***	2302.06***	241.66 ***	2210.86***
Within R^2	0.2353	0.2353	0.2279	0.2279
Between R^2	0.5469	0.5484	0.5479	0.5493
Overall R^2	0.5337	0.5354	0.5352	0.5368

Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

Table 7

Regression Results of determinants of Electricity per capita consumption with mobility

	(1.a)w	(1.b)w	(2.a)t	(2.b)t
PANDEMIC & LOCKDOWN EVOLUTION				
Covid death (per Million)	-0.0008*** (0.00009)	-0.0009*** (0.00009)	-0.0008*** (0.00009)	-0.0009*** (0.00008)
Mobility (working/transit time)	0.0089*** (0.0004)	0.0073*** (0.0005)	0.0069*** (0.00004)	0.0047** (0.00005)
Monthly dummy (April)		-0.0020** (0.0003)		-0.0026*** (0.0003)
MACROECONOMIC POLICIES				
Policy rate	0.0028*** (0.00010)	0.0028*** (0.0001)	0.0028*** (0.0001)	0.0029*** (0.00010)
Fiscal measures	0.0092*** (0.0024)	0.0098*** (0.0024)	0.0105*** (0.0025)	0.0016*** (0.0025)
COUNTRY LEVEL CONTROLS				
GDP per capita (US$)	0.9164*** (0.2083)	0.9185*** (0.2126)	0.9051*** (0.2084)	0.9812*** (0.2126)
Electricity prices (US$ per MWh)	-0.3253*** (0.1317)	-0.3232*** (0.1343)	-0.3231** (0.1317)	-0.3200** (0.1343)
Affordability	0.3957 (0.5384)	0.4092 (0.5494)	0.3845 (0.5387)	0.4128 (0.5494)
SECTORAL CONTROLS				
Working days Cooling Heating	Yes	Yes	Yes	Yes
Constant	0.0249 (0.0174)	0.0243 (0.0018)	0.0258 (0.0174)	-0.0242 (0.0178)
N	7,414	7,413	7,414	7,414
N countries	36	36	36	36
Wald $\chi2$	2162.89***	2205.34***	2009.26***	2076.94***
Within R^2	0.2198	0.2235	0.2069	0.2127
Between R^2	0.6986	0.7034	0.6937	0.7045
Overall R^2	0.6943	0.6892	0.6795	0.6903

Note: *, **, *** indicate respectively level of significance of 10, 5 and 1 percent.

4. Conclusions

Empirical estimates of the size of the economic shocks triggered by the pandemic and lockdown evolution have been scarce since official economic indicators are only made available with a significant lag. In this paper, we provide an illustration by tracking the evolution of high-frequency variables, which proxy economic activity.

Proxy measures of economic activity allow us to investigate the economic impact of lockdowns, which have been the main public health policy implemented by governments around the world to contain the pandemic. It has been argued that these measures, which are useful in "flattening the curve" of health costs, may come at high economic costs.

The analysis in this paper also confirms the significant cost of such measures in terms of reduction in economic activity. Interestingly, it shows that beyond the impact of the lockdowns, also the spread of the disease itself has an economic impact distinct from that of lockdown measures, as the incidence of death per population increases the drop in activity associated with the spread of the disease, and is statistically highly significant, though the coefficient is lower than the one associated with lockdown measures. The results suggest that the de facto lockdown index has a much larger effect than the de jure lockdown index, pointing to variations in the seriousness with which the lockdown arrangements were enforced.

At a time when countries in the region are grappling with ways of relaxing lockdown measures, our results suggest that policy makers should be cautious in reopening their economies too fast. The drop in economic activity observed when lockdowns are in place is not solely explained by the lockdown restrictions themselves but is also associated with the behavioral response to the spread of the disease. Therefore, a fast reopening that generates a rebound in the spread of the disease can be damaging not only in human terms but also in economic ones. An unexpected increase in the infection rates or the number of deaths after opening up might slow down or even revert positive economic trends.

We also identify some emerging encouraging results linking expansionary policy together with accommodative monetary policy and expansionary fiscal policies bringing about recovery in economic activity. The result that the policy rate and the fiscal measures had a significant positive impact on electricity consumption point at the effectiveness of expansionary policies.

The applicability of such data would diminish with time when economic actors adjust their behavior to the new environment. Still, these data appear to be invaluable for short-term assessments. More effort should go into establishing and calibrating the relationships between these proxies and the actual economic output.

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