LISBON SCHOOL OF ECONOMICS & MANAGEMENT
UNIVERSIDADE DE LISBOA

MASTER

ECONOMICS

MASTER´S FINAL WORK

DISSERTATION

HOW COVID-19'S IMPACT ON POLLUTANT EMISSIONS COMPARES TO PREVIOUS PANDEMICS

FRANCISCA SAMPAIO XAVIER DE OLIVEIRA

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SUPERVISION:
PROF. JOÃO TOVAR JALLES

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Dedicated to my grandmother, Avó Zi.

GLOSSARY

AD – Advanced.

BE – Between Effects.

CO2 – Carbon Dioxide.

COVID-19 – Corona Virus Disease 2019.

Ebola – Ebola Hemorrhagic Fever.

EM – Emerging Market.

EU – European Union.

GDP – Gross Domestic Product.

GLS – Generalized Least Squares.

I.I.D – Independently and Identically Distributed Random Variables.

IMF – International Monetary Fund.

KT – Kiloton.

LCU – Local Currency Unit.

LI – Low Income.

MERS – Middle East Respiratory Syndrome

ML – Maximum Likelihood

N1H1 – Influenza Type A Virus.

NO2 – Nitrogen Dioxide.

OECD – Organization for Economic Co-operation and Development.

OLS – Ordinary Least Squares.

SARS – Severe Acute Respiratory Syndrome.

WB – World Bank.

ZIKA – Zika Virus Disease.

ABSTRACT, KEYWORDS AND JEL CODES

This dissertation analyses the impact of the past major pandemics and epidemics of the 21st century – SARS, H1N1, MERS, Ebola and Zika – on pollutant emissions (more specifically, carbon dioxide), separately in Low Income Countries, Emerging Market Economies and Advanced Economies.

The dataset on pandemics and epidemics used was put together by Ma et al. (2020) and all other variables were retrieved from the WB's World Bank Indicators, for the time span 1980-2020.

We also studied the relation between nitrogen dioxide (NO2) emissions and the number of new weekly cases and deaths (per million) of COVID-19, using a dataset from Jalles et al. (2021).

Estimations were made via Ordinary Least Squares (OLS) with time and country fixed effects and concluded that pandemic shocks lead to overall decreases in pollutant emissions.

KEYWORDS: Pandemic shocks; Pollutant emissions; COVID-19; Advanced Market Economies; Emerging Market Economies; Low Income Countries.

JEL CODES: C23, Q48, Q54.

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HOW COVID-19'S IMPACT ON POLLUTANT EMISSIONS COMPARES TO PREVIOUS PANDEMICS

1. INTRODUCTION

Climate change is of increasing importance due to the steady rise in the global average surface temperature and the severity of climate shocks. According to the World Meteorological Organization (WMO), the decade 2011-2020 has been the warmest on record. Against this background, this thesis will focus on the impacts of pandemics on the environment, more specifically on pollutant emissions.

Unlike previous pandemics which affected only some countries, COVID-19 has impacted severely the day-to-day life of people everywhere. It can be distinguished from previous pandemics due to the fact that it was sudden, systemic (Bongiovanni et al., 2021) and global. All countries were affected almost simultaneously.

In an attempt to try and reduce the risk of contagion, governments all around imposed mandatory lockdowns. As consequence, the world stopped or at least it slowed down.

In our opinion, the most relevant repercussions of the containment measures and restrictions were the drastic decrease in the use of high-carbon fuels and the fall in oil consumption (Siitonen et al., 2010; Kwon, 2005).

First estimates from the Global Carbon Project (GCP) suggest that in 2020 fossil CO2 emissions had the biggest relative fall since the second world war. The study estimates a decline of 12% in the US, 11% in the EU, 9% in India and 1.7% in China, compared to 2019.

However, we must take into consideration that any empirical analysis done by looking at data from the past, will most likely provide us with lower bound results.

In this thesis, we used a longitudinal dataset on pandemics and epidemic outbreaks across countries, to trace the impact of such exogenous shocks on emissions, studying its size and persistence in the short to medium run. This dataset was put together by Ma et al. (2020) since 2000, namely SARS (2003), N1H1 (2009), MERS (2012), Ebola (2014) and Zika (2016). All other data was retrieved from WB´s World Development Indicators and we used a sample of 148 countries – 41 Low Income countries, 71 Emerging Market Economies and 36 Advanced Economies – for the time span of 1980-2020.

For the analysis of COVID-19 (2020), we used a dataset from Jalles et al. (2021) covering energy consumption, NO2 emissions and covid statistics from 138 countries. However, we only studied the countries for which we have data on emissions: 2 Low Income Countries, 18 Emerging Market Economies and 24 Advanced Economies (44 in total).

During this process, a few research questions are expected to be answered.

Firstly, we want to know if a reduction in emissions is observed and, if so, if that reduction is permanent or temporary. During crises and pandemics, one usually witnesses a fall in consumption which leads to a decrease in production. As a result, emissions go down. However, these normally go up to their pre-crisis average (cyclical).

Secondly, one may expect the initial share of renewables in total energy consumption in a certain country to influence how and if a pandemic will trigger a transition into renewable/greener energy. We will study the validity of this expectation.

Another research question we intend to answer is if the oil, gas and coal use will bounce back after dropping drastically as a share of total energy.

Finally, if a pandemic does indeed trigger a transition into renewable energy, we will study if the increase in the share of renewables is permanent or temporary.

As expected, this study allowed us to conclude that the five previous pandemics led to overall decreases in CO2 emissions and in some cases triggered falls in economic activity. Similarly, we observe falls in NO2 emissions as the COVD-19 pandemic first appears and aggravates.

Still, we would need more data on this pandemic (perhaps in five years' time) to be able to fully analyse its impacts on emissions and on the transition into sustainable energy production it may trigger.

The remainder of this thesis is organized in the following way: section 2 reviews the literature on the topics global warming, pandemic shocks and determinants of pollutant emissions; section 3 outlines the empirical methodology; section 4 describes our data and the impact of the previous pandemic shocks on CO2 emissions, on green electricity production and on economic activity, as well as the relation between NO2 emissions and the number of COVID-19 related cases and deaths; section 5 discusses our main results; and section 6 concludes.

2. LITERATURE REVIEW

Carbon dioxide (CO2) is considered one of the main causes of global warming. As the world's demand for electricity is increasing with economic growth (Iwata et al., 2012), whether the Environmental Kuznets Curve (EKC) exists for CO2 emissions has been a central topic in environmental economics.

The EKC hypothesis claims that an inverted U-shaped relation exists between income and environmental pollutants. In our data, we observe that emissions monotonically increase with per capita income (Shafik, 1994; Holtz-Eakin and Selden, 1995) and energy consumption (Liu, 2005) as it's in the Advanced Economies groups we see the largest values for emissions.

During pandemics, and especially during COVID-19, pollutant emissions are expected drop due to a variety of factors. Because of the imposed lookdowns we observed a drastic fall in road traffic, which is the largest contributor of the transport sector to pollutant emissions (Kwon, 2005). Following the studies by Gierdraitis et al. (2010) and Lane (2011), which conclude that carbon dioxide is highly correlated with GDP as GDP growth leads to a higher CO2 quantity in the earth's atmosphere, we studied the effect of the logarithm of GDP per capita on emissions and arrived at the same conclusion.

Therefore, the fall in economic activity which accompanied this pandemic (Global Economic Prospects, 2020; Hur et al., 2020) is also predicted to decrease emissions. Hur et al. (2020) included economic considerations in the variation of the epidemiology model SIR developed by the Imperial College London - this model had been originally developed in 1927 by Kermack and McKendrick and it separates the total population into three groups: S for susceptible (at risk of contracting the disease), I for infectious, and R for recovered, deceased, or otherwise immune. By doing so, they reached models which formalized a trade-off between preventing the spreading of disease and decreasing economic output. According to their analysis of these models, in the long run, containment measures such as lockdowns (which happened earlier during the COVID-19 pandemic) seem to be better than the alternative of taking no action to prevent the spread of disease. Introducing testing policies on top of lockdowns can provide us an even more favourable outcome.

One of the most promising measures for reducing global CO2 emissions and the dependence on imported fossil fuels is the improvement of energy efficiency (Siitonen et al., 2010). With this background, we studied the share of green electricity production in the countries affected by the previous pandemics and how that share was affected by the shocks. However, we must be aware that during difficult times consumers may have incentives to consume goods of inferior environmental quality as these are usually cheaper, which leads to an over-exploitation of resources that are associated with environmental degradation effects (Del Río and Labandeira, 2009). In our study, we observed overall decreases in green energy production in Low Income countries, which validate the previous statement.

Still, authors such as Papandreou (2015) claim that crises provide us with opportunities for new institutional pathways. Because there is a higher competition for scarce resources, economic crises should lead to the implementation of greener policies. Although this may be costly at first, the benefits of these policies in terms of potential savings must be considered. Therefore, advocates of this view demand a redesign of policy frameworks and international cooperation.

Because Friedl et al. (2003) found that imports are also shown to reduce CO2 emissions in certain countries, in this thesis we also test the impact of imports on emissions.

Brzezinski (2020) estimated the short to medium run impact of the H3N2 (1968), SARS, H1N1, MERS, Ebola and Zika pandemics and attempted to predict the impact of COVID-19 on CO2 emissions and energy transition into renewable electricity. Similar to the results we obtained, his analysis found that in OECD countries (included in our Advanced Economies groups) previous pandemics had a negative impact on CO2 emissions and led to significant improvements in the transition to renewable energy.

Although these results suggest that pandemics create opportunities for the transition to green energy, the viability of this transition depends on government policies that secure the investment on green/renewable energy technologies both during and after pandemic episodes. Even though COVID-19 is somewhat similar to the pandemics studied in the previously mentioned paper, this one will have a much larger impact on the environment as it had on human lives.

3. EMPIRICAL APPROACH

Pandemic outbreaks are largely exogenous shocks to the economic, health and energy systems. In this paper we estimate a series of statistic reduced-form regressions inspired from the dynamic approach followed by Jalles (2019).

The first regression to be estimated is written as follows:

$$y_{i,t} = \alpha_i + \mu_t + \beta_k PS_{i,t} + \theta X_{i,t} + \varepsilon_{i,t} \qquad (1)$$

where $y_{i,t}$ is the logarithm of CO2 emissions in country i in period t; α_i are country fixed effects, to control for country-invariant heterogeneity; μ_t are time fixed effects, to control for time-invariant heterogeneity; $PS_{i,t}$ is our dummy variable for pandemic shocks, which takes the value 1 when a pandemic shock occurred and 0 otherwise[1]; $X_{i,t}$ is a vector of control variables that includes the share of green electricity production, imports of goods and services (% of GDP) and the logarithm of GDP per capita (constant LCU); and $\varepsilon_{i,t}$ is an i.i.d disturbance term satisfying the standard assumptions of constant variance and zero mean.

In this study, we estimated the response of CO2 emissions to pandemic shocks through Ordinary Least Squares (OLS) with robust standard errors clustered.

We then re-estimate equation (1) by splitting the sample into three subgroups to inspect whether initial conditions related to income differences change the baseline results: Low Income Countries, Emerging Market Economies and Advanced Economies.

4. DATA AND STYLIZED FACTS

In our analysis, we used data on the following variables retrieved from the WB´s World Development Indicators: CO2 emissions (kt), electricity production from oil, gas and coal sources (% of total)[2], imports of goods and services (% of GDP) and GDP per capita (constant LCU).

[1] $PS_{i,t}$ only takes the value 1 for the year in which the pandemic first took place. It's 0 for the remaining years of the pandemic.

[2] As we were unable to obtain a more appropriate indicator, the variable "share of electricity production from green/ renewable sources" is defined as:
share of electricity production from green/ renewable sources = 100% - share of electricity production from oil, gas and coal sources (i.e., pollutant sources).

The dataset on pandemics and epidemics since 2000 was put together by Ma et al. (2020), namely SARS (2003), H1N1 (2009), MERS (2012), Ebola (2014) and Zika (2016) (Table A1).

For the analysis of these pandemics, we used a sample of 148 countries – 41 Low Income countries, 71 Emerging Market Economies and 36 Advanced Economies – for the time span of 1980-2020. However, the dataset retrieved from the WB only has data on emissions until 2018 and data on electricity production until 2016 and so our analysis was be limited by this.

For the analysis of COVID-19 (2020), we used a dataset from Jalles et al. (2021) covering energy consumption, NO2 emissions and covid statistics from 138 countries. However, we only studied the countries for which we have data on emissions available: 2 Low Income Countries, 18 Emerging Market Economies and 24 Advanced Economies (44 countries in total) (Table A2).

All variables used in this study are summarized in Table I.

Table I – All variables used in this study

Variable	Definition	Unit	Treated as:
CO2 emissions (kt)	Carbon Dioxide emissions.	Kiloton	Logarithm
Electricity production from oil, gas and coal sources (% of total)	Share of electricity produced using pollutant sources.	Percentage	Percentage
Green electricity production (% of total)	Share of electricity produced using non-pollutant sources.	Percentage	Percentage
GDP per capita (constant LCU)	Gross Domestic Product per person.	Constant Local Currency Unit	Logarithm
Imports (% of GDP)	Imports of goods and services as a percentage of GDP.	Percentage of GDP	Percentage
GDP growth	Calculated in the following way: $GDP\ Growth_t=[(GDP_t-GDP_{t-1})/GDP_{t-1}]*100$	Percentage	Percentage
NO2 emissions	Nitrogen Dioxide emissions.	Index Number	Logarithm
New cases per million	New weekly cases of COVID-19.	Number	Number
New deaths per million	New weekly deaths due to COVID-19.	Number	Number
Energy consumption	All energy consumption.	Index Number	Number

Although we can make some comparisons between COVID-19 and previous pandemics with the information available, we must highlight that there are some important differences: the sample used in the study of COVID-19's impact on emissions and energy consumption contains less countries for a weekly (not yearly) time span of 68 weeks – starting on the 13th of January 2020 until the 9th of May 2020 –, and the proxy for pollutant emissions is Nitrogen Dioxide (NO2) emissions and not Carbon Dioxide (CO2) emissions.

Regarding the five previous pandemics, we first studied whether there was an increase or decrease in pollutant emissions during those shocks and if that increase/ decrease was permanent or temporary.

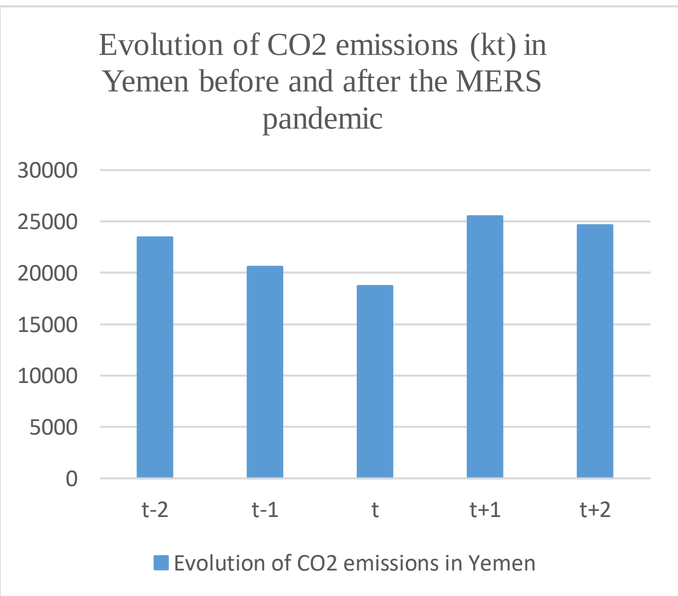
To do so, we analysed the behaviour of the proxy for pollutant emissions (CO2 emissions) for each group of countries in the two years prior to each pandemic shock (t-2 and t-1), in the year of (t) and in the two years following the shock (t+1 and t+2).

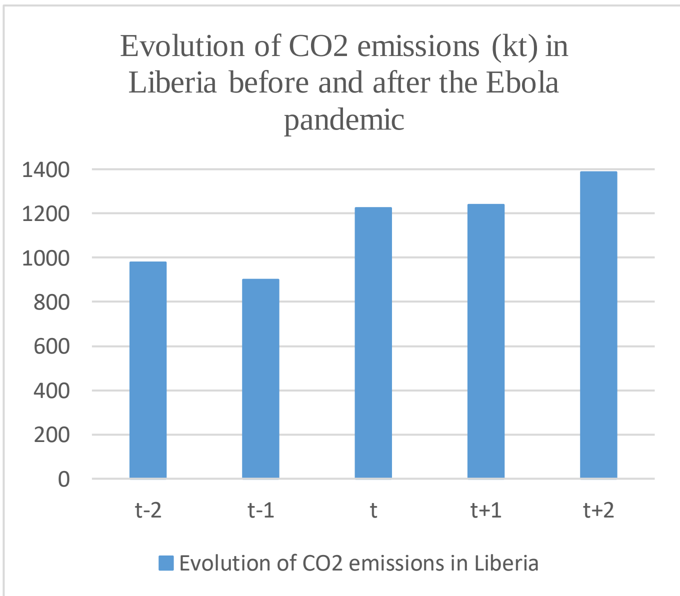
Starting with Low Income countries, data from Ma et el. (2020) shows that only Vietnam and Mongolia suffered through the SARS pandemic. However, in Figure 1, we see that CO2 emissions were not impacted by the shock as these continued to increase at approximately the same rhythm in the years following the pandemic shock. We observe a similar scenario for the LI countries reached by the H1N1 and Zika pandemics.

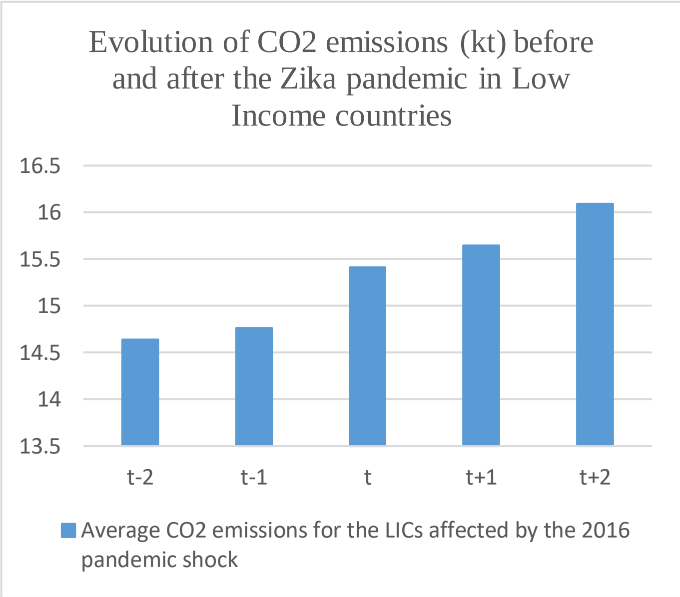
In Yemen – the only LIC affected by MERS –, CO2 emissions decreased in the year of the shock, rose to higher than pre-pandemic values in the years that followed and did not recover to their pre-pandemic shock values until 2015 (year in which emissions were the lowest they had ever been since 1998).

The Ebola pandemic was accompanied by a permanent increase in emissions in the only LI country affected – Liberia.

Fig. 1. Evolution of CO2 emissions in the Low Income Countries affected by each pandemic.







Source: Author's calculations.

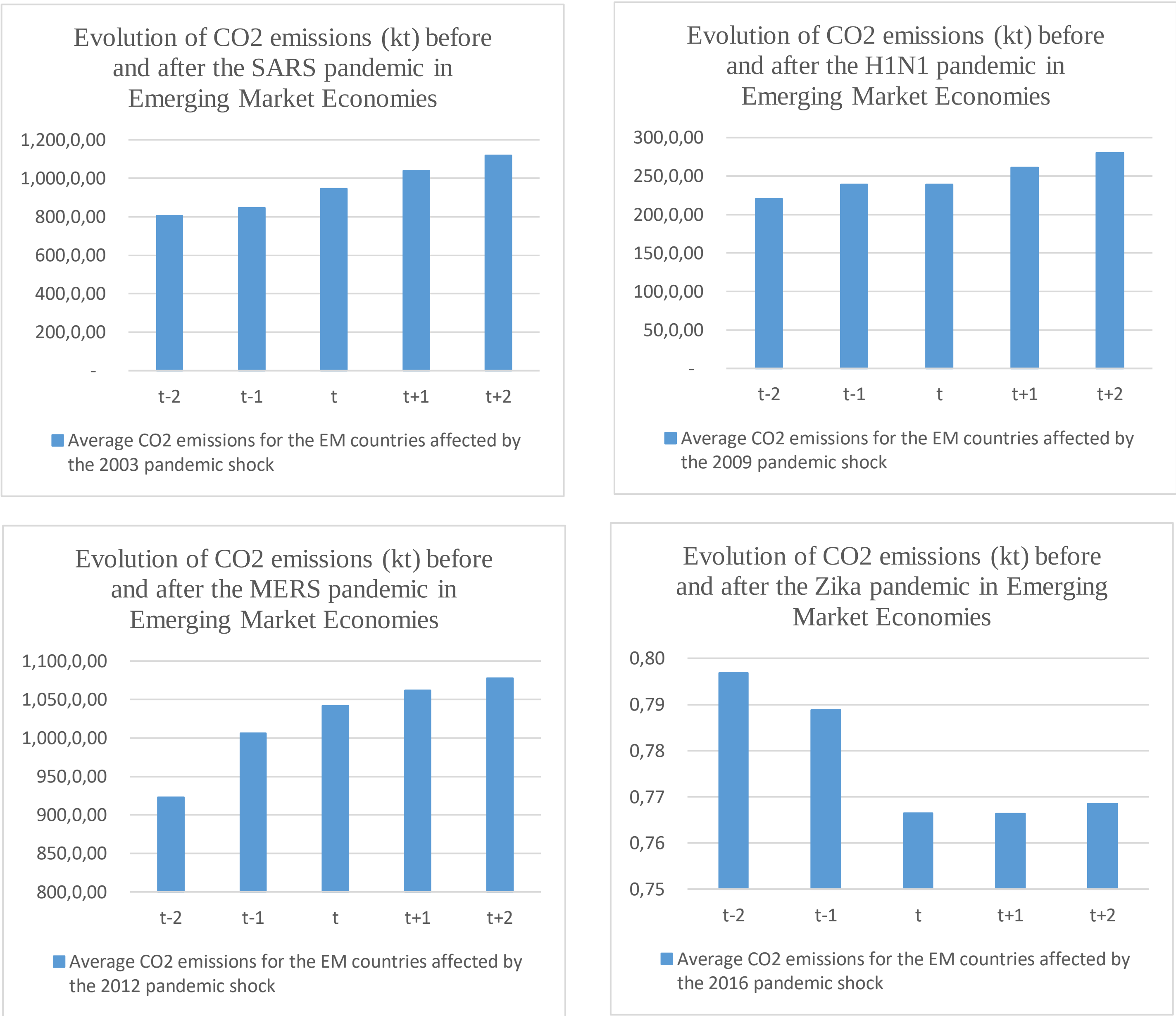
Figure 2 shows us that following the SARS and H1N1 pandemics, emissions in the Emerging Market economies affected began to rise slightly more rapidly.

The opposite occurs following the MERS shock as the increase in emissions slowed down.

Pollutant emissions decreased noticeably in the year of the Zika pandemic shock and there's no record of these going back to their pre-pandemic values.

According to the data obtained regarding the pandemic shocks, no Emerging Market Economy was affected by the Ebola pandemic.

Fig. 2. Evolution of CO2 emissions in the Emerging Market Economies affected by each pandemic.



Source: Author's calculations.

Finally, moving on to Advanced Economies, figure 3 shows us that the SARS pandemic did not impact emissions as these continued to increase.

On the other hand, H1N and MERS led to overall decreases in emissions.

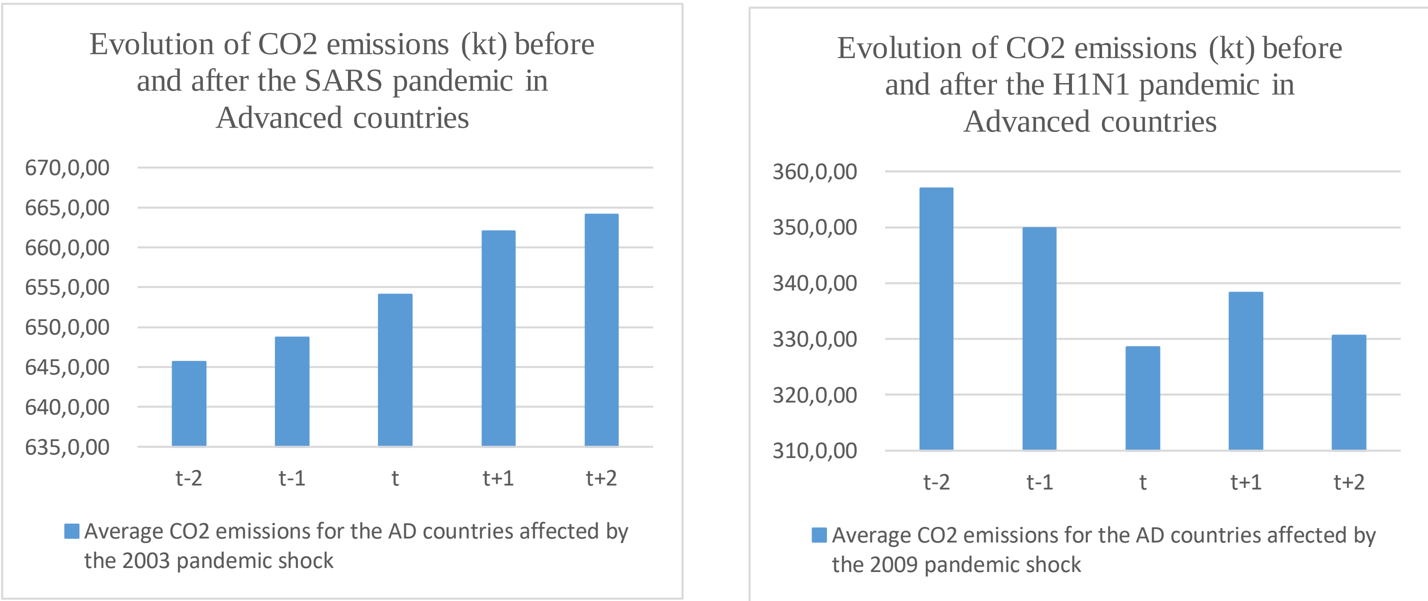
CO2 emissions' values were somewhat stable in the years prior to and of the Ebola pandemic. However, there is a drastic increase in the following year.

Prior to the Zika pandemic shock in 2016, pollutant emissions in the Advanced Economies affected[3] were already falling and continued to do so until 2018 (year in which we witness an increase to pre-shock values).

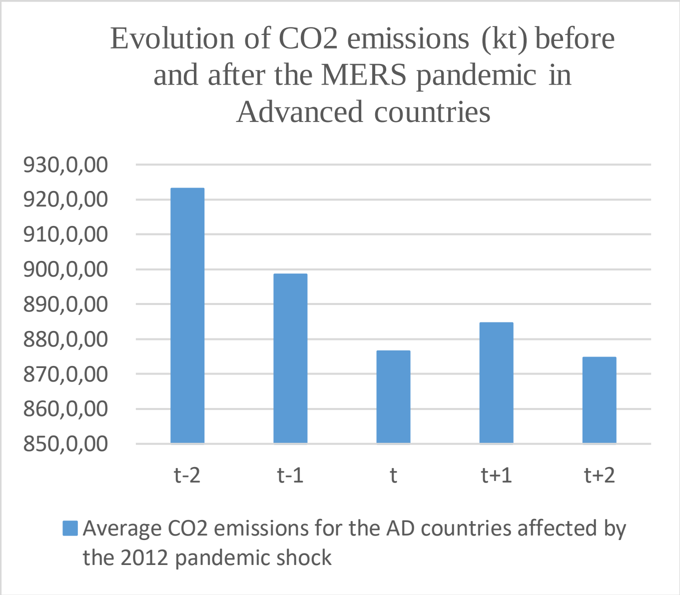
In sum, it's in this group of countries that the environment seems to have benefited the most from the pandemics, since the lowest values for emissions were recorded in the years of the H1N1, MERS and Ebola shocks.

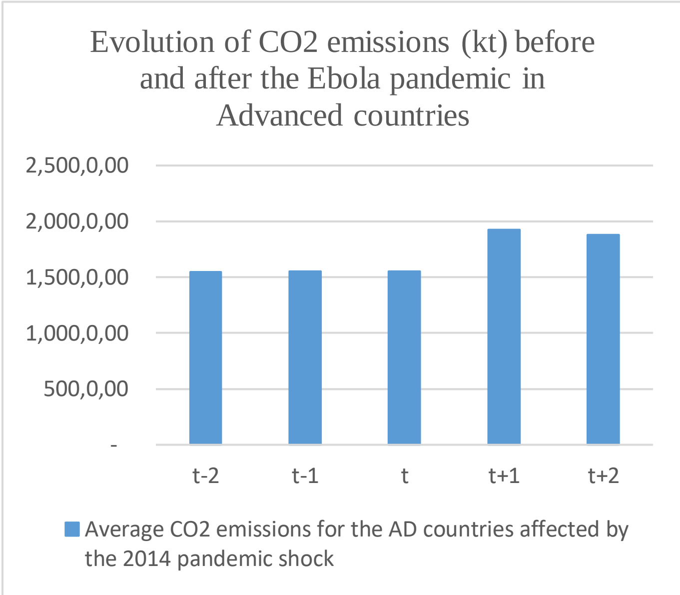
This may lead one to believe that the pandemics lead AD economies to invest in greener energy (Papandreou, 2015). This is proved in the analysis that follows, as the percentage of electricity produced using non pollutant sources increases in this group of countries, either in the year of the pandemic or in the year that follows.

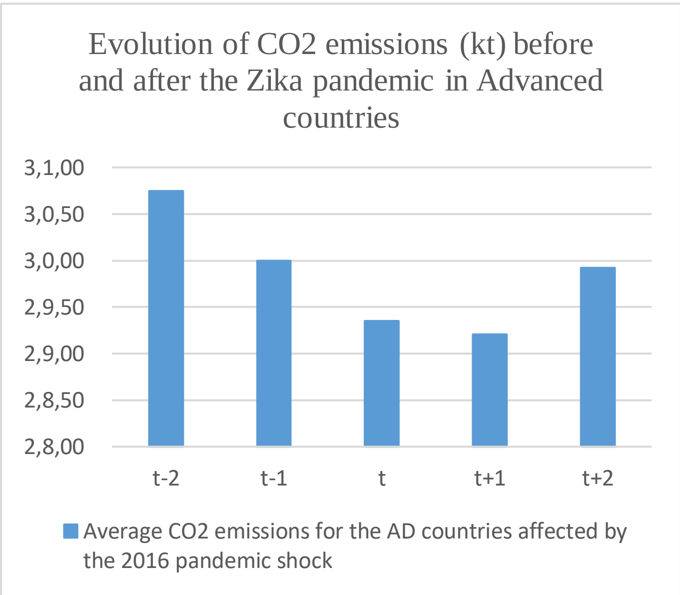
Fig. 3. Evolution of CO2 emissions in the Advanced Economies affected by each pandemic.



[3] Puerto Rico was also affected by this pandemic but is not included in our analysis as we were not able to find data on emissions for this country.







Source: Author's calculations.

To study if pandemics trigger a transition intro greener energy, we considered, as proxy for green energy production, total electricity production excluding the percentage of electricity produced using pollutant sources. To do so, we excluded electricity production from oil, gas and coal sources from total electricity production.

Using this new variable, we studied how the production of electricity through non pollutant sources (i.e., green electricity production) was impacted by each pandemic[4] in each group of countries.

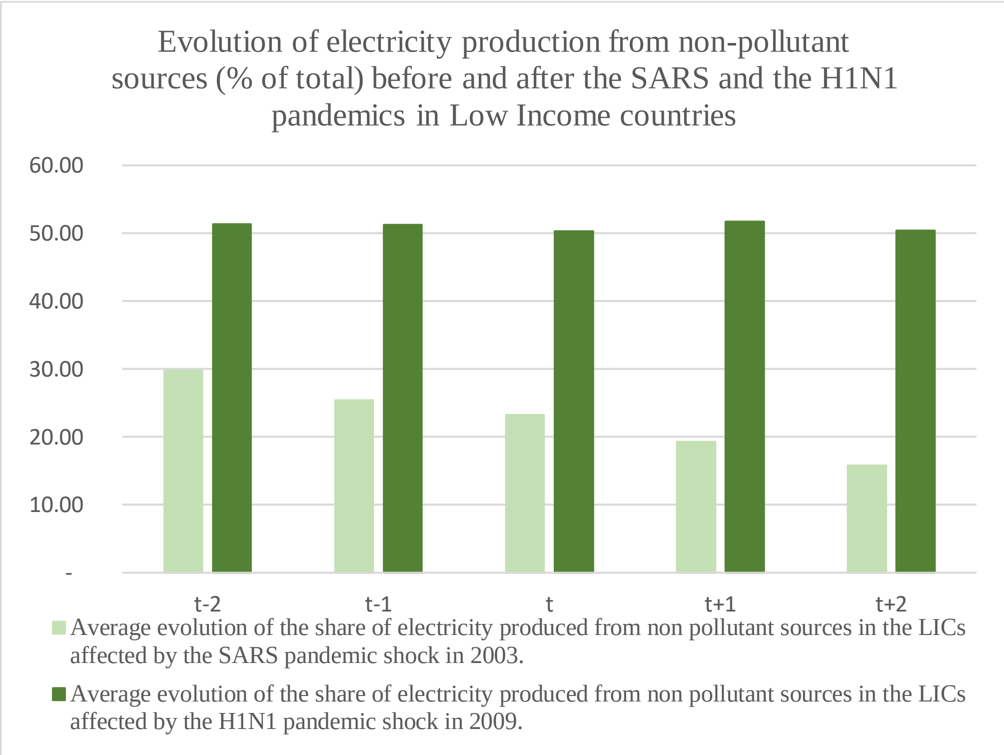
Starting with Low Income countries in figure 4, the 2003 pandemic shock led to a decrease in the percentage of green electricity production. Although we see a slight increase in this percentage in the year that followed the 2009 pandemic, it drops in the following year to lower than pre-pandemic values.

As mentioned before, the 2012 MERS pandemic affected only one Low Income country – Yemen – and according to the data retrieved from the World Bank, all electricity produced in this country is derived from very pollutant sources – more specifically oil, gas and coal.

Following the literature (Wooders and Runnals, 2008), we conclude that pandemic shocks may have led to overall decreases in green electricity production in the affected LICs due to the lack of incentives from the governments (i.e., low energy prices and lack of taxes and regulation) to develop and operate greener technologies during these sensitive times. Even though we could not test this for the Ebola pandemic as we found no data on electricity production for Liberia, we are confident that it had the same effects on green electricity production as the previous pandemics in this group of countries.

[4] We were unable to study this for the case of Zika, as we found no data on the WB regarding electricity production available after 2016.

Fig. 4. Evolution of the percentage of electricity produced using green/renewable energy in the Low Income Countries affected by each pandemic.

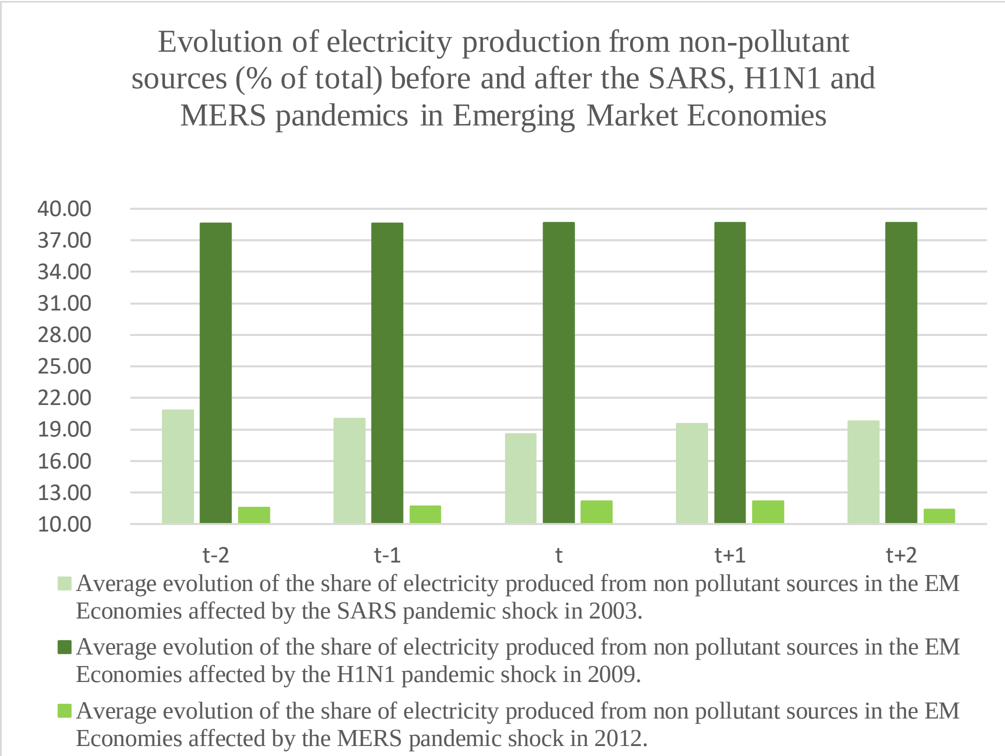


Source: Author's calculations.

Figure 5 shows that the percentage of electricity production from non-pollutant sources was decreasing before the 2003 pandemic in EM economies, hitting its lowest value in the year of the shock. However, this percentage began to rise in the years that came after.

While the H1N1 pandemic did not significantly impact green electricity production, we observe a small increase in the year of the MERS pandemic.

Fig. 5. Evolution of the percentage of electricity produced using green/renewable energy in the Emerging Market Economies affected by each pandemic.



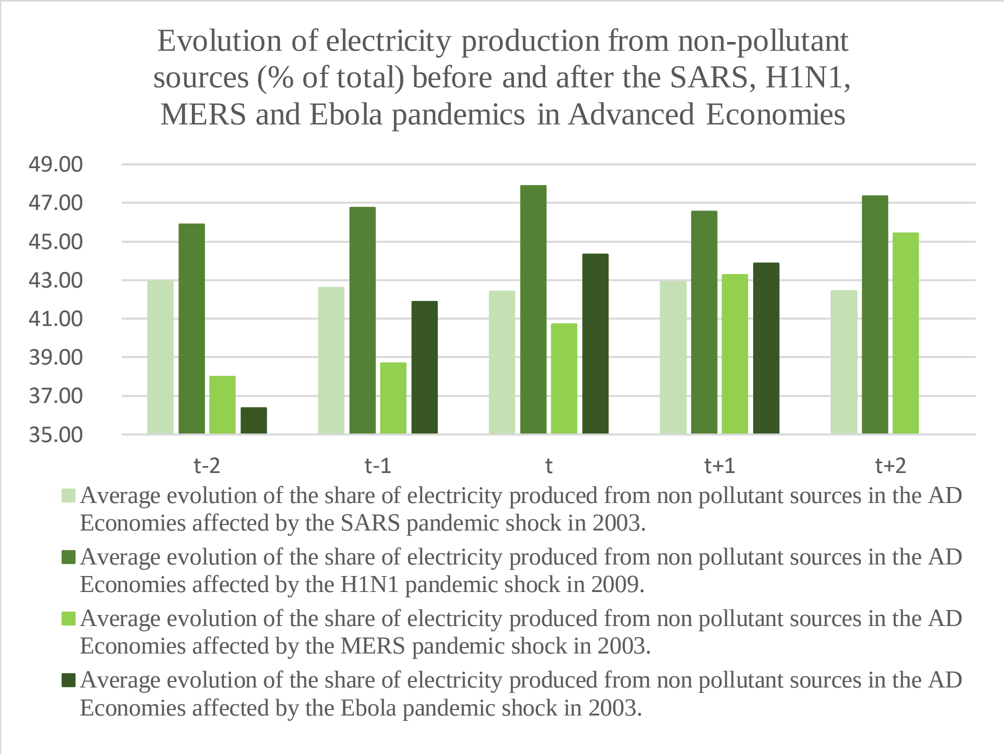
Source: Author's calculations.

In figure 6 we observe that prior to the SARS pandemic, the percentage of electricity produced using non-pollutant sources was declining in Advanced Economies and although we see an increase in the year that followed the shock, this percentage quickly goes down to lower than pre-pandemic values.

The remaining pandemics – H1N1, MERS and Ebola[5] – had overall positive effects in green electricity production.

[5] The study of the Ebola pandemic shock ends in 2015 (t+1) as we only found data on electricity production until this year.

Fig. 6. Evolution of the percentage of electricity produced using green/renewable energy in the Advanced Economies affected by each pandemic.



Source: Author's calculations.

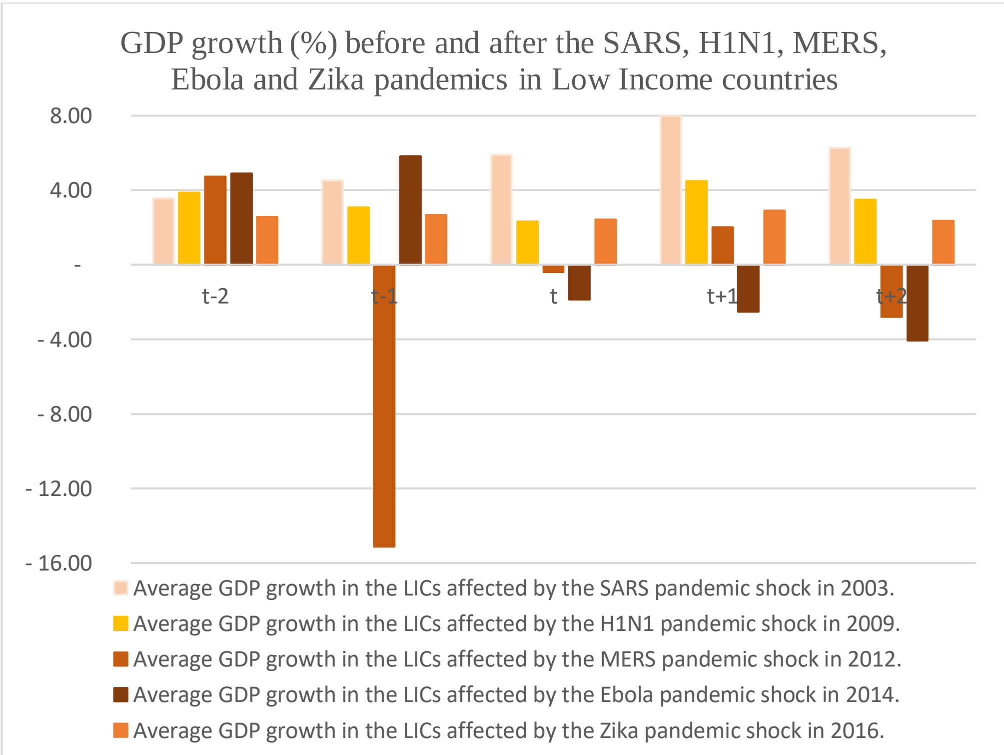
Another research question we intended to answer was if the oil, gas and coal use would bounce back in the years after the pandemic shocks. This can be answered through the previous analysis on the share of green electricity production (i.e., total share of electricity production excluding the share produced using oil, gas and coal).

As mentioned previously, the percentage of electricity produced using oil, gas and coal did not decrease as consequence of the pandemic shocks in all groups of countries as we had anticipated. In fact, for Low Income countries, only the H1N1 pandemic triggered a slight transition into green energy, but the oil, gas and coal use bounced back in the following years. In the case of Emerging Market Economies, the SARS and H1N1 pandemic also provoked a transition into cleaner energy production but the percentage of electricity produced using pollutant sources did not bounce back; on the other hand, the use of these pollutant sources did recover following the MERS pandemic. Although the pandemics caused a decrease in the use of pollutant sources for electricity production in the Advanced Economies affected, these recovered following the SARS pandemic shock.

To study the short to medium-run impact of past major pandemics and epidemics on economic activity, we considered GDP growth[6] as proxy for economic activity and, once again, analysed how it reacted to each pandemic in each group of countries.

The SARS, H1N1, MERS and ZIKA pandemics don't seem to have significantly impacted economic activity in the LICs affected, as GDP grew to higher that pre-pandemic values in the following year. However, Liberia did not recover from the Ebola shock, which decreased GDP to negative values once it reached the country (figure 7).

Fig. 7. GDP growth in the Low Income countries affected by each pandemic, calculated in constant LCU per capita values.

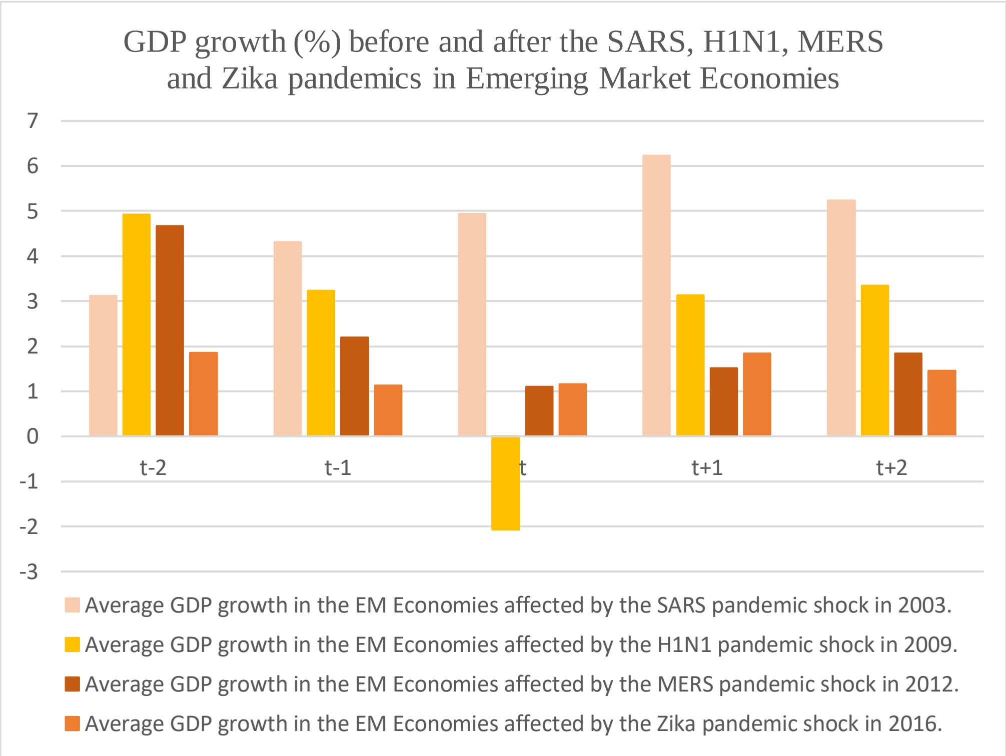


Source: Author's calculations.

In figure 8 we see that H1N1, MERS and Zika affected economic activity in EM Economies. Although GDP recovered in the years after H1N1 and Zika, the impact of the MERS shock was more noticeable as GDP did not recover in the years that came after.

[6] To calculate GDP growth, we used data on GDP per capita (constant LCU) retrieved from the World Data Bank.

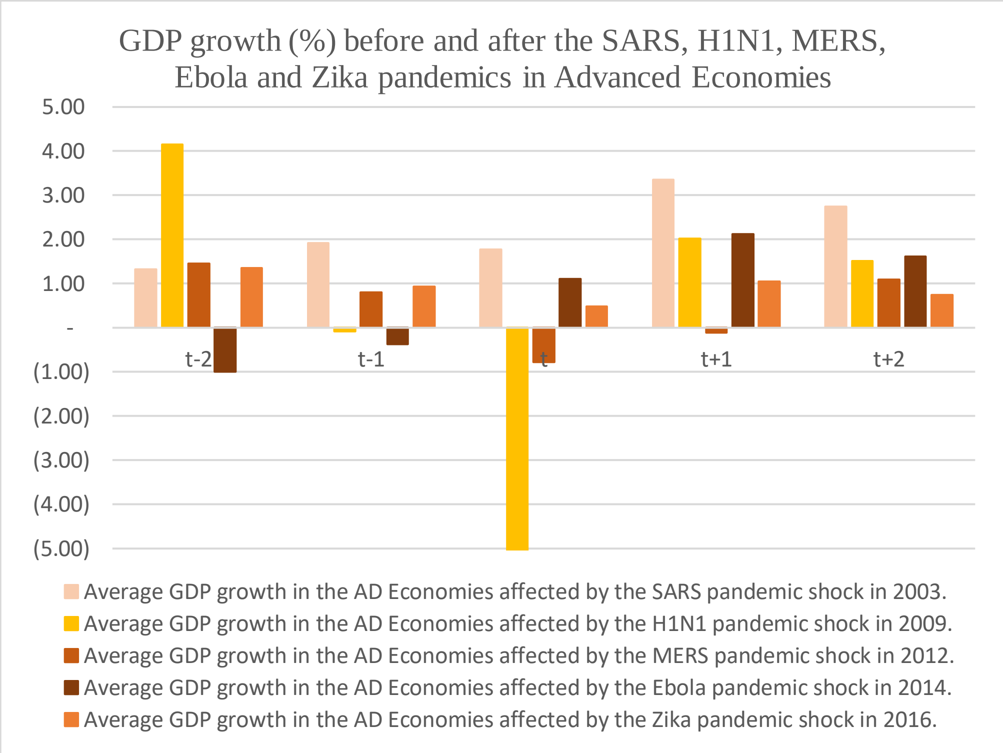
Fig. 8. GDP growth in the Emerging Market Economies affected by each pandemic, calculated in constant LCU per capita values.



Source: Author's calculations.

Finally, figure 9 shows us that SARS, Ebola and Zika did not affect economic activity considerably in Advanced Economies. Even though GDP fell in the years of the SARS and Zika shocks, economic activity recovered in the year that followed. Prior to the H1N1 and MERS pandemics, GDP was already declining (hitting its lowest values in the year of the shock) but begin to improve in the years that came after.

Fig. 9. GDP growth in the Advanced Economies affected by each pandemic, calculated in constant LCU per capita values.



Source: Author's calculations.

When observing the figures representing the evolution of carbon dioxide emissions (fig.1 – fig. 3) and GDP growth (fig.7 – fig.9) simultaneously, one may be able to notice a possible spurious correlation between the variables. To control for this, we included in our empirical analysis the logarithm of GDP per capita, as well as other control variables.

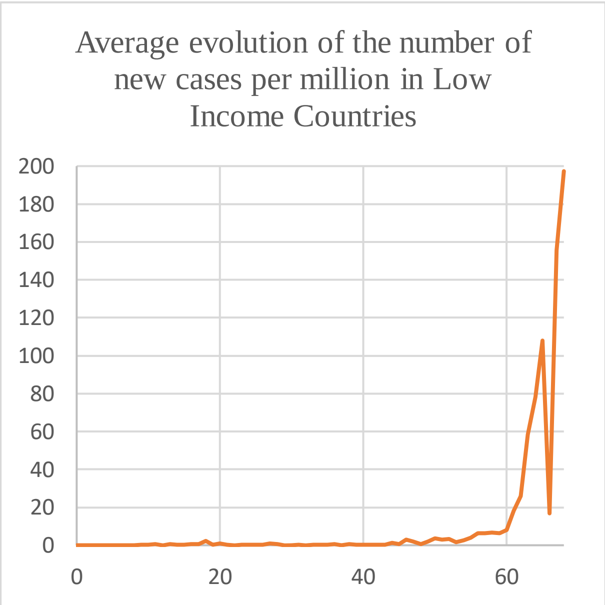
In order to attempt to compare the previous pandemic shocks with the current COVID-19 pandemic, we began by studying the relation between energy consumption[7] and NO2 emissions (which is our proxy for pollutant emissions in the COVID-19 analysis) with the number of covid related new weekly cases and deaths (per million).

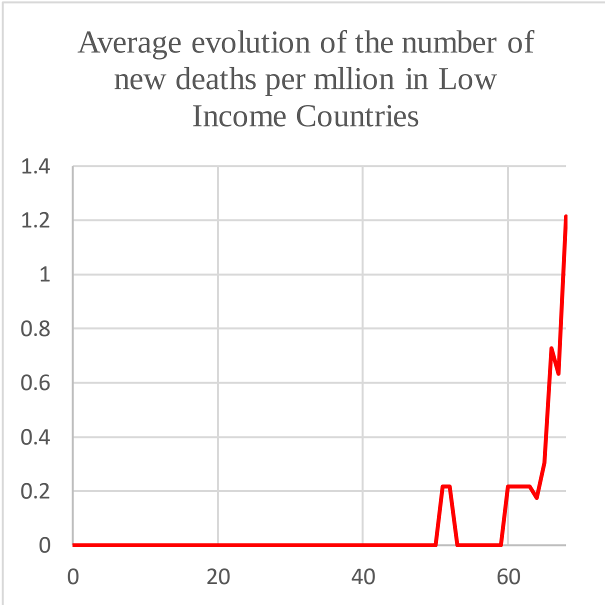
Figure 10 shows us the evolution of these variables in Low Income countries. We can observe that NO2 emissions decreased in the first 8 weeks of our analysis (between the 13th of January 2020 and the 1st of March 2020) and were starting to recover, until the first cases of covid appeared in week 11. As time passes, emissions appear to go back to higher than pre-pandemic values (week 53 - January 18, 2021) as the number of new

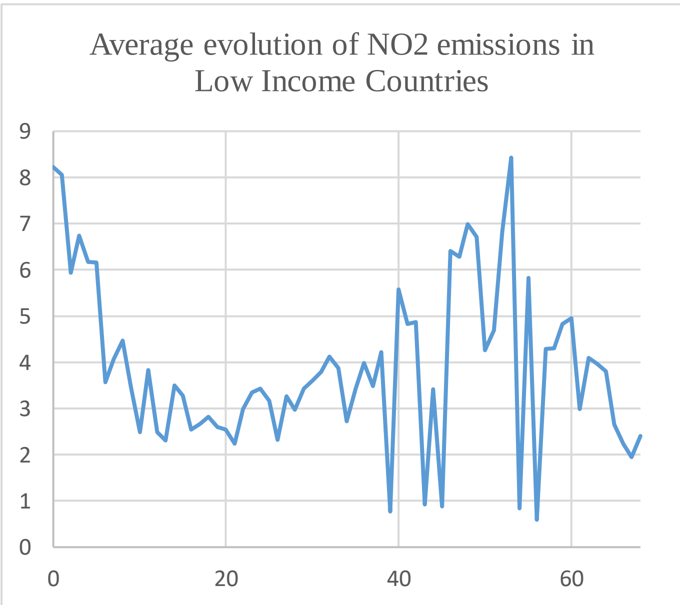
[7] Our dataset contains no data on energy consumption for the studied LICs.

weekly cases and deaths decrease. However, as the pandemic aggravates, emissions return to lower values.

Fig. 10. Average evolution of the studied variables in Low Income Countries before and during the COVID-19 pandemic.





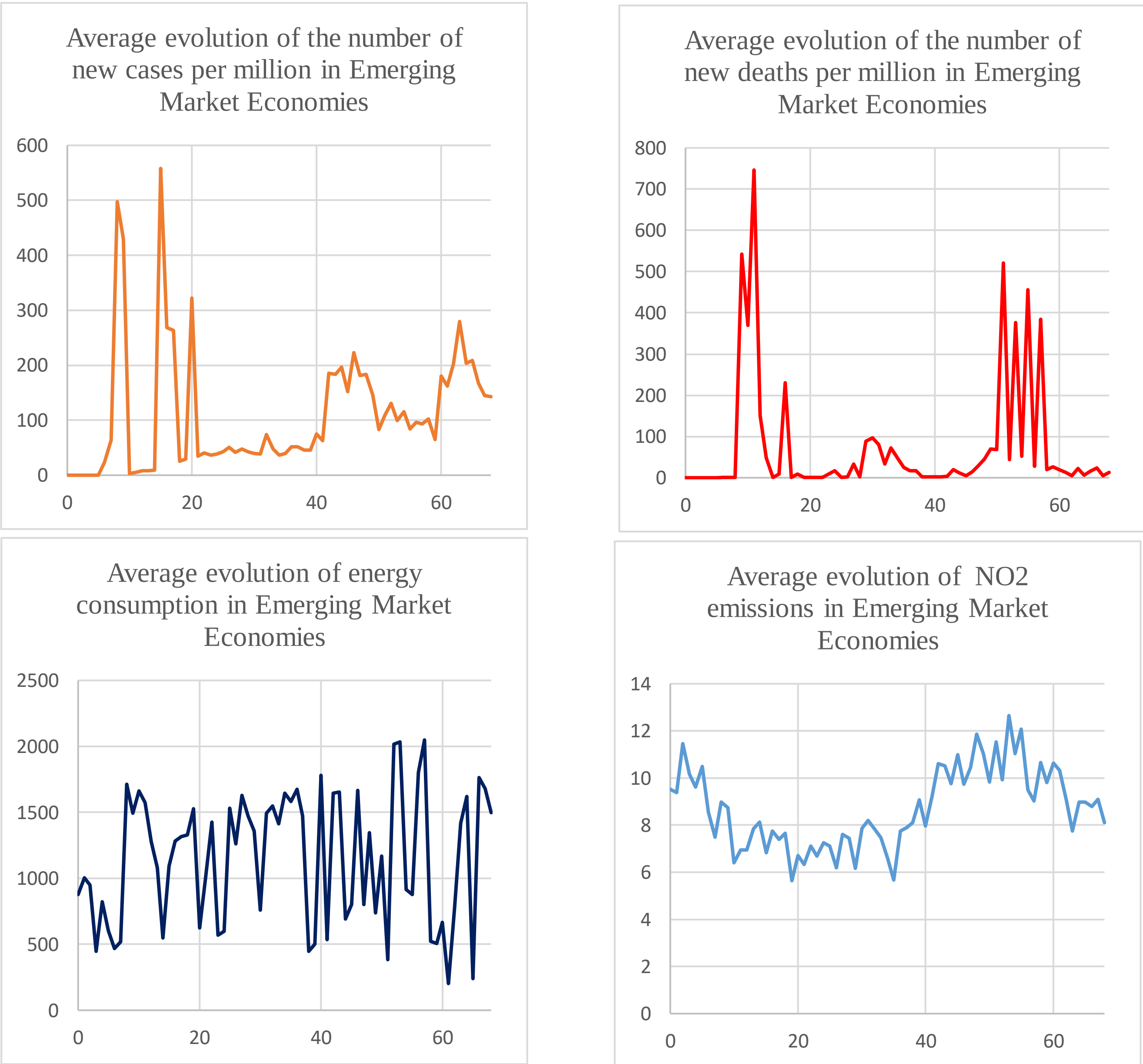


Week 20 - June 1st, 2020; Week 40 - October 19, 2020; Week 60 – March 8, 2021.

Source: Author's calculations.

Figure 11 shows us a similar scenario for Emerging Market Economies, with noticeable decreases in energy consumption and NO2 emissions when cases of covid first appear and start resulting in deaths. These variables appear to the correlated as emissions stabilize between the 21st and 31st weeks, around the same time as the number of new cases and deaths sort of stagnate. In week 32 we see an increase in cases with is followed by decrease in emissions. As was the case for LICs, in EM economies emissions too increase to higher than pre-pandemic values (week 55) as the number of weekly new cases and deaths decrease but return to lower values as the pandemic worsens.

Fig. 11. Average evolution of the studied variables in Emerging Market Economies before and during the COVID-19 pandemic.



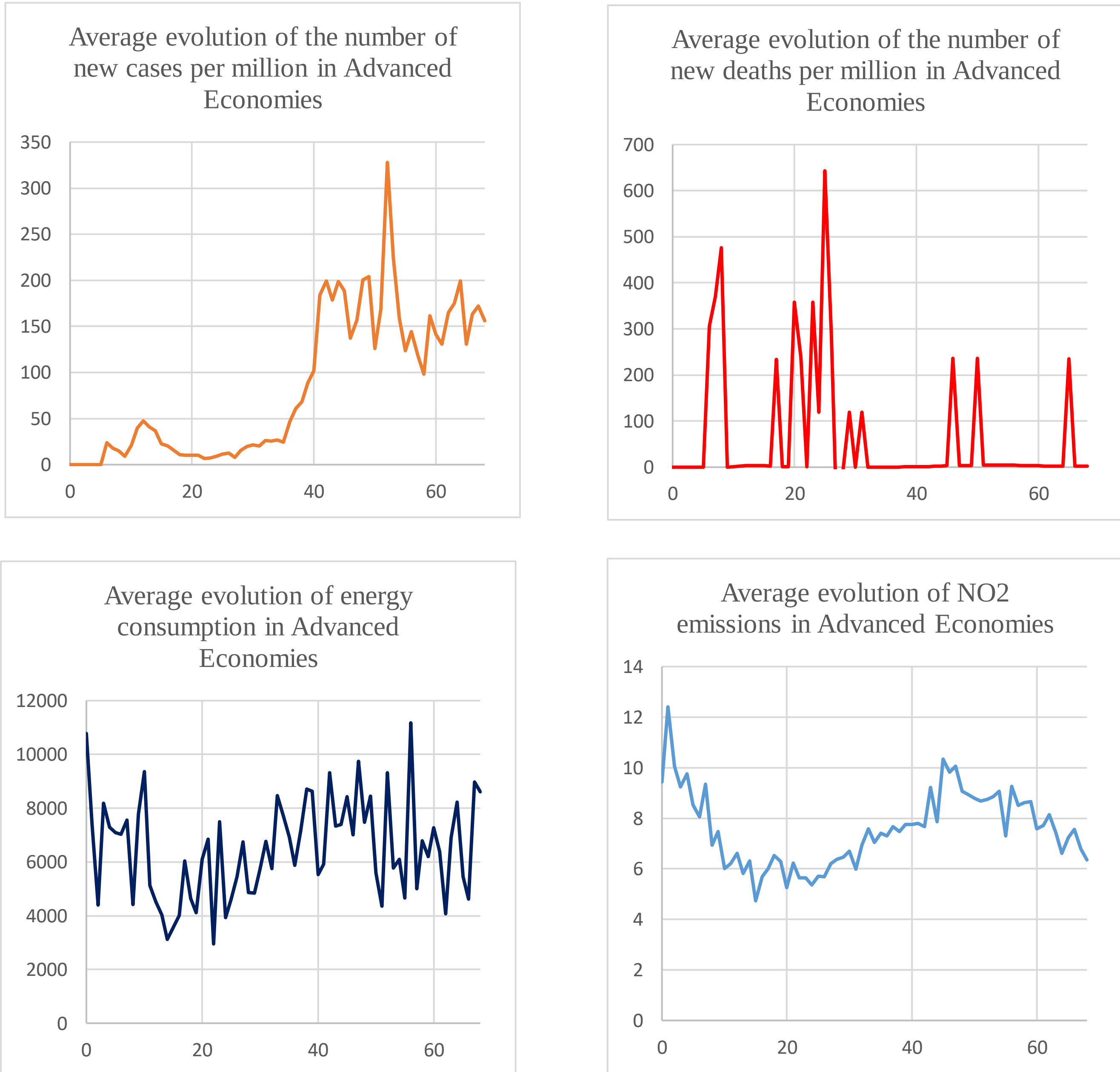
Week 20 - June 1st, 2020; Week 40 - October 19, 2020; Week 60 – March 8, 2021.

Source: Author's calculations.

In figure 12 we can also observe a drop in energy consumption and emissions as the virus appears in Advanced Economies.

For example, week 52 – in which we observe the highest number of new cases – is followed by an increase in the number of deaths and by a decline in energy consumption.

Fig. 12. Average evolution of the studied variables in Advanced Economies before and during the COVID-19 pandemic.



Week 20 - June 1st, 2020; Week 40 - October 19, 2020; Week 60 – March 8, 2021.

Source: Author's calculations.

Unlike previous pandemics which affected only some countries, COVID-19 can be distinguished from previous pandemics because it was sudden, systemic (Bongiovanni et al. 2021) and global. All countries were affected almost simultaneously. Therefore, we expect the impacts of this pandemic to be far greater than those of any previous ones. In particular when it comes to pollutant emissions, the positive effect of COVID-19 on the environment (i.e., the reduction of pollutant emissions) will most likely be even more noticeable, in part due to the confinements imposed by governments.

As far as we could study given the limited data on such a recent event, the current pandemic led to overall decreases in energy consumption and, as result, decreases in pollutant emissions in all groups of countries.

However, our study regarding previous pandemics concluded that the previous statement is not valid in the case of Low Income countries. This is in part due to the lack of investment in the development and operation of green technologies (Wooders and Runnals, 2008). In fact, these pandemic shocks were accompanied by declines in green electricity production in LI countries (Fig. 4.).

Still, we would need to study the impact of COVID-19 on emissions and energy production in a few years' time to be able to fully comprehend the dimension of such shock.

5. EMPIRICAL RESULTS

5.1 Baseline

To obtain econometrically accurate results, we used STATA to estimate a series of panel regressions.

Table II illustrates the unconditional impact of the five previous pandemics on emissions. As we had initially predicted, pandemic shocks lead to decreases in emissions (falls in consumption during pandemic periods trigger falls in production which led to decreases in emissions). More specifically, whenever there is a pandemic shock, emissions are predicted to decrease around 8,3% when considering all groups of countries. However, if we look into the direct impact of pandemics on emissions in each group of countries individually, we can see that the previous statement is only valid for AD countries – as the coefficient is only statistically significant for this group.

TABLE II - DIRECT IMPACT OF PANDEMICS ON CO2 EMISSIONS

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Pandemic shock	-0.083*	-0.073*	-0.015	0.064
	(0.047)	(0.042)	(0.068)	(0.748)
Observations	6,428	1,245	3,104	2,079
R-squared	0.425	0.333	0.481	0.524

Notes: OLS estimates with time and country fixed effects of; robust standard errors in parentheses; constant term included but omitted.
*** p<.01, ** p<.05, * p<.1

5.2 Sensitivity and robustness checks

5.2.1 Sensitivity

Moreover, it is relevant to highlight that the coefficient is smaller in absolute terms for all countries, and is no longer significant for AD Economies, when also considering the other (control) variables, as reported in Table III. This could indicate that the impact of pandemics on emissions may be mitigated, for example, when there's a high percentage of green electricity production.

As anticipated, the percentage of electricity produced using green sources - Green_elec_prod (% of total) - has a positive effect on the environment. More specifically, a one-unit increase in the share of electricity produced using green methods is predicted to trigger a .011 points' decrease in pollutant emissions when considering all countries. This is still the case when analysing the groups separately.

Although Friedl et al. (2003) claim that imports tend to decrease a country's emissions' level – as more imports mean lower production and therefore less emissions – our estimations regarding that variable were not significant (using the OLS estimator).

Our results regarding GDP's impact on emissions meet Gierdraitis et al. (2010) and Lane (2011)'s conclusion that an increase in this variable triggers an increase in emissions.

TABLE III - IMPACT OF PANDEMICS ON CO2 EMISSIONS

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Pandemic_shock	-0.079*	-0.034	0.057	-0.13
	(0.044)	(0.034)	(0.048)	(0.126)
Green_elect_prod (% of total)	-0.011***	-0.007***	-0.01***	-0.006***
	(0.002)	(0.002)	(0.003)	(0.002)
Imports (% of GDP)	-0.001	-0.002	-0.001	0.002
	(0.001)	(0.002)	(0.002)	(0.002)
Gdp_constantlcu_log	0.468***	0.48**	0.389***	0.967***
	(0.085)	(0.194)	(0.103)	(0.164)
Observations	4,042	1,168	1,968	906
R-squared	0.563	0.512	0.691	0.677

Notes: OLS estimates with time and country fixed effects; robust standard errors in parentheses; constant term included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

Although our results don't change significantly if we take the logarithm of GDP per capita as the only control variable besides pandemic shocks (Table A3), when we take the share of green electricity production instead, the impact of pandemic shocks on CO2 emissions are no longer significant (Table A4). We also observed that excluding imports from the set of control variables does not led to significant changes from Table III (Table A5)

We also estimated the regression used in Table II without time fixed effects and observed some important changes: only pandemic shocks in AD Economies are predicted to decrease CO2 emissions, pandemic shocks in EM Economies and increases in the share of imports in LI Countries are predicted to increase emissions (Table A6).

Going further, we did a small geographical analysis similar to Table III, in which we tested the impact of pandemic shocks on emissions for two country groups: European Union and Latin America and Caribbean (Table A7). This analysis' conclusion differs from Table II in 2 points: 1. Pandemic shocks are not predicted to decrease (with significance) CO2 emissions in neither group (individually); and 2. while Table III met Gierdraitis et al. (2010) in the sense that increases in GDP lead to increases in emissions, this is not the case if we analyse European Union separately.

5.2.2 Robustness

We are aware that results may vary depending on the estimators used. Therefore, we decided to also include estimates for Between Effects, GLS Random Effects and ML Random Effects, shown in Table IV, besides the OLS estimator used in Tables I and II.

Overall, the outcomes are considerably similar with the exception of BE, which only provided us with predictions if we don't consider country fixed effects (shown in Table A8). All other estimators predict a (more or less) 7% decrease in emissions whenever there is a pandemic shock; a decrease in emissions if the share of green electricity production increases; and an increase in emissions if GDP increases.

Opposite to the results we obtain from OLS estimators, GLS Random Effects and ML Random Effects anticipate (with significance) that a rise in imports would decrease emissions (Friedl et al., 2003).

We can conclude that most of the results obtained via OLS estimations are robust: CO2 emissions are predicted to decrease whenever there is a pandemic shock and if the percentage of electricity produced using green sources increases; and are predicted to increase with GDP increases.

However, our initial result regarding the impact of imports on CO2 emissions is not robust as it varies between increasing and decreasing emissions depending on the estimators used.

TABLE IV - ALTERNATIVE ESTIMATORS, ALL COUNTRIES

Regressors	(1)	(2)	(3)	(4)
Estimator	OLS	Between Effects	GLS Random Effects	ML Random Effects
Pandemic_shock	-0.079*	0	-0.074**	-0.079**
	(0.044)		(0.037)	(0.036)
Green_elec_prod (% of total)	-0.011***	-0.081	-0.011***	-0.011***
	(0.002)		(0.000)	(0.000)
Imports (% of GDP)	-0.001	-0.045	-0.001***	-0.001***
	(0.001)		(0.000)	(0.000)
Gdp_constantlcu_log	0.468***	-0.128	0.394***	0.432***
	(0.085)		(0.021)	(0.022)
Observations	4,042	4,042	4,042	4,042
R-squared	0.563	0.031	0.563	

Notes: Estimates with time and country fixed effects; robust standard errors in parentheses; constant term included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

5.3 COVID-19

In this section, we started by estimating the impact of weekly deaths (new_deaths_per_million) on the logarithm of NO2 emissions (no2_log) with time and country fixed effects and observed that increases in the number of deaths are predicted to (marginally) decrease emissions in AD economies – as was the case for the previous pandemic shocks – and increase in EM economies.

Our estimations on LI countries do not provide us with significant results due to insufficient observations (Table V). However, if we test this with only country fixed effects, we observe that increases in the number of deaths are predicted to decrease emissions in this group of countries (Table A9).

TABLE V - DIRECT IMPACT OF COVID RELATED WEEKLY DEATHS ON NO2 EMISSIONS

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
New_deaths_per_million	-0.000	-0.000*	0.000**	-0,000
	(0.000)	(0.000)	(0.000)	
Observations	2,256	1,223	1,015	18
R-squared	.081	.124	.111	1.

Notes: OLS estimates with time and country fixed effects; robust standard errors in parentheses; constants term included but omitted.
*** p<.01, ** p<.05, * p<.1

We also estimated the impact of energy consumption on NO2 emissions, with country and time fixed effects, and observed that, with the dataset we have available, an increase in energy consumption is only (significantly) predicted to increase emissions in EM economies (Table A10). This is also true if we exclude time fixed effects (Table A11).

Our results given the limited data found are robust (see Table A12 for different estimators) but sensitive to time effects. However, Eurostat estimates show that in the year of the COVID-19 pandemic shock (2020), pollutant emissions significantly decreased by 10% compared to the previous year, in the EU. A similar decrease can be predicted for the remaining countries.

6 CONCLUSION AND IMPLICATIONS

The problem when discussing energy economics is indeed the excess of pollutant emissions. For that reason, it is important for governments to introduce greener policies and incentives to firms.

In this thesis we observed that pandemic shocks tend to lead to decreases in emissions, mostly in Advanced Economies. Our initial analysis of CO2 emissions in the two years prior to each pandemic shock (t-2 and t-1), in the year of (t) and in the two years following the shock (t+1 and t+2) showed us that in Low Income countries all previous pandemics were followed by increases in emissions; for emerging countries only Zika had the opposite effect (decrease in emissions); and in the advanced countries all but the SARS pandemic triggered decreases in emissions. Complying with this is our econometric analysis, which showed that the previous pandemic shocks are only predicted to decrease emissions with significance in the Advance Economies' group.

Our study on the impact of COVID-19 shows drops in NO2 emissions as the pandemic first appears and aggravates, in all groups of countries.

The mentioned declines in pollutant emissions are related to a series of policies introduced by governments to help fight the transmission of disease during pandemics and epidemics, especially during COVID-19.

There are some measures in current studies which stand out, that were summarized by Bricongne et al. (2021).

A more stringent and earlier lockdown, as data from the IMF (2020) suggests, is more efficient in containing the number of infections. In fact, Alvarez et al. conclude that it is optimal to implement a strict lockdown for only two weeks after the first Covid-19 cases. Still, this doesn't necessarily mean that future lockdowns won't be needed.

Some models have exhibited heterogeneous impacts of lockdowns depending on population density, age and workers category (Dave et al. 2021) and have advocated for targeted measures on senior citizens and employees whose job cannot be performed remotely.

Even though a comparison across measures is difficult in econometric terms, the cancellation of public activities and events appears to be the most adequate measure as it limits human contact and, as result, limits the transmission of disease (Deb et al. 2020). However, the temporary shutdown of schools and public transports may lead to higher costs than benefits. Meaning the benefits of said measures are not as large as the impact they have on the economy (Deb et al. 2020) – not to mention, the repercussion it may have on people's mental health.

Nonetheless, even in the absence of lockdown measures, the dissemination of viruses affects economic activity. This occurs as a result of voluntary social distancing (Firth et al., 2020).

The benefits of sanitary measures based on the generalized use of masks and mass testing have also been highlighted by studies such as Summers et al. (2020) and Shaw et al. (2020).

Finally, and as it is of most relevance due to our country's ongoing easing of measures imposed during COVID-19, one should be aware that this must been done slowly, if herd immunity (Toda, 2020) has not been reached.

The actions and economic incentives of governments post pandemic crises are likely to influence the global pollutant emissions path for decades. Therefore, policy makers should look at pandemics as opportunities to make big changes, especially when it respects the environment.

Undoubtedly, the biggest drawback in our analysis was the lack of up-to-date information on emissions, for which we only found data on until 2018.

The initial idea of this thesis was to compare the impact of the most recent pandemic – COVID-19 – on pollutant emissions with the five previous pandemics – SARS, H1N1, MERS, Ebola and Zika. And although we can predict its impact to be much larger based on the limited information obtained, we would need more data (perhaps in five years' time) to be able to fully analyse its impacts on the environment, economy and the transition into sustainable energy production it may trigger.

Therefore, an idea for future work would be to do this and study if COVID-9 led to a greater decrease in pollutant emissions and if that decrease was temporary or permanent – may this change occur from the investment and improvement of green technologies and/or changes in the consumption habits of the population.

There are also studies which conclude that, overall, financial crises lead to significant reductions in pollutant emissions (Stavytskyy et al., 2016; Jalles, 2019). Some authors claim this because the human activity with the biggest impact on the global environment is the use of energy, therefore a reduction in industrial activity brought forward by a financial crisis leads to a decline in the damage to the environment (Siddiqi, 2000). However, the study of the Global Financial Crisis in Spain developed by Sobrino and Monzon (2014) gives credit to the increase in energy efficiency rather than the decrease in energy usage, more specifically the increase in energy efficiency in transportation. Hence an interesting study would be to test whether there are non-linearities which depend on the status of the country, as there is a difference between a country which (only) faces a pandemic and a country which faces both a pandemic and a recession.

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8 APPENDICES

Table A1 - List of Pandemic and Epidemic Episodes considered in this thesis

Starting Year	Event Name	Affected Advanced Economies	Affected Emerging Market Economies	Affected Low Income Countries	Number of Countries
2003	SARS	AUS, CAN, CHE, DEU, ESP, FRA, GBR, HKG, IRL, ITA, KOR, NZL, SGP, SWE, USA	CHN, IDN, IND, MYS, PHL, ROU, RUS, THA, ZAF	MNG, VNM	26

2009	H1N1	AUS, AUT, BEL, CAN, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, IRL, ISL, ISR, ITA, JPN, KOR, LTU, LUX, LVA, MLT, NLD, NOR, NZL, PRI, PRT, SGP, SVK, SVN, SWE, USA	LB, ARG, ARM, BGR, BHS, BIH, BLR, BLZ, BRA, BRB, BWA, CHL, CHN, COL, CPV, CRI, SMA, DOM, DZA, ECU, EGY, FJI, FSM, GAB, GEO, GTM, HRV, HUN, IDN, IND, IRN, IRQ, JAM, JOR, KAZ, KNA, LBN, LCA, LKA, MDV, MEX, MKD, MNE, MUS, MYS, NAM, PAK, PAN, PER, PHL, PLW, POL, PRY, QAT, ROU, RUS, SAU, SLV, SWZ, SYC, THA, TON, TUN, TUR, TUV, UKR, URY, VEN, VUT, WSM, ZAF	AFG, BDI, BGD, BOL, BTN, CIV, CMR, COD, COG, DJI, ETH, GHA, HND, HTI, KEN, KHM, LAO, LSO, MDA, MDG, MLI, MNG, MOZ, MWI, NGA, NIC, NPL, PNG, RWA, SDN, SLB, STP, TCD, TJK, TZA, UGA, VNM, YEM, ZMB, ZWE	146
2012	MERS	AUT, DEU, FRA, GBR, GRC, ITA, KOR, NLD, USA	CHN, EGY, IRN, JOR, LBN, MYS, PHL, QAT, SAU, THA, TUN, TUR	YEM	22
2014	Ebola	ESP, GBR, ITA, USA		LBR	5
2016	Zika	CAN, PRI, USA	AGR, BRA, CHL, COL, CRI, DOM, ECU, LCA, PAN, PER, PRY, SLV, URY	BOL, HND	18
Total Pandemic and Epidemic Events					217

Source: based on Ma et al. (2020)

Table A2 - List of countries considered in the COVID-19 analysis

Starting Year	Event Name	Advanced Economies	Emerging Market Economies	Low Income Countries	Number of Countries
2020	COVID-19	AUS, AUT, CAN, CHE, CYP, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HKG, IRL, ISL, ITA, JPN, KOR, NLD, NZL, SVK, SWE, USA	ARE, BGR, BIH, BRA, CHL, CHN, COL, HRV, HUN, IND, IRN, JOR, MEX, PHL, POL, RUS, THA, ZAF	MNG, VNM	44

Source: based on Jalles et al. (2021)

Table A3 - Impact of pandemics on CO2 emissions.

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Pandemic_shock	-0.1**	-0.044	-0.017	-0.001
	(0.04)	(0.038)	(0.052)	(0.08)
Gdp_constantlcu_log	0.706***	0.473***	0.764***	0.89***
	(0.151)	(0.166)	(0.222)	(0.165)
Observations	6,109	1,236	2,948	1,925
R-squared	0.564	0.435	0.67	0.669

Notes: OLS panel estimates with time and country fixed effects; robust standard errors in parentheses; constant term included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

Table A4 - Impact of pandemics on CO2 emissions.

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Pandemic_shock	-0.066	-0.045	0.063	-0.034
	(0.047)	(0.038)	(0.055)	(0.135)
Green_elect_prod (% of total)	-0.01***	-0.007***	-0.013***	-0.005**
	(0.002)	(0.002)	(0.003)	(0.002)
Observations	4,399	1,175	2,155	1,069
R-squared	0.478	0.396	0.616	0.505

Notes: OLS panel estimates with time and country fixed effects; robust standard errors in parentheses; constants included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

Table A5 - Impact of pandemics on CO2 emissions.

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Pandemic_shock	-0.09**	-0.029	0.032	-0.068
	(0.045)	(0.035)	(0.05)	(0.135)
Green_elect_prod (% of total)	-0.01***	-0.007***	-0.01***	-0.008***
	(0.002)	(0.002)	(0.003)	(0.002)
Gdp_constantlcu_log	0.465***	0.466**	0.311**	0.884***
	(0.097)	(0.192)	(0.123)	(0.193)
Observations	4,255	1,168	2,048	1,039
R-squared	0.55	0.507	0.03	0.643

Notes: OLS panel estimates with time and country fixed effects; robust standard errors in parentheses; constants included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

Table A6 - Impact of pandemics on CO_2 emissions – with country fixed effects.

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Pandemic_shock	0.021	-0.036**	0.095***	0.007
	(0.02)	(0.013)	(0.032)	(0.039)
Green_elect_prod (% of total)	-0.012***	-0.007***	-0.012***	-0.012***
	(0.002)	(0.003)	(0.003)	(0.002)
Imports (% of GDP)	0.001	-0.003	0.003	0.005**
	(0.001)	(0.002)	(0.002)	(0.002)
Gdp_constantlcu_log	0.849***	0.544***	0.847***	1.4***
	(0.071)	(0.11)	(0.096)	(0.172)
Observations	4,042	1,168	1,968	906
R-squared	0.465	0.442	0.525	0.530

Notes: OLS panel estimates with country fixed effects; robust standard errors in parentheses; constant term included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

Table A7 - Impact of pandemics on CO_2 emissions in the European Union and in Latin America and Caribbean.

Regressors	(1)	(2)	(3)
Country group	All	European Union	Latin America and Caribbean
Pandemic_shock	-0.079*	0.034	-0.034
	(0.044)	(0.045)	(0.028)
Green_elect_prod (% of total)	-0.011***	-0.008***	-0.008***
	(0.002)	(0.003)	(0.002)
Imports (% of GDP)	-0.001	-0.001	0.004
	(0.001)	(0.003)	(0.003)
Gdp_constantlcu_log	0.468***	0.216	0.418**
	(0.085)	(0.247)	(0.153)
Observations	4,042	709	670
R-squared	0.563	0.373	0.838

Notes: OLS estimates with time and country fixed effects; robust standard errors in parentheses; constant term included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

Table A8 - Alternative estimators, all countries - with time fixed effects.

Regressors	(1)	(2)	(3)	(4)
Estimator	OLS	Between Effects	GLS Random Effects	ML Random Effects
Pandemic_shock	-0.079*	39.301***	-0.074**	-0.079**
	(0.044)	(5.08)	(0.037)	(0.036)
Green_elec_prod (% of total)	-0.011***	-0.018***	-0.011***	-0.011***
	(0.002)	(0.004)	(0.000)	(0.000)
Imports (% of GDP)	-0.001	-0.027***	-0.001***	-0.001***
	(0.001)	(0.006)	(0.000)	(0.000)
Gdp_constantlcu_log	0.468***	0.021	0.394***	0.432***
	(0.085)	(0.058)	(0.021)	(0.022)
Observations	4,042	4,042	4,042	4,042
R-squared	0.563	0.000	0.563	

Notes: Estimates with time fixed effects; robust standard errors in parentheses; constant term included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1

Table A9 - Direct impact of covid related weekly deaths on NO2 emissions - with country fixed effects.

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
New_deaths_per_million	-0.000	-0.000	0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	2,256	1,223	1,015	18
R-squared	.000	.004	.004	.000

Notes: OLS estimates with country fixed effects; standard errors in parentheses; constant term included but omitted..*** p<.01, ** p<.05, * p<.1

Table A10 - Direct impact of energy consumption on NO2 emissions.

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Energy	0.000	-0.000	0.000	insufficient
	(0.000)	(0.000)	(0.000)*	observations
Observations	1,311	966	345	
R-squared	0.11	0.144	0.2	

Notes: OLS estimates with country and time fixed effects; robust standard errors in parentheses; constant term included but omitted.
*** p<.01, ** p<.05, * p<.1

Table A11 - Direct impact of energy consumption on NO2 emissions – with country fixed effects.

Regressors	(1)	(2)	(3)	(4)
Country group	All	Advanced Economies	Emerging Market Economies	Low Income Economies
Energy	0.000	0.000	0.000**	Insufficient
	(0.000)	(0.000)	(0.000)	observations
Observations	1,311	966	345	
R-squared	0.001	0.001	0.011	

Notes: OLS estimates with country fixed effects; robust standard errors in parentheses; constant term included but omitted.
*** p<.01, ** p<.05, * p<.1

Table A12 - Impact of covid related weekly deaths on NO2 emissions – Alternative estimators, all countries.

Regressors	(1)	(2)	(3)
Estimator	OLS	GLS Random Effects	ML Random Effects
New_deaths_per_million	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Observations	2,256	2,256	2,256
R-squared	0.081	0.081	

Notes: Estimates with time and country fixed effects; robust standard errors in parentheses; constant term included but omitted; with control variables.
*** p<.01, ** p<.05, * p<.1