CLIMATE-CHANGE PLEDGES, ACTIONS, AND OUTCOMES

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Abstract
We study countries' compliance with the targets pledged in international climate-change agreements and the impact of those agreements and specific climate laws and policies on greenhouse-gas emissions and economic outcomes. To do so, we compile and codify data on international agreements and measures enacted at the national and sub-national levels. We find that compliance with targets has been mixed. Still, countries that signed the Kyoto Protocol or the Copenhagen Accord experienced significant reductions in emissions when compared to non-signatories. Having quantifiable targets led to further reductions. Effects from the Paris Agreement are not yet evident in the data. Carbon taxes and the introduction of emission-trading schemes led to material reductions in emissions. Other climate laws or policies do not appear to have had, individually, a material effect on emissions. The impact on GDP growth or inflation from most measures was largely insignificant. Overall, much more ambitious targets would be needed to offset the impact of economic and population growth on emissions and contain the expansion of the stock of gases. (JEL: Q54, O44)

1. Introduction

Greenhouse-gas (GHG) emissions since the Industrial Revolution have caused material changes to our environment. The cumulative flow of emissions has altered the stock of gases in the atmosphere and is thought to be the most likely cause of global warming and extreme-weather events. As such, GHG emissions are increasingly becoming one of the biggest threats to lives and livelihoods. In response to this escalating problem,

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three international treaties have been signed, with the overarching aim of reducing emissions: the Kyoto Protocol, the Copenhagen Accord, and the Paris Agreement. The pledges made by countries in each of the international treaties differ in the coverage, timelines, and targets set by the various signatories. Moreover, in working towards their targets, countries resorted to different policies and laws over time.

This paper seeks to study the targets pledged by different countries in each of the international agreements, to quantitatively assess countries' compliance with their stated targets, and to gauge the impact on GHG emissions of each of the agreements, as well as the specific policies and laws enacted over time. The paper also explores the indirect impact on economic outputs stemming from these actions.

To do so, the paper combines and codifies historical sectoral- and country-level data on emissions and activity, along with information on individual countries' stated goals in each of the treaties, and climate-action laws and policies enacted over time. We use the data in three sets of exercises. In the first set of exercises, we compute comparable individual countries' targets pledged in each of the international agreements and compare those targets with countries' actual emission reductions over time. In the second set of exercises, we study the impact on emissions stemming from signing each of the three climate-change agreements, from stating quantifiable targets, and from implementing specific climate-related measures, including carbon taxes and emission-trading schemes (ETSs). To help mitigate estimation biases arising from the potential endogeneity of the various interventions, we use propensity matching estimators in the form of inverse probability weighted (IPW) regressions. In addition, to study the dynamic effects of the various climate agreements and measures and to allow for a possible two-way feedback from emissions, we use local projection methods (Jordá 2005) augmented with IPW (Jordá and Taylor 2016 and Angrist et al. 2018).[1] Finally, in a third set of exercises we seek to gauge the indirect effects from the various interventions; specifically, we extend the IPW augmented local projection analysis to investigate the dynamic responses of GDP growth and inflation to the different agreements and specific climate-change measures.

To set the stage, the paper starts by documenting the evolution of total and per capita emissions across different countries since the 1970s, underscoring their main covariates. The trends in emissions are tightly associated with activity and population growth. In absolute levels, the top emitters since the 1970s have been China, the United States, Russia, Japan, Germany and Canada, with Saudi Arabia, South Korea, India, and Iran joining more recently to the list. Among these top emitters, six are also in the top-ten list of oil-producing nations. Other oil-producing countries also record very high per capita emissions, but they make smaller contributions to total emissions.[2]

1. The two empirical strategies, IPW regressions and IPW local projections, complement each other and lead to comparable results: The first provides the "static" or steady-state effects, while the second helps characterize the timing and trajectory of the effects.

2. The emissions measure we used (and on which the agreements are based) corresponds to territorial emissions, that is, those produced within a country's geographical borders, as opposed to consumption

We find that compliance with emission-reduction targets has been mixed, with several countries undershooting their targets.[3] Nevertheless, signing the Kyoto Protocol or the Copenhagen Accord has led to significant reductions in emissions, when compared to the (control) group of countries that did not sign the agreements. In contrast, signing the Paris Agreement does not appear to have led (yet) to any significant reduction in emissions.[4] Moreover, having quantifiable targets helped further in reducing emissions. Of all climate-related measures enacted, two stand out as having a material impact on emission reductions: carbon taxes and the introduction of ETSs. A few other specific climate-related laws or policies, as well as the total number of climate-related laws enacted, appear to have statistically significant but quantitatively small effects on emissions. The estimated effects on GDP growth and inflation from these measures are largely insignificant.

Overall, it is clear that much more ambitious targets and stricter compliance would be needed to offset the large impact of economic and population growth on the flow of emissions and contain a further expansion in the stock of GHGs.

The findings that signing an agreement and having quantifiable targets matter have an interesting parallel in the micro-evidence presented by Ramadorai and Zeni (2020); using data from a sample of North American public firms, the authors find that firms that consistently report plans for future emission reduction and abatement exhibit more consistent reductions in emissions than firms that do not. (They also provide evidence that the announcement of the Paris Agreement had a significant impact on carbon abatement activities among these firms; in contrast, we do not see an effect from the Paris Agreement in the aggregate data.)

The importance of carbon taxes in reducing emissions over time and across countries is consistent with recent work by Metcalf (2019); using data on Canadian provinces over the 1990–2016 time period, he finds evidence of a significant negative impact of the British Columbia carbon tax on emissions.[5] Our findings on carbon taxes support the conclusions from Hassler, Krusell, and Nycander (2016) emphasizing the quantitative importance of carbon taxes for reducing emissions; using a quantitative model, the authors argue that while the optimal carbon tax is relatively modest, carbon taxes are more effective than alternative policies such as quantity-based systems or subsidies to green technology.[6]

emissions embodied in the goods and services consumed by the residents of the country. Hence, the relevance of oil production as determinant.

3. Relatively few countries overshot their targets, and those who overshot tended to have less ambitious targets to start with.

4. As we discuss later, it might still be too early to see the effects from the Paris Agreement, given that our sample finishes in 2018.

5. See Metcalf (2019) for a survey of the literature on emission reduction impacts of carbon taxes.

6. Hassler, Krusell, Olovsson, and Reiter (2020) take the argument further using a quantitative integrated assessment model to show that carbon taxes that are based on overly pessimistic views on the climate challenge (i.e. higher carbon taxes) are less costly to welfare than taxes based on overly optimistic views on climate change.

The finding of negligible effects of carbon taxes on GDP growth is consistent with the results documented by Metcalf and Stock (2020), who estimate a zero to modest positive impact on GDP growth rates, focusing on a sample of European countries. Importantly, they find no robust evidence of a negative effect of the tax on either employment or GDP growth. The significant effect of carbon taxes on emissions in our paper is also in line with their study. Our results on the impact of carbon taxes and ETSs are also consistent with evidence by Kanzig (2021), who uses high-frequency data on changes in carbon futures prices in the European carbon market to estimate the effects of carbon pricing shocks on emissions and economic activity. The author finds that while carbon pricing is successful at reducing emissions, it has less persistent effects on real GDP.

The paper is organized as follows. The next section describes the data used in the various exercises and discusses the trends in emissions over the 1970–2018 period. Section 3 provides a characterization of the three international climate-change agreements, computes country-specific targets pledged in each of the agreements, and contrasts the targeted emissions pledged with actual emissions. It also provides a description of specific climate-change-related laws and policies adopted by different countries. Section 4 studies the impact of climate-related pledges, laws and policies on emissions as well as their effect on other economic variables. Section 5 offers concluding remarks.

2. Data

Our study compiles and codifies data from a number of different sources. This section describes the data sources for each of the variables used in the analysis and outlines the trends in emissions across regions and countries from 1970 to 2018.

2.1. Emissions

We use historical emission data from two sources. The first is the Climate Analysis Indicators Tool (CAIT) Climate Data Explorer compiled by the World Resources Institute (2017). We use this series in Section 3 to construct the targets pledged by each country in each of the international agreements. The original dataset records historical GHG emissions (which include carbon dioxide, methane, nitrous oxide, and fluoridated gases) for 196 countries, by sector, for eleven sectors (including energy, transportation, agriculture, industrial processes, land use changes, waste, etc.) from 1850 to 2014. As we explain in more details in Section 3, we combine this data with the pledges made by countries in each of the international agreements. Given that emission-reduction pledges are often sector-specific (i.e. they state a targeted reduction in emissions for a specific sector), we use the data from this source to compute the implied reduction in emissions in millions of metric tons of carbon dioxide equivalent ($MTCO_2$ eq.) from the starting year of each pledge. This allowed us to have aggregate comparable targeted emission reductions across time and countries. Since the stated targets also differ across countries in terms of benchmark years (vis-à-vis which emission reductions are pledged), we make the targets comparable by computing the pledged reductions in terms of the emission levels in the starting year of each pledge. Because this dataset ends in 2014, we used the sectoral emissions in 2014 as the benchmark year for the Paris Pledge.

The second source of data on emissions, which we use both to assess compliance against the targets and in our regression analysis, come from the Emission Database for Global Atmospheric Research (EDGAR) compiled by Crippa et al. (2019). This database contains records of fossil CO_2 emissions from 212 countries over the 1970 through 2018 period.[7]

While EDGAR reports data on both GHG emissions and fossil CO_2 emissions, our regressions focus on the latter, as the series of GHG emissions ends in 2015, whereas fossil CO_2 runs until 2018. We show in the next section that both series are highly correlated since fossil CO_2 emissions are the main component of GHG emissions. As explained in detail in Crippa et al. (2019), the series are computed using energy-balance statistics from the International Energy Agency (IEA), which are based on country-specific sectoral activity and technology-mix data, combined with information on fuel consumption. For more information, we refer interested readers to Crippa et al. (2019).

2.2. Climate-Change Agreements

Information on climate-change agreements and climate-change pledges are obtained from the official documentation of the United Nations Framework Convention on Climate Change (UNFCCC 2008, 2010, and 2011), as well as processed information on the Copenhagen Accord and the Paris Agreement from the CAIT Climate Data Explorer database (World Resources Institute 2015 and 2016). In order to quantify the emission-reduction pledges in a way that they are comparable across countries, we augment this information using estimated emissions under business-as-usual (BAU) scenarios from the World Resources Institute's CAIT 2.0 (2015) and Fenhann's Pledge Pipeline (2019). We complement this with information from the World Resources Institute (2018) and Climate Analytics and New Climate Institute (2020). This is necessary to compute targets for countries whose pledges are expressed in terms of BAU scenarios.

Given that the target for European Union (EU) countries is reported collectively for the union in these agreements, in order to calculate country-specific targets for EU countries, we use information from European Commission (2020) and European Union (2020) regulations that specify the distribution of emission-reduction targets for each country within the EU.

7. While this dataset also reports GHG emissions by sector, the level of disaggregation is lower than in the CAIT database, with five sectors as opposed to eleven, which makes it somewhat less accurate for the computation of targeted emission reductions, hence our choice to use the CAIT sectoral data to compute targets.

2.3. *Climate-Related Laws and Policies*

Data on climate-related laws and policies were taken from the Grantham Research Institute's Climate Change Laws of the World Database (2020). This database includes information on climate-related laws and policies that are currently in implementation for 198 countries. The data include the starting date and keywords for each law or policy. This database is supplemented with information on carbon price initiatives (carbon taxes and ETS) obtained from the World Bank's Carbon Pricing Dashboard (2020a). This dataset lists carbon taxes and ETS, together with their start date, jurisdiction and coverage.

2.4. *Other Variables*

We obtain background data on real Gross Domestic Product (GDP), expressed in constant 2010 US dollar, GDP growth rates, total and urban population, inflation rates, and oil rents as a percentage of GDP from the World Bank's World Development Indicators database (2020b).

2.5. *Trends in Emissions*

To set the stage for our analysis, we start by describing the underlying trends in emissions over the period we analyse. Both total GHG emissions and fossil CO_2 emissions have more than doubled over the 1970–2015(18) period.[8,9] Countries' per capita emissions show a different trend, with visible declines over the 1980s and 1990s followed by a rapid increase from 2000 onward (see Figure 1). Since the time series on GHG emissions ends in 2015, for the remainder of the analysis, we use the series on fossil CO_2 emissions, which goes on to 2018. Historically, both series show a very high correlation, not least because fossil CO_2 is the main component of GHG emissions.

The total volume of emissions by region, plotted in Figure 2, indicates that the rise in total emissions over the past two decades has been driven by higher emissions from the Asia-Pacific region, primarily China. Emissions from North America and Europe, which were the largest emitting regions until the 1990s, appear to have stabilized in the following decade and a half, and are gradually declining, albeit from high levels. Emissions from the remaining regions have been increasing, particularly in the South Asian region, led most notably by India. Sub-Saharan Africa remains the region with the lowest total emissions. Interestingly, emissions from the Middle East (the largest oil-producing region in the world) remain at a lower level than in the West or East Asia.

8. Fossil CO_2 emissions include sources from fossil fuel use (combustion, flaring), industrial processes (cement, steel, chemicals, and urea), and product use. GHG emissions comprise fossil CO_2, CH_4, N_2O, and F-gases.

9. The latest year for which data on GHG emissions are available is 2015, and the latest year for fossil CO_2 emissions is 2018.

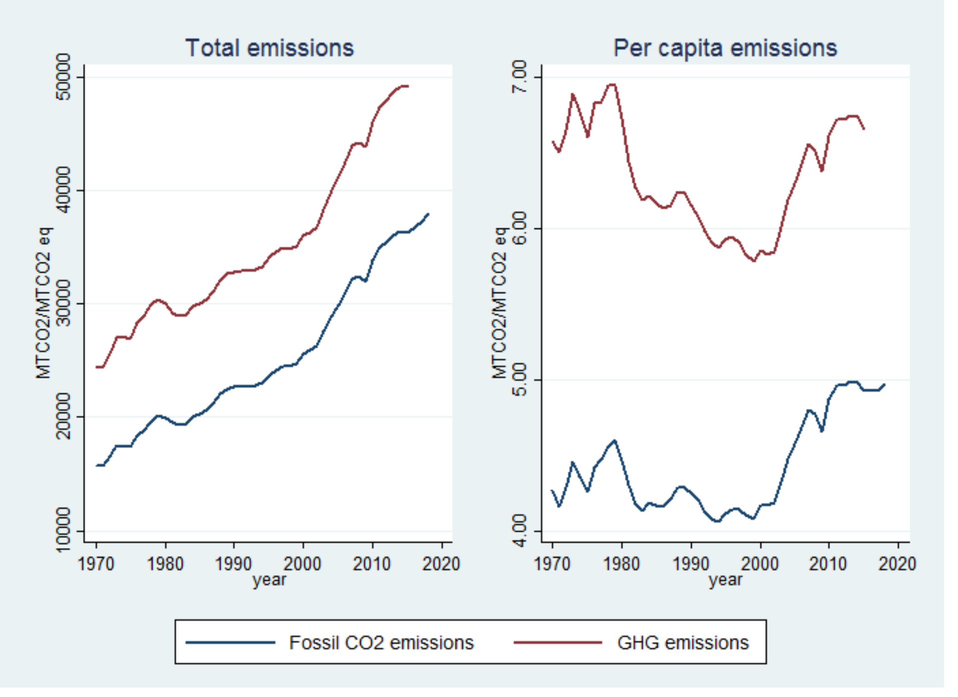


FIGURE 1. Trends in total and per capita emissions. The figures plot the trends in global fossil CO_2 emission and GHG emissions in total and per capita terms. Data on emissions are from EDGAR.

Per capita emissions, however, remain highest by far in North America, followed by Europe and Central Asia. These regions show a gradual decline since the 2000s. In contrast, East Asia and the Middle East seem to be converging upwards to the European level.

In order to identify the main contributors to fossil CO_2 emissions, we examine total and per capita emissions by country. Figure 3 plots per capita emissions against total emissions. The plot identifies a few countries that record high emissions on both total and per capita dimensions. Country codes are displayed for the countries in the top 10% of per capita emissions or total emissions in the respective year.

By and large, it is the same set of countries that appear in both 1970 and 2018. India and China are outliers in that they show relatively low per capita emissions but high total emissions. The United States records higher per capita emissions than either of these countries, being the largest emitter of fossil CO_2 in 1970 and the second highest in 2018. As Figure 4 shows, most high-income countries record higher emissions, though the relationship with income is more strongly positive for per capita emissions. The clustering of points indicates that countries within Europe, North America, and Latin America are more homogeneous in terms of per capita income and emissions

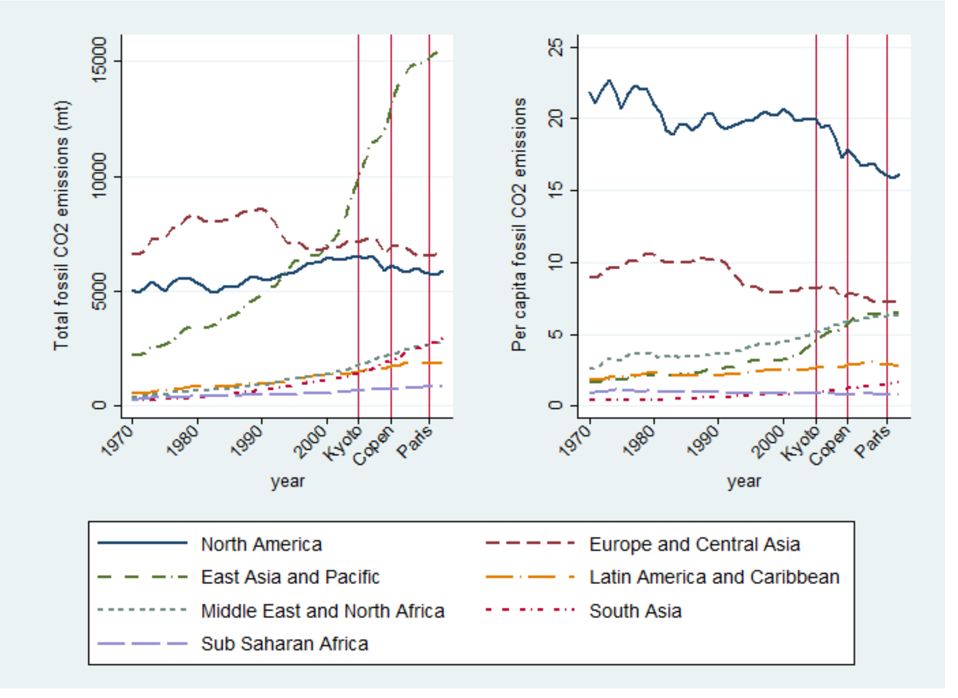


FIGURE 2. Trends in total and per capita emissions by region. The figures plot the trends in fossil CO_2 emissions in total and per capita terms by region, as defined by the World Bank. The vertical lines indicate the year of signing of the Kyoto, Copenhagen, and Paris Agreements. Data on emissions are from EDGAR.

than countries in East and South Asia, Sub-Saharan Africa, Middle East, and North Africa.

Based on the countries identified as having the highest total emissions in 2018, we now examine the trends in the top-ten countries in terms of total emissions. These ten countries account for more than two-thirds (67.3%) of total emissions in 2018. Among them, the United States, Canada, Russia, and China were also among the top-ten oil-producing countries in 2018; they were already among the top-ten emitters in 1970, which compounds their contribution to cumulative GHG emissions. Iran and Saudi Arabia, in turn, rank among the top-ten emitting countries in 2018 as well as among the top-ten oil-producing nations.

Figure 5 shows that total emissions have grown very rapidly in most of these countries over the past five decades (note that the graph shows trends in the log of emissions), with particularly rapid growth in China, India, Iran, South Korea, and Saudi Arabia. Total emissions in the remaining countries, notably the United States, Russia, Japan, and Canada have remained stable at very high levels. The only country in which total emissions have declined, albeit from a high starting position, is Germany. In terms of per capita emissions, the biggest emitters are Saudi Arabia, the United States, and Canada, though per capita emissions have decreased slightly in Canada and the United

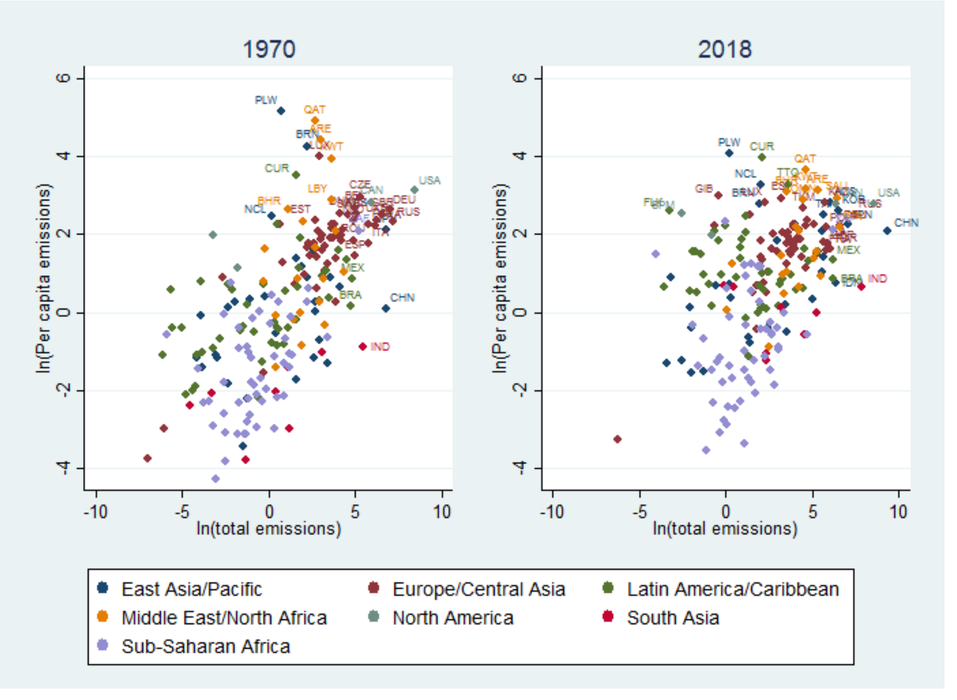


FIGURE 3. Total and per capita emissions by country in 1970 and 2018. The figures plot total emissions against per capita emissions (in logs) for 1970 and 2018. Data on emissions are from EDGAR.

States over the past decade. Steep increases in per capita emissions are observed in India, China, Iran, and South Korea.

Table 1 provides a numerical summary of the results illustrated in the previous graphs.

There is clearly an important sectoral dimension to emissions. The main contributing sector to both GHG and fossil CO_2 emissions is the power and energy sector, according to the data for both fossil CO_2 emissions for 2018 and GHG emissions for 2014. Table 2 provides the sectoral decomposition for fossil CO_2 emissions in 2018 for the top emitters in Table 1.

3. Climate Agreements and Actions

This section provides an overview of the emission reduction pledges, how we construct comparable targets across countries for the pledges made under three international agreements, and the progress made in terms of achieving these targets. After discussing the three pledges, we move to specific climate-change–related laws and policies adopted around the world.

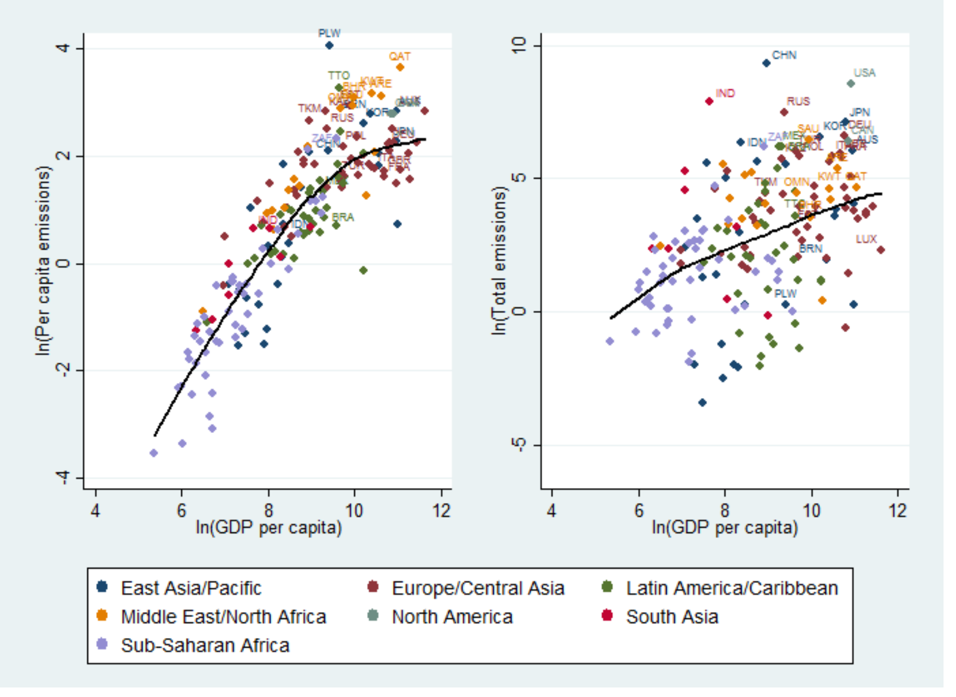


FIGURE 4. Emissions and GDP per capita relationship in 2018. The figures show the scatterplots and fitted line (i.e. the lowess smoothed relationship) between total and per capita emissions and per capita GDP for 2018. All variables are converted to logs. Data on emissions are from EDGAR, and data on per capita GDP is from the World Development Indicators database.

3.1. Emission Pledges

The first international agreement signed was the Kyoto Protocol, which was accorded in 1997 but came into force in 2005, with the round ending in 2012. The second was the Copenhagen Accord, which came into effect in December 2009 with targets for 2020. The third treaty was the Paris Agreement, which entered into force in November 2016 with targets for 2030.[10]

3.1.1. Comparable Targets. To compute comparable targets across countries, we examine the emission reduction targets declared by each country. Among the countries that are party to each pledge, we start with the set of countries that have specified a numerical target for emission reduction. Different countries have different baseline years against which reductions in emissions are benchmarked. To facilitate comparability across countries, we use these quantified targets to compute the targeted

10. The Doha Amendment to the Kyoto Protocol was adopted for a second commitment period from 2013 to 2020, but it has not yet entered into force.

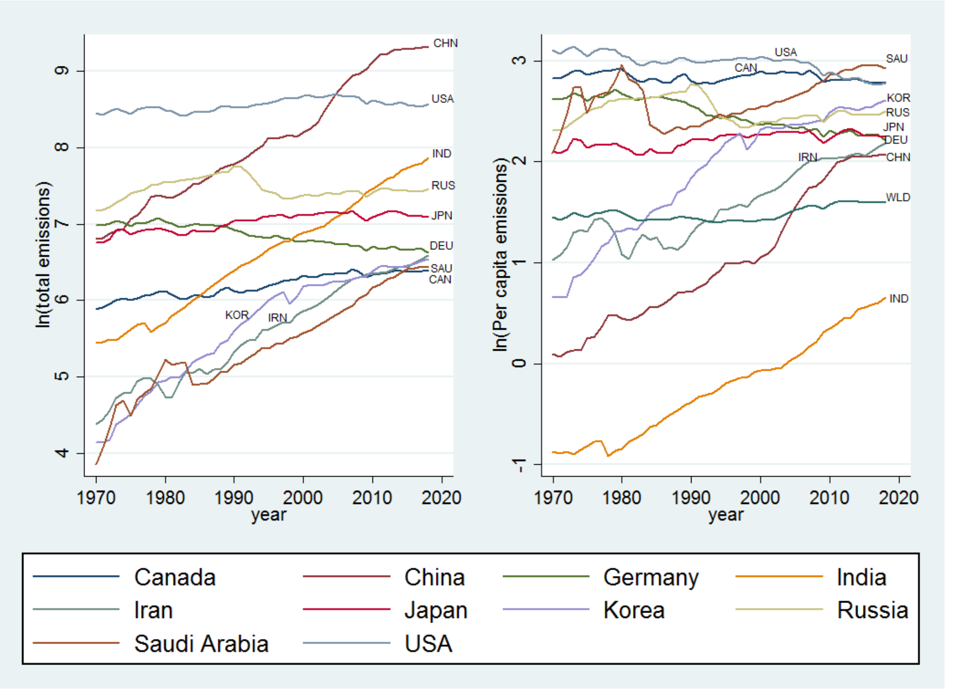


FIGURE 5. Trends in emissions among top-ten emitters. The figures plot the trends in total and per capita emissions (in logs) for the ten countries with the highest levels of total emissions in 2018. Data on emissions are from EDGAR.

emissions reductions (in $MTCO_2$ eq.) relative to the level of emissions in the starting year of the pledge for all countries; this allows us to compare the magnitudes of the targets on a given pledge across the various countries. Some countries specify their targets relative to a particular sector rather than total emissions (e.g. emission reductions in the energy sector alone) or based on their activity projections; again, for comparability, we translate these emission targets (based on sectors or projections) into reductions relative to the aggregate level of emissions in the starting year of the pledge. To do so, we need information on baseline emission levels, in some cases for specific sectors (e.g. energy), as well as BAU scenario emission projections for future years. For a few countries that specify targets in terms of carbon intensity of their GDP, we also need GDP projections. Using publicly available information from several sources (as described in Section 2), we compute comparable targets for the majority of countries making quantified target reduction pledges. For many countries setting their pledges based on reductions from future BAU scenarios, the targeted emission level by the end year of the pledge is actually higher than that recorded in the start year.

As the explanation above suggests, the computation of comparable targets across countries varied widely in terms of complexity. We can further illustrate this using some examples of pledges made under the Paris Agreement. First, consider the Canadian

TABLE 1. Fossil CO_2 emissions by region and top emitting countries.

Country/region	Per capita emissions 1970	Per capita emissions 2018		Total emissions 1970	Total emissions 2018		Share of world's emissions 1970 (%)	Share of world's emissions 2018 (%)	
World	4.27	4.97	⇑	15775.86	37887.22	⇑			
East Asia and Pacific	1.47	6.58	⇑	2160.05	15340.13	⇑	13.69	40.49	⇑
EU27+UK	9.51	6.78	⇓	4198.20	3457.29	⇓	26.61	9.13	⇓
Europe and Central Asia	8.39	7.28	⇓	6585.20	6649.63	⇑	41.74	17.55	⇓
Latin America and Caribbean	1.78	2.80	⇑	526.30	1830.03	⇑	3.34	4.83	⇑
Middle East and North Africa	5.43	6.34	⇑	356.70	2813.35	⇑	2.26	7.43	⇑
North America	21.81	16.14	⇓	5050.28	5870.12	⇑	32.01	15.49	⇓
South Asia	0.37	1.63	⇑	261.43	2958.00	⇑	1.66	7.81	⇑
Sub-Saharan Africa	0.73	0.80	⇑	270.75	860.82	⇑	1.72	2.27	⇑
International shipping and aviation				565.14	1565.15	⇑	3.58	4.13	⇑
World's top emitters and oil producers									
China	1.10	7.95	⇑	905.87	11255.88	⇑	5.74	29.71	⇑
United States	22.37	16.14	⇓	4688.52	5275.48	⇑	29.72	13.92	⇓
India	0.42	1.94	⇑	232.12	2621.92	⇑	1.47	6.92	⇑
Russia	10.10	12.14	⇑	1314.17	1748.35	⇑	8.33	4.61	⇓
Japan	8.18	9.42	⇑	857.80	1198.55	⇑	5.44	3.16	⇓
Germany	13.77	9.15	⇓	1082.02	752.65	⇓	6.86	1.99	⇓
Iran	2.79	8.87	⇑	79.47	727.81	⇑	0.50	1.92	⇑
South Korea	1.94	13.59	⇑	62.58	695.36	⇑	0.40	1.84	⇑
Saudi Arabia	8.06	18.63	⇑	47.02	624.99	⇑	0.30	1.65	⇑
Canada	16.86	16.08	⇓	361.59	594.20	⇑	2.29	1.57	⇓
Brazil	1.16	2.37	⇑	110.16	500.09	⇑	0.70	1.32	⇑
UAE	82.54	22.44	⇓	19.44	214.11	⇑	0.12	0.57	⇑
Iraq	2.34	4.78	⇑	23.19	188.10	⇑	0.15	0.50	⇑
Kuwait	51.34	23.91	⇓	38.34	100.34	⇑	0.24	0.26	⇑

Notes. The table reports total and per capita fossil CO_2 emissions (in $MTCO_2$ eq.) and contribution to global emissions for 1970 and 2018 by region as well as for the countries accounting for highest emissions and oil production. Data on emissions come from EDGAR.

TABLE 2. Sectoral contributions to emissions by top emitters.

Country	Power industry	Transport	Buildings	Other industrial combustion	Other sectors
Brazil	13.81%	40.49%	7.48%	22.27%	15.94%
Canada	14.99%	29.61%	15.93%	32.87%	6.60%
China	40.74%	8.37%	6.92%	27.00%	16.97%
Germany	38.41%	20.76%	18.15%	14.66%	8.03%
India	46.26%	11.03%	7.43%	25.63%	9.65%
Iran	23.82%	19.13%	22.67%	20.57%	13.81%
Iraq	50.72%	14.20%	5.71%	12.74%	16.63%
Japan	46.35%	16.46%	9.52%	20.20%	7.48%
Kuwait	39.81%	12.56%	0.65%	32.28%	14.70%
Russia	46.37%	14.02%	10.28%	15.10%	14.23%
Saudi Arabia	39.52%	20.77%	0.75%	21.98%	16.98%
South Korea	48.72%	14.39%	9.33%	19.08%	8.49%
United Arab Emirates	42.03%	15.62%	0.35%	30.42%	11.57%
United States	35.23%	34.54%	11.39%	13.86%	4.98%
World	36.59%	21.50%	9.29%	20.85%	11.76%

Notes. The table reports sectoral contributions to fossil CO_2 emissions for 2018 among the countries accounting for highest emissions and oil production. Data on fossil CO_2 emissions come from EDGAR.

pledge of a 30% reduction in emissions from 2005 levels by 2030. Computing a comparable target for this pledge required only data on emissions for Canada in 2005 and emissions in the starting year of the pledge, making it a relatively easy target to quantify. The targets for individual EU countries were slightly more involved—even though the EU made a collective pledge of a 40% reduction from 1990 levels, the targeted reductions were distributed unevenly amongst member countries so that this additional layer of information was required to compute individual country targets. China pledged to reduce CO_2 emissions per unit of GDP to below 60%–65% of the 2005 level by 2030, so computing the comparable target required data on emissions and GDP in 2005, projected GDP for 2030, and emissions in the start year. The most difficult pledges to quantify were those that specified reductions for specific sub-sectors under a BAU scenario. For example, Trinidad and Tobago pledged a 30% reduction in emissions in the transportation sector from the BAU scenario for 2030. This meant we needed data on projected BAU emissions for the transport sector for 2030, and total and transport sector emissions for the start year of the pledge.

Table 3 summarizes the main aspects of the pledges made under the three agreements. The full set of computed target reductions by country is given in Online Appendix A.

The quantification of total emission reductions from the year in which the agreement was signed provides a measure of how ambitious (or not) targets were at the time at which they were set. While the targets established in the Kyoto Protocol are the most straightforward to compute, it appears that when compared to emission levels in 2005 (the year in which the Protocol came into effect), the targets allow an

TABLE 3. Summary of targeted emission reductions.

	Kyoto	Kyoto (without Russia)	Copenhagen	Paris
Number of signatories proposing targets or NAMAs (excluding EU28 in total)	37	36	100	188
Start year considered	2005	2005	2010	2014[a]
Countries with quantified emission reduction targets	37	36	59	151
Countries with quantifiable objectives	30[b]	29	54[c]	117[d]
Contribution to world GHG emissions by signatories with quantifiable objectives in starting year (%)	22.95	17.73	75.48	83.39
Contribution to world GHG emissions by all signatories	24.44	19.22	81.93	98.85
Total emissions by signatories with quantifiable objectives in start year	9442.768	7295.786	33418.17	39474.53
Targeted reduction from starting year (conditional)	−679.83	400.4885	3397.412	5402.837
Targeted reduction from starting year (unconditional)	−679.83	400.4885	1427.219	2839.568
Targeted % reduction from starting year (conditional)	−7.2	5.49	10.17	13.69
Targeted % reduction from starting year (unconditional)	−7.2	5.49	4.27	7.19

Notes. a. To calculate the targeted reduction in emissions from the start date of the pledge, we need sector specific emissions data for the baseline year as well as for the starting year. The year 2014 is taken as the starting year for the Paris Agreement because this is the last year for which sector specific GHG emissions data are available.

b. No data for emissions pre-1990 for five Eastern European countries and no total emissions data for Liechtenstein and Monaco for 1990.

c. No total emissions data for Liechtenstein and Monaco for 1990. BAU estimates missing for the rest.

d. Emissions target expressed in carbon intensity of GDP for Chile, Malaysia, and Singapore—GDP projections are also necessary for computing targeted emissions. No total emissions data for Liechtenstein and Monaco for 1990. BAU estimates missing for the rest. Targeted reduction in emissions is computed as the difference between targeted emissions and starting emissions in the sectors covered by the pledge.

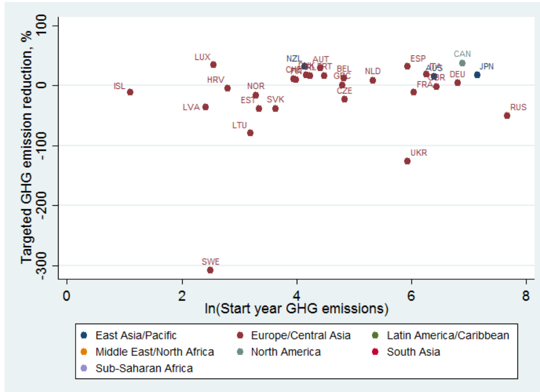
overall increase in emissions. This in large part owes to the extremely high emissions in Russia in 1990, which is the baseline year from which emission reductions are computed.[11] Indeed, excluding Russia, the total targeted emissions involve a reduction of 400 $MTCO_2$ eq., which is a 5.5% reduction in emissions from 2005.

The targets set in the Copenhagen and Paris Agreements appear more ambitious overall in terms of the targeted reduction in emissions from the starting year of the agreement. This is true for both absolute and relative reductions, though comparisons between pledges are not as straightforward given that the implementation timelines became longer in Copenhagen and Paris. Moreover, unlike the Kyoto Protocol in which the targets were fixed and unconditional, the two latter agreements allow countries to specify both unconditional targets as well as targets that are conditional on assistance and action from other, generally developed, countries. There is considerable variation between the unconditional and conditional targeted reductions, with the total unconditional target amounting to less than half of the total conditional target under the Copenhagen Accord and just over a half in the Paris Agreement. Figures 6(a)–(c) plot the targeted unconditional emission reductions as a percentage of the total GHG emissions in the starting year against total GHG emissions in the starting year. Countries without quantifiable targets are excluded. The figures show significant dispersion in the pledges made by different countries across the three treaties, spanning a wide quantitative range from large targeted reductions to large targeted increases in emissions.

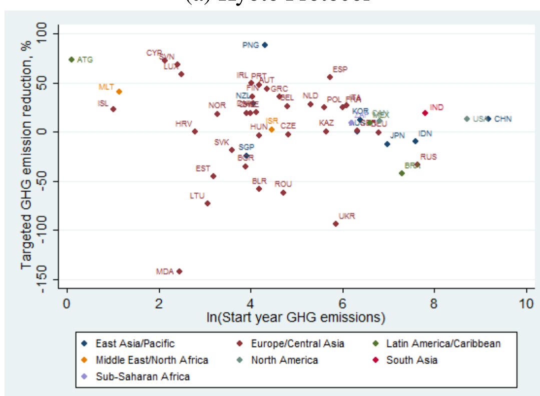
3.1.2. Target Achievements. Given that the commitment periods under the Kyoto Protocol and the Copenhagen Accord have come to an end, we are in a good position to examine how well countries adhered to their emission-reduction targets. We start by examining emission reductions in signatory and non-signatory countries. For the Kyoto Protocol, we compute the decrease in GHG emissions from 2005 to 2012 as a percentage of the 2005 emissions level. Given that we only have data running till 2018, for the Copenhagen Accord, we use fossil CO_2 emissions to assess the progress that has been made so far under this agreement and compute the decrease in fossil CO_2 emissions from the starting year of 2010 to 2018 as a percentage of the 2010 emissions level. Table 4 presents some summary statistics of observed emission reductions weighted by start year emissions levels. Note that a positive value indicates a reduction in emissions, whereas a negative value indicates an increase.

Table 4 shows that GHG emissions increased, on average, among non-signatories of the Kyoto Protocol over the commitment period of 2005–2012, while emissions fell among signatories. The Copenhagen Accord appears to have been less effective by comparison, with fossil CO_2 emissions increasing, on average, among both signatory and non-signatory countries though the increase is significantly smaller among the signatories to the pledge. While these numbers provide a crude indication of the effect

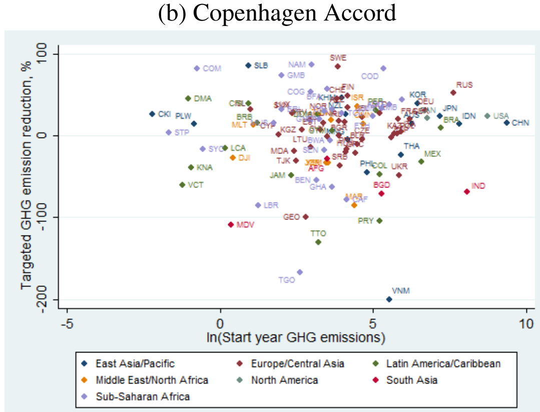
11. The Kyoto Protocol allowed Russia to increase emissions substantially relative to its 2005 levels.



(a) Kyoto Protocol



(b) Copenhagen Accord



(c) Paris Agreement

FIGURE 6. Targeted reductions and total emissions. The figures plot the targeted unconditional reduction in emissions as a percentage of the emissions in the starting year against the log of start year emissions for the Kyoto, Copenhagen, and Paris Agreements. The graphs in panel (b) and (c) exclude outliers: Latvia, Kiribati, and Madagascar. Note that the axis plots targeted reductions so negative values refer to pledges that involve an increase in emissions from the start year of the pledge.

TABLE 4. Summary of emission reductions.

Pledge	Summary statistic	% reduction in emissions	
		Non-signatory	Signatory
Kyoto Protocol	Mean	−18.19	7.67
	25th percentile	−57.90	−1.78
	Median	−13.50	7.43
	75th percentile	4.63	15.06
Copenhagen Accord	Mean	−23.59	−10.30
	25th percentile	−34.93	−23.33
	Median	−27.68	−5.03
	75th percentile	−16.19	5.04

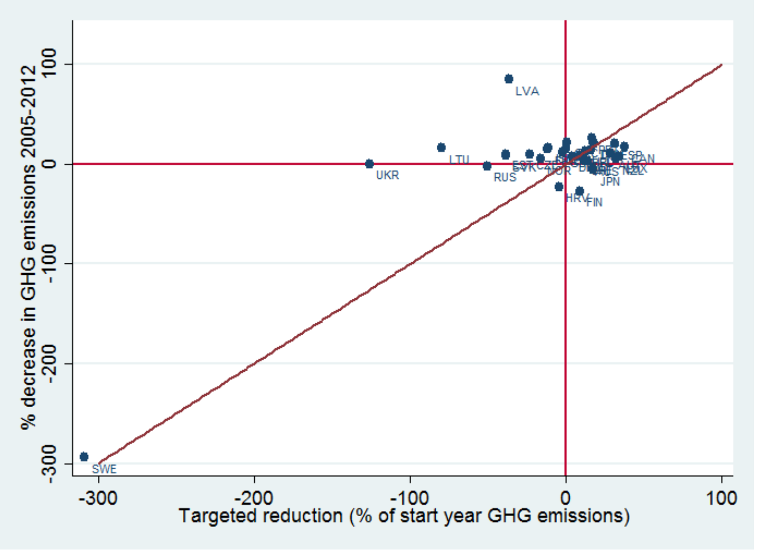
Notes. The table reports summary statistics for the reduction in GHG emissions between 2005 and 2012 for signatories and non-signatories of the Kyoto Protocol and the reduction in fossil CO_2 emissions between 2010 and 2018 for signatories and non-signatories of the Copenhagen Accord. All summary statistics are weighted by emissions in the starting year. Note that a positive value indicates a reduction in emissions, while a negative value indicates an increase.

of signing the pledges, the impact of the pledges on emissions is examined in more details in Section 4.

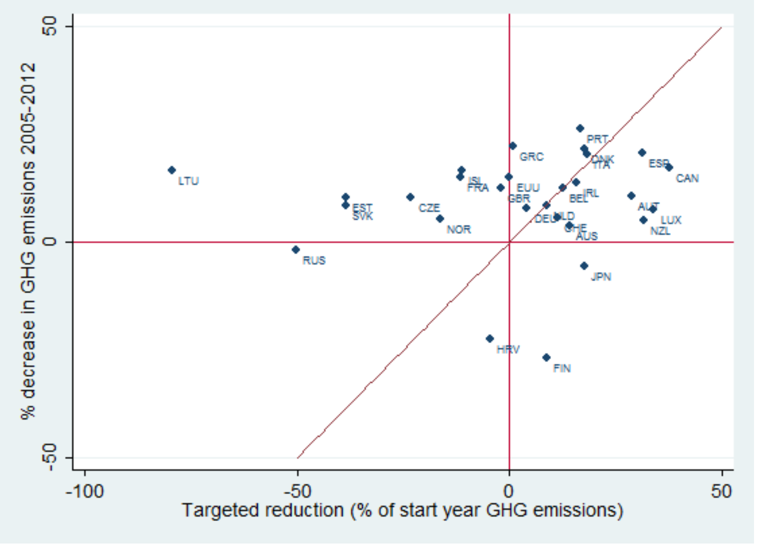
Next, we explore, at country level, how well the targets set under these two pledges were achieved. Figure 7(a) plots the decrease in GHG emissions from the starting year of 2005 until 2012 (as a percentage of the 2005 emissions level) against the targeted reduction as a percentage of the emission levels in 2005. By comparing these two values for each country, we can see which countries reached their targets. The actual reduction in emissions is larger than or equal to the targeted reduction for countries to the left of the 45° line, and the reduction in emissions falls short of the target for countries to the right of the 45° line.

When examining success by country, there is a wide variation in both the achievement and ambitiousness of targets. Countries to the left of the 45° line (in red) represent the countries that met their target, with countries further from the line having significantly overachieved their target. Countries to the right of the 45° line are those that failed to achieve their targeted emission reduction. The graph indicates that while there are some clear outliers in terms of over-achievement of targets (e.g. Latvia and Ukraine, which pledged increases in emissions), only a few countries actually set targets to reduce emissions from the 2005 emission level (recall that most countries used 1990 as their baseline year) and then met this target (these are the countries in the area to the right of the *Y*-axis and above the 45° line). All of the countries that specified a target involving an increase in emissions from the 2005 level, with the exception of Croatia, achieved their target.[12] The EU15 countries also collectively overachieved their target—the target reduction was 258 $MTCO_2$ eq. and actual reduction was 462

12. Sweden appears as an outlier in the Kyoto Protocol. It is clear why: By the time the Protocol was signed, Sweden, which fell under the EU umbrella, was actually allowed a 4% increase in emissions relative to its 1990 levels. Since we compute the targeted reduction in emissions from the start year of the



(a) All signatories



(b) All signatories excluding Sweden, Ukraine and Latvia

FIGURE 7. Achievement of targets under the Kyoto Protocol. The figure plots the decrease in GHG emissions from the starting year of 2005 to 2012 (as a percentage of the 2005 GHG emissions level) against the targeted reduction as a percentage of the emissions in the start year for the Kyoto Agreement. The red line is the $Y = X$ line. The graph is plotted with (a) and without (b) Sweden, Ukraine, and Latvia.

$MTCO_2$ eq. Though there is huge variation in compliance across countries, adding the emissions and targets of all countries, the group of 30 countries for which targets are quantified actually met the required emissions reduction. Total emissions by these countries as a whole amounted to 8,864 $MTCO_2$ eq. in 2012, compared to a targeted emissions level of 10,057.11 $MTCO_2$ eq.

The Copenhagen Accord specified GHG emission reduction targets for 2020. We undertake a similar comparison to that used for the Kyoto Protocol by contrasting targeted unconditional emission reductions with emission reductions recorded to date (2018). Note that the targeted reductions are as a percentage of GHG emissions in the starting year of the pledge, whereas the reduction to date is as a share of fossil CO_2 emissions in the starting year. As said, GHG and CO_2 are highly correlated. For this comparison to reflect the true progress under the Accord, we are implicitly assuming that GHG emissions and fossil CO_2 emissions change at the same rate.

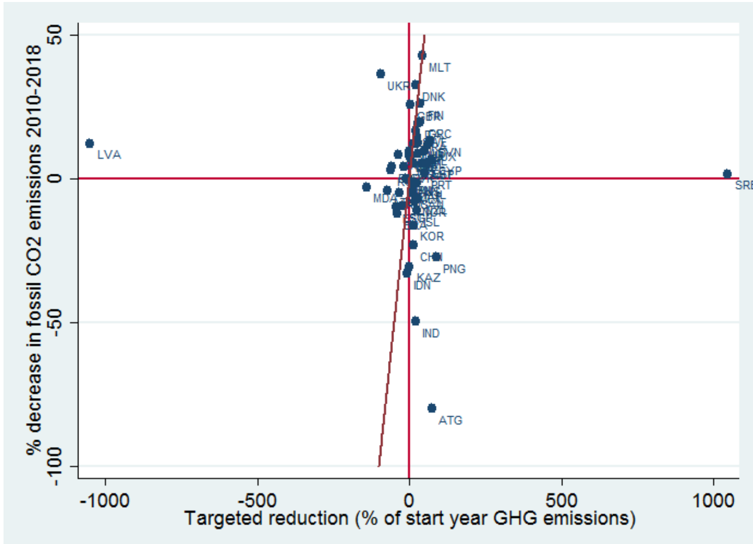
As Figure 8 illustrates, 21 countries had reached or exceeded the targeted emission reduction (countries to the left of the 45° line) by 2018, while 35 had not, though countries close to the 45° line are those that were reasonably close to achieving their targets. As was the case with the Kyoto Protocol, the vast majority of countries that had already achieved their targets by 2018 were those that specified an increase in emissions from the starting year, 2010, (in the official pledges, many countries continued to specify their baseline year as 1990 under the Copenhagen Accord), with only a few countries, such as Denmark and Malta, having achieved more ambitious targets. Germany, Japan, and Russia were the only countries among the top-ten emitters that had already achieved their target level of emissions as of 2018. It is conceivable that with the Covid-19 pandemic and the implied reduction in emissions caused by lower activity, many more countries would have met the targets.

3.2. Climate-Change Actions

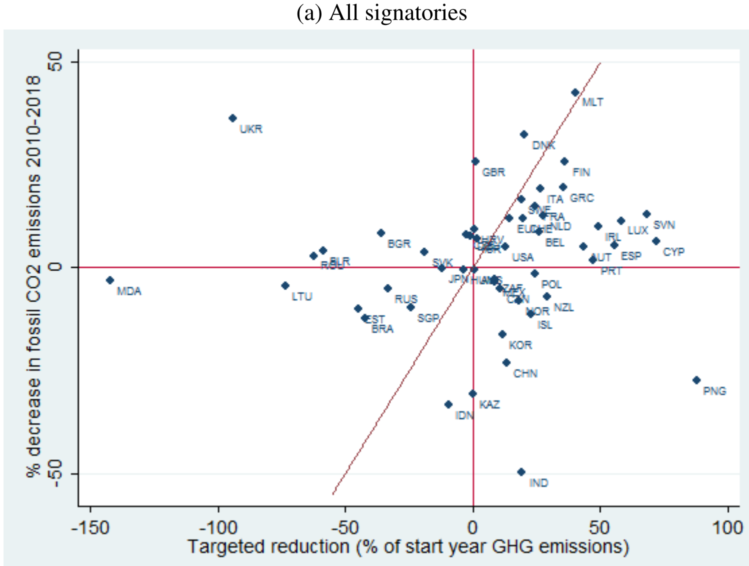
Aside from the signing of international climate-change–related pledges, and often as part of those pledges, many countries have adopted a range of laws, policies, and instruments to mitigate the impact of climate change. Using the Climate Change Laws of the World database, which records information on 1,809 laws and policies in 200 countries which were in implementation up to the end of 2019, we measure the number of climate-related laws and policies that are in force in a given country and year.[13] The database also provides keywords for each of these actions, which we use to gauge the number of policies or actions related to various aspects of climate-change actions

pledge, which was 2005, when emissions in Sweden had already reduced substantially, the resulting target becomes a very large targeted increase.

13. The database does not include laws or policies that were abolished, so the numbers for some years could be underestimated. However, the World Bank's Carbon Pricing Dashboard, which lists all carbon taxes and ETSs ever implemented, shows that very few (just three, of which only one was a national-level action) carbon taxes or ETSs have been abolished to date. As such, it is unlikely that underestimation of the number of laws and policies is large.



(a) All signatories



(b) All signatories excluding Latvia and Serbia

FIGURE 8. Progress made under the Copenhagen Accord. The figure plots the decrease in fossil CO_2 emissions from the starting year of 2010 to 2018 (as a percentage of the 2010 emissions level) against the targeted unconditional GHG emission reduction as a percentage of the GHG emissions in the start year for the Copenhagen Accord. The red line is the $Y = X$ line. The graph is plotted with (a) and without (b) Latvia and Serbia.

TABLE 5. Laws and policies related to climate change.

	Number of laws passed	Number of policies passed	Countries with at least one law	Countries with at least one policy
Pre-1970	8	1	6	1
1970–1979	6	0	10	1
1980–1989	17	2	18	3
1990–1999	78	31	62	23
2000–2009	272	276	119	135
2010–2019	394	724	156	176
Total to date	**775**	**1034**	**156**	**176**

Notes. Computed using data from the Climate Laws of the World Database.

TABLE 6. Climate-related laws and policies by sector.

		Number of policies/laws in action by sector							
		Adaptation	Energy demand	Energy supply	Institutions	Transport	LULUCF	R&D	**Total**
Pre-1970	No.	7	0	1	4	1	0	0	**9**
	%	77.8	0.0	11.1	44.4	11.1	0.0	0.0	
1970–1979	No.	1	4	2	3	1	0	0	**6**
	%	16.7	66.7	33.3	50.0	16.7	0.0	0.0	
1980–1989	No.	5	6	8	11	1	2	3	**19**
	%	26.3	31.6	42.1	57.9	5.3	10.5	15.8	
1990–1999	No.	32	37	41	64	11	11	14	**109**
	%	29.4	33.9	37.6	58.7	10.1	10.1	12.8	
2000–2009	No.	139	236	299	271	108	99	136	**548**
	%	25.4	43.1	54.6	49.5	19.7	18.1	24.8	
2010–2019	No.	466	396	535	561	205	241	215	**1,118**
	%	41.7	35.4	47.9	50.2	18.3	21.6	19.2	

Notes. Computed using data from the Climate Laws of the World Database. The sum of the sector columns can add up to more than the total number of laws/policies as some laws and policies cover multiple sectors.

including measures for adaptation to climate change, management of energy demand and energy supply, transportation, land use and forestry, and R&D. We combine this information with data from the Carbon Pricing Dashboard, which contains information on carbon taxes and ETSs implemented by country and year.

Table 5 summarizes the number of climate-related laws and policies by decade and the number of countries with at least one climate-related law or policy. The number and distribution of policies or laws by sector are listed in Table 6.

Table 5 shows that most climate-related actions (executive or legislative) were taken over the past few decades. While laws were relatively more common in the earlier decades, policies become more common from the 2000s such that as of 2019 there were 1,034 climate-related policies and 775 climate-related laws that had been enacted across the world.

TABLE 7. Carbon taxes and ETSs.

	Number of carbon taxes		Number of ETS		Number of countries with	
	National/ regional	Sub- national	National/ regional	Sub- national	Carbon tax	ETS
Pre-1990	0	0	0	0	0	0
1990–1999	6	0	0	0	6	0
2000–2009	10	1	3	2	9	31
2010–2019	25	5	7	20	23	34

Note. Computed using data from the Carbon Pricing Dashboard.

As shown in Table 6, the areas covered by climate-related laws and policies vary over the years. Most of the earliest laws and policies are related to climate-change adaptation or energy demand, while in the later years policies and laws related to energy supply and institutions have become more common. There has also been an increase in the number of laws and policies related to land use, land use change, and forestry (LULUCF), as well as R&D over the last few decades.

Table 7 lists out the number of national and sub-national carbon taxes and emissions trading schemes being implemented over the years as well as the number of countries where at least one carbon tax or ETS is implemented.

The first carbon-pricing initiatives in the database are the Polish and Finnish Carbon Taxes implemented in 1990. Since then, there has been a gradual increase in the number of carbon pricing initiatives implemented around the world. While most of the carbon taxes are enacted at a national level, most of the ETS are implemented at the sub-national level in the United States, Canada, China, and Japan. Only two initiatives in the dataset have been abolished as of 2019—the Australian national level ETS, which was introduced in 2012 and abolished in 2015, and the Ontario ETS, which was implemented in 2017 and abolished in 2019. Note that while the EU ETS counts as a single initiative, its jurisdiction spans all the EU countries as well as Norway, Iceland, and Liechtenstein.

4. Impact of Climate Agreements and Actions

In this section, we combine our datasets on emissions and pledges with information on climate-related laws and policies to examine the relation between total fossil CO_2 emissions (for which data are available until 2018) and the climate-change pledges and actions. The analysis is based on a panel of 186 countries.

4.1. Static Specification: Controls and Endogeneity Correction

Our baseline specification controls for per capita GDP, population, share of urban population, and, for a smaller sample, oil rents as a percentage of GDP, as summarized in Table 8.

TABLE 8. Covariates of emissions.

	Total fossil CO_2 emissions (in logs)			
	(1)	(2)	(3)	(4)
GDP per capita (in logs)	0.843***	0.707***	0.848***	0.696***
	[0.010]	[0.061]	[0.010]	[0.060]
Population (in logs)	1.106***	1.250***	1.109***	1.219***
	[0.006]	[0.176]	[0.006]	[0.158]
Urban population (% of total)	0.011***	0.008*	0.009***	0.008*
	[0.001]	[0.004]	[0.001]	[0.005]
Oil rents (% of GDP)			0.020***	0.002
			[0.001]	[0.004]
Country and Year FE	No	Yes	No	Yes
N	7,991	7,991	7,189	7,189
R^2	0.903	0.884	0.907	0.885

Notes. The table reports the results of regressing total fossil CO_2 emissions (in logs) on GDP per capita (in constant 2010 US dollar) and population (in logs), urban population as a percentage of the total and oil rents as a percentage of GDP. Columns (1) and (3) do not control for country and year fixed effects. All regressions include a constant term. The values in brackets are robust standard errors. * and *** indicate significance at the 10% and 1% levels, respectively.

As expected, the main control variables, GDP per capita and population, show statistically significant positive associations with total emissions, with the estimated coefficient on population increasing in magnitude when country- and year-fixed effects are controlled for. The magnitudes are large. A 1% increase in GDP per capita is associated with a 0.84% increase in emissions, while a 1% increase in population is associated with a 1.1% increase in emissions. The share of urban population has a smaller correlation with emissions, with the effect becoming less significant when controlling for country- and year-fixed effects. While oil rents have a much smaller quantitative impact on emissions than the other factors, the association between emissions and oil rents also becomes insignificant once country- and year-fixed effects, along with income and population have been controlled for. This is because most of the oil-production effect on emissions is absorbed in the country-specific effect. Since its inclusion also results in a smaller sample size, we exclude it from the following regressions.

To this set of controls, we add variables that capture the effects of climate-change pledges and actions. The first set of regressions examines the effect of the climate-change pledges on emissions. We start with three indicator variables that take the value 1 when the corresponding agreements has been signed (0 before and 1 thereafter) with a one-year lag to allow for time between the signature of the agreement and its implementation. To distinguish whether simply signing the agreement has a different effect from having a quantifiable target for emission reduction, we include an indicator that takes a value 1 when the target is quantifiable.[14]

14. The relationship between covariates and emissions appears to be relatively stable in the pre-agreement period (1970–2000), except for a slight change in the relationship with GDP per capita in the 1990s. Similarly, the effects are more or less homogeneous across levels of development, especially in the pre-agreement period. See Online Appendix Tables B.1 and B.2 for more details.

The second set of regressions explores the impact of specific climate-related actions undertaken by different countries. We generate indicator variables for the implementation of a carbon tax and of ETS at the national level.[15] A second variable (or set of variables) aims at capturing other specific climate-related laws and policies. We use two specifications for modelling the effect of climate laws and policies on emissions: The first simply uses the total number of climate laws and policies that are in place, while the second uses the number of laws or policies disaggregated by area of implementation. As with the indicators for signing climate agreements, the number of climate-related laws and policies is included in the model with a one-year lag. All the regressions include country- and year-fixed effects.

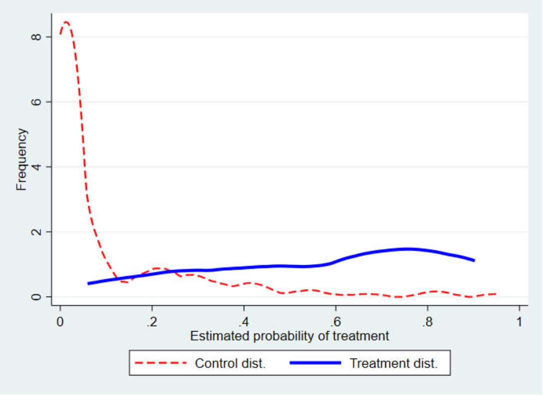
To address potential endogeneity in the decision to sign a climate-pledge, we use IPW regression estimation. In the first stage, we estimate the probability of signing each climate pledge as a function of GDP per capita, population, share of urban population, and emissions observed in the previous year to obtain a propensity score, the inverse of which is used to weigh the regressions described previously. As discussed in Jordá and Taylor (2016), the idea behind this method is that it focuses the estimator on a rebalanced sample in parts of the treatment and control group that are similar to each other.

Given that for each pledge, a country only faced the decision of whether to sign and not when to sign it (the years in which the pledges are ratified are fixed), we use cross-sections of the data from the year of each pledge being ratified to estimate these propensities using a probit model. Figures 9(a)–(c) show the smooth kernel density estimates of the distribution of the propensity scores for signing for countries adopting (treatment) and not adopting (control) each pledge. These figures check for overlap between the two groups, which allows for the proper identification of the average treatment effect (ATE).

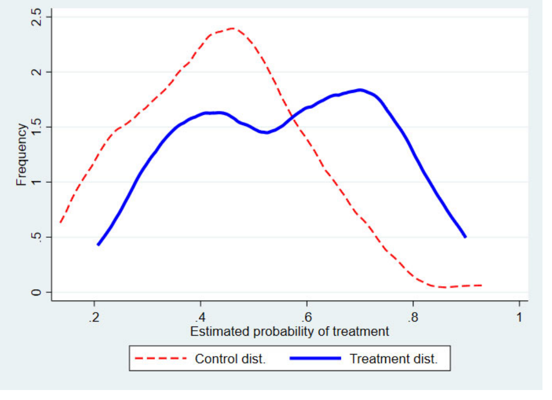
The distribution of propensity scores for treated and untreated groups show considerable overlap, though it appears that a few observations are likely to get very high weights (in the case of the Kyoto Protocol, which was signed by just 36 countries in our sample), while some others are likely to get very low weights (in the case of the Paris Agreement, which was signed by 176 countries in our sample). For this reason, we truncate the minimum and maximum weights to 1.11 and 10, respectively. The computed weights for each of the pledges are then compiled as a panel, assuming that the propensities prior to signing each pledge are fixed. These weights are then used for the four regression models discussed earlier, assuming that the propensities for signing climate pledges are similar to the propensities for adopting different climate-related actions.[16] The results of the regressions examining the impact of signing climate agreements and adopting climate-changed-related laws and policies, with and without weighting by inverse probabilities, are given in Tables 9 and 10.

15. The database mentions that the carbon prices are not necessarily comparable between initiatives due to differences in sectors covered, specific exemptions and compensation methods. Given these limitations, we do not use the carbon prices in the analysis.

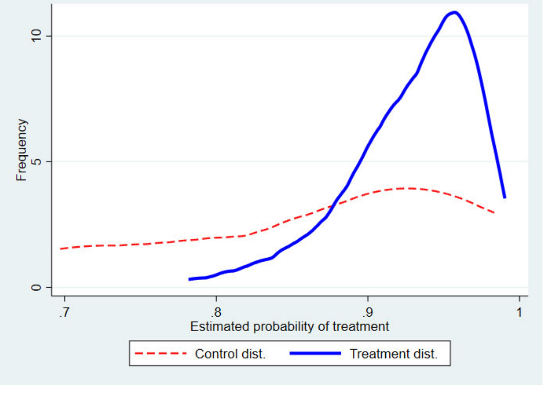
16. In the subsequent section, where we estimate the dynamic effects of one policy option at a time, we relax this assumption, estimating the propensity for adoption of each option separately.



(a) Kyoto Protocol



(b) Copenhagen Accord



(c) Paris Agreement

FIGURE 9. Overlap check: distribution of treatment propensity score. The figure plots the smooth kernel density estimates of the distribution of the propensity scores for signing for treatment and control countries.

TABLE 9. Emissions and climate agreements.

	ln(total fossil CO_2 emissions) (1)	(2)	(3)	(4)
Signed Kyoto	−0.438***	−0.423***	−0.349***	−0.344***
	[0.023]	[0.023]	[0.029]	[0.029]
Signed Copenhagen	−0.166***	−0.156***	−0.137***	−0.129***
	[0.025]	[0.028]	[0.026]	[0.028]
Signed Paris	0.049	0.078	0.111	0.13
	[0.291]	[0.120]	[0.291]	[0.120]
Have quantified objectives			−0.118***	−0.103***
			[0.027]	[0.027]
Using IPW	No	Yes	No	Yes
N	7,870	7,870	7,870	7,870

Notes. The table reports the results of regressing total fossil CO_2 emissions (in logs) on lagged indicators for signing different climate-related pledges. All regressions include a constant and control for country and year fixed effects as well as real GDP per capita (in constant 2010 US dollar), population (in logs), and urban population as a percentage of the total. Columns (1) and (3) report the unweighted OLS estimates, while the results in the remaining columns are estimated using inverse probability weighting. The values in brackets are robust standard errors. *** indicates significance at the 1% level.

The regression outcomes in Table 9 indicate that the results from weighted and unweighted regressions are very similar. Columns (1) and (2) show that signing the Kyoto and Copenhagen Agreements are associated with significantly lower emissions, holding population and income constant. However, being a signatory to the Paris Agreement does not show any impact on emissions; this could be of course because we have only two years of data post-Paris. (Recall that the agreement came into force in November of 2016.) The magnitude of these estimated effects are large: The results from column (2) in the table indicate that signing the Kyoto Agreement results in 34% lower fossil CO_2 emissions when compared with countries that did not sign the agreement.

How do we reconcile this large estimated fall with the rather unambitious targets set in Kyoto? The answer is in the counterfactual or control group: Countries that did not sign the Kyoto Protocol recorded a steep rise in emissions. Hence, signing Kyoto had an effect, not so much in reducing emissions but in preventing countries from increasing emissions too rapidly. Signing the Copenhagen Accord led to a reduction in emissions in the order of 14%.[17,18] Having quantified objectives for the pledges show a further negative effect on emissions (columns (3) and (4)). This effect is much

17. As a placebo check, we also re-estimate the model in column (1) including leads of the indicators for signing the pledges to verify whether emissions started falling in the year prior to the agreements. The results show that emissions reductions are observed in the year before the agreement in the case of the Kyoto Protocol but not for the other two agreements. This can be explained by the fact that while the Kyoto Protocol, came into force legally in 2005, it was accorded in 1997; that is, in 1997, countries accorded that the commitment period would be from 2005 to 2012. See Online Appendix Table C.1 for these results.

18. We also estimate the regressions again, leaving out the outliers observed in Figures 7(b) and 8(b). The results in Tables 9 and 10 are not sensitive to their exclusion. See Online Appendix D for these results.

TABLE 10. Emissions and climate actions.

	ln(total fossil CO_2 emissions)			
	(1)	(2)	(3)	(4)
Number of climate related laws	−0.036***	−0.036***		
	[0.003]	[0.003]		
Number of climate related policies	−0.001	0.000		
	[0.003]	[0.004]		
Have national level carbon tax	−0.215***	−0.208***	−0.222***	−0.211***
	[0.021]	[0.022]	[0.022]	[0.022]
Have national level ETS	−0.325***	−0.309***	−0.342***	−0.332***
	[0.020]	[0.020]	[0.021]	[0.021]
Number of policies by sector				
Adaptation			0.016***	0.018***
			[0.006]	[0.006]
Demand management			−0.020***	−0.019***
			[0.005]	[0.005]
Supply management			−0.026***	−0.026***
			[0.004]	[0.005]
Transport			−0.012*	−0.003
			[0.007]	[0.007]
LULUCF			0.014**	0.006
			[0.006]	[0.007]
R&D			−0.008	−0.011*
			[0.005]	[0.006]
Using IPW	No	Yes	No	Yes
N	7,870	7,870	7,870	7,870

Notes. The table reports the results of regressing total fossil CO_2 emissions (in logs) on the lagged number of climate related laws and policies implemented as well as indicators for having a national carbon tax and ETS. All regressions include a constant and control for country and year fixed effects as well as real GDP per capita (in constant 2010 US dollar), population (in logs), and urban population as a percentage of the total. Columns (1) and (3) report the unweighted OLS estimates, while the results in the remaining columns are estimated using inverse probability weighting. The values in brackets are robust standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

larger for the Copenhagen Accord, where more than 40% of signatory countries did not specify numerical targets. On the other hand, all countries had numerical targets under the Kyoto Protocol—accordingly, the sum of the coefficients on signing the agreement and having a quantified objective in the Copenhagen Accord is very similar to the coefficient on signing the Kyoto Protocol in the regressions where having a quantified target is not controlled for.

Table 10 shows the estimated effects of climate-related laws and policies on emissions. These estimates suggest that the number of climate-related laws and the presence of nation-wide carbon taxes and ETSs are significantly associated with lower emissions. Given the inclusion of country and time effects, the figures in the table should be read as relative to the emissions in countries that did not implement such policies. In terms of magnitudes, the regressions suggest a reduction of emissions in the order of 19% due to carbon taxes, relative to countries without a national carbon tax.

The presence of a national level ETS also shows a negative correlation with emissions, with the effect in the order of 27%.

The number of climate-related policies shows no association with emissions, while the number of laws passed appears to affect emissions negatively. More specifically, emissions appear to decrease by 4% for each additional climate-related law that is enacted. This suggests that the distinction between executive and legislative actions is important. Legal steps can have an important role alongside specific policies, like carbon taxes or ETS. When examining the number of laws or policies by area, a few areas appear to be significantly associated with emissions—for instance, the number of policies related to demand and supply management, and R&D are negatively correlated with emissions, while the number of policies related to adaptation is positively correlated. The magnitude of the effects of such laws and policies are quantitatively much smaller than the effects of a carbon tax or ETS. Therefore, for the analysis of dynamic effects that follows, we focus specifically on being signatory to the Kyoto and Copenhagen pledges, and on the two most (statistically) significant policies, national carbon taxes and ETS.

4.2. Dynamic Effects on Emissions

The previous sections provided evidence on the relationships between emissions and international climate-change agreements and specific climate-change actions by accounting for selection into the treatments based on observable variables. However, causal inference might be further affected by potential feedback from emission levels to climate-change actions or to the willingness to sign international agreements. For instance, a country with a low level of emissions may find it easier to sign a climate agreement than a country with a high level of emissions (or, with a different sign, a country with high level of emissions might face more international peer pressure to join the agreement). To address this reverse-causality problem, we estimate the dynamic effect of climate-change actions on emissions using the Jordá (2005) local projection method with IPW, adapted to panel data as in Jordá and Taylor (2016).

The identifying assumption implicit in the estimation of local projections is that once past emissions, and current and past international shocks (captured by time fixed effects) are controlled for, the estimation is only left with the exogenous component of climate interventions. By applying IPW regression adjusted estimation within this framework, we are further facilitating comparability between treatment and control groups. As such, we estimate the following set of equations weighted by inverse propensities:

$$\ln(emissions_{i,t+h}) = \gamma(L)\ln(emissions_{i,t-1}) + \rho(L)X_{i,t-1} + \theta_h\tau_{i,t} + \delta(L)\tau_{i,t-1} + \alpha_i + W_t + \varepsilon_{i,t}, \quad h = 0, 1, 2, \ldots, 7, \quad (1)$$

where $X_{i,t-1}$ contains a set of controls, including GDP, population and urbanization, $\tau_{i,t}$ is the policy variable of interest (the treatment), and we allow for lags of up to three years for all regressors. α_i and W_t are country and time fixed effects, and $\varepsilon_{i,t}$ is

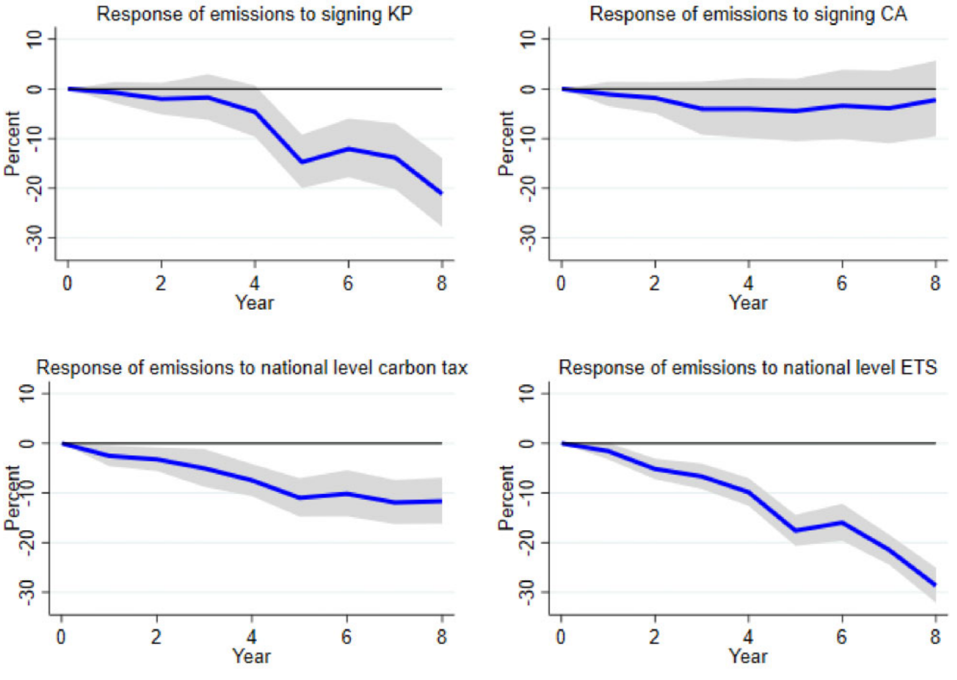


FIGURE 10. Dynamic effects of pledges, carbon taxes, and ETSs on emissions. The figure plots the estimated effect of a change in the climate action policy in year t on emissions, h periods in the future, for each of the policies considered.

the random error term. The coefficient θ_h captures the effect of a change in the climate action policy in year t on emissions, h periods in the future.

Equation (1) is estimated separately for each value of h and for each of the following climate-change actions separately: being a signatory to the Kyoto Protocol, being a signatory to the Copenhagen Accord, having a national level carbon tax, and having a national level ETS. As such, the propensities for each of these actions are also estimated separately and applied to each set of regressions. As explained in the previous section, the propensity for signing a pledge is estimated using data only for the specific year of the pledge being ratified. However, in the case of carbon taxes or ETS, since a country is able to decide both whether and when they enact such a policy, the propensities for enacting a nation-wide carbon tax or ETS are estimated using the full panel dataset.[19]

Figure 10 plots the values of θ_h against h for each of the climate-change actions considered. The effect on emissions from each of the four interventions builds up gradually over time. By the fourth and fifth year, the estimated dynamic effects

19. While inflation rates are not significantly correlated with the probability of signing the Kyoto or Copenhagen Agreements, they are correlated with the implementation of an ETS. Therefore, for the propensity estimation in this section, we also include inflation rates as a control. The updated graphs for checking overlap for these treatments are in Online Appendix E.

are broadly similar to the results shown in the previous sections, with all policies considered, except for the signing of the Copenhagen Agreement, demonstrating significant and persistent negative effects on emissions. As before, these numbers should be interpreted relative to the counterfactual provided by countries that did not put in place similar interventions. As already hinted at in Table 4, in the case of the Kyoto Protocol, the dynamic effects are driven by both falling emissions in the treatment group and continued increase in emissions in the control group (relative to the pre-agreement period). The effect of the Copenhagen Accord is to a larger extent driven by the continued rise in the control. To the extent that countries in that control group recorded significant increases in emissions, the actual reductions in global emissions is of course much more modest.

4.3. Dynamic Effects on Other Economic Variables

Motivated by the pubic debate on the potential spillovers of climate-change pledges and actions to the rest of the economy, we extend the analysis to study the impact of pledges and actions on other macroeconomic variables, specifically GDP growth and inflation.

For this purpose, we estimate a set of IPW regressions similar to those specified in equation (1) using GDP growth and inflation rates as dependent variables, with a few modifications. First, in keeping with the differenced specification of the dependent variables, we use the differences of all controls specified in equation (1). Second, as there are several countries experiencing episodes of hyper-inflation in the time period considered (e.g. 35 countries record consumer price inflation in excess of 100% over the sample), we exclude the top 6% of the inflation distribution, such that the highest inflation rate observed in our sample is 30%.[20] Third, given that the timing of the Kyoto Protocol and the enactment of the EU-ETS coincide with the global financial crisis and EU debt crisis, we further augment the specification of fixed effects to allow for region-specific trends in growth and inflation.[21] Accordingly, we estimate the following set of equations weighted by inverse propensities:

$$\Delta Y_{i,t+h} = \gamma_{11}(L)\Delta Y_{i,t-1} + \gamma_{21}(L)\Delta P_{i,t-1} + \rho_1(L)\Delta X_{i,t-1} + \theta_{h1}\tau_{i,t} + \delta_1(L)\tau_{i,t-1} + \alpha_i + \rho_g + W_t + \rho_g * W_t + \varepsilon_{i,t}, \quad h = 0, 1, 2, \ldots, 7, \tag{2}$$

20. The high inflation or hyper-inflation does not appear correlated with the signature of pledges or the adoption of climate-change actions.

21. Using this same augmented specification for the emissions equation gives very similar results to those reported in Section 4.2.

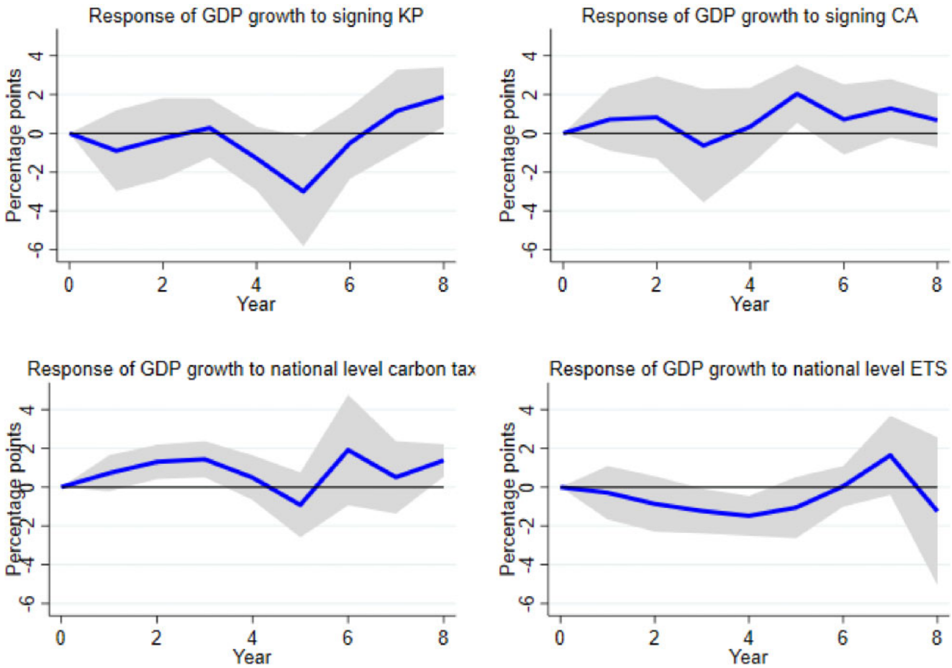


FIGURE 11. Dynamic effects of pledges, carbon taxes, and ETSs on GDP growth. The figure plots the estimated effect of a change in the climate action policy in year t on GDP growth, h periods in the future, for each of the policies considered.

$$\Delta P_{i,t+h} = \gamma_{12}(L)\Delta Y_{i,t-1} + \gamma_{22}(L)\Delta P_{i,t-1} + \rho_2(L)\Delta X_{i,t-1} + \theta_{h2}\tau_{i,t} + \delta_2(L)\tau_{i,t-1} + \alpha_i + \rho_g + W_t + \rho_g * W_t + \varepsilon_{i,t}, \quad h = 0, 1, 2, \ldots, 7, \tag{3}$$

where ΔY refers to GDP growth and ΔP refers to inflation, $\Delta X_{i,t-1}$ includes controls such as emissions, population, and urbanization in first differences, $\tau_{i,t}$ is the policy variable, and lags of upto three years are included for all regressors. α_i, ρ_g, and W_t are country, region, and time fixed effects and $\varepsilon_{i,t}$ is the random error term. θ_h is the effect of a change in the climate action policy in year t on emissions, h periods in the future.

The estimated effects on GDP growth and inflation are illustrated in Figures 11 and 12.

As shown in Figures 11 and 12, the impact of the climate-change pledges and policies on GDP growth and inflation is largely insignificant. These results are consistent with Metcalf and Stock (2020), who do not find any significant negative impact of carbon taxes on GDP growth. They are also in line with Kanzig (2021), who finds that the tightening of the carbon pricing regime within the European carbon

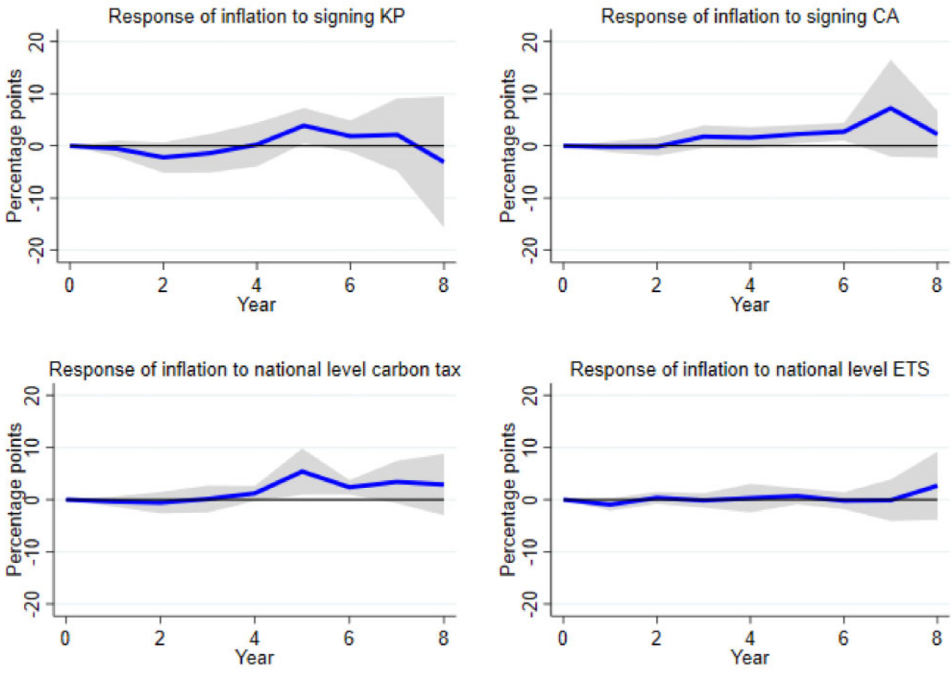


FIGURE 12. Dynamic effects of pledges, carbon taxes, and ETSs on inflation. The figure plots the estimated effect of a change in the climate action policy in year *t* on inflation, *h* periods in the future, for each of the policies considered.

market has had persistent negative effects on emissions, but less persistent effects on real GDP.

5. Conclusion

The paper computes comparable emission targets set in the context of the three main international climate-action treaties; it studies compliance with those targets across countries; and it assesses the overall impact of the international treaties, as well as specific climate-change actions, on the level of emissions. The paper finds that countries' compliance with emission-reduction targets has been highly heterogeneous, with many countries undershooting their targets. Signing the Kyoto Protocol and the Copenhagen Accord has led to significant reductions in emissions when compared with countries that did not sign in the treaties. In contrast, the Paris Agreement has not appeared to have led (yet) to any material reduction. Having quantifiable goals in the context of the Copenhagen Accord has been helpful in further reducing emissions.

In terms of specific actions, the paper finds that carbon taxes and ETS have led to material reductions in emissions. Other climate-related laws and policies appear to have, individually, smaller impacts on emissions. However, the number of climate-related laws is associated with significant reductions in GHG emissions. The impact of climate-related pledges and actions on economic variables such as GDP growth and inflation appear largely insignificant.

Overall, more ambitious targets and stricter compliance would be needed to offset the large impact of economic and population growth on the flow of emissions and contain a further damaging expansion in the stock of GHGs.

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Supplementary data

Supplementary data are available at *JEEASN* online.