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Abstract

This data report constructs a reproducible country–year panel linking territorial greenhouse gas emissions from the EDGAR database with annual GDP growth from World Bank statistics for 1970–2024. Focusing on major emitters, the analysis first documents the full data-processing workflow in Stata, including import, cleaning, merging and the generation of emissions-growth and decoupling indicators. Time-series plots and summary statistics reveal that, while CO₂ and CH₄ levels typically continue to rise or plateau after the 2015 Paris Agreement, emissions growth rates slow in several high-income economies despite continued GDP volatility. A simple decoupling classification shows that absolute decoupling (GDP growth with falling emissions) is concentrated in a small subset of advanced countries, whereas most others achieve only relative decoupling or remain closely coupled. Introductory analysis confirms a positive but heterogeneous association between GDP growth and emissions, highlighting that the findings are descriptive correlations rather than causal estimates of Paris-era climate policy impacts.

Post-Paris Agreement Decoupling: A Data-Driven Assessment of GDP Growth & Greenhouse Gas Emissions

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Part I: Motivation & Data Context

Dataset Selection and Research Questions

This data report analyses how territorial CO₂, CH₄ and N₂O emissions and GDP growth evolved between 1970–2015 and 2016–2024 for major emitters using IEA/EDGAR emissions and World Bank–derived GDP growth data. The report documents the data-cleaning and merging steps, descriptive statistics, visualisations, and summary indicators linking GDP growth and CO₂/CH₄ emissions growth across the two periods.

The analysis is structured around three main research questions:

- i. How have levels and growth rates of CO₂, CH₄, and N₂O emissions evolved for these economies over 1970–2015 versus 2016–2024 in respect to the Paris Agreement?
- ii. How strongly does GDP annual growth co-move with CO₂, CH₄ and N₂O emissions growth over the two periods?
- iii. Does the GDP per capita–emissions relationship appear weaker after the Paris Agreement, indicating partial decoupling?

Data Significance and Relevance

Territorial CO₂, CH₄ and N₂O emissions are among the primary drivers of anthropogenic climate change and represent a key indicator for tracking progress towards the Paris temperature goals of limiting warming below 2 °C. Long-run emissions series combined with GDP growth provide an empirical basis to study whether economic development has become less carbon intensive, an issue at the heart of environmental economics debates on decoupling and the environmental Kuznets curve.

The chosen country sample is highly relevant because these economies rank among the largest contributors to current or historical emissions, and together account for a

substantial share of global GDP, energy use, and population. Understanding whether the 2015 Paris Agreement coincides with visible changes in their emissions trajectories helps assess the effectiveness of international climate cooperation and informs policy discussions on burden-sharing, equity, and transition speed. Policymakers, as well as researchers, benefit from data-driven analyses relating to the emission-GDP relationship like this one.

Part II: Technical Implementation

Coding Setup and Documentation

This statistical analysis was conducted in Stata/MP 19.0, which was used to clean, merge, transform, and analyse the data. The emissions data was taken from the Emissions Database for Global Atmospheric Research (EDGAR), using annual country-level time series for CO₂, CH₄, and N₂O emissions over 1970–2024. For the economic data, the World Bank World Development Indicators (WDI) was used, specifically GDP per capita (annual % growth) for the same set of countries and years. These two sources are merged by country code and year to construct a balanced panel suitable for descriptive analysis and decoupling analysis.

We organised our work around Stata do-files with clear, organised order (1. import & cleaning 2. merge, 3. ranking, 4. summarise_12countries, 5. decoupling, 6. visualise), as well as a master file, which includes all the code. Thus, the entire workflow can be re-run from raw data to final outputs in one click, from data import and cleaning to descriptive analysis, decoupling indicators, and graph export.

To organise the workflow and ensure reproducibility, data was managed in the project via a shared GitHub repository: https://github.com/Nutthawattak/Group_2

Within the repository, there was a simple folder structure:

- (1) Data folder contains raw datasets, process folder which contains intermediate Stata .dta files, and final folder, contains final .dta files that is used for analysis directly in this report.
- (2) Code folder, contains the do-file for this data report.
- (3) Output folder contains figures, tables, graphs, and final report.

Data Preparation and Management

As the raw EDGAR emission files (CO₂, CH₄, N₂O) and World Bank GDP growth data were loaded, we faced a problem with the EDGAR Excel files for CO₂, CH₄ and N₂O

emissions (1970–2024). We attempted to upload “Total by country” sheet directly into Stata using the default import excel command; however, the EDGAR spreadsheets are not in a simple rectangular format. The “Total by country” sheet contains multiple header rows, and explanatory notes above the actual data table. As a result, Stata either treated the sheet as non-rectangular or assigned problematic variable names, and the direct import produced no usable observations. To solve this, we first inspected the raw sheet in Excel and identified the exact range of the data table (the row where the real header starts and the last row of country entries). We then used Stata’s `cellrange ()` option to import only the relevant block of data and `firstrow` to treat the first row of that block as names.

```

. *Import&Cleaning Datasets
.
. clear all

. set more off

.
. local countries "USA CHN GBR IND RUS JPN DEU KOR IDN SAU IRN CAN"

.
. * 1) CO2
. import excel using "C:\Users\Admin\Documents\Github\Group_2\Data\Raw\IEA_EDGAR_CO2_1970_2024.xlsx", ///
> sheet("TOTALS BY COUNTRY") cellrange(A10:BH235) firstrow clear
(60 vars, 225 obs)

.
.
. capture isid Country_code_A3

. if _rc {
.     gen id = _n
.     reshape long V_, i(id) j(year)
. }

. else {
.     reshape long V_, i(Country_code_A3) j(year)
(j = 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1
> 998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024)

.
.
. * 2) CH4
. clear all

. set more off

.
. import excel using "C:\Users\Admin\Documents\Github\Group_2\Data\Raw\EDGAR_CH4_1970_2024.xlsx", ///
> sheet("TOTALS BY COUNTRY") cellrange(A10:BH233) firstrow clear
(60 vars, 223 obs)

.
.
. capture isid Country_code_A3

. if _rc {
.     gen id = _n
.     reshape long V_, i(id) j(year)
. }

. else {
.     reshape long V_, i(Country_code_A3) j(year)
(j = 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1
> 998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024)

.
.
. * 3) N2O
. clear all

. set more off

.
. import excel using "C:\Users\Admin\Documents\Github\Group_2\Data\Raw\EDGAR_N2O_1970_2024.xlsx", ///
> sheet("TOTALS BY COUNTRY") cellrange(A10:BH233) firstrow clear
(60 vars, 223 obs)

.
.
. capture isid Country_code_A3

. if _rc {
.     gen id = _n
.     reshape long V_, i(id) j(year)
. }

. else {
.     reshape long V_, i(Country_code_A3) j(year)
(j = 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1
> 998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024)

```

Figure 1-3. Data Importation

```

.
. rename Y_ co2_gg

. gen double co2_mt = co2_gg/1000

. label var co2_gg "CO2 emissions (Gg)"
. label var co2_mt "CO2 emissions (MtCO2)"

.
. sort Country_code_A3 year

.

.
. rename Y_ ch4_gg

. generate double ch4_mt = ch4_gg/1000

.
. label var ch4_gg "CH4 emissions (Gg)"
. label var ch4_mt "CH4 emissions (MtCH4)"

.
.
. sort Country_code_A3 year


rename Y_ n2o_gg
generate double n2o_mt = n2o_gg/1000

label var n2o_gg "N2O emissions (Gg)"
label var n2o_mt "N2O emissions (MtN2O)"

sort Country_code_A3 year

```

```

.
. *4. GDP Annual Growth
. clear all

. set more off

.
. import delimited using "C:\Users\Admin\Documents\Github\Group_2\Data\Raw\WB_WDI_NY_GDP_MKTP_KD_ZG.csv", ///
> varnames(1) clear
(encoding automatically selected: ISO-8859-1)
(45 vars, 14,114 obs)

. rename ref_area_label Name

. rename ref_area Country_code_A3

.
.
. ds, has(type numeric)
time_period obs_value decimals unit_mult comment_obs

. local yearvars `r(varlist)'

.
. local firstvar : word 1 of `yearvars'

. local firstyear = real(substr("`firstvar'", -4, 4))

.
. local i = 1

. foreach v of local yearvars {
2. rename `v' gdp_`i'
3. local ++i
4. }

.
. rename gdp_1 year

. rename gdp_2 gdp_annual_growth

. keep Country_code_A3 year gdp_annual_growth Name

. sort Country_code_A3 year

.
. keep if year >= 1970 & year <= 2024
(1,387 observations deleted)

. drop if missing(gdp_annual_growth)
(0 observations deleted)

.
. label var gdp_annual_growth "GDP annual growth (%)"

```

Figure Description: We handled all data preparation by harmonising variable names and formats, cleaning the datasets so they can be used consistently in later analysis, and creating separate processed versions of each dataset in a process folder. In the original EDGAR files, emissions are reported in gigagrams (Gg), so we converted all series into megatonnes (Mt) by dividing by 1,000 (1 Gg = 0.001 Mt) and stored them as co2_mt, ch4_mt and n2o_mt to keep units consistent across tables and figures.

Figure 4-8. Rename variable names and standardise formats

```

* 2) combine dataset (CO2 + CH4 + N2O + GDP)

use "C:\Users\Admin\Documents\Github\Group_2\Data\process\edgar_co2_1970_2024_panel.dta", clear

* merge CH4
merge 1:1 Country_code_A3 year using
"C:\Users\Admin\Documents\Github\Group_2\Data\process\edgar_ch4_1970_2024_panel.dta", keep(3) nogen

* merge N2O
merge 1:1 Country_code_A3 year using
"C:\Users\Admin\Documents\Github\Group_2\Data\process\edgar_n2o_1970_2024_panel.dta", keep(3) nogen

* merge with GDP annual growth
merge 1:1 Country_code_A3 year using
"C:\Users\Admin\Documents\Github\Group_2\Data\process\gdp_annual_growth_panel.dta", keep(3) nogen

* add post-paris agreement
capture confirm variable post_paris
if _rc {
    gen post_paris = year>=2016
}

keep Country_code_A3 Name year ///
    co2_gg co2_mt ch4_gg ch4_mt n2o_gg n2o_mt ///
    gdp_annual_growth post_paris

order Country_code_A3 Name year ///
    co2_gg co2_mt ch4_gg ch4_mt n2o_gg n2o_mt ///
    gdp_annual_growth post_paris

save "C:\Users\Admin\Documents\Github\Group_2\Data\process\multigas_gdp_countries.dta", replace

```

```

. * 2) combine dataset (CO2 + CH4 + N2O + GDP)
. use "C:\Users\Admin\Documents\Github\Group_2\Data\process\edgar_co2_1970_2024_panel.dta", clear
.
. * merge CH4
. merge 1:1 Country_code_A3 year using "C:\Users\Admin\Documents\Github\Group_2\Data\process\edgar_ch4_1970_2024_panel.dta", keep(3) nogen

```

Result	Number of obs
Not matched	0
Matched	12,265

```

.
. * merge N2O
. merge 1:1 Country_code_A3 year using "C:\Users\Admin\Documents\Github\Group_2\Data\process\edgar_n2o_1970_2024_panel.dta", keep(3) nogen

```

Result	Number of obs
Not matched	0
Matched	12,265

```

.
. * merge with GDP annual growth
. merge 1:1 Country_code_A3 year using "C:\Users\Admin\Documents\Github\Group_2\Data\process\gdp_annual_growth_panel.dta", keep(3) nogen
(variable Name was str42, now str50 to accommodate using data's values)

```

Result	Number of obs
Not matched	0
Matched	9,792

```

.
. * add post-paris agreement
. capture confirm variable post_paris

. if _rc {
.     gen post_paris = year>=2016
. }

.
. keep Country_code_A3 Name year ///
>     co2_gg co2_mt ch4_gg ch4_mt n2o_gg n2o_mt ///
>     gdp_annual_growth post_paris

.
. order Country_code_A3 Name year ///
>     co2_gg co2_mt ch4_gg ch4_mt n2o_gg n2o_mt ///
>     gdp_annual_growth post_paris

.
. save "C:\Users\Admin\Documents\Github\Group_2\Data\process\multigas_gdp_countries.dta", replace
file C:\Users\Admin\Documents\Github\Group_2\Data\process\multigas_gdp_countries.dta saved

```

Figure Description: We combined the cleaned datasets into a single, harmonised panel that links emissions and economic variables at the country-year level. Starting from the processed CO₂ panel, we then merged in CH₄ and N₂O using a 1:1 key on country code and year. We then merged this multi-gas panel with the GDP annual growth data using the same identifiers and generated a post Paris agreement period indicator (set as after 2016) to distinguish observations before and after the Paris Agreement.

Figure 9-11. Combine datasets and creates post Paris Agreement indicator

```
*Ranking
use "C:\Users\Admin\Documents\Github\Group_2\Data\process\multigas_gdp_countries.dta", clear

keep if inrange(year, 2016, 2024)
collapse (mean) co2_mt_mean=co2_mt (mean) co2_gg_mean=co2_gg ///
      (first) Name, by(Country_code_A3)

gsort -co2_mt_mean
gen rank = _n
list rank Country_code_A3 Name co2_mt_mean, noobs

save "C:\Users\Admin\Documents\Github\Group_2\Data\process\ranking.dta", replace

use "C:\Users\Admin\Documents\Github\Group_2\Data\process\multigas_gdp_countries.dta", clear
merge m:1 Country_code_A3 using "C:\Users\Admin\Documents\Github\Group_2\Data\process\ranking.dta", keep(
match) nogen

save "C:\Users\Admin\Documents\Github\Group_2\Data\final\multigas_gdp_countries_final.dta", replace
```

rank	Countr~3	Name	co2_mt_~n
1	CHN	China	12032.707
2	USA	United States	4818.0167
3	IND	India	2643.5231
4	RUS	Russian Federation	1862.5112
5	JPN	Japan	1099.3531
6	IRN	Iran, Islamic Republic of	737.78162
7	DEU	Germany	683.0402
8	IDN	Indonesia	644.81318
9	KOR	Korea, Republic of	638.70157
10	SAU	Saudi Arabia	605.38802
11	CAN	Canada	579.85947
12	BRA	Brazil	480.25073
13	MEX	Mexico	473.92027
14	ZAF	South Africa	452.99223
15	TUR	Turkey	433.66389
16	AUS	Australia	394.80279
17	GBR	United Kingdom	342.80894
18	ITA	Italy	325.32124
19	VNM	Viet Nam	324.63681
20	FRA	France	310.55696
21	POL	Poland	308.24662
22	THA	Thailand	278.81515
23	MYS	Malaysia	262.34215
24	EGY	Egypt	259.92916
25	ESP	Spain	243.88359
26	KAZ	Kazakhstan	235.4378

Figure Description: We choose a country sample in a transparent, data-driven way. By using the global emissions panel, we computed average CO₂ emissions over a chosen reference period and ranked all countries accordingly. We then selected the 11 largest emitters as a core group that captures a substantial share of global emissions and reflects diverse economic structures, including advanced economies, emerging markets, and fossil-fuel exporters. We manually added the United Kingdom as a twelfth sample, due to its relevance for this class. The list of 12 countries was saved and later used as a filter for the analysis in the report.

Figure 12-13 Rank average CO₂ emissions of all countries.

```

*****Summarise table
clear all
set more off

* 1. Load merged panel
use "C:\Users\Admin\Documents\Github\Group_2\Data\final\multigas_gdp_countries_final.dta", clear

* keep sample period
keep if inrange(year,1970,2024)
keep if inlist(Country_code_A3, ///
"CHN","USA","IND","RUS","JPN","IRN","DEU") ///
| inlist(Country_code_A3, ///
"KOR","IDN","CAN","SAU","GBR")

* Summary statistics (mean, sd, min, max) by country x period
collect clear
table Country_code_A3 post_paris, ///
stat(mean co2_mt) stat(sd co2_mt) stat(min co2_mt) stat(max co2_mt) ///
stat(mean gdp_annual_growth) ///
stat(sd gdp_annual_growth) ///
stat(min gdp_annual_growth) ///
stat(max gdp_annual_growth)

export delimited using
"C:\Users\Admin\Documents\Github\Group_2\Output\Table\Table1_emissions_gdp_pre_post.csv" , replace

```

Figure Description: We generated a descriptive overview for our 12 focus countries that connects the processed data back to our research questions. The script generates summary statistics for emissions and annual real GDP growth, separately for the pre- and post-Paris Agreement periods. It also calculates means, standard deviations and ranges by country and period.

Figure 14. Code for statistics

```

. *5) Coupling Table (CO2+CH4))
. clear all

. set more off

.
. * 1. Load pre-merged multi-gas + GDP dataset
.
. use "C:\Users\Admin\Documents\Github\Group_2\Data\final\multigas_gdp_countries_final.dta", clear

.
.
. keep if inlist(Country_code_A3, ///
> "CHN","USA","IND","RUS","JPN","IRN","DEU") ///
> | inlist(Country_code_A3, ///
> "KOR","IDN","CAN","SAU","GBR")
(9,089 observations deleted)

.
. keep if inrange(year, 1990, 2024)
(220 observations deleted)

. encode Country_code_A3, gen(country_id)

. xtset country_id year

Panel variable: country_id (unbalanced)
Time variable: year, 1990 to 2024
Delta: 1 unit

```

```

.
. * Use Mt variables for emissions (levels)
. rename co2_mt co2

. rename ch4_mt ch4

.
. * CO2 and CH4 growth rates (% per year, log-difference)
. bys country_id (year): gen co2_growth = 100 * (ln(co2) - ln(L.co2))
(12 missing values generated)

. bys country_id (year): gen ch4_growth = 100 * (ln(ch4) - ln(L.ch4))
(12 missing values generated)

.
.
. * 3. Absolute and relative decoupling indicators
.
.
. gen abs_decouple_co2 = (gdp_annual_growth > 0 & co2_growth < 0)

. gen rel_decouple_co2 = (gdp_annual_growth > 0 & co2_growth > 0 ///
> & co2_growth < gdp_annual_growth)

.
. gen abs_decouple_ch4 = (gdp_annual_growth > 0 & ch4_growth < 0)

. gen rel_decouple_ch4 = (gdp_annual_growth > 0 & ch4_growth > 0 ///
> & ch4_growth < gdp_annual_growth)

.
. * Save full panel with decoupling flags
. save "C:\Users\Admin\Documents\Github\Group 2\Data\final\co2_ch4_decoupling_panel.dta", replace
file C:\Users\Admin\Documents\Github\Group 2\Data\final\co2_ch4_decoupling_panel.dta saved

.
. * 4. Aggregate over 2016-2024 (Paris Agreement period)
. *-----
.
. keep if year >= 2016
(312 observations deleted)

.
. bys Country_code_A3: egen n_years = count(year)

.
. bys Country_code_A3: egen abs_co2 = total(abs_decouple_co2)

. bys Country_code_A3: egen rel_co2 = total(rel_decouple_co2)

.
. bys Country_code_A3: egen abs_ch4 = total(abs_decouple_ch4)

. bys Country_code_A3: egen rel_ch4 = total(rel_decouple_ch4)

.
. bys Country_code_A3: keep if _n == 1
(95 observations deleted)

.
. gen decouple_total_co2 = abs_co2 + rel_co2

. gen share_decouple_co2 = decouple_total_co2 / n_years

. gen share_abs_co2 = abs_co2 / decouple_total_co2 if decouple_total_co2 > 0

.
. gen decouple_total_ch4 = abs_ch4 + rel_ch4

```

```

. gen share_decouple_ch4 = decouple_total_ch4 / n_years

. gen share_abs_ch4      = abs_ch4 / decouple_total_ch4 if decouple_total_ch4 > 0

.

. set linesize 255

.

. list Country_code_A3 ///
>   abs_co2 rel_co2 decouple_total_co2 share_decouple_co2 share_abs_co2 ///
>   abs_ch4 rel_ch4 decouple_total_ch4 share_decouple_ch4 share_abs_ch4, ///
>   noobs sep(0) clean

```

Countr~3	abs_co2	rel_co2	decoup~2	sh~e_co2	sh~s_co2	abs_ch4	rel_ch4	decoup~4	sh~e_ch4	sh~s_ch4
CAN	3	2	5	.5555556	.6	2	5	7	.7777778	.2857143
CHN	1	8	9	.1	.1111111	4	5	9	.1	.4444444
DEU	4	1	5	.5555556	.8	6	0	6	.6666667	.1
GBR	7	1	8	.8888889	.875	8	0	8	.8888889	.1
IDN	1	1	2	.2222222	.5	0	3	3	.3333333	0
IND	1	5	6	.6666667	.1666667	0	8	8	.8888889	0
IRN	0	5	5	.5555556	0	1	1	2	.2222222	.5
JPN	6	1	7	.7777778	.8571429	6	1	7	.7777778	.8571429
KOR	3	4	7	.875	.4285714	1	6	7	.875	.1428571
RUS	1	4	5	.5555556	.2	2	2	4	.4444444	.5
SAU	4	2	6	.6666667	.6666667	4	3	7	.7777778	.5714286
USA	4	2	6	.6666667	.6666667	1	5	6	.6666667	.1666667

```

.

. * 5. Prepare wide dataset for graph

.

. preserve

.

. keep Country_code_A3 abs_co2 rel_co2 abs_ch4 rel_ch4

.

. tempfile wide

. save `wide'
File C:\Users\Admin\AppData\Local\Temp\ST_799c_000002.tmp saved as .dta format

.

. use `wide', clear

. keep Country_code_A3 abs_co2 rel_co2

. gen gas = "CO2"

. rename abs_co2 abs

. rename rel_co2 rel

. tempfile co2

. save `co2'
File C:\Users\Admin\AppData\Local\Temp\ST_799c_000003.tmp saved as .dta format

```

```

.
. use `wide`, clear

. keep Country_code_A3 abs_ch4 rel_ch4

. gen gas = "CH4"

. rename abs_ch4 abs

. rename rel_ch4 rel

.

. append using `co2`

.

. graph bar abs rel, ///
>   over(gas, label(labsize(tiny))) ///
>   over(Country_code_A3, label(labsize(vsmall))) ///
>   stack ///
>   legend(order(1 "Absolute" 2 "Relative") size(vsmall)) ///
>   ytitle("Number of years (2016-2024)", size(vsmall)) ///
>   title("CO2 and CH4 decoupling years after the Paris Agreement")

.

. graph export "C:\Users\Admin\Documents\Github\Group_2\Output\Graph\co2_ch4_decoupling_combined_2016_2024.png", replace
file C:\Users\Admin\Documents\Github\Group_2\Output\Graph\co2_ch4_decoupling_combined_2016_2024.png saved as PNG format

. graph save "C:\Users\Admin\Documents\Github\Group_2\Data\final\Graph\co2_ch4_decoupling_combined_2016_2024.gph", replace
file C:\Users\Admin\Documents\Github\Group_2\Data\final\Graph\co2_ch4_decoupling_combined_2016_2024.gph saved

. restore

```

Figure Description: We created absolute and relative decoupling indicators for CO₂ and CH₄ at the country-year level. Absolute decoupling is defined as years in which GDP grows while emissions fall, and relative decoupling as years in which both grow but emissions grow more slowly than GDP. Focusing on the Paris period (2016-2024), the script counts for each country how many years exhibit absolute or relative decoupling and computes the share of post-Paris years with any decoupling, as well as the proportion of those years that are absolute. This provides a simple country-level indicator of progress towards decoupling economic growth from greenhouse gas emissions.

Figure 15-20. Code for absolute and relative decoupling analysis and visualisation of results

```

**** CO2 + GDP growth (dual axis)

use "C:\Users\Admin\Documents\Github\Group_2\Data\final\multigas_gdp_countries_final.dta", clear
keep if inrange(year,1970,2024)

* range (can change)
local xmin = 1970
local xmax = 2024

local countries "USA CHN GBR IND RUS JPN DEU KOR IDN SAU IRN CAN"

foreach cc of local countries {

    twoway ///
        (line co2_mt year if Country_code_A3=="`cc'", yaxis(1) lpattern(solid)) ///
        (line gdp_annual_growth year if Country_code_A3=="`cc'", yaxis(2) lpattern(solid)), ///
        ///
        yscale(range(`co2min' `co2max') axis(1)) ///
        yscale(range(`gdpmin' `gdpmax') axis(2)) ///
        xlabel(1970(6)2024) ///
        xscale(range(1970 2024)) ///
        ///
        ytitle("CO2 emissions (Mt)", axis(1)) ///
        ytitle("GDP growth (%)", axis(2)) ///
        xtitle("Year") ///
        legend(order(1 "CO2 (Mt)" 2 "GDP growth (%)")) ///
        xline(2016, lpattern(dash)) ///
        title("`cc': CO2 emissions and GDP growth") ///
        name(co2_gdp_`cc', replace)

    graph export "C:\Users\Admin\Documents\Github\Group_2\Output\Graph\co2_gdp_`cc'_ts.png", replace
    graph save "C:\Users\Admin\Documents\Github\Group_2\Data\final\Graph\co2_gdp_`cc'.gph", replace
}

* CO2+GDP 12 countries (panel)
graph combine ///
    co2_gdp_USA co2_gdp_CHN co2_gdp_GBR ///
    co2_gdp_IND co2_gdp_RUS co2_gdp_JPN ///
    co2_gdp_DEU co2_gdp_KOR co2_gdp_IDN ///
    co2_gdp_SAU co2_gdp_IRN co2_gdp_CAN, ///
    cols(3) xcommon ///
    title("CO2 emissions (Mt) & GDP growth (%) - 12 countries")

graph export "C:\Users\Admin\Documents\Github\Group_2\Output\Graph\co2_gdp_12countries_panel.png", replace
graph save "C:\Users\Admin\Documents\Github\Group_2\Data\final\Graph\co2_gdp_12countries_panel.gph",
replace

```

```

* 4) CH4 + N2O + GDP growth (dual axis)

use "C:\Users\Admin\Documents\Github\Group_2\Data\final\multigas_gdp_countries_final.dta", clear

* range (can change)
local xmin = 1970
local xmax = 2024

local countries "USA CHN GBR IND RUS JPN DEU KOR IDN SAU IRN CAN"

foreach cc of local countries {

    twoway ///
        (line ch4_mt year if Country_code_A3=="`cc'", ///
            yaxis(1) lpattern(solid)) ///
        (line n2o_mt year if Country_code_A3=="`cc'", ///
            yaxis(1) lpattern(solid)) ///
        (line gdp_annual_growth year if Country_code_A3=="`cc'", ///
            yaxis(2) lpattern(solid)), ///
        ///
        yscale(range(`gasmin' `gasmax') axis(1)) ///
        yscale(range(`gdpmin' `gdpmax') axis(2)) ///
        xscale(range(`xmin' `xmax')) ///
        xlabel(1970(6)2024) ///
        ///
        ytitle("CH4 & N2O emissions (Mt)", axis(1)) ///
        ytitle("GDP growth (%)", axis(2)) ///
        xtitle("Year") ///
    legend(order(1 "CH4 (Mt)" 2 "N2O (Mt)" 3 "GDP growth (%)")) ///
        xline(2016, lpattern(dash)) ///
        title("`cc': CH4 & N2O (Mt) and GDP growth") ///
        name(ch4n2o_gdp_`cc', replace)

    graph export "C:\Users\Admin\Documents\Github\Group_2\Output\Graph\ch4n2o_gdp_`cc'_ts.png", replace
    graph save "C:\Users\Admin\Documents\Github\Group_2\Data\final\Graph\ch4n2o_gdp_`cc'.gph", replace
}

* CH4+N2O+GDP of 12 Countries
graph combine ///
    ch4n2o_gdp_USA ch4n2o_gdp_CHN ch4n2o_gdp_GBR ///
    ch4n2o_gdp_IND ch4n2o_gdp_RUS ch4n2o_gdp_JPN ///
    ch4n2o_gdp_DEU ch4n2o_gdp_KOR ch4n2o_gdp_IDN ///
    ch4n2o_gdp_SAU ch4n2o_gdp_IRN ch4n2o_gdp_CAN, ///
    cols(3) xcommon ///
    title("CH4 & N2O emissions (Mt) & GDP growth - 12 countries")

graph export "C:\Users\Admin\Documents\Github\Group_2\Output\Graph\ch4n2o_gdp_12countries_panel.png",
replace
graph save "C:\Users\Admin\Documents\Github\Group_2\Data\final\Graph\ch4n2o_gdp_12countries_panel.gph",
replace

```

Figure Description: We created time-series graphs plotting CO₂ emissions and GDP growth on dual y-axes for each country, with a vertical reference line in 2016 to separate the pre- and post-Paris Agreement periods. Similar plots are created for CH₄ and N₂O emissions against GDP growth. We also created a separate figure showing the years of relative and absolute decoupling for the selected countries over 2016–2024. All graphs are exported as .png files and stored in the final/ folder of the GitHub repository.

Figure 21-24. Code for visualisation of time-series graphs plotting emissions and GDP growth.

Part III: Descriptive Analysis and Export of Results for Presentation

Summary Statistics Table

The merged emissions-GDP dataset contains annual observations for China, India, Russia, the United Kingdom, the United States, Japan, Germany, Indonesia, Saudi Arabia, Iran, Canada, and Korea from 1970–2024, with variables for CO₂ emissions in MtCO₂, annual GDP growth (%), country code, and year. For each country, the code computes descriptive statistics separately for the pre-Paris period (1970–2015) and post-Paris period (2016–2024): mean and standard deviation of CO₂ levels and GDP growth, minimum and maximum values, summarised in Table 1 exported from Stata.

Table 1. Mean and standard deviation of CO2 pre- Paris Agreement (1970–2015) and post-Paris Agreement (2016–2024) in the selected countries

	0	post_paris 1	Total	DEU			
Country_code_A3				Mean			
CAN				CO2 emissions (MtCO2)	968.4876	683.0402	921.778
Mean				GDP annual growth (%)	2.075667	.8394111	1.873371
CO2 emissions (MtCO2)	482.333	579.8595	498.2919	Standard deviation			
GDP annual growth (%)	2.784853	1.875771	2.636094	CO2 emissions (MtCO2)	126.4278	75.56257	159.7614
Standard deviation				GDP annual growth (%)	2.030008	2.25739	2.098114
CO2 emissions (MtCO2)	70.74598	21.21458	74.58778	Minimum value			
GDP annual growth (%)	2.056174	3.016512	2.233038	CO2 emissions (MtCO2)	768.1326	579.9356	579.9356
Minimum value				GDP annual growth (%)	-5.545165	-4.095138	-5.545165
CO2 emissions (MtCO2)	358.1619	548.4454	358.1619	Maximum value			
GDP annual growth (%)	-3.16615	-5.038233	-5.038233	CO2 emissions (MtCO2)	1189.107	789.2489	1189.107
Maximum value				GDP annual growth (%)	5.255006	3.67	5.255006
CO2 emissions (MtCO2)	594.6474	612.5836	612.5836	GBR			
GDP annual growth (%)	6.728642	5.950528	6.728642	Mean			
CHN				CO2 emissions (MtCO2)	569.8891	342.8089	532.7305
Mean				GDP annual growth (%)	2.287902	1.358194	2.135768
CO2 emissions (MtCO2)	3952.591	12032.71	5274.792	Standard deviation			
GDP annual growth (%)	9.254596	5.658745	8.666184	CO2 emissions (MtCO2)	61.5123	35.23347	102.5912
Standard deviation				GDP annual growth (%)	2.192356	5.038857	2.80844
CO2 emissions (MtCO2)	3113.939	839.3672	4157.605	Minimum value			
GDP annual growth (%)	3.586054	1.953385	3.617203	CO2 emissions (MtCO2)	415.8847	292.4193	292.4193
Minimum value				GDP annual growth (%)	-4.620553	-10.29692	-10.29692
CO2 emissions (MtCO2)	911.5013	10773.73	911.5013	Maximum value			
GDP annual growth (%)	-1.57	2.340189	-1.57	CO2 emissions (MtCO2)	690.2576	391.8614	690.2576
Maximum value				GDP annual growth (%)	6.523849	8.575951	8.575951
CO2 emissions (MtCO2)	10881.1	13124.73	13124.73				
GDP annual growth (%)	19.3	8.570086	19.3				

JPN				IND			
Mean				Mean			
CO2 emissions (MtCO2)	1123.545	1099.353	1119.587	CO2 emissions (MtCO2)	848.4588	2643.523	1142.197
GDP annual growth (%)	2.49276	.4109913	2.152107	GDP annual growth (%)	5.384536	5.841465	5.459306
Standard deviation				Standard deviation			
CO2 emissions (MtCO2)	139.6207	89.52223	132.3398	CO2 emissions (MtCO2)	600.597	290.6596	873.0844
GDP annual growth (%)	2.632319	1.941348	2.633761	GDP annual growth (%)	2.8391	4.684648	3.16187
Minimum value				Minimum value			
CO2 emissions (MtCO2)	846.4325	972.267	846.4325	CO2 emissions (MtCO2)	212.7961	2311.977	212.7961
GDP annual growth (%)	-5.693236	-4.168765	-5.693236	GDP annual growth (%)	-5.238183	-5.777725	-5.777725
Maximum value				Maximum value			
CO2 emissions (MtCO2)	1323.49	1228.654	1323.49	CO2 emissions (MtCO2)	2278.229	3153.829	3153.829
GDP annual growth (%)	8.413548	2.696574	8.413548	GDP annual growth (%)	9.627783	9.689592	9.689592
KOR				IRN			
Mean				Mean			
CO2 emissions (MtCO2)	336.0499	638.7016	380.8872	CO2 emissions (MtCO2)	297.3251	737.7816	369.3998
GDP annual growth (%)	7.354463	2.352828	6.61348	GDP annual growth (%)	2.797985	2.952954	2.823344
Standard deviation				Standard deviation			
CO2 emissions (MtCO2)	198.2614	29.87283	212.7675	CO2 emissions (MtCO2)	179.4321	70.9255	233.7046
GDP annual growth (%)	4.094176	1.491415	4.212189	GDP annual growth (%)	8.279137	3.570102	7.681906
Minimum value				Minimum value			
CO2 emissions (MtCO2)	62.33527	590.365	62.33527	CO2 emissions (MtCO2)	80.40354	642.3063	80.40354
GDP annual growth (%)	-5.129448	-.7094154	-5.129448	GDP annual growth (%)	-21.59965	-3.070588	-21.59965
Maximum value				Maximum value			
CO2 emissions (MtCO2)	647.6916	680.496	680.496	CO2 emissions (MtCO2)	636.5399	828.9896	828.9896
GDP annual growth (%)	14.89832	4.304735	14.89832	GDP annual growth (%)	23.17125	8.815086	23.17125
USA				RUS			
Mean				Mean			
CO2 emissions (MtCO2)	5160.742	4818.017	5104.659	CO2 emissions (MtCO2)	1813.428	1862.511	1826.05
GDP annual growth (%)	2.807799	2.435061	2.746806	GDP annual growth (%)	.7280019	1.914295	1.033049
Standard deviation				Standard deviation			
CO2 emissions (MtCO2)	461.0352	217.6516	447.7938	CO2 emissions (MtCO2)	214.0685	92.91316	190.2632
GDP annual growth (%)	2.036455	2.099761	2.031873	GDP annual growth (%)	6.786083	2.787526	5.997166
Minimum value				Minimum value			
CO2 emissions (MtCO2)	4448.829	4466.877	4448.829	CO2 emissions (MtCO2)	1607.381	1734.638	1607.381
GDP annual growth (%)	-2.5765	-2.163029	-2.5765	GDP annual growth (%)	-14.53107	-2.653655	-14.53107
Maximum value				Maximum value			
CO2 emissions (MtCO2)	5928.761	5118.374	5928.761	CO2 emissions (MtCO2)	2436.269	2009.154	2436.269
GDP annual growth (%)	7.236453	6.055053	7.236453	GDP annual growth (%)	10.00007	5.866492	10.00007
Total				SAU			
Mean				Mean			
CO2 emissions (MtCO2)	1317.904	2238.858	1472.117	CO2 emissions (MtCO2)	250.3652	605.388	308.4599
GDP annual growth (%)	4.176143	2.715473	3.931555	GDP annual growth (%)	5.041531	2.75896	4.66802
Standard deviation				Standard deviation			
CO2 emissions (MtCO2)	1815.566	3237.687	2145.579	CO2 emissions (MtCO2)	147.8971	26.67978	189.4803
GDP annual growth (%)	5.324451	3.449613	5.086274	GDP annual growth (%)	10.13551	4.380267	9.443295
Minimum value				Minimum value			
CO2 emissions (MtCO2)	31.12367	292.4193	31.12367	CO2 emissions (MtCO2)	52.00829	577.1045	52.00829
GDP annual growth (%)	-21.59965	-10.29692	-21.59965	GDP annual growth (%)	-16.10909	-3.804765	-16.10909
Maximum value				Maximum value			
CO2 emissions (MtCO2)	10881.1	13124.73	13124.73	CO2 emissions (MtCO2)	611.4483	652.5111	652.5111
GDP annual growth (%)	52.59209	12.00059	52.59209	GDP annual growth (%)	52.59209	12.00059	52.59209

Table 1(con). Mean and standard deviation of CO2 pre-Paris Agreement (1970–2015) and post-Paris Agreement (2016–2024) in the selected countries

	Countr~3	sd_co2~h	sd_gdp~h	vol_ra~o
1.	CAN	3.346728	2.233038	.6672303
2.	CHN	4.235531	3.617203	.854014
3.	DEU	3.523253	2.098114	.5955049
4.	GBR	3.967454	2.80844	.7078695
5.	IDN	6.225656	3.205168	.5148322
6.	IND	3.200355	3.16187	.987975
7.	IRN	6.029222	7.681906	1.274112
8.	JPN	3.713444	2.633761	.7092501
9.	KOR	5.759789	4.212189	.7313095
10.	RUS	4.136934	5.997166	1.449664
11.	SAU	8.868847	9.443295	1.064771
12.	USA	3.502833	2.031873	.5800657

Table 2. Volatility table

The summary statistics show very different CO₂ growth profiles. China and India are the highest average emissions with strong upward trends, especially in pre-Paris Agreement period, while Indonesia, Iran, Korea, Russia and Saudi Arabia also display high and volatile emissions growth. In contrast, Germany, the UK, Japan, Canada and the US have much lower average growth in CO₂ and, in several cases, flat or declining emissions in the post-Paris Agreement period, even as GDP continues to grow.

The volatility table shows that CO₂ growth is generally more volatile than GDP growth (volatility ratio < 1 in most cases), especially in Indonesia and Korea where CO₂ growth fluctuates strongly relative to output. Only Iran, Russia and Saudi Arabia have ratios above 1, indicating that in these more resource-dependent economies GDP growth is more volatile than CO₂ emissions.

Data Visualization and Exploration

Time-series graphs using Stata plot CO₂ emissions and annual GDP growth on dual axes for each country, highlighting the different dynamics of level trends. Figure 25 displays CO₂ emissions (blue) and GDP growth (red) for the sample countries over the entire 1970-2024 period.

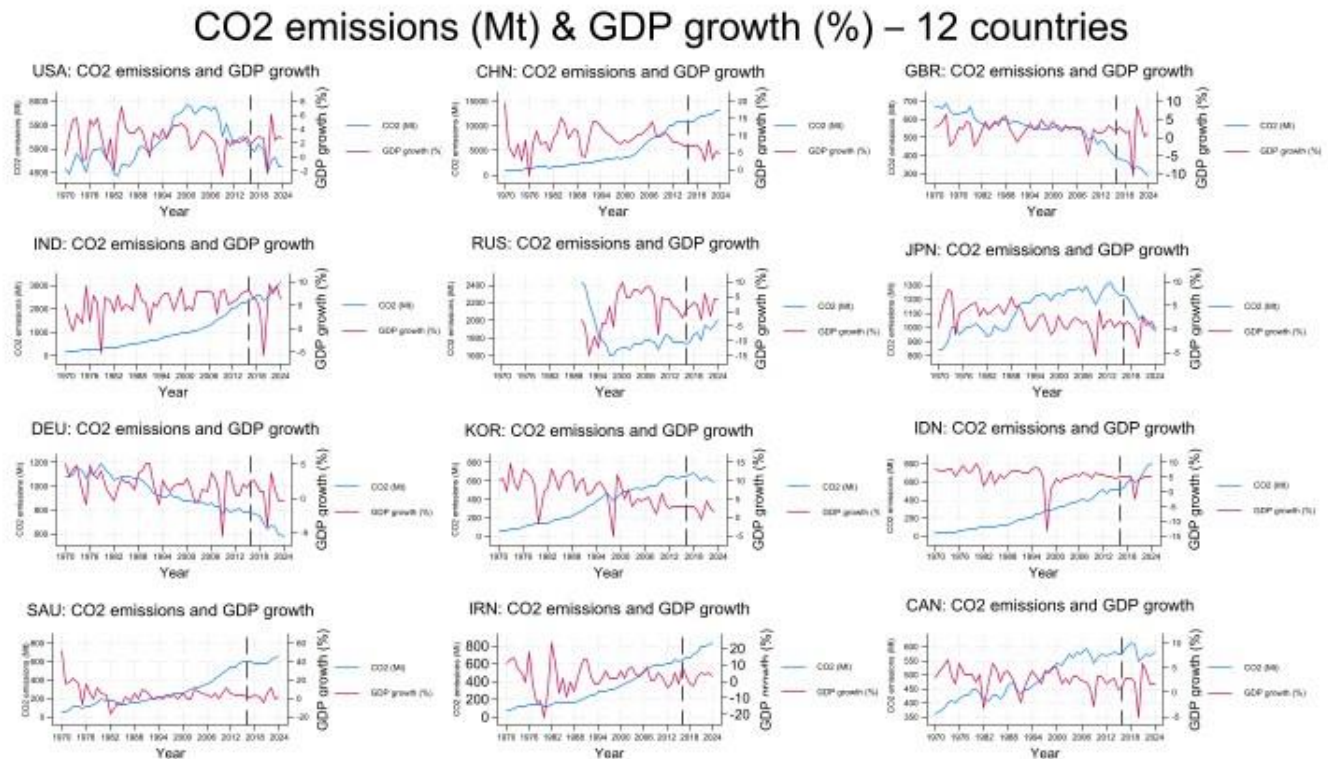


Figure 25. CO₂ emissions and GDP growth for the selected countries over 1970-2024.

The time-series graphs of CO₂ emissions and GDP growth summarise how output and emissions evolve across countries. In the United States, emissions peak in the mid-2000s and then decline, while GDP growth remains volatile with deep contractions in 2008 and 2020. In China, pre-Paris years combine rapid GDP growth with steadily rising emissions, whereas post-Paris observations show more moderate growth but still high CO₂ levels.

The United Kingdom and Germany display clearer downward trends in CO₂, especially after 2015, despite fluctuating GDP, while Japan's emissions peak in the early 2010s and then fall as growth stabilises. India and Russia show continued, often steep increases in CO₂, alongside rising (India) or oscillating (Russia) GDP. Canada and Korea exhibit flattening or gently declining emissions post-Paris, in contrast to Saudi Arabia and Iran, where CO₂ continues to rise amid stagnant GDP.

Overall, the graphs suggest that some high-income economies achieve declining or stabilising emissions despite persistent GDP volatility, whereas many middle- and lower-income countries still experience growing CO₂ emissions alongside economic expansion.

Figure 26 looks at other gases' emissions in the 12 countries with comparison to GDP.

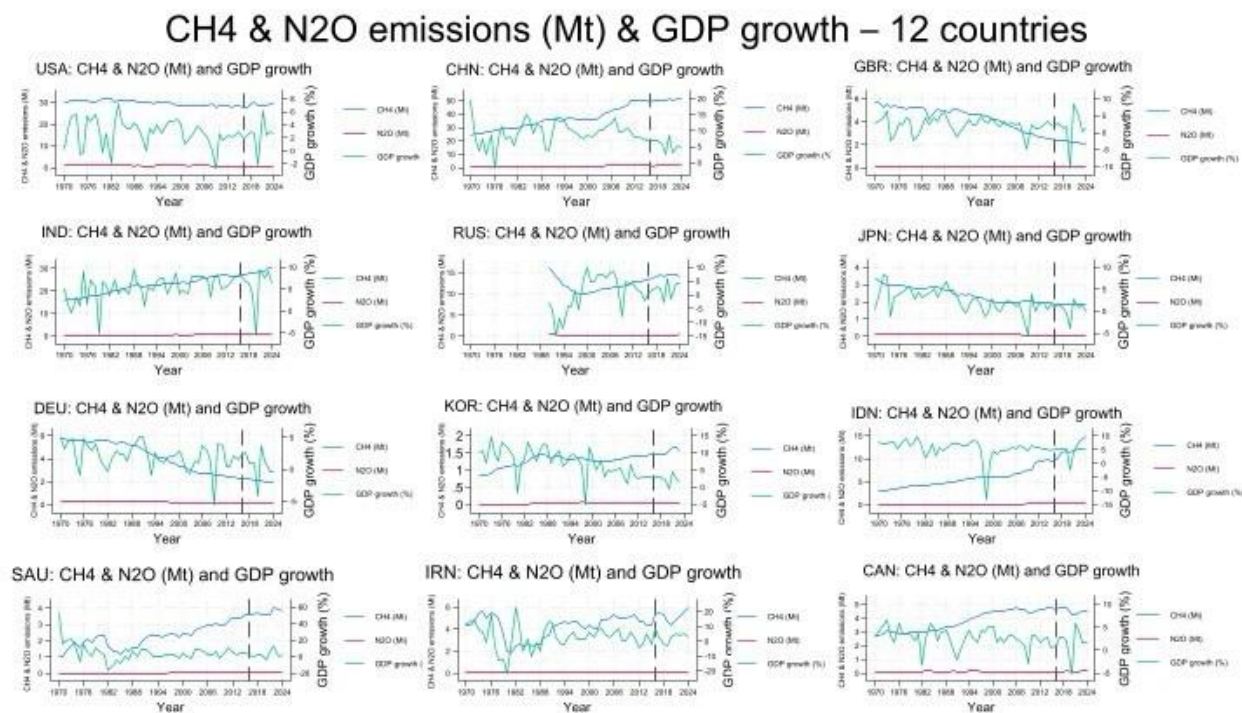


Figure 26. CH₄ and N₂O emissions and GDP growth for the selected countries over 1970-2024.

Across the 12 countries, CH₄ and N₂O emissions are broadly flat or slowly declining, while annual GDP growth fluctuates strongly. There is no systematic pattern of emissions falling when GDP rises, suggesting methane and nitrous oxide are only weakly linked to short-run macroeconomic cycles and are driven more by sectoral structures and long-term policies than by annual growth.

The decoupling analysis classifies each post-Paris year as absolute decoupling (GDP grows while CO₂ or CH₄ falls) or relative decoupling (emissions grow more slowly than GDP). For each country–emission pair, results are summarised as shares of absolute and relative decoupling years, plus the overall share of post-Paris years with any decoupling. Table 3 reports the counts of relative and absolute decoupling years, and Figure 27 displays these shares visually by country.

Table 3. Summary of relative and absolute decoupling for all chosen countries over 2016-2024.

Countr~3	abs_co2	rel_co2	decoup~2	sh~e_co2	sh~s_co2	abs_ch4	rel_ch4	decoup~4	sh~e_ch4	sh~s_ch4
CAN	3	2	5	.5555556	.6	2	5	7	.7777778	.2857143
CHN	1	8	9	1	.1111111	4	5	9	1	.4444444
DEU	4	1	5	.5555556	.8	6	0	6	.6666667	1
GBR	7	1	8	.8888889	.875	8	0	8	.8888889	1
IDN	1	1	2	.2222222	.5	0	3	3	.3333333	0
IND	1	5	6	.6666667	.1666667	0	8	8	.8888889	0
IRN	0	5	5	.5555556	0	1	1	2	.2222222	.5
JPN	6	1	7	.7777778	.8571429	6	1	7	.7777778	.8571429
KOR	4	4	8	.8888889	.5	2	6	8	.8888889	.25
RUS	1	4	5	.5555556	.2	2	2	4	.4444444	.5
SAU	4	2	6	.6666667	.6666667	4	3	7	.7777778	.5714286
USA	4	2	6	.6666667	.6666667	1	5	6	.6666667	.1666667

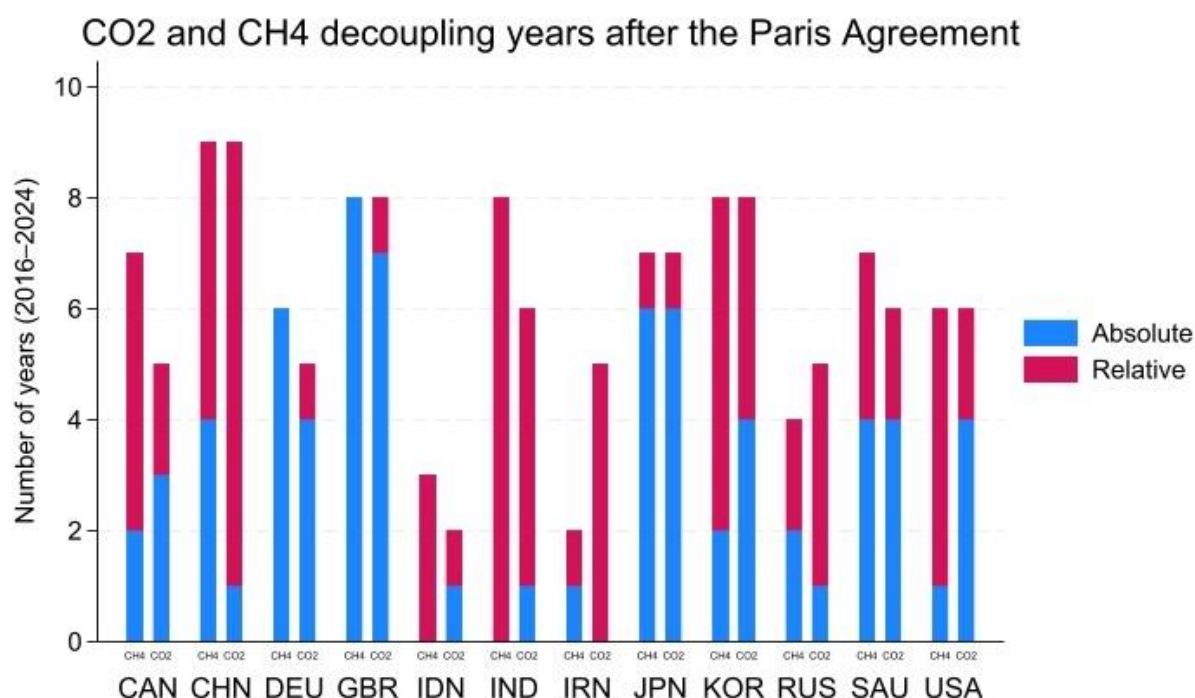


Figure 27. Share of relative and absolute decoupling for the selected countries over 2016-2024.

The results show a group of strong absolute decouplers (the UK, Germany, and Japan) for most post-Paris years, with a high proportion of shares where GDP expands and both CO₂ or CH₄ emissions fall. In the US and Saudi Arabia, around two thirds of post-Paris years are decoupling, but decoupling is more relative, indicating slower emissions growth rather than consistent cuts. China and India decouple in most cases only in the relative definition, with GDP growth out pacing emissions growth instead of sharp emission declines. Canada, Korea, Russia, and Iran form an intermediate group that decouples in roughly half of the post-Paris years, with mixes of absolute and relative periods. Indonesia stands out as the least decoupled, with very few years in which GDP growth is not accompanied by rising emissions.

Part IV: Discussion and Conclusions

Key Findings Summary

Across most of the major emitter countries, emissions continue to rise or plateau after 2016; however, the growth rate of emissions slowed or decreased drastically compared with the pre-Paris Agreement period. GDP growth remained volatile during the entire period, with spikes occurring in times of major global economic distress, including the 2008 housing crisis and the 2020 Covid-19 pandemic. The analysis shows evidence of large negative growth shocks coinciding with downturns in emissions, particularly for the pandemic. Structural, consistent downward trends are more visible in advanced higher-income economies.

The decoupling analysis reveals that absolute decoupling is concentrated in a small group of high-income countries during the post-Paris Agreement period. Most countries show a mix of relative and absolute decoupling in the post-Paris Agreement period. The data confirms a positive association between GDP growth and emissions, thus the analysis documents patterns rather than identifying causal impacts of the Paris Agreement on national emission trajectories.

Policy and Research Implications

These patterns observed in the data support the view that the Paris Agreement period has thus far been characterized more by slower growth in emissions than by deep, broad cuts compatible with the 2 °C pathway (Forner, 2025). The continued coupling of GDP and emissions highlights the challenges of aligning development objectives with strict climate targets and reinforces the importance of direct, clear policies that shift energy mix, raise energy efficiency, and accelerate low-carbon structural change.

Further research could deepen this analysis by incorporating drivers such as energy intensity, sectoral output shares, renewable energy investment, and country-specific policies. Another area for further exploration is the offshoring of emissions by high-income countries to reduce those recorded within their national carbon accounts, suggesting that apparent decoupling trends may not accurately represent the countries' true environmental performance (Ritchie, 2021).

Technical Reflection

Methodologically, the project achieves the goal of being a transparent, reproducible analysis that integrates emissions data with GDP growth data, with distinct variables, documentation, and Stata scripts. Challenges encountered included handling inconsistent values, generating working scripts, and constructing functioning decoupling indicators, though these were addressed after careful examination and robust checks on the code.

References

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