Market and Non-Market Climate Policies in Combination: New Evidence from the OECD's CAPMF and the European Commission's EDGAR datasets

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Abstract

This paper examines the effectiveness of climate policy packages by analyzing the interaction between market-based and non-market-based instruments in reducing carbon dioxide (CO_2) emissions intensity. To this end, we compile a novel dataset[1] by merging the OECD Climate Actions and Policies Measurement Framework (CAPMF) with the European Commission's Emissions Database for Global Atmospheric Research (EDGAR). The CAPMF provides detailed indicators of climate policy stringency across fiscal and regulatory dimensions, while EDGAR supplies consistent measures of fossil CO_2 emissions per unit of GDP for a panel of countries between 2018 and 2023. Using random-effects panel regressions, we show that climate policy is only effective when market-based instruments (such as carbon taxes and Cap and Trade systems) and non-market-based instruments (such as regulations and standards) work jointly. The non-market based instruments are strongly associated with reductions in CO_2 intensity but appear to capture the role of international cooperation and reporting requirements in certain settings. Market-based instruments, in contrast, appear to have a negative impact on climate policy when implemented in isolation and not in a broader policy package that combines fiscal and regulatory approaches. Our study highlights the importance of complementarities between the two approaches. The results provide robust empirical evidence that climate policy packages are more effective than stand-alone measures, underscoring the role of coherent policy mixes in achieving global decarbonization goals.

[1] Click here to download the compiled dataset and the related R code.

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1 Introduction

Since the signing of the Paris Agreement in 2015, countries worldwide have adopted a wide range of policies to steer their economies toward low-carbon development. The academic literature has traditionally emphasized stand-alone carbon pricing as the cornerstone of climate mitigation. Many models suggest that uniform carbon taxes, set at sufficiently high levels, could in isolation reduce emissions at the lowest economic cost by internalizing the externalities associated with greenhouse gas (GHG) emissions.

In practice, however, no government relies exclusively on carbon pricing. Instead, most countries deploy a mix of fiscal and regulatory instruments, often under the mandates of different ministries and agencies. When designed as coherent packages, these combinations of carbon pricing, fiscal incentives, investment support, and regulatory interventions can be highly effective in advancing climate action. Such packages address multiple market failures simultaneously, reduce implementation barriers, and close financing gaps, as highlighted in recent research. Beyond their environmental benefits, they can also support short-term economic recovery and long-term structural transformation. Evidence from Africa, Latin America, the European Union, North America, and Asia illustrates how coherent climate policy packages have stimulated clean energy investment, fostered industrial innovation, and created new employment opportunities. Progress in decarbonisation technologies has also reinforced climate resilience, for example through improved energy efficiency and weatherized infrastructure.

Despite these advances, significant knowledge gaps remain—particularly outside high-income economies. A 2023 survey by the Coalition of Finance Ministries for Climate Action (CFMCA) concluded that "insufficient information is available to answer a number of pressing climate-related policy and analytical questions, spanning a broad range of issues" (CFMCA, 2023). Few existing models are able to adequately capture the role of industrial and innovation policies, S-shaped adoption patterns, technological tipping points, or climate thresholds. These limitations are being gradually reduced as macroeconomic, energy, and climate models are increasingly integrated and hybrid modeling frameworks are developed. Yet, the complex interactions between different policy instruments remain insufficiently understood.

While such knowledge gaps persist, they should not justify inaction. More and more countries—including many low- and middle-income economies—are implementing ambitious climate policy packages that combine *fiscal* and *regulatory* measures. Building on the growing literature that emphasizes the importance of coherent policy mixes, this paper contributes empirical evidence on the interaction between different categories of instruments. Specifically, we focus on the combination of fiscal instruments with regulatory approaches—distinguishing between market-based and non-market policies—to assess whether their joint implementation generates synergetic effects in reducing GHG emissions.

Box 1. Key Concepts Used in This Paper

Policy package for climate action. A policy package (also policy mix or portfolio of instruments) is a coordinated set of tools—such as carbon pricing, subsidies, regulations, and information measures—designed to work together to achieve climate mitigation or adaptation more effectively than stand-alone policies. Packages aim to enhance coherence, overcome barriers, address multiple market failures, and reduce trade-offs across economic, social, and environmental objectives.

Climate-related instruments. We distinguish two broad categories:

1. *Fiscal instruments* (typically overseen by Ministries of Finance):
   (a) Carbon pricing (carbon taxes, emissions trading systems, excises);
   (b) Fiscal support (tax incentives, subsidies, social transfers);
   (c) Public investment and financial management (infrastructure spending, guarantees, equity participation);
   (d) Other budgetary actions (green procurement, green budgeting).
2. *Regulations* (typically overseen by line ministries):
   (a) Emission performance standards;
   (b) Energy efficiency standards;
   (c) Limits on activities and consumption;
   (d) Bans and prohibitions.

Other approaches include voluntary carbon markets (e.g., avoidance and removal credits, verified emission reductions) and information-based instruments (labelling, monitoring, certification, nudging).

Policy interaction. Policy interaction describes how different instruments influence each other's effectiveness or efficiency when implemented together. Interactions may be complementary (reinforcing), neutral, or conflicting (undermining). For example, a carbon tax and a subsidy for renewable energy may jointly accelerate emissions reductions (complementarity), while overlapping regulations and pricing instruments may lead to redundancy or excessive costs (conflict). Apart from effectiveness and efficiency, policy interactions have other important dimensions, such as political acceptability and social effects. Understanding policy interactions is essential for designing coherent climate packages.

2 Literature Review

The focus on carbon pricing:

Traditionally, most economists have emphasized carbon pricing as the cornerstone of climate policy. Carbon pricing ensures that emitters internalize the cost of climate externalities, consistent with the "polluter pays" principle. By sending a price signal, it encourages a shift toward cleaner energy sources, energy savings, and reduced demand for energy services. When applied uniformly across the economy at sufficiently high levels, it reduces emissions where marginal abatement costs are lowest, thus minimizing the overall economic burden. It also generates government revenues, which can be recycled to support low-income households or invested in clean technologies.

For these reasons, carbon pricing has been widely advocated as the most efficient instrument for climate mitigation. Arguments in favor of a stand-alone carbon pricing approach include: (i) addressing the core market failure by pricing emissions; (ii) ensuring least-cost abatement by equalizing marginal abatement costs across sectors; (iii) providing continuous incentives for innovation without ongoing regulatory intervention; (iv) avoiding distortions and redundancies associated with subsidies or mandates; and (v) offering transparency, flexibility, and administrative simplicity compared to complex policy mixes (Wall Street Journal, 2019; Financial Times, 2019).

A growing focus on climate policy packages:
Although textbook models often privilege a single carbon price as the first-best instrument, observed policy practice is decisively multi-instrument. Cross-country inventories—most comprehensively the OECD's Climate Actions and Policies Measurement Framework (CAPMF)—show that governments combine market-based tools with regulations, and public investments across sectors. In 2020 the average country in the CAPMF database had 31 of 56 tracked instruments in place (France had 45), and *policy stringency*[2] has generally risen over time—clear evidence that jurisdictions do not rely on pricing alone. IPCC AR6 likewise emphasizes instrument mixes and policy interactions as the norm rather than the exception.

Several theoretical arguments explain why policy packages may outperform stand-alone pricing:

1. Multiple market failures. A single Pigouvian price addresses the emissions externality but not other distortions that shape low-carbon transitions: knowledge spillovers from R&D and learning-by-doing, information frictions, split incentives, capital-market imperfections, and network externalities. Foundational reviews in environmental economics therefore recommend combining a carbon price with technology-push (R&D) and adoption-pull (deployment) policies, as well as standards that overcome information and agency problems (Jaffe et al. 2005; Goulder & Parry 2008).

2. Political acceptability. Political economy considerations limit the level and stability of carbon prices unless revenues and co-policies address visibility of costs, distributional concerns, and perceived effectiveness. Evidence suggests support rises when revenues are recycled in citizen dividends or used to lower distortionary taxes; conversely, misperceptions about regressivity and effectiveness can erode support, as seen in France after the Gilets Jaunes mobilization. These insights justify packages that combine pricing with targeted transfers, salience-enhancing communication, and complementary investments (Klenert et al. 2018; Carattini et al. 2018; Douenne & Fabre 2022).

3. Path dependence. Energy, transport, and urban systems exhibit strong path dependence: sunk infrastructure and co-evolved institutions create "carbon lock-in," slowing the response to price signals alone. Research on lock-in shows that pricing typically needs to be paired with planning, standards, and public investment (e.g., mass transit, grid upgrades) to unlock cleaner equilibria and avoid long-lived high-carbon choices (Erickson et al. 2015).

4. Technology and innovation. Price incentives can redirect innovation toward cleaner technologies (e.g., in autos), but sustained cost declines typically require both demand-pull (prices or

[2] Policy stringency refers to the strength of the policy signal, measured by the explicit or implicit cost imposed on environmentally harmful activities (*cf.* section 4).

quotas) and technology-push (R&D, demonstration, and early deployment support). Empirical work links higher energy/carbon prices to more clean patents, shows carbon-price-induced direction of technical change, and documents the role of non-price drivers in major cost reductions (e.g., solar PV). Packages that sequence R&D, demonstrations, and scale-up alongside rising prices therefore accelerate diffusion at lower overall cost (Aghion et al. 2016).

5. Policy sequencing. Because political constraints, administrative capacity, and sectoral readiness differ across time and sectors, policy sequencing can ratchet up ambition more effectively than a one-off price reform. Case-based and theoretical work proposes sequences in which early technology and deployment policies build constituencies and reduce costs, paving the way for broader, more stringent pricing and standards later—while guarding against excess rents or lock-ins (Meckling et al. 2017).

Empirical evidence:

Empirical research increasingly supports the superiority of climate policy mixes. Goulder and Parry (2008) already noted that "no single instrument is clearly superior along all dimensions relevant to policy choice." More recent contributions confirm that well-designed policy packages can significantly reduce GHG emissions and stimulate innovation (D'Arcangelo et al., 2024; Stechemesser et al., 2024).

A growing strand of literature stresses complementarities between instruments. Stern, Stiglitz, and Taylor (2022) highlight the need for multiple interventions in the presence of multiple failures. Blanchard, Gollier, and Tirole (2022) argue that carbon pricing requires regulatory complements such as bans and standards. Fay and Hallegatte (2015) suggest tailoring policy packages to national contexts and political constraints. Fries (2021) underscores the role of complementary innovation policies. Cocker (2025) finds systematic evidence that combinations often outperform stand-alone measures, even if trade-offs are unavoidable. Similarly, Hoppe et al. (2023) conclude that "policy mixes are, theoretically and empirically, superior to stand-alone policy instruments." Comparative studies across China, India, Brazil, the EU, and the UK (Anadon et al., 2022) emphasize that interactions determine effectiveness, with policies evaluated jointly often producing outcomes greater than the sum of their parts.

This growing consensus is reflected in policy reports as well. Parry (2021) argues that carbon pricing should be embedded in broader mitigation strategies. The World Bank (2021) cautions that pricing is "not a silver bullet." Finally, a joint report by the OECD, IMF, UNCTAD, World Bank, and WTO stresses that decarbonization requires "a package of coordinated and strategically sequenced climate change policies, in which carbon pricing can play a central role" (OECD et al., 2024). Despite this growing consensus and the high quality of existing conceptual and policy-oriented contributions, empirical evidence on the effectiveness of *different combinations* of climate policy instruments remains scarce. In particular, little is known about how fiscal and regulatory measures interact in practice and whether their effects are complementary, substitutive, or conditional on broader institutional settings. This paper seeks to address this gap by providing empirical evidence on how combinations of fiscal and regulatory instruments affect the mitigation of CO_2 emissions, thereby contributing to the debate on the design of effective climate policy packages.

3 Estimation Strategy

Our empirical strategy is to exploit panel data on CO_2 intensity (measured as fossil CO_2 emissions relative to GDP) for a set of countries over the period 2018–2023. The objective is to identify how changes in market-based (fiscal) instruments *and* non-market (regulatory) instruments affect national CO_2 intensity levels. To assess whether these two categories of instruments interact, we include an interaction term between market and non-market stringency measures. This allows us to capture whether the effect of one category of instruments depends on the presence of the other, and whether their combination generates reinforcing or offsetting effects.

Formally, the dependent variable is the natural logarithm of fossil CO_2 intensity, defined as the ratio of fossil CO_2 emissions to GDP. We estimate the following specification with country random effects:

$$\begin{aligned}\ln(\mathrm{CO_2}/\mathrm{GDP})_{it} = \alpha \; + \; \beta_1 \, \mathrm{MarketStringency}_{it} \; + \; \beta_2 \, \mathrm{NonMarketStringency}_{it} \\ + \; \beta_3 \left(\mathrm{MarketStringency}_{it} \times \mathrm{NonMarketStringency}_{it}\right) \; + \; \gamma' X_{it} \; + \; u_i \; + \; \varepsilon_{it}.\end{aligned} \tag{1}$$

where i indexes countries and t indexes years. X_{it} denotes a vector of additional policy variables, including 'greenhouse gas emission targets', 'fossil fuel production policies', 'international cooperation measures', and 'greenhouse gas reporting requirements'. u_i represents country-specific random effects, and ε_{it} is the idiosyncratic error term.

3.1 Empirical Strategy

We begin by considering the role of **market-based instruments**, such as carbon pricing or emissions trading schemes. These instruments internalize the social cost of emissions and incentivize abatement where it is cheapest. The coefficient β_1 thus captures the direct effect of market stringency on emissions intensity.

Next, we include **non-market instruments**, which encompass regulatory standards and command-and-control measures that directly constrain emissions or mandate specific technologies and practices. The coefficient β_2 reflects the independent contribution of such non-market measures.

To account for potential complementarities or conflicts between the two approaches, we add an **interaction term** between market and non-market stringency. The coefficient β_3 indicates whether the joint implementation of both categories of instruments amplifies or diminishes their individual effects.

Beyond these core variables, we control for other relevant climate policy dimensions. **GHG emissions targets** (**β_4**) capture the ambition of national climate goals, though their impact depends on credibility and enforcement. **Fossil fuel production policies** (**β_5**) represent restrictions or incentives related to fossil fuel extraction and use. **International cooperation** (**β_6**) proxies for participation in multilateral initiatives, while **GHG emissions reporting requirements** (**β_7**) reflect monitoring and transparency mechanisms that can strengthen compliance and accountability.

This specification allows us to evaluate both the direct effects of individual policy dimensions and their interactions in shaping emissions intensity outcomes.

3.2 Model Choice

To determine the most suitable estimator for our panel dataset, we conducted a **Hausman test** to compare fixed effects and random effects models (see Appendix). The resulting p-value of 0.69 suggests that the random effects specification is more appropriate for our data, as the difference between estimators is statistically insignificant.

We also assessed the validity of the model by examining key assumptions. The linearity assumption was tested by plotting each regressor against the log of CO_2 intensity (Figure 1), showing broadly linear relationships. To evaluate normality of residuals, we compared the distribution of residuals with a normal distribution using both histograms and Q–Q plots. Homoscedasticity was assessed through residual-versus-fitted plots, while no multicollinearity assumption was tested using Variance Inflation Factors (VIF). These diagnostic checks, presented in the Appendix, support the robustness of our empirical specification.

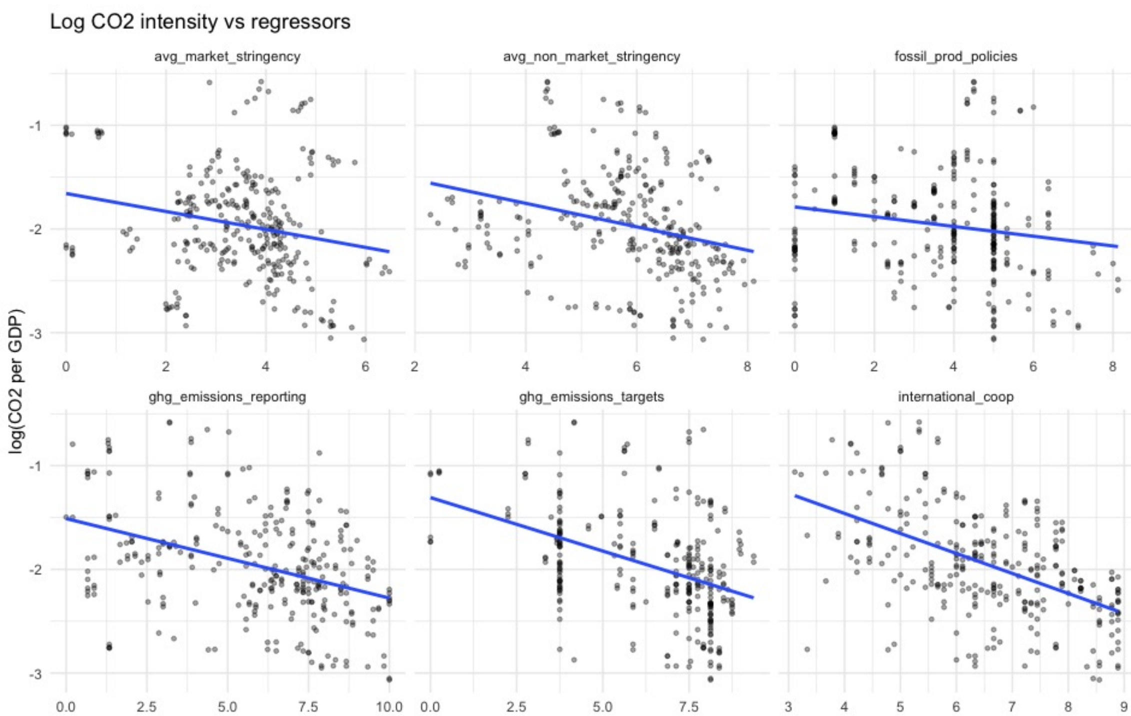

Figure 1: Log CO_2 intensity versus regressors. Each panel shows a bivariate scatter with an OLS fit line; axes correspond to variable units used in the analysis.

Source: Author's analysis.

4 Data and Measurement

The main data source used to estimate Equation (1) is the **OECD Climate Actions and Policies Measurement Framework (CAPMF)**. This database covers both fiscal instruments (classified here as *market-based instruments*) and regulatory policies (classified as *non-market-based instruments*).

The OECD CAPMF attributes a **stringency score** to each policy ranging from 1 to 10 to reflect the degree of implementation. In this context, *stringency* refers to the strength of the policy signal, measured by the explicit or implicit cost imposed on environmentally harmful activities. A policy is considered "highly stringent" when its CAPMF score falls between 7 and 10 (see figure 2). The stringency scores (1 to 10) are available for both market-based and non-market-based instruments, as well as for the other control variables: GHG emissions targets, fossil fuel production policies, international cooperation (e.g., Paris Agreement participation, UNFCCC processes, international financing), and GHG emissions reporting.

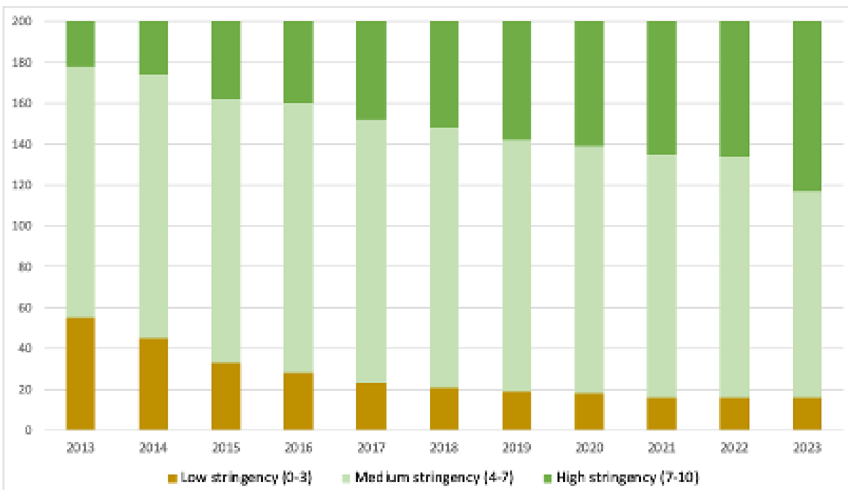

Figure 2: Based on the OECD CAPMF, accessed in February 2025. U.S. data missing from OECD dataset. The value of the stringency indicator varies from 0 (no stringency) to 10 (maximum stringency).

The two core regressors of our model—market stringency and non-market stringency—were computed as the **average stringency across four key sectors** reported in the CAPMF dataset: electricity, industry, buildings, and transport. For the dependent variable, **fossil CO_2 intensity**, we merged the CAPMF dataset with the European Commission's **Emissions Database for Global Atmospheric Research (EDGAR)**, which provides country-level information on CO_2 emissions per unit of GDP. The resulting dataset contains information about the 49 countries for which stringency scores were available (*cf.* abstract). Table 1 reports the summary statistics for our compiled dataset. Figure 3 presents the distribution of the dependent variable (CO_2 per GDP), while Figure 4 shows the distributions of all independent variables.

Table 1: Summary statistics

Variable	Unique	Missing Pct.	Mean	SD	Min	Median	Max
c02_per_gdp	294.000	0.000	0.200	0.100	0.000	0.100	0.600
avg_market_stringency	269.000	0.000	3.500	1.300	0.000	3.700	6.500
avg_non_market_stringency	218.000	0.000	5.800	1.300	2.300	6.000	8.100
ghg_emissions_targets	42.000	0.000	6.300	2.100	0.000	7.200	9.400
fossil_prod_policies	32.000	0.000	3.700	2.000	0.000	4.000	8.100
international_coop	51.000	0.000	6.600	1.400	3.100	6.700	8.900
ghg_emissions_reporting	101.000	0.000	5.900	2.600	0.000	6.500	10.000

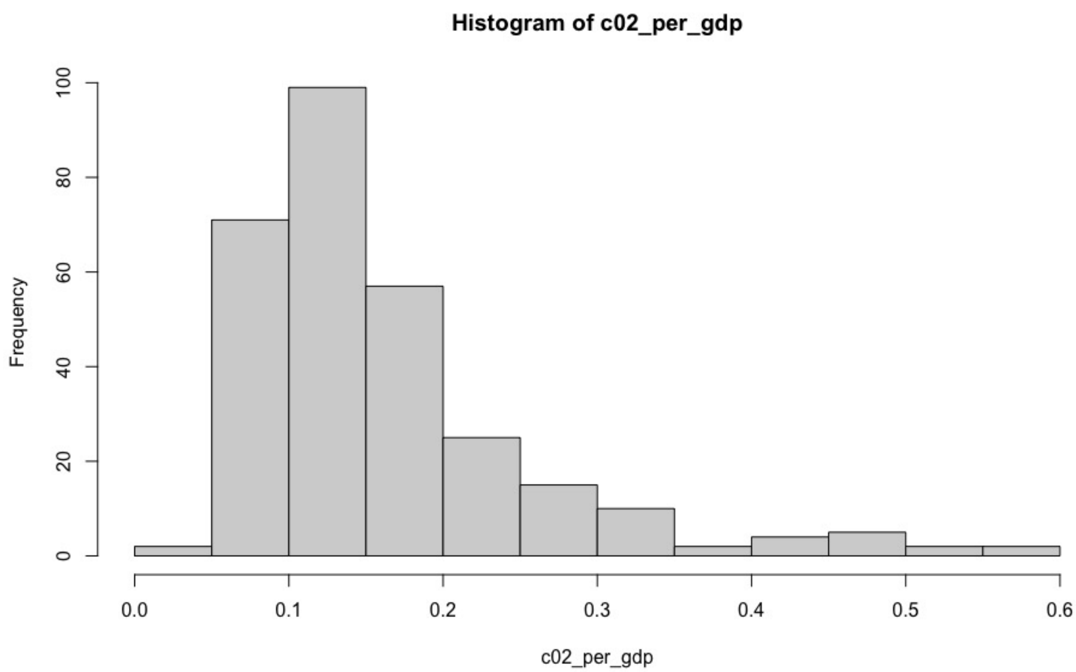

Figure 3: Heavily skewed distribution of the dependent variable (CO2/GDP)

Source: Author's analysis.

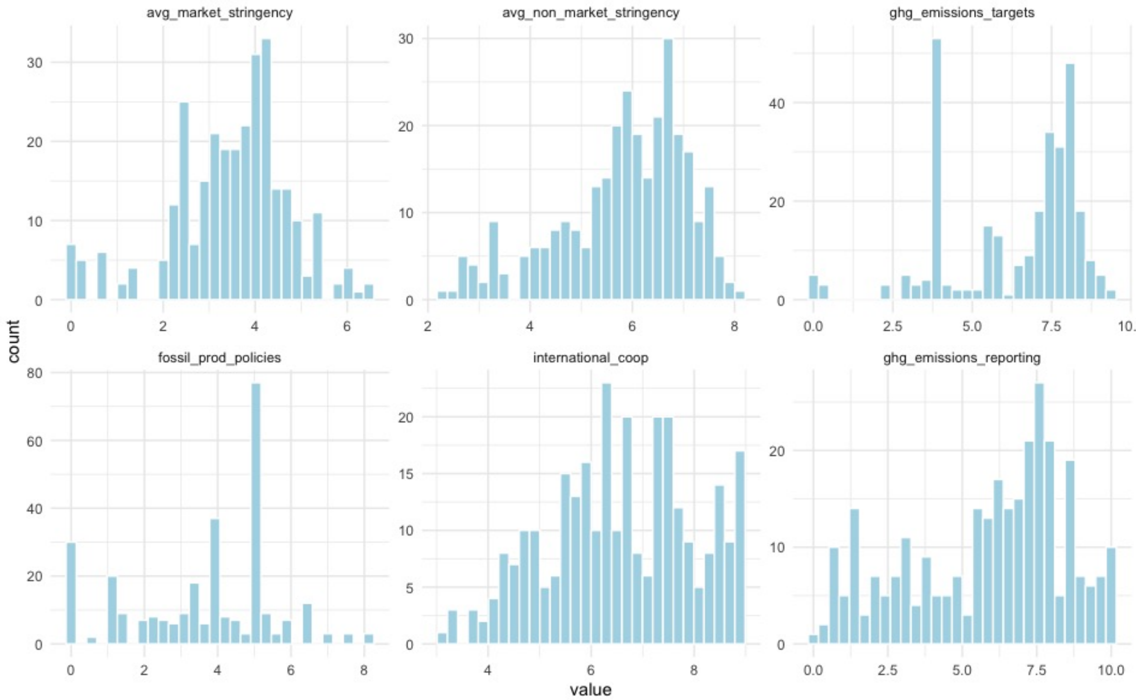

Figure 4: Distribution of independent variables

Source: Author's analysis.

5 Results

We begin by presenting the baseline results in Table 2. In column 1, we estimate a specification including only market-based and non-market-based policy instruments. The coefficient on market stringency is negative but small and not statistically significant, whereas the coefficient on non-market stringency is large, negative, and highly significant. The estimate implies that a one-unit increase in non-market stringency is associated with a 14 percent decline in CO_2 intensity, highlighting the effectiveness of regulatory approaches in lowering emissions relative to GDP.

In column 2, we augment the specification by including an interaction term between market and non-market instruments. The interaction coefficient is negative and significant at the 10 percent level, suggesting complementarities between the two types of instrument. Specifically, the estimate indicates that the joint implementation of both instruments reduces CO_2 intensity by about 1.4 percent beyond the sum of their individual effects. The coefficient on non-market stringency remains negative and significant, pointing again to its strong role in reducing emissions intensity. And although insignificant, the coefficient on market stringency becomes positive when the interaction term is introduced suggesting that this type of instrument might even be detrimental to climate mitigation when implemented in isolation.

Column 3 extends the specification by incorporating additional policy dimensions (control variables): greenhouse gas emissions targets, fossil fuel production policies, international cooperation, and emissions reporting. Once these controls are included, the coefficient on non-market stringency becomes very small and statistically insignificant, while international cooperation and reporting emerge as strongly negative and highly significant drivers of emissions reductions. This pattern suggests that earlier specifications may have overstated the role of non-market stringency because it partly captured the effects of cooperation and reporting. Indeed, the estimate for international cooperation implies that a one-unit increase is associated with a 4.8 percent decline in CO_2 intensity, while the effect of enhanced reporting requirements is about 1.1 percent.

Interestingly, the coefficient on market stringency remains positive and is now significant at the 5 percent level in this richer specification. A one-unit increase in market stringency is now associated with a 9.5 percent surge in CO_2 intensity, conditional on the broader policy environment. In addition, the coefficient on non-market stringency is now also positive and associated with harmful environmental effects. Crucially however, the interaction term between market and non-market instruments remains negative and gains in significance, suggesting that the two instruments reduce CO_2 intensity *only* when implemented together. Put differently, the results indicate that market and non-market measures by themselves may have ambiguous or even undermining effects, but when combined they exert a clear and substantial downward impact on emissions intensity.

These findings point to an important conclusion: *policy mixes matter*. Non-market instruments appear to proxy for international dimensions of climate governance in simpler specifications, but once cooperation and reporting are controlled for, the distinct role of market stringency becomes visible. Moreover, the effectiveness of climate policy is visible when market and non-market instruments are combined, rather than when they are deployed in isolation.

Table 2: Baseline Estimates: Market and Non-Market Stringency Effects

	Model 1	Model 2	Model 3
avg_market_stringency	−0.022	0.065	0.095**
	(0.018)	(0.053)	(0.045)
avg_non_market_stringency	−0.141***	−0.096***	0.001
	(0.012)	(0.028)	(0.026)
avg_market_stringency × avg_non_market_stringency		−0.014*	−0.014**
		(0.008)	(0.007)
ghg_emissions_targets			−0.003
			(0.004)
fossil_prod_policies			−0.006
			(0.007)
international_coop			−0.048***
			(0.006)
ghg_emissions_reporting			−0.011***
			(0.004)
Num.Obs.	294.000	294.000	294.000
R2	0.326	0.334	0.527
R2 Adj.	0.321	0.327	0.515
AIC	−1816.800	−1818.700	−1909.300
BIC	−1802.100	−1800.300	−1876.100
RMSE	0.080	0.080	0.060

* $p < 0.100$, ** $p < 0.050$, *** $p < 0.010$

5.1 Robustness: Clustered Standard Errors

To ensure that our baseline findings are not driven by correlation of the error structure within countries, we re-estimate the models using standard errors clustered at the country level. The results are reported in Table 3.

In column 1, the coefficient on market stringency remains negative and insignificant, while non-market stringency continues to display a strong negative and significant association with CO_2 intensity. The estimate suggests that a one-unit increase in non-market stringency is associated with a 14 percent reduction in emissions intensity, consistent with the baseline results.

In column 2, where the interaction between market and non-market stringency is introduced, the interaction coefficient remains negative but does not show any statistical significance. However, the precision of the non-market stringency estimate is reduced, with the coefficient now significant only at the 5 percent level rather than the 1 percent level.

In column 3, after adding further policy dimensions, the qualitative pattern of results remains intact. Market stringency continues to exhibit a positive and statistically significant coefficient, corresponding to a 9.5 percent increase in CO_2 intensity for a one-unit increase. The interaction term between market and non-market instruments remains negative and significant, reinforcing the importance of their joint implementation. Importantly, international cooperation and emissions reporting remain robustly negative and significant even with clustered standard errors, implying reductions in CO_2 intensity of 4.8 percent and 1.1 percent, respectively.

Overall, clustering at the country level increases the standard errors and reduces the level of statistical significance for some coefficients, but the underlying conclusions remain unchanged. International cooperation, and reporting consistently emerge as effective policy drivers, while market and non-market stringency play their intended roles only when combined together. These results confirm the robustness of our baseline findings to alternative inference procedures.

Table 3: Robustness: Accounting for Within-Country Correlation

	Model 1	Model 2	Model 3
avg_market_stringency	−0.022	0.065	0.095*
	(0.024)	(0.087)	(0.056)
avg_non_market_stringency	−0.141***	−0.096**	0.001
	(0.019)	(0.042)	(0.029)
avg_market_stringency × avg_non_market_stringency		−0.014	−0.014*
		(0.014)	(0.008)
ghg_emissions_targets			−0.003
			(0.005)
fossil_prod_policies			−0.006
			(0.007)
international_coop			−0.048***
			(0.009)
ghg_emissions_reporting			−0.011**
			(0.005)
Num.Obs.	294.000	294.000	294.000
R2	0.326	0.334	0.527
R2 Adj.	0.321	0.327	0.515
AIC	−1816.800	−1818.700	−1909.300
BIC	−1802.100	−1800.300	−1876.100
RMSE	0.080	0.080	0.060
Std.Errors	Custom	Custom	Custom

* p <0.100, ** p <0.050, *** p <0.010

6 Conclusion

This paper examined how market-based and non–market-based climate policy instruments—and their interaction—affect fossil CO_2 intensity (CO_2/GDP) across countries during 2018–2023. Using a random-effects panel specification motivated by a Hausman test, and validating key modeling assumptions, we find strong evidence that the effectiveness of climate policy hinges on the *package*, not any single instrument.

First, in restricted specifications, non–market stringency is strongly associated with lower CO_2 intensity: a one-unit increase corresponds to an estimated 14 percent decline. By contrast, market stringency on its own is imprecisely estimated. Second, adding an interaction term reveals significant complementarities: joint tightening of market and non–market instruments reduces CO_2 intensity by an additional 1.4 percent beyond the sum of separate effects. Third, once we control for broader policy dimensions—notably international cooperation and GHG reporting—the independent effect of non–market stringency becomes small and insignificant, while market stringency turns positive and significant (i.e., economically and environmentally harmful), and the effects of the later two instruments are only meaningful when deployed in combination. International cooperation and reporting themselves are robustly associated with lower intensity (about 4.8 and 1.1 percent per unit, respectively). These patterns persist when standard errors are clustered at the country level, indicating robustness of the qualitative conclusions.

Policy implications. The results point to three lessons for policy design. (i) Climate policies make sense only when *market* and *non–market* instruments are deployed together; neither appears efficient on its own. (ii) Institutional features that raise credibility and accountability—international cooperation and transparent reporting—are first-order complements to core policy tools. (iii) Interpreting single-instrument estimates in isolation can be misleading: apparent effects of non–market regulations in simple models partly proxy for cooperation and reporting; once those are controlled for, the distinct contributions of market and non-market stringencies become visible.

Limitations and future research. Our sample period is short (2018–2023), and stringency indicators may contain measurement error. Endogeneity concerns (e.g., policy responses to emissions trends) remain: while our controls and robustness checks mitigate bias, causal claims should be made with caution. Future work could extend the panel, explore sectoral heterogeneity, allow for non-linearities and thresholds, and pursue identification strategies (e.g., instrumental variables, policy shocks, or staggered adoption designs). Assessing distributional and competitiveness effects, and the sequencing of instruments over time, would further inform the construction of durable policy packages.

In sum, the evidence supports a pragmatic conclusion: effective mitigation is delivered by coherent *policy packages*. Combining pricing with targeted regulation and credible governance mechanisms yields larger and more reliable reductions in CO_2 intensity than deploying instruments in isolation.

A Assumption Checks

In this appendix, we present diagnostic graphs used to check the validity of our model assumptions.

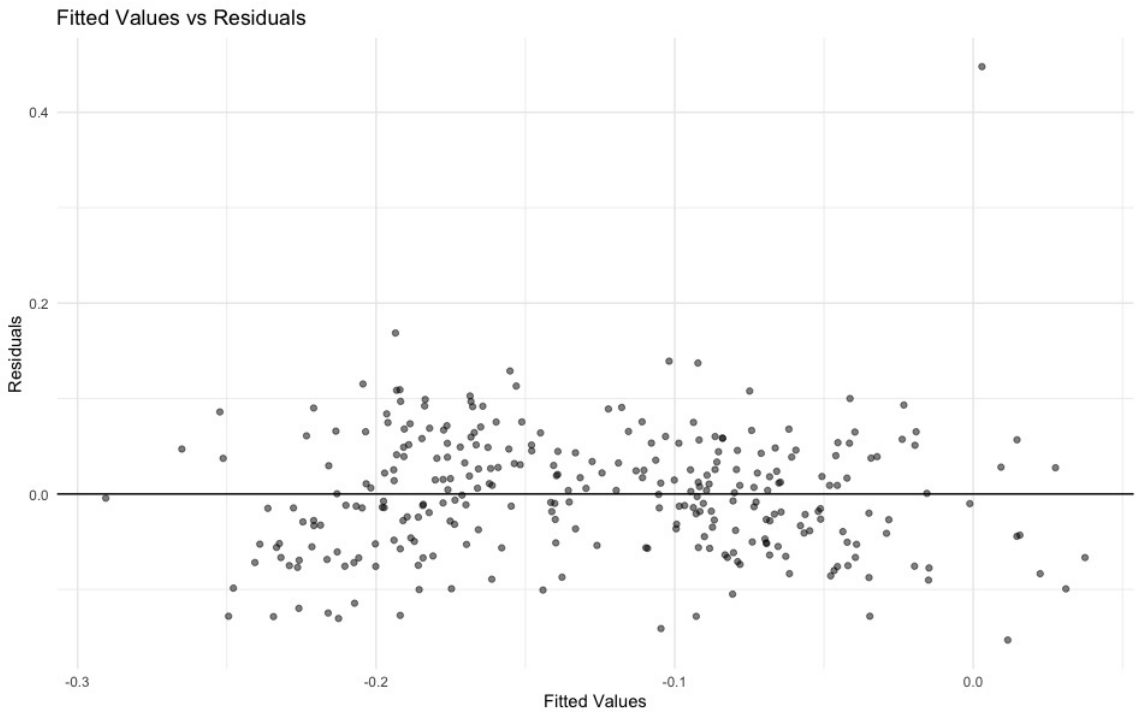

Figure 5: Homoscedasticity assumption

Source: Author's analysis.

```
> model <- lm(log(c02_per_gdp) ~ avg_market_stringency + avg_non_market_stringency +
+               ghg_emissions_targets + fossil_prod_policies +
+               international_coop + ghg_emissions_reporting,
+             data = interactions_panel_2018_2023)
> vif(model)
    avg_market_stringency avg_non_market_stringency     ghg_emissions_targets
                 1.806781                  1.778620                  1.690162
     fossil_prod_policies         international_coop   ghg_emissions_reporting
                 1.799530                  2.015540                  1.599294
```

Figure 6: No multicollinearity assumption

Source: Author's analysis.

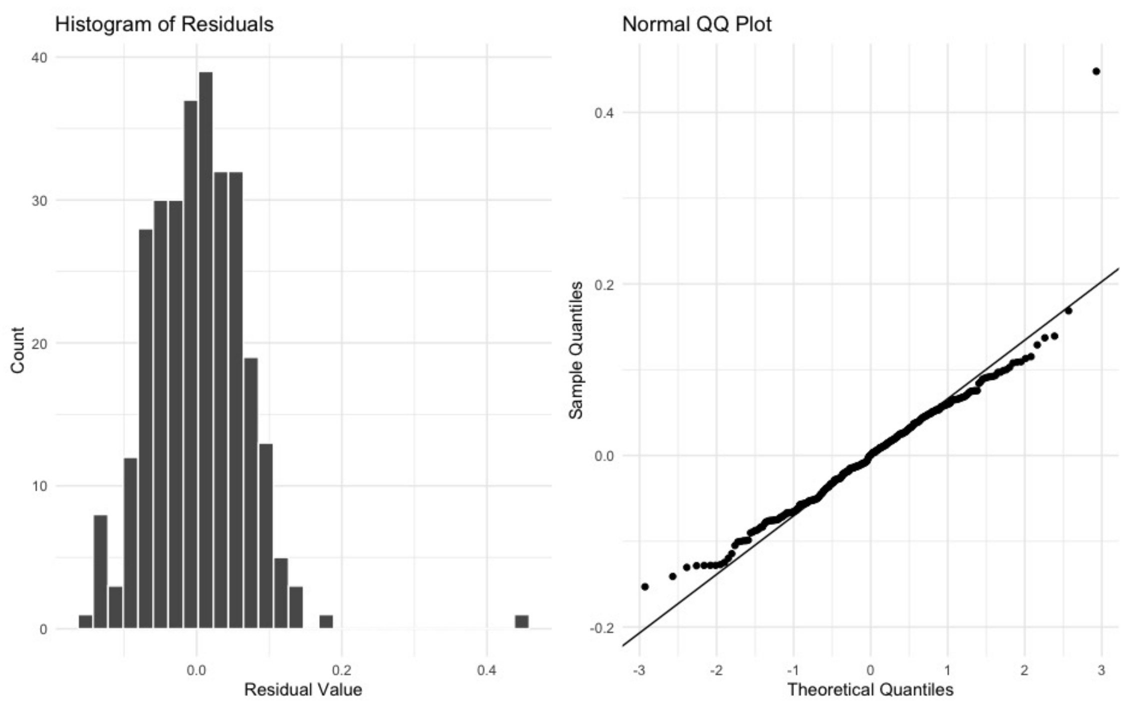

Figure 7: Normality of errors assumption

Source: Author's analysis.

```
> phtest(fe_model, re_model)

        Hausman Test

data:  log(c02_per_gdp) ~ avg_market_stringency + avg_non_market_stringency +  ...
chisq = 4.7533, df = 7, p-value = 0.69
alternative hypothesis: one model is inconsistent
```

Figure 8: Hausman test

Source: Author's analysis.

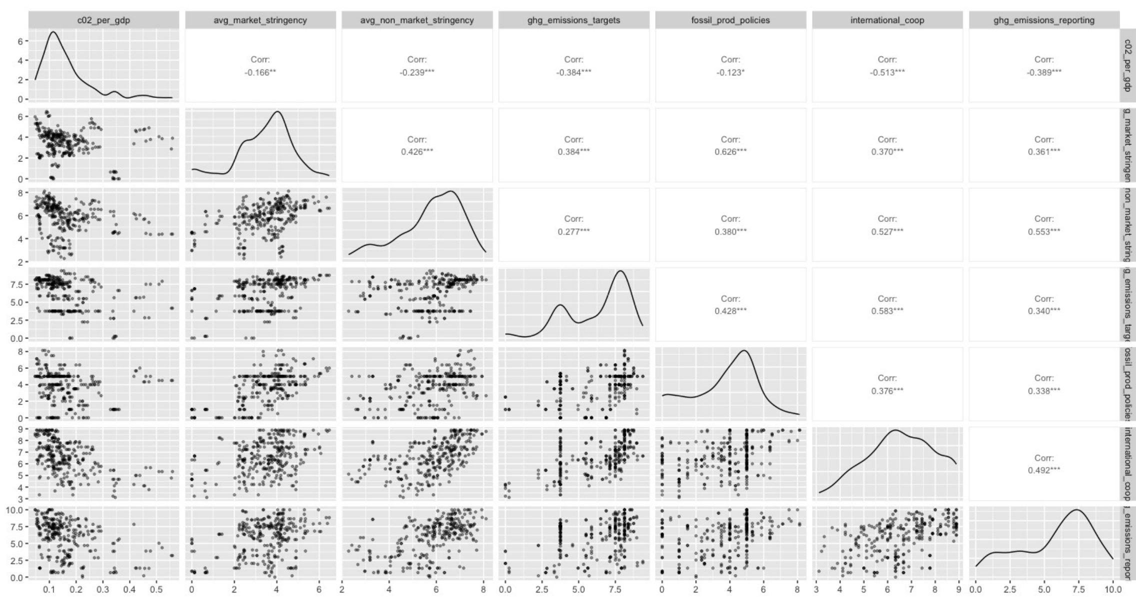

Figure 9: Pair plot of the dataset

Source: Author's analysis.

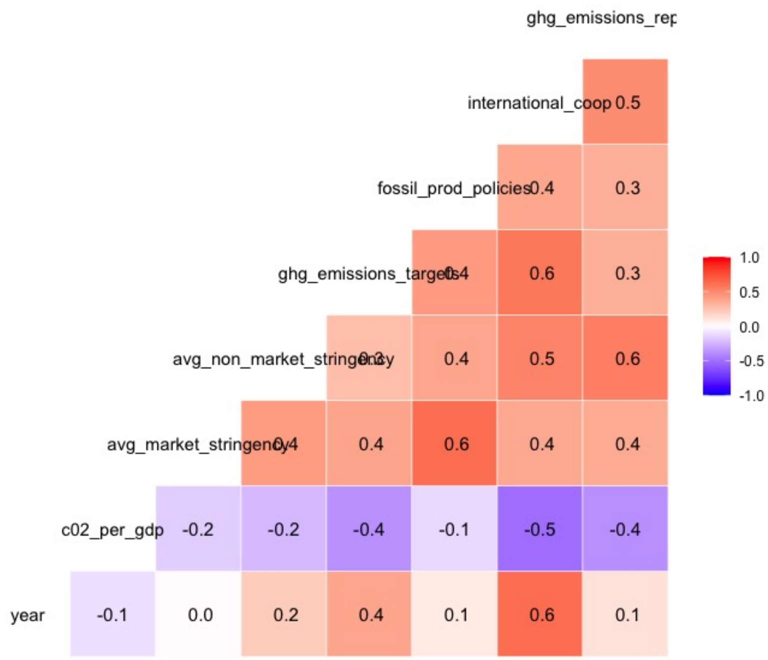

Figure 10: Correlation matrix

Source: Author's analysis.

References

[1] Fay, M., & Hallegatte, S. (2015). *Decarbonizing Development: Three Steps to a Zero-Carbon Future*. World Bank.

[2] Goulder, L. H., & Parry, I. W. H. (2008). Instrument choice in environmental policy. *Review of Environmental Economics and Policy*.

[3] Stern, N., Stiglitz, J., & Taylor, C. (2022). The economics of immense risk, urgent action and radical change: towards new approaches to the economics of climate change. *Journal of Economic Methodology*, 29(3), 181–216.

[4] Blanchard, O., Gollier, C., & Tirole, J. (2022). The Portfolio of Economic Policies Needed to Fight Climate Change. Peterson Institute for International Economics, Working Paper 22-18.

[5] Fries, S. (2021). *Transforming energy systems: Economics, policies and change*. Edward Elgar Publishing.

[6] Cocker, F. G. (2025). Mixes of policy instruments for the full decarbonisation of energy systems: a review. *Energies*, 18(1), 148.

[7] Stechemesser, A., et al. (2024). Climate policies that achieved major emission reductions: Global evidence from two decades. *Science*, 385, 884–892.

[8] D'Arcangelo, F. M., Kruse, T., & Pisu, M. (2024). Identifying and tracking climate change mitigation strategies with a cluster-based assessment. *npj Climate Action*, 3(1), 86.

[9] Hoppe, J., Hinder, B., Rafaty, R., Patt, A., & Grubb, M. (2023). Three decades of climate mitigation policy: what has it delivered? *Annual Review of Environment and Resources*, 48(1), 615–650.

[10] Anadon, L. D., Jones, A., & Peñasco, C. (2022). Ten Principles for Policymaking in the Energy Transition: Lessons from Experience. EEIST Report.

[11] Parry, I. (2021). Carbon pricing in broader mitigation strategies. International Monetary Fund.

[12] World Bank. (2021). *Carbon Pricing for Climate Action*. Washington, DC: World Bank.

[13] OECD, IMF, UNCTAD, World Bank, & WTO. (2024). *Working Together for Better Climate Action: Carbon Pricing, Policy Spillovers, and Global Climate Goals*. OECD Publishing.

[14] Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2005). A tale of two market failures: Technology and environmental policy. *Ecological Economics*, 54(2-3), 164–174.

[15] Goulder, L. H., & Parry, I. W. H. (2008). Instrument choice in environmental policy. *Review of Environmental Economics and Policy*, 2(2), 152–174.

[16] Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., & Stern, N. (2018). Making carbon pricing work for citizens. *Nature Climate Change*, 8(8), 669–677.

[17] Carattini, S., Carvalho, M., & Fankhauser, S. (2018). Overcoming public resistance to carbon taxes. *Wiley Interdisciplinary Reviews: Climate Change*, 9(5), e531.

[18] Douenne, T., & Fabre, A. (2022). French attitudes on climate policies: Evidence from the Yellow Vests movement. *Journal of Environmental Economics and Management*, 110, 102554.

[19] Erickson, P., Kartha, S., Lazarus, M., & Tempest, K. (2015). Assessing carbon lock-in. *Environmental Research Letters*, 10(8), 084023.

[20] Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, 124(1), 1–51.

[21] Meckling, J., Sterner, T., & Wagner, G. (2017). Policy sequencing toward decarbonization. *Nature Energy*, 2(12), 918–922.

[22] Coalition of Finance Ministies for Climate Action (2023), "Strengthening the Role of Ministries of Finance in Driving Climate Action A Framework and Guide for Ministers and Ministries of Finance", Synthesis Report, July.