The Impact of Green Financial and Monetary Policy on the Low-Carbon Energy Transition: Global Empirical Evidence

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Abstract

Aligning economic pathways with a 2°C climate target implies rapid decarbonisation and a substantial increase in renewable energy (RE) investment and deployment. The financial system plays a key role in mobilising these investments. To support these efforts and address related climate risks, financial regulators and central banks increasingly adopted green financial and monetary policies (GFMP). However, empirical evidence on the effects of GFMP on the low-carbon energy transition remains scarce. This paper sheds light on the impacts of GFMP on RE capacity, a measure of RE investment and key transition indicator. I construct a country-level GFMP index capturing the flow and stock of policy intensity and mix across 26 countries for the years 2000 to 2023. Leveraging this index, I deploy two-way fixed effects and quantile panel regressions to quantify aggregate, policy type-specific, and heterogeneous conditional effects. Results show a positive relationship between GFMP intensity and RE capacity. On average, each adopted GFMP is associated with an addition of 0.016 gigawatt RE capacity per million capita, corresponding to 4.8 Mt CO_2 emissions avoided when displacing fossil energy sources. Distinguishing by policy type, I find incentive-based instruments are about twice as effective as informational instruments. Both the adoption of GFMP and the size of effect shows heterogeneity. This study provides an early empirical quantification of the impact of GFMP on the energy transition, and presents an index that can inform future research. Findings hold important policy implications on the green transition.

Keywords: Low-carbon energy transition, Climate finance, Climate-related risks, Green monetary policy, Financial regulation, Macroprudential policy

1. Introduction

Climate change, famously described as the "greatest market failure the world has ever seen" (Stern, 2007) poses substantial risks to social and economic systems. To mitigate the most severe impacts the global economy must drastically decarbonize. The IPCC highlighted that the window of opportunity for such an orderly transition is closing rapidly (IPCC, 2022). As the largest source of global CO_2 emissions this applies particularly to the power sector, where Paris-aligned pathways imply a substantial increase in renewable energy (RE) deployment (Luderer et al., 2018). However, there is an investment gap of USD 400 billion per year to meet the COP28 pledge of tripling installed RE capacity by 2030 (IEA, 2024), implying a required increase in current annual investment levels of about 60%. The financial system plays a key role in closing this finance gap by allocating funds and pricing related climate risks, thereby enabling a smooth low-carbon transition. For example, because low-carbon energy technologies tend

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to be more capital-intensive than incumbent high-carbon solutions, the cost and availability of capital set in financial markets is a key determinant of investment, energy mix, and the rate of decarbonisation (Egli et al., 2018; Hirth and Steckel, 2016). The increasing awareness for the implications of financial and climate interactions, for example on inflation and financial stability, has led to the launch of private and public initiatives (e.g., GFANZ, NGFS) and discussions on the role of regulators and central banks in "greening" financial flows (Campiglio et al., 2018; Dikau and Volz, 2021; Boneva et al., 2022). Against this context, a growing number of financial regulators and monetary authorities, including the United Kingdom's Financial Conduct Authority and the European Central Bank, have added green financial and monetary policies (GFMP) to their toolkits (NGFS, 2024). These are measures that (in)directly target the structure and conditions of the financial system to address climate-related concerns. To date, mostly two kinds of policies have been adopted. First, informational instruments such as disclosure requirements and climate stress testing, which aim to increase climate-related information (e.g., climate risk exposure, vulnerability, and management) available to financial actors. Second, incentive-based instruments such as capital requirements or asset eligibility rules that change the financial incentive structure by altering the relative prices to which market participants are exposed. These incentive-based policies present a more direct intervention, designed to steer capital towards low-carbon investments that promote an orderly transition (Baer et al., 2021).

While a variety of GFMP instruments have been adopted, empirical evidence on their impact on a smooth transition remains scarce. The motivation of this paper is to shed light on the economic impacts of GFMP by empirically assessing the relationship between countries' GFMP and low-carbon transition performance. More specifically, I investigate whether GFMP intensity can explain countries' renewable energy (RE) capacity. This is of special interest, because power sector decarbonisation via RE deployment is a top priority on the global political agenda, and a key indicator of countries' transition towards a low-carbon economic system.

I collect data on GFMP adoption across 26 countries for the years 2000 to 2023, and group adopted instruments into distinctive policy types. I create a country-level GFMP index that captures the flow and stock of policy intensity and mix over time. Here, intensity refers to the volume of implemented policies. Methodologically, I follow a two-way fixed effects panel regression approach, investigating the relationship between GFMP and RE capacity across countries over time. I distinguish between policy types to estimate instrument-specific impacts and short- vs. long-term effects. Additionally, I apply quantile panel regression techniques to obtain coefficients at different points of the dependent variable's distribution, capturing asymmetric effects from heterogeneity and potential nonlinear relationships.

Results are threefold. First, I find a significant positive relationship between the stock of GFMP and RE capacity. On average, each adopted GFMP is associated with an addition of 0.016 gigawatt RE capacity per million capita. This corresponds to about 4.8 Mt CO_2 emissions avoided annually when displacing fossil energy sources. Second, disentangling the aggregate impact by policy type, I find positive effects for informational instruments (climate stress testing, green finance guidelines, disclosure requirements) and incentive-based policies (credit allocation, green bonds, prudential climate risk management), but the latter being about twice as effective. Findings suggest that while GFMP can accelerate the low-carbon transition, policymakers wishing to promote transition efforts may want to tilt policy mixes towards incentive-based measures. Third, quantile analysis reveals effects are heterogeneous across the distribution, but not systematically different.

This study contributes to the literature in three respects. First, it provides an early empirical assessment of GFMP's real-economy impacts and sheds light on the heterogeneity of outcomes, providing a deeper understanding of the effects of GFMP beyond theoretical models. Second, I present a structured, comprehensive and novel GFMP index, which can be utilised in future studies investigating other relevant transition outcome variables that are beyond the scope of this paper. Third, the coverage of major economies, representing 75% of global emissions and 82% of world GDP, offers a comparative perspective and high policy relevance which can inform harmonization and policy cooperation efforts of financial regulators and central banks. The remainder of the paper is structured as follows. Section two lays out the theoretical background. Section three describes the data. Section four outlines the research design. Section five presents results. Section six concludes.

2. Background

2.1. Context and literature

GFMPs are tools deployed by financial authorities and central banks to address climate-related concerns in the financial sector. First, GFMP can help tackle physical and transition climate risks. Physical risks arising from acute or chronic impacts of changes in the climate system can result in significant economic damages and impairment of financial assets' underlying economic activities (Burke et al., 2015; Dietz et al., 2016). Transition risks stemming, for example, from changes in climate policies, the cost and availability of technologies, or demand and supply patterns, can lead to sudden adjustments in asset prices and financial instability (Battiston et al., 2017; Bolton et al., 2020; Roncoroni et al., 2021). GFMP instruments like climate stress testing and disclosure requirements support policymakers and financial market participants to identify, quantify, manage, and price such risks. For example, investors are increasingly demanding a "carbon risk premium" as compensation for their exposure to high-emission firms (Bolton and Kacperczyk, 2021). Second, GFMP can support making "finance flows consistent with a pathway towards low greenhouse gas emissions", as noted in Article 2 of the Paris Agreement (UN, 2015). For instance, capital allocation rules can incentivize redirecting investments into low-carbon activities. Consequently, regulators and central banks have increasingly implemented GFMP to respond to climate risks and meet wider sustainability objectives implied in their mandates. Recent examples include the carbon emission reduction facility introduced by the People's Bank of China in 2021, the climate stress test conducted by the European Central Bank in 2022, and climate risk disclosure requirements established by Japan's Financial Services Agency in 2023.

In line with these developments, a growing body of academic research is devoted to GFMP. First, numerous conceptual frameworks and theoretical models study different GFMP instruments and approaches of how and under which conditions financial supervisors can align their policies to the realities of climate change. Conducting a systemic literature review, Hidalgo-Oñate et al. (2023) find that research on GFMP approaches has focused on disclosure requirements, climate stress testing, differentiated capital requirements, and green finance frameworks. Baer et al. (2021) identify a promotional gap in European GFMP, concluding that regulators primarily focus on prudential objectives via informational instruments rather than actively steering the transition through incentive-based instruments. In line with their prominence in the regulatory arena, climate stress testing frameworks, which estimate financial impacts of a climate scenario versus a business-as-usual baseline, have been deployed and assessed by multiple authors (Reinders et al., 2023; Pang and Shrimali, 2024; Gasparini et al., 2023). In turn, Chenet et al. (2021) argue that this primarily informational approach pursued to date is limited in addressing climate-related financial challenges, because of the inherent radical uncertainty around climate impacts which makes 'efficient' price discovery difficult. Accordingly, a variety of incentive-based instruments has been simulated in macro-financial models, suggesting that, despite temporary financial stability trade-offs, climate-augmented financial and monetary policies can reduce inflation volatility, while supporting green investments and overall welfare (Dafermos and Nikolaidi, 2021; Dunz et al., 2021; Monasterolo and Raberto, 2017; Schoenmaker, 2021), thereby inducing a virtuous cycle of emission reductions, long-term stable financial sector and economic growth (Lamperti et al., 2021).

Second, it is increasingly researched which institutional, economic and political characteristics contribute to the adoption and diffusion of GFMP. Among the relevant factors identified are, for example, the central bank governance framework, the economy's carbon intensity, and the country's vulnerability and exposure to climate change (D'Orazio, 2022b; D'Orazio and Popoyan, 2023; Feldkircher and Teliha, 2024; Gupta et al., 2023). Cojoianu et al. (2025) analyse the socioeconomic determinants of green finance policies and find that adoption is driven by both market and institutional factors, primarily exposure to the fossil fuel industry and the level of societies' climate change awareness. Shears et al. (2025) provide a systematic assessment of how and why central banks address climate risks by re-risking fossil fuel investments and de-risking clean energy investments, suggesting that central bank climate risk management is associated with a country's climate policy ambition rather than its economic exposure to transition risks. In a similar vein, but focusing on central bank public communication strategies about climate and associated policies, Campiglio et al. (2025) identify underlying institutional factors rather than exposure to climate-related risks as the key driver of central banks' engagement with climate-related topics.

Third, an evolving but under-researched theme is the empirical assessment of GFMP. Early attempts to shed light on GFMP's empirical effects were made by D'Orazio and Dirks (2022) who identify a negative relationship between climate-related financial policies and carbon emissions in G20 countries, and Miguel et al. (2024) who investigate the impact of climate-related capital requirements on bank lending and find that while regulated banks reduce brown lending, the net effect on real economic activity and emissions is neutral due to substitution effects. Conducting a comparative analysis of green financial policies in OECD countries, Steffen (2021) detects a positive link between low-carbon financial policy intensity and GDP per capita. Using machine learning methods, D'Orazio and Pham (2025) examine climate-related financial policy sequencing patterns, and identify the relative importance of policy and economic characteristics in predicting countries' decarbonisation outcomes. Andries et al. (2025) examine the relationship between climate-related financial policies and bank's systemic risk, documenting that more stringent policies, restricting (carbon-intensive) lending, are associated with increased financial distress. While the contributions to date have progressed our understanding of the drivers and (theoretical) outcomes of GFMP, empirical studies remain surprisingly scarce. This is partly because existing empirical research typically examines policies directly targeting polluting sectors but less so policies directed at the financial sector intended to indirectly address climate transition objectives. As highlighted by the NGFS (2024), and considering the substantial public and private resources involved in policy development and compliance, it is crucial to examine the impacts of GFMP on the low-carbon energy transition in more depth.

Conceptually, GFMP are transmitted through financial intermediaries in the credit and banking system to the real economy via three key channels: the price or interest rate channel, the lending quantity channel, and the portfolio re-balancing channel (Monasterolo et al., 2024). By way of these transmission channels, GFMP lead to increased liquidity for companies willing to invest in low-carbon activities, de-risking of green investments, and thus relatively higher green capital productivity. This translates into increased green investment demand, a reduction in the low-carbon infrastructure and energy investment gap, and changes in the sector and technology composition of the economy. Ultimately, these financial adjustments affect macroeconomic performance, including consumption, GDP, sovereign debt, and energy mix. More specifically, the link between financial sector conditions and low-carbon energy deployment is rooted in the fact that the cost of capital (CoC) for energy investments is a key determinant for the competitiveness of RE technologies, which are relatively more capital intensive vis-a-vis fossil fuel alternatives. Indeed, energy modeling has shown how the CoC drives overall energy system cost, technology mix and the rate of energy system decarbonisation (Polzin et al., 2021). For example, Egli et al. (2018) estimate that 40% of the decline in electricity generation cost in the early RE industry is stemming from more favourable financing conditions (lower CoC). Hirth and Steckel (2016) demonstrate that the share of RE in the cost-optimal energy mix comprises 40% under a CoC of 3%, but is almost zero at a CoC of 15%. Schmidt et al. (2019) show how interest rate dynamics, for example induced by financial and monetary policies, can change the CoC of low-carbon technologies and thereby promote or jeopardize RE deployment. In a similar vein, analysing the relationship between financial capital and energy transitions, Best (2017) concludes that policies that affect the structure and conditions of the financial system can facilitate the use of relatively more capital-intensive RE technologies compared to fossil-fuel energy generation types. To sum up, financial conditions (i.e., CoC), which are affected by GFMP, are a major determinant of energy investment and mix. Therefore, there is a strong logical chain between GFMP and RE deployment, transmitted through macro-financial channels (Figure 1).

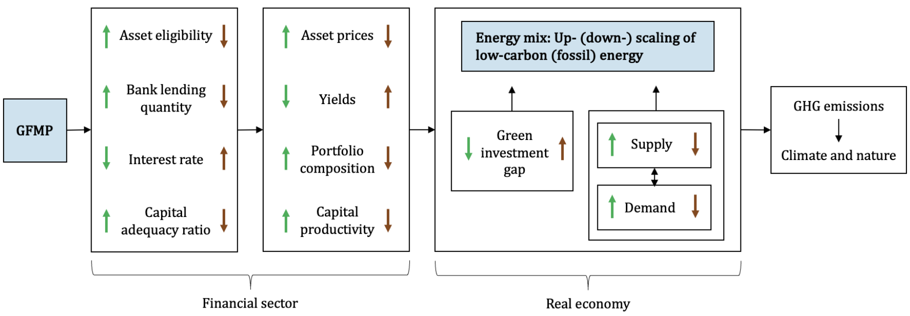

Figure 1: Stylised macro-financial transmission channels of GFMP

Note: Based on Monasterolo et al. (2024). Upward- (downward) facing arrows indicate positive (negative) trend. Green (brown) arrows indicate potential effects on low- (high-) carbon economic activities.

2.2. *Hypotheses*

Based on the conceptual framework, the stock of GFMP codifies a country's policy ambition regarding the greening of the financial system and sustainable transformation of the economy. This implies that higher policy intensity, as measured by the number of adopted GFMP, can be expected to enable a more rapid transition. That is, when GFMP effectively induce financial institutions to reduce their high-carbon asset exposure and provide more favourable conditions for low-carbon investments, one would expect a more pronounced up-scaling of RE technologies for countries with a larger stock of GFMP. This scaling-up takes the form of increasing RE capacity, a proxy of renewable energy investment and key indicator of transition performance. From these conceptual macro-financial mechanisms, the following hypotheses arise.

H1: There is a positive relationship between a country's stock of GFMP and RE capacity.
H2: Incentive-based GFMP instruments have a more positive relationship with RE capacity than informational instruments.

3. Data

3.1. GFMP data

I collect data on GFMP adoption from datasets on climate-related financial policies provided in D'Orazio (2021, 2022a), the Green Monetary and Financial Policies Tracker by the E-axes Forum on Climate Change, Macroeconomics and Finance, and manual research of official documents. Manuel research involves review of climate-related publications by financial regulators and central banks from 2020 to 2023 to increase time coverage. This data collection process yields GFMP observation across 26 countries for the years 2000 to 2023. I group observations into six distinctive policy types: Credit allocation, green bonds, green finance guidelines, climate stress testing, other prudential climate risk management, and other disclosure requirements (non-financial institutions). Next, I create a country-level GFMP index (c, t) which is increased by 1 in year t when country c adopts a GFMP, thus capturing the flow and stock of policy intensity and mix over time.

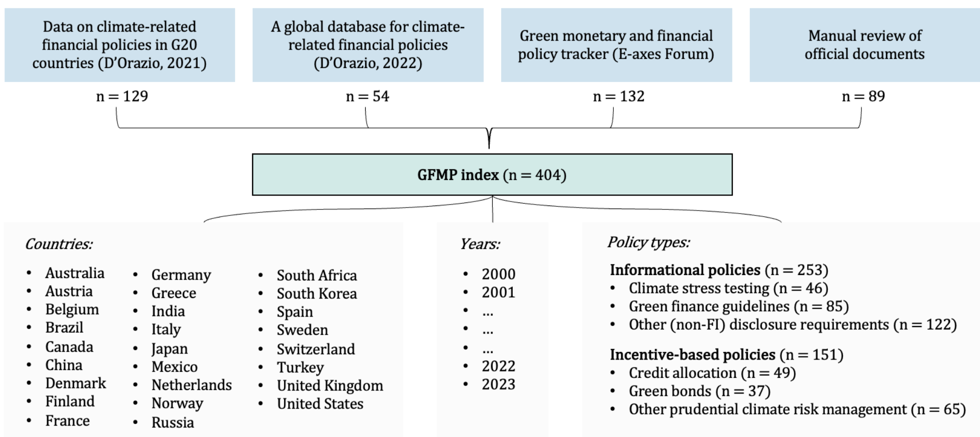

Figure 2: Data for GFMP index construction

The GFMP index presents a heterogeneous picture of countries' policy ambition. While leaders such as France and Germany adopted 32 and 25 polices, laggards such as Turkey and South Africa implemented 5 and 6 policies (Figure 3). Disentangling the stock of adopted GFMP into policy types, it becomes apparent that informational instruments dominate, but incentive-based instruments have seen an uptake in recent years, especially after the launch of the NGFS in 2017 (Figure 4)[2]. Policy mixes differ by country, with some relying mostly on conventional informational measures (e.g., disclosure requirements), and others integrating more incentive-based instruments (e.g., credit allocation). European Union countries not only tend to have implemented a larger number of GFMP relative to other regions, but also show more homogeneity in policy mix, even though at different intensities (Figure 5). This is partially driven by common EU-wide strategies executed by the European Banking Authority (EBA) and the European Central Bank (ECB).

Figures 3 to 5 show that most countries - albeit to different levels - have started to develop a versatile GFMP toolbox. Notable, the data reveals continuous progression in policy uptake over time, indicating ongoing policy

[2]See Appendix A for more details on underlying policy instruments.

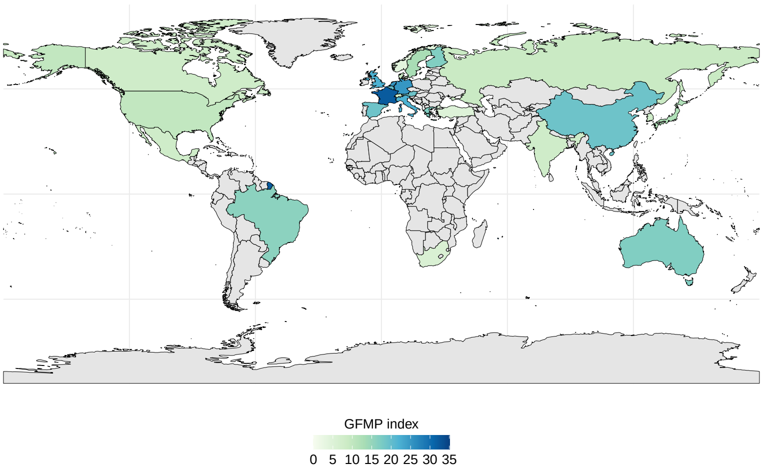

Figure 3: GFMP heatmap (2022)

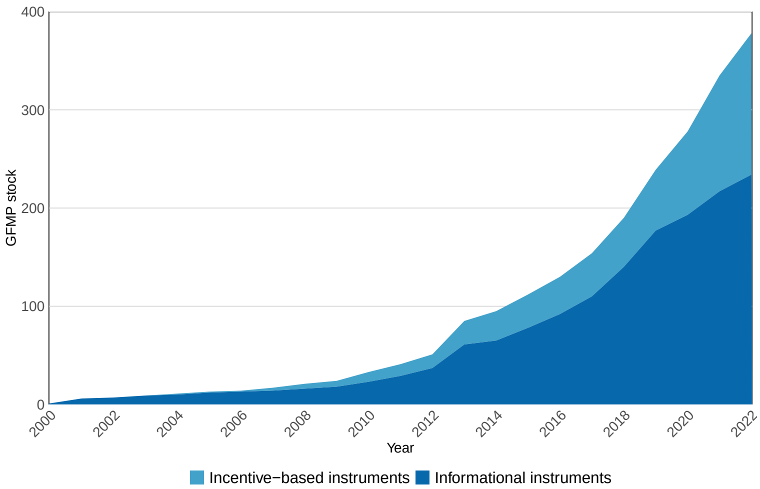

Figure 4: GFMP adoption by policy type

innovation in many countries. This is in line with the development that, firstly, countries increasingly acknowledge climate-related risks to the financial system and stability, and thus policymakers and central bankers are exploring options to embed climate concerns into prevailing regulatory regimes (Carney, 2015; NGFS, 2019; Elderson, 2024). And secondly, the role of the financial system in enabling the green transformation by scaling-up climate finance has gained considerable importance over the last two decades (Bolton et al., 2024; Carney, 2021). To test the validity of the constructed GFMP index as a measure of "greeness" of financial regulators and central banks, I compare country ranks against the Green Central Banking Scorecard[3] by Eames and Barmes (2022), which since 2021 assesses and ranks G20 central banks' actions across research and advocacy, monetary policy, financial policy, and leading by example. The GFMP index shows a rank correlation of 0.9 with the Green Central Banking Scorecard, substantiating the credibility of the index as a meaningful indicator of countries' performance in green financial and monetary policy.

[3]Green Central Banking is a platform that provides information on the role of finance and central banks in climate and environmental change by curating research and policy proposals from academics, central banks, and think tanks. The Green Central Banking Scorecard, produced in collaboration with the UK not-for-profit group Positive Money, is based on literature review, expert consultations, and bilateral interactions with central bankers and supervisors.

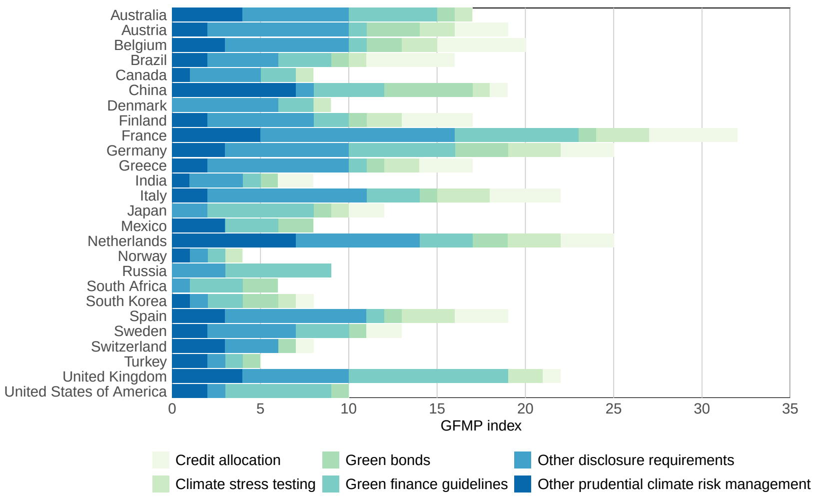

Figure 5: Cumulated number of GFMP (2022)

3.2. *Other data*

Data on RE capacity is collected from the International Renewable Energy Agency (IRENA). A set of economic and financial control variables is collected from public sources. More specifically, GHG emissions, resource rents, population, GDP, share of domestic credit provision, and regulatory quality is obtained from The World Bank Group. Data on inflation and financial development is gathered from the International Monetary Fund (IMF), and the OECD Climate Actions and Policies Measurement Framework (CAPMF) provides a measure of climate policy stringency. Table 1 summarizes data and corresponding sources. Table 2 presents aggregate descriptive statistics.

Table 1: Overview of data and sources

Data	**Source**
GFMP	D'Orazio (2021, 2022a) E-axes Forum policy tracker Review of regulators' publications
Renewable energy capacity	International Renewable Energy Agency
GHG emissions Resource rents Population GDP Domestic credit provision Regulatory quality	The World Bank Group
Inflation (CPI) Financial development	International Monetary Fund
Climate policy stringency	OECD (CAPMF)

Table 2: Key descriptive statistics

Statistic	N	Mean	St. Dev.	Median	Min	Max
RE capacity per million capita (GW)	598	0.2	0.3	0.1	0.0	1.8
GDP per capita (USD)	598	44,995	20,164	49,936	3,094	91,068
Emissions intensity (MtCO2/billion USD GDP)	598	0.2	0.1	0.2	0.05	0.7
Resource rents (perc. of GDP)	598	2.2	3.6	0.5	0.01	21.5
Climate policy stringency [0;10]	529	2.8	1.7	2.4	0.2	7.2
Inflation (perc.)	598	3.5	5.5	2.3	−1.7	72.3
Regulatory quality [-2.5;+2.5]	598	1.0	0.7	1.3	−1.1	2.0
Financial development [0;1]	598	0.7	0.2	0.7	0.3	1.0
Domestic credit provision (perc. of GDP)	598	104.9	45.3	105.8	12.2	221.1

4. Methodology

The core model follows a two-way fixed effects panel regression approach, investigating the relationship between GFMP and RE capacity across countries over time. RE capacity as the outcome variable of interest is motivated by the following facts. As the largest contributor to global CO_2 emissions, the energy sector and its decarbonisation through increased RE technology deployment is a key policy priority in many countries. As such, economic pathways in line with the Paris Agreement's 1.5–2°C target always imply a substantial increase in RE capacity (Luderer et al., 2018), highlighting the need to better understand which policies, including GFMP, can contribute to an acceleration in RE uptake. Adding to this, there is an investment gap of USD 400 billion per year between 2024 and 2030 to meet the COP28 pledge of tripling installed RE capacity by 2030 (IEA, 2024). With the financial sector playing a key role in mobilising private (and public) capital to fund these investments, it is of natural interest to investigate the role of GFMP in scaling up RE capacity, a measure of RE investment and transition indicator. In doing so, I consider the aggregate impact, distinguish between policy types to estimate instrument-specific impacts, and between short- and long-term effects. As an alternative model, I conduct quantile panel regression analysis to explore asymmetric effects across the distribution.

4.1. Two-way fixed effects model (TWFE)

When a GFMP is adopted, it will start to affect financial dynamics and thus economic and energy outcomes. Some policies may kick in immediately, others materialize more gradually or with a delay. So, RE capacity in year t is, among other things, a function of the overall stock of GFMP implemented in the years (t-1), (t-2), (t-3) and so on. The main specification (Equation 1) explores this aggregate effect of GFMP on RE capacity, with $GFMP_{it}$ being the total stock of GFMP in country i and year t. Y_{it} is the dependent variable: RE capacity per million capita. X_{it} is a set of k control variables detailed below.

$$Y_{it} = \alpha_i + \gamma_t + \beta_1 \text{GFMP}_{it} + \sum_{k=2}^{K} \beta_k X_{k,it} + \varepsilon_{it} \quad (1)$$

Taking on a more granular perspective on policy instruments, Equation 2 differentiates between policy types. $INFO_{it}$ represents the stock of informational GFMP, including disclosure requirements (non-FIs), green finance guidelines, and climate stress testing. $INCE_{it}$ is the stock of incentive-based GFMP, covering credit allocation, green bonds, and other prudential climate risk management. The coefficients of interest, β_1 and β_2, capture the effect of the different policy instrument types.

$$Y_{it} = \alpha_i + \gamma_t + \beta_1 \text{INFO}_{it} + \beta_2 \text{INCE}_{it} + \sum_{k=3}^{K} \beta_k X_{k,it} + \varepsilon_{it} \quad (2)$$

To factor in potential lags between the time of adoption and effects induced by the policies, I break the overall impact down into short- and long-term effects by aggregating policies in two different metrics: the stock of short-term policies and the stock of long-term policies.[4] In Equation 3, $STGFMP_{it}$ refers to the short-term stock of GFMP, capturing policies adopted in the years t, t-1, and t-2, and $LTGFMP_{it}$ refers to the long-term stock of GFMP, capturing policies adopted in the years t-3, t-4, ..., t-23. As a robustness test, the definition of the short- and long-term stock is varied by moving the threshold from 3 to 4 and 5 years, respectively. This is in line with Gumber et al. (2024), who analyse more than 12,000 RE project timelines across 48 countries and find an average commissioning time of about 3 years, with some RE technologies such as offshore wind taking just over 5 years.

$$Y_{it} = \alpha_i + \gamma_t + \beta_1 \text{STGFMP}_{it} + \beta_2 \text{LTGFMP}_{it} + \sum_{k=3}^{K} \beta_k X_{k,it} + \varepsilon_{it} \quad (3)$$

Across all models, α_i is added as country fixed effects to control for time-invariant factors such as different socio-economic characteristics, political environments and renewable energy potentials. In turn, γ_t captures unobserved time

[4] Eskander and Fankhauser (2020) follow a similar approach.

fixed effects, controlling for inter-temporal trends that are homogeneous across countries, such as the global decline in low-carbon technology costs. X_{it} is a set of control variables: GDP per capita, emissions intensity, inflation, regulatory quality, financial development, and domestic credit provision control for relevant economic, financial and governance features. Climate policy stringency accounts for non-GFMP climate-related policies such as carbon prices or feed-in-tariffs. Natural resource rents as share of GDP from extracting and selling resource endowments (e.g., oil, gas and coal) captures the economic desirability for countries maintaining a fossil-fuel based status quo versus transitioning to a RE system. Lastly, ε_{it} is the error term.

4.2. Quantile regression model

As an alternative model, I deploy a quantile panel regression to quantify conditional heterogeneous effects of the factors driving RE capacity by separately estimating coefficients at different points of the dependent variable's distribution (Equation 4). For a given quantile $\tau \in (0,1)$, the model is written as:

$$Q_{Y_{it}}(\tau \mid X_{it}, \alpha_i, \gamma_t) = \alpha_i + \gamma_t + \beta_1^{\tau}\text{GFMP}_{it} + \sum_{k=2}^{K} \beta_k^{\tau} X_{k,it} + \varepsilon_{it}^{\tau} \tag{4}$$

where $Q_{Y_{it}}(\tau \mid X_{it}, \alpha_i, \gamma_t)$ is the conditional τ-th quantile of renewable energy capacity per capita for country i in year t, α_i country-specific fixed effects, γ_t time-specific fixed effects, β_1^{τ} the coefficient of interest for the stock of GFMP at quantile τ. β_k^{τ} are the quantile-specific coefficients for the k control variables X_{it}, including GDP per capita, emissions intensity, resource rents, climate policy stringency, inflation, regulatory quality, financial development, and domestic credit provision. $\varepsilon_{it}(\tau)$ is the quantile error term. I use bootstrapped, and in a robustness test Kernel-based, standard errors as they do not impose strong parametric assumptions and account for heteroskedasticity and autocorrelation. This approach allows effects to differ across the distribution of Y_{it}, thereby providing insights beyond the mean effects captured by standard fixed effects models (see Appendix B for more details). As such, it sheds light on asymmetric policy responses across lower, median, or upper portions of the distribution, and captures potentially nonlinear relationships without requiring a strict functional form (Machado and Silva, 2019).

5. Results

5.1. Aggregate results

I find a significant positive relationship between countries' GFMP and RE capacity (Table 3), supporting the expected relationship formulated in Hypothesis 1. In the main specification (Column 1), on average, each adopted GFMP is associated with an addition of 0.016 gigawatt RE capacity per million capita. For the average sample country, this corresponds to 4.89 Mt CO_2 emissions avoided annually when displacing fossil energy sources, equivalent to taking about 1.1 million passenger vehicles off the street. Reviewing the key controls of the main specification, significant positive coefficients are identified for four variables. Aligned with conceptual expectations, this is the case for GDP per capita, as higher income allows more investment into RE. Similarly, higher climate policy stringency and regulatory quality represent a larger role of low-carbon objectives in the political arena and higher capabilities of public institutions, both favorable factors for RE uptake. Interestingly, the coefficient of resource rent is positive, suggesting that countries that obtain a relatively larger share of GDP from natural resources tend to have larger RE capacity. On the one hand, this could be explained by additional capital inflows from resources that can be re-invested into RE. On the other hand, this raises an interesting political economy question around the incentives of resource-rich countries in maintaining and exploiting a fossil-based economy vis-a-vis pro-actively transitioning towards a low-carbon state. The sign and significance of the coefficient of interest is robust to different standard error specifications (e.g., Driscoll-Kraay standard errors) including heteroskedasticity, autocorrelation, and cross-sectional dependence.

5.2. Policy-type specific results

Disentangling the impact by GFMP type (Table 4), I find positive effects for both informational instruments (disclosure requirements, climate stress testing, green finance guidelines) and incentive-based instruments (credit allocation, green bonds, prudential climate risk management). However, instrument types differ in economic significance of

Table 3: Aggregate results

	Dependent variable: RE capacity per million capita			
	(1)	(2)	(3)	(4)
GFMP	0.016***	0.026***	0.025***	0.018***
	(0.003)	(0.003)	(0.003)	(0.002)
GDP per capita	0.00001**	−0.00000	−0.00000	0.00001***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Emissions intensity	−0.280	−0.346***	−0.354***	−0.302
	(0.247)	(0.116)	(0.118)	(0.242)
Resource rent	0.022***	0.005	0.004	0.018***
	(0.005)	(0.003)	(0.003)	(0.004)
Climate policy stringency	0.070***	0.066***	0.004	0.093***
	(0.017)	(0.011)	(0.022)	(0.008)
Inflation	0.001	0.002	0.001	0.001
	(0.001)	(0.002)	(0.002)	(0.001)
Regulatory quality	0.179***	0.161***	0.208***	0.149***
	(0.041)	(0.028)	(0.032)	(0.038)
Financial development	−1.129***	−0.621***	−0.628***	−1.016***
	(0.148)	(0.095)	(0.097)	(0.137)
Domestic credit provision	−0.0002	0.002***	0.002***	−0.00000
	(0.0004)	(0.0003)	(0.0003)	(0.0004)
Constant		0.180***		
		(0.068)		
FE (time)	Yes	No	Yes	No
FE (country)	Yes	No	No	Yes
Observations	529	529	529	529
R^2	0.352	0.635	0.369	0.796
Adjusted R^2	0.280	0.629	0.330	0.784
Residual Std. Error		0.208 (df = 519)		
F Statistic	28.673*** (df = 9; 475)	100.263*** (df = 9; 519)	32.277*** (df = 9; 497)	215.768*** (df = 9; 497)

Note: Averages with standard errors in parentheses. Main specification in Column 1, specifications with no or partial fixed effects in Columns 2 to 4. Significance levels: *p<0.1; **p<0.05; ***p<0.01

effects. The coefficient of incentive-based measures (0.024) is twice as large as the coefficient for informational ones, indicating a relatively higher impact of the former in promoting RE deployment. This aligns with macro-financial theory and supports Hypothesis 2. Further, it provides empirical evidence for the increasingly pivotal role incentive-based GFMP assumed in countries' policy mixes over the last decade. A limitation of this analysis is that potential interactions and synergies between policy types are not considered when evaluating their outcomes. As such, the type-specific analysis presents a static rather than dynamic perspective on existing policy mixes. Overall, findings suggest that GFMP can accelerate the low-carbon energy transition, and thus, serve as a complementary pillar to conventional climate policy.

Table 4: Policy type-specific results

	Dependent variable: RE capacity per million capita
Informational GFMP	0.012***
	(0.004)
Incentive-based GFMP	0.024***
	(0.006)
Control variables	Yes
Observations	529
R^2	0.356
Adjusted R^2	0.283
F Statistic	26.250*** (df = 10; 474)

Note: Averages with standard errors in parentheses. Significance levels: *p<0.1; **p<0.05; ***p<0.01

5.3. *Sensitivity and heterogeneity analysis*

5.3.1. *Short- and long-term results*

When distinguishing between the short-term and long-term effect, on average, each GFMP is associated with an increase of 0.023 gigawatt RE capacity per million capita over the long-term (Table 5). On average, this corresponds to 7.04 Mt CO_2 emissions avoided annually when displacing fossil energy sources, equivalent to abatement of CO_2 emissions of 938,000 G20 citizens. I find a smaller but at the 10% level significant effect of 0.008 gigawatt RE capacity per million capita for the short-term. The larger effect when considering the long-term policy stock relative to the overall stock including recent short-term policies suggests that in order to translate into RE impacts, GFMP require multiple time periods to be transmitted to the real economy. This is as expected considering that the financial and economic adjustments underlying the scaling up of RE capacity may not be immediately responsive. However, certain limitations of this approach should be acknowledged. For example, distinguishing between short-term and long-term effects of GFMP may oversimplify the time lag dimension between policy adoption and effect, thereby overlooking more granular temporal dynamics in the economic transmission of GFMP.

Table 5: Short- and long-term results

	Dependent variable: RE capacity per million capita		
	Main specification (1)	Sensitivity A (2)	Sensitivity B (3)
GFMP ST(3)	0.008* (0.005)		
GFMP LT(3)	0.023*** (0.004)		
GFMP ST(4)		0.009** (0.004)	
GFMP LT(4)		0.026*** (0.005)	
GFMP ST(5)			0.010*** (0.004)
GFMP LT(5)			0.030*** (0.006)
Control variables	Yes	Yes	Yes
Observations	529	529	529
R^2	0.359	0.360	0.362
Adjusted R^2	0.286	0.287	0.289
F Statistic (df = 10; 474)	26.529***	26.625***	26.862***

Note: Averages with standard errors in parentheses. In Column 1, the short-term stock of GFMP is defined as policies adopted in the previous 3 years (t, t-1, t-2), and the long-term GFMP stock as policies adopted in all years prior to the previous 3 years (t-3, ..., t-23). In Columns 2 and 3, the threshold is changed to 4 and 5 years, respectively. Significance levels: *p<0.1; **p<0.05; ***p<0.01

5.3.2. *Quantile heterogeneity*

To explore heterogeneity of effects, quantile analysis is conducted. Quantile regression results describe the relationship between the variables of interest at different points of the distribution of the dependent variable, ranging from the 10th percentile to the 90th percentile. This provides conditional effects and a richer understanding than standard OLS regression, which estimates average effects for the full distribution.

The pattern of GFMP coefficients across quantiles indicate several important findings (Table 6). First, confirming aggregate results of the TWFE model in Section 5.1, there are consistent positive effects within the magnitude of 0.013 to 0.024 gigawatt RE capacity per million capita. This implies that GFMP are effective in scaling up RE independent of countries' current level of RE deployment. Second, quantile coefficients show heterogeneity (Figure 6), with the effect about 1.7 times larger at the 50th percentile compared to the 10th percentile. The steepest growth in effect occurs between Q20 and Q50, after which from Q60 upwards the increase levels off, with the coefficient flattening out. However, the difference in lower vs. upper quantiles is not systematically different. While supporting the main findings, the model also underscores the importance of obtaining conditional estimates across quantiles to obtain a more granular understanding and identify potentially non-linear impacts.

Table 6: Quantile-based results

	Dependent variable: RE capacity per million capita								
	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90
GFMP	0.014***	0.013***	0.014***	0.018***	0.024***	0.023***	0.021***	0.020***	0.019***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.006)	(0.009)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	529	529	529	529	529	529	529	529	529

Note: Averages by quantiles with bootstrapped standard errors in parentheses. Significance levels: *p<0.1; **p<0.05; ***p<0.01

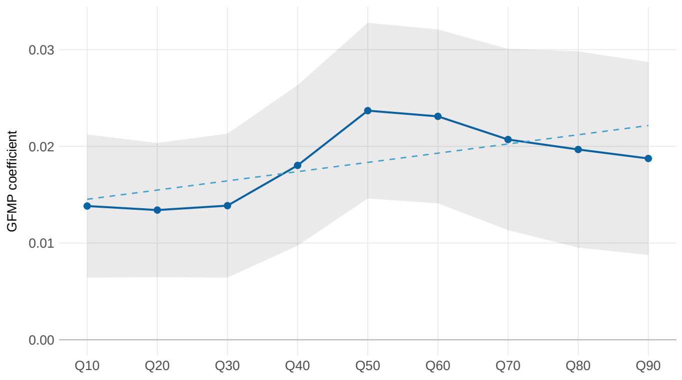

Figure 6: GFMP effects by quantile

Note: Relationship between increasing GFMP stock by one policy and RE capacity (gigawatt) per million capita for the 10th to 90th percentile of the RE capacity distribution. Dashed line represents smoothed trend line. Shaded area shows the 95% confidence interval with bootstrapped standard errors.

5.4. Robustness tests

While the main analysis provides a thorough assessment of the influence of GFMP on RE capacity, I conduct additional tests by employing alternative variable measurements and model specifications to further enhance the robustness of findings (Table 7). To avoid potential bias from the indicator selection on conclusions, the first robustness test replaces the dependent variable with three alternative measures of energy sector impacts. The first measure, RE electricity production per million capita, is closely related to RE capacity but adds a real-economy dimension in that it tests whether GFMP impacts also materialise in terms of realised electricity production. The second measure, FF electricity production per million capita, sheds light on whether GFMP affect the low-carbon transition by "only" scaling-up RE or also phasing-down FF. The third measure, RE share in the electricity mix, is an indicator of energy decarbonisation and tests whether GFMP leads to a relative substitution of RE and FF production. In the second robustness test, I deploy the GFMP measure weighted by countries' regulatory quality to account for potential influence from varying levels of institutional quality and policy enforcement of regulators. Further, I add a quadratic term of the GFMP variable to the initial model to address potential non-linear effects on RE capacity. Adding the quadratic term explicitly accounts for the possibility that the impact of GFMP might vary across policy intensities, offering a potentially more nuanced relationship. The results of these robustness tests support the significance and direction of the baseline model effects, as both RE electricity production and RE share in the electricity mix are positively associated with GFMP. I find no effect on FF electricity production, suggesting that GFMP promote the transition primarily by supporting low-carbon energy rather than phasing-down high-carbon energy. This apparent failure to effectively penalize FF highlights the need for further research into financial incentive structures and political economy considerations around incumbent FF energy. Weighting GFMP by regulatory quality yields results aligned with the baseline model. The quadratic term is negative and significant, indicating that a greater adoption of GFMP may have a positive but diminishing effect on RE capacity. Overall, performing these robustness tests does not change the conclusion that GFMP promotes RE deployment.

Table 7: Alternative TWFE specifications

	Dependent variable:				
	RE electr. prod.	FF electr. prod.	RE share electr. mix	RE capacity	RE capacity
GFMP	0.037***	0.014	0.274**		0.033***
	(0.012)	(0.013)	(0.110)		(0.006)
$GFMP^2$					-0.0005***
					(0.0002)
Reg.qual. weighted GFMP				0.015***	
				(0.003)	
Control variables	Yes	Yes	Yes	Yes	Yes
FE (time)	Yes	Yes	Yes	Yes	Yes
FE (country)	Yes	Yes	Yes	Yes	Yes
Observations	529	529	529	529	529
R^2	0.122	0.345	0.264	0.301	0.363

Note: Averages with standard errors in parentheses. Columns 1 to 3 show the main TWFE model specification with alternative dependent variables: RE electricity production per million capita, FF electricity production per million capita, and RE share in electricity mix. Column 4 deploys GFMP weighted by countries' regulatory quality, Column 5 adds a quadratic term of GFMP to capture non-linear effects, both with RE capacity per million capita as the dependent variable. Significance levels: *p<0.1; **p<0.05; ***p<0.01

6. Conclusion

This paper shows that, apart from financial stability objectives, GFMP can promote the transition to a low-carbon economy via RE deployment. In the aggregate dimension, I find a positive effect of GFMP on RE capacity, a key indicator of countries' transition performance. Zooming into policy types, I find incentive-based instruments are about twice as effective as informational instruments. When distinguishing between short-term and long-term effects, adopting a GFMP has a substantially larger impact on RE capacity over the long-term. This empirical analysis gives rise to several policy implications. Given that overall GFMP are found to be effective but mainly deliver effects in the long-term, a more active and rapid developed of GFMP is warranted if mandated. Put simply, to contribute to tomorrow's decarbonisation, policies would need to be implemented today. Moreover, while informational measures may align closer with conventional market neutrality principles, incentive-based instruments seem to be more effective in delivering real economic impacts. Accordingly, policymakers wishing to promote an orderly transition should re-think current policy design and consider tiliting their policy mixes. Lastly, given the diversity in GFMP adoption across countries, there is a case for increased policy cooperation and harmonization, for example via initiatives like the NGFS or Coalition of Finance Ministers for Climate Action. Avenues for further research include, for example, in-depth analyses of individual GFMP, and examining effects on other transition indicators such as green innovation, low-carbon consumption or financing flows.

CRediT authorship contribution statement

Lukas Rischen: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing

Compliance with ethical standards

No competing interests to declare.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used Chat GPT-4o and Claude Sonnet 4 in order to improve language and readability as well as to assist in coding. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Appendix A. Further descriptive statistics

Table A.8: Mean RE capacity (GW) by country

	Country	RE capacity	RE capacity per million capita
1	Australia	8.7	0.4
2	Austria	2.4	0.3
3	Belgium	3.8	0.3
4	Brazil	8.3	0
5	Canada	7.8	0.2
6	China	165.5	0.1
7	Denmark	4.9	0.9
8	Finland	1.1	0.2
9	France	12.3	0.2
10	Germany	59.3	0.7
11	Greece	3.3	0.3
12	India	29.3	0
13	Italy	16.5	0.3
14	Japan	25.5	0.2
15	Mexico	3.8	0
16	Netherlands	6	0.4
17	Norway	1.2	0.2
18	Russia	0.5	0
19	South Africa	2.4	0
20	South Korea	4.8	0.1
21	Spain	23.3	0.5
22	Sweden	4.5	0.4
23	Switzerland	1	0.1
24	Turkey	5	0.1
25	United Kingdom	15.2	0.2
26	United States of America	77.4	0.2

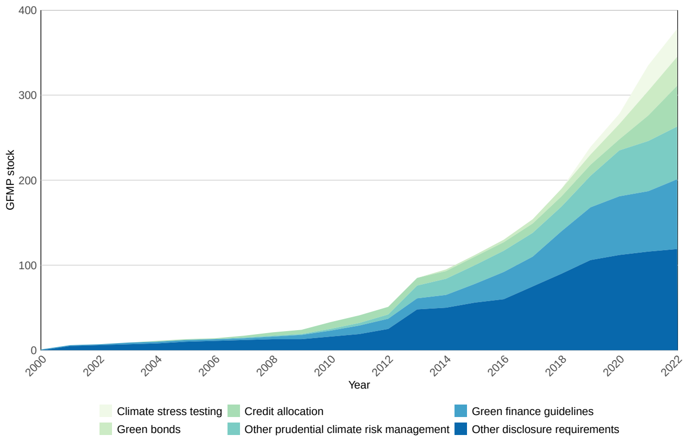

Figure A.7: GFMP adoption by policy type

Appendix B. Quantile analysis - objective and check function

In quantile regression, instead of minimising the sum of squared residuals like in OLS, a weighted sum of absolute residuals is minimised, where the weights depend on the quantile τ. The objective function the model minimises to obtain the best-fitting parameters is given by:

$$\min_{\alpha_i,\gamma_t,\beta_k^\tau} \sum_{i=1}^{N} \sum_{t=1}^{T} \rho_\tau \left(Y_{it} - (\alpha_i + \gamma_t + \beta_1^\tau \text{GFMP}_{it} + \sum_{k=2}^{K} \beta_k^\tau X_{k,it}) \right) \tag{B.1}$$

This function ensures that the estimated coefficients β_k^τ describe how explanatory variables $X_{k,it}$ affect different quantiles of Y_{it} rather than just the mean. The check function $\rho_\tau(u)$ defines how residuals u are penalized and is given by:

$$\rho_\tau(u) = u \cdot (\tau - I(u < 0)) \tag{B.2}$$

where $I(\cdot)$ is an indicator function:

$$I(u < 0) = \begin{cases} 1, & \text{if } u < 0 \\ 0, & \text{otherwise.} \end{cases} \tag{B.3}$$

This function ensures that positive and negative residuals are weighted differently based on the quantile τ, allowing effects to differ across the distribution of Y_{it}, thereby providing insights beyond the mean effects captured by standard fixed effects models.

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