Essays on Oil abundance, Financial Development and Climate Resilience

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Dedication

To my family, for their unwavering support and encouragement during my studies. Their belief in me kept me motivated through challenging times. To my kids, to my parents, and to my wife — thank you for walking this journey with me.

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Contents

1. General introduction

This thesis is motivated by the case of Venezuela, a country endowed with vast oil reserves, a favorable geographic location, and a history of attracting human capital through migration. For several decades, Venezuela experienced sustained economic growth, macroeconomic stability, and improvements in infrastructure and public services. However, following the nationalization of the oil industry and the creation of a state-owned company with full control over the sector, the government expanded its intervention in the economy. One of the most significant consequences of this shift was the emergence of financial repression—policies that constrained the financial system, limited the effectiveness of monetary policy, and ultimately hampered long-term development. Today, Venezuela's shallow and constrained financial sector illustrates the broader risks faced by fossil fuel–rich countries with underdeveloped financial systems: limited capacity for business cycle smoothing, restricted access to credit, and insufficient tools to support the ecological transition.

This research investigates the relationship between fossil fuel wealth, institutional structures, and financial development, and examines the implications for the energy transition and climate resilience. It argues that while fossil fuel abundance can embolden governments to intervene in ways that repress financial systems, doing so undermines an essential tool for both economic development and financing the transition toward low-carbon growth.

The first two studies use dynamic panel data models estimated via the Arellano and Bond (1991) GMM estimator. The first article examines the relationship between oil abundance, the presence of national oil companies (NOCs), and financial repression. It finds that oil-rich countries with dominant NOCs are more likely to adopt interest rate controls which, while expanding credit in the short run, constrain private credit in the long run. The paper contributes by proposing a novel mechanism to endogenize the adoption of interest rate controls as a form of financial repression, offering new insights into the financial curse observed in oil-rich countries with NOCs.

The second article explores whether financial development can mitigate the carbon curse—the tendency of fossil fuel–rich countries to exhibit high carbon intensity. The analysis shows that stronger financial systems are associated with lower carbon emissions per unit of GDP, particularly when financial development supports structural transformation toward the service sector and reduces reliance on fossil fuel subsidies. Its novelty lies in jointly examining two related hypotheses linked to the natural resource curse, the financial curse and the carbon curse.

The third article assesses the effects of extreme weather events (EWEs) on financial development. Using the staggered Difference-in-Differences estimator developed by Callaway and Sant'Anna (2021), the study finds that EWEs negatively affect financial sector indicators, particularly in low- and middle-income countries, with the strongest impacts observed on financial institutions. The findings underscore the vulnerability of shallow financial systems to climate shocks.

Taken together, these three studies highlight a central policy implication, financial repression undermines a country's ability to translate natural resource wealth into sustainable development. Financial development not only enhances macroeconomic resilience but also enables countries to respond more effectively to climate-related challenges. Strengthening financial systems should therefore be a priority for resource-rich countries seeking to escape the traps of underdevelopment, economic volatility, and environmental degradation.

2. Oil Abundance, National Oil Companies and Financial Repression[1]

2.1 Introduction

A well-functioning banking system is vital for economic growth, serving as a conduit for credit intermediation and financial stability. It provides information on potential investments, enhances resource allocation, and promotes trading and risk management (Beck and Levine, 2005). However, many large oil producers struggle with less advanced financial systems, limiting their capacity to diversify economically and secure funds for investment. In these contexts, particularly where state-owned companies dominate the oil industry, governments often resort to financial repression intervening in financial markets to lower borrowing costs for quasi-fiscal activities [2] (Menaldo, 2015).

Financial repression involves direct government intervention in the financial sector to implicitly tax financial institutions. This intervention is not primarily motivated by the need to address credit market imperfections; rather, it arises from fiscal challenges. Governments implement strategies such as interest rate controls to finance their operations at lower costs. As a result, they depend on the implicit taxation of the financial sector due to difficulties in raising funds through more conventional means [3] (Montiel, 2011).

In this paper, we analyze whether countries with significant oil rents, national oil companies

[1]I thank the participants of the 20th World Congress of the International Economic Association (Medellín, 2023), Dr. Javier Pérez for his comments at the VII National Colloquium of Doctoral Students in Economics (Barranquilla, 2024), the participants of the RIEF 2025 Annual Conference, and colleagues at the EAFIT and Universidad del Rosario seminars for their valuable feedback.

[2]Quasi-fiscal operations include activities undertaken by state-owned banks and enterprises, and sometimes by private sector companies at the direction of the government, where the prices charged are below the usual or market rates (IMF (2007)). Examples include subsidized bank loans provided by the central bank or other government-owned banks.

[3]Governments can intervene in the equilibrium of the financial system through various methods, including interest rate controls, direct credit allocation, high reserve requirements, state-owned banks, entry barriers for new domestic banks, capital account restrictions, prudential regulations, supervision of the banking sector, and unconventional monetary policies.

[4], and a fiscal dependence on oil revenue tend to use interest rate controls to reduce the financing costs for the non-financial public sector. Specifically, as oil rents become increasingly important for the sustainability of public finances in a given country, there are greater incentives to implement various measures that repress the financial system.

Luong and Weinthal (2010) state that mineral-rich countries often lack the institutional constraints necessary to prevent the ruling elite from relying on oil rents and engaging in excessive public spending. As a consequence, these countries struggle to establish strong fiscal regimes that support sound macroeconomic policies, which are crucial for coping with adverse oil price shocks. The authors argue that mineral-rich states are *cursed* by the public ownership models they adopt to manage their mineral wealth. Similarly, Brunnschweiler and Poelhekke (2021) find that domestic (public) ownership tends to result in lower levels of investment in exploration. Additionally, national oil companies typically operate in a protected domestic market, limiting their exposure to competition. Moreover, oil firms under public ownership often enjoy better access to international capital markets and, as a result, rely less on the financial services provided by domestic banking systems Wolf (2009).

Resource-rich countries, particularly those with high oil revenues, often exhibit low levels of financial system development. Mlachila and Ouedraogo (2020) identify several explanations for this phenomenon, commonly referred to as the *financial curse* [5]. One explanation is the concentrated structure of oil-rich economies, which exposes them to terms-of-trade shocks (Hausmann and Rigobon, 2003). In such environments, banks tend to demand higher interest rates, making credit more expensive. Additionally, the Dutch disease effect shifts productive resources toward the nontradable sector, thereby lowering both productivity growth and credit availability (Benigno and Fornaro, 2013).

Another factor is the misuse of windfalls; when revenues are used primarily for consumption smoothing, this discourages the development of a robust financial system (Gylfason, 2006). Furthermore, inadequate institutions for contract enforcement make banks reluctant to lend. The effectiveness of enforcement and the reliability of the financial sector require credible institutions, which are often compromised by rent-seeking and corruption (Bhattacharyya and Hodler, 2014).

Evidence from oil-dependent countries supports the notion of low financial development.

[4]In this document, the terms national oil companies, public ownership, and government ownership are used interchangeably to refer to entities and arrangements where the government has significant control over oil resources

[5]The lesser financial development exhibited by resource-abundant countries.

For instance, Berglof and Lehmann (2009) find that in Russia, bank lending plays a limited role in corporate investment. Similarly, Samargandi et al. (2014) develop a composite indicator of financial development for Saudi Arabia, demonstrating that its banking sector remains underdeveloped. Elhannani et al. (2016) show that while financial development has enhanced economic growth in Algeria, it has not mitigated the negative effects of oil rents. Gylfason and Zoega (2001), Nili and Rastad (2007), (Bhattacharyya and Hodler, 2014), Beck (2011), Kurronen (2015), Beck and Poelhekke (2023), and Mlachila and Ouedraogo (2020) provide empirical evidence that the banking sector tends to be smaller in resource-dependent economies. They cite several reasons for these findings as the high share of mineral exports in total exports reduces the level of bank credit to the private sector, and the impaired ability to enforce contracts in countries with low levels of democracy further exacerbates the issue. Additionally, they provide evidence that financial sector growth slows in resource-rich countries during commodity price shocks, attributed to repressed financial systems and weak governance structures.

The ownership structure of oil-extracting companies in petroleum-rich states such as Russia, Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan reveals significant insights into how oil wealth impacts state institutions Luong and Weinthal (2010). In these countries, when the government exerts a dominant role over the oil industry-often through state ownership or centralized control-there tends to be a weakening of state institutions. This centralization of oil wealth can hinder political and economic development, as it reduces the incentive for the government to diversify its economy or engage its citizens in governance. The flow of oil revenues directly into state coffers diminishes governmental accountability. Since these revenues come from external sources rather than domestic taxation, the state has less incentive to respond to the needs and demands of its citizens. This dynamic can lead to a lack of transparency, reduced civic engagement, and ultimately a governance structure that is less responsive to the populace Ahmadov (2013).

Brunnschweiler and Poelhekke (2021) examine the influence of oil company ownership from 1867 to 2008 and find a strong positive relationship between switching to Foreign (private) and Partnership (with over 50% domestic shares) ownership regimes and increased exploration and discoveries. In contrast, nationalization leads to a decline in these activities. Overall, their findings suggest that oil wealth weakens state institutions when the government has a dominant role in the industry, and domestic (public) ownership reduces investment in exploration, resulting in fewer discoveries. The negative impact of National Oil Companies (NOCs) on economic development and exploration activities can be attributed to insufficient public resources for these projects.

Nations with substantial oil rents and state-owned oil companies may become overly reliant on these resources. As a result, when oil revenues decline, these governments might turn to alternative financing methods beyond tax collection or debt issuance—such as financial repression. This research seeks to explain the underdevelopment of the financial sector in oil-rich countries and to examine whether the ownership structure of resource companies influences the relationship between natural resource wealth and financial development. Specifically, the research addresses the following questions: Does the ownership structure of oil companies affect the relationship between natural resource endowment and financial development? If so, are countries with abundant oil resources and publicly owned national companies more likely to rely on financial repression?

In exploing the scope of financial repression, Abiad et al. (2009) explains that state intervention in the financial sector was prominent in both developing and developed countries until the 1980s, with many banks owned or controlled by the government and interest rates regulated. Theoretical arguments for financial repression cite market failures and information frictions. Although many countries liberalized their financial sectors post-1980s, the 2008-09 global financial crisis reignited discussions on government regulation to prevent financial instability (Jafarov et al., 2019). Additionally, the Covid-19 pandemic resulted in the largest single-year surge in global debt since 1970 (Kose et al., 2022), prompting renewed debate on financial repression as a second-best solution to lower debt levels. By imposing interest rate ceilings, governments can reduce borrowing costs for the non-financial public sector. However, such measures weaken price signals in the credit market, distorting resource allocation for investment and hindering overall financial development.

In their assessment, Jafarov et al. (2019) evaluate government-mandated limits on interest rates, reflecting the resurgence of financial repression measures. They extended the database compiled by Abiad et al. (2009), which covers 90 jurisdictions from 1973 to 2005, and extended it until 2017. This extension is limited to the interest rate ceiling indicator due to data constraints. They evaluated the impact of interest rate controls on the per capita real GDP growth rate using panel data analysis, estimating that these controls could subtract between 0.4 and 0.7 percentage points from economic growth.

To answer our research questions, we utilize the database provided by Jafarov et al. (2019), which compiles information on the presence of interest rate controls across 90 countries from 1973 to 2017, highlighting the significance of administrative or legal controls on interest rates. To test the hypothesis, we employ the GMM dynamic panel system estimator, chosen for its suitability given the inertia of financial indicators, which tend to vary little between successive years (Mlachila and Ouedraogo, 2020). Additionally, the use of GMM is justified by the existence of unobservable country-specific characteristics, the presence of a lagged endogenous variable among the explanatory variables, and the fact that the total number of countries analyzed exceeds the number of years.

This document departs from previous literature by offering a different explanation for the lower financial development of oil-rich countries. It does so by endogenizing the decision to implement interest rate controls as a response to fiscal dependence on oil revenues, particularly when oil companies are state-owned. In environments with low institutional quality, this fiscal dependence exposes governments to adverse shocks in oil revenues. Consequently, these governments often resort to financial repression to cover their financing needs, which in turn slows down the development of the financial system.

Our working hypothesis posits that when a government's fiscal revenues are predominantly derived from oil rents, it may experience reduced public scrutiny over how these resources are utilized. This lack of oversight arises as the government becomes less reliant on non-oil tax revenue, reducing the need for accountability to citizens. As a result, this can lead to a concentration of power in the executive branch, facilitating autocratic governance that can capture and distribute oil rents without significant checks and balances.

In this context, the complete control of exploration, production, and revenue distribution by National Oil Companies (NOCs) further exacerbates the issue. Findings indicate that the interplay of substantial oil revenues and the presence of NOCs can adversely impact the development of the financial system, potentially stifling financial innovation, limiting access to capital, and hindering overall economic diversification.

Our contribution is to offer a new mechanism explaining why banking systems remain persistently underdeveloped in oil-producing economies. While the resource-curse and financial-curse literatures document weaker financial systems in resource-rich countries, they rarely identify how specific institutional and fiscal features generate incentives for governments to repress finance. We bridge this gap by focusing on the interaction between oil abundance, public ownership of the oil sector, and fiscal dependence on NOC revenues.

We show that when national oil companies operate in environments with low institutional quality, governments become fiscally dependent on the revenue streams they generate. This dependence creates a weak fiscal structure, where public spending pressures remain high, but NOC transfers fluctuate sharply with international oil prices. These negative shocks to fiscal revenues increase the government's need to mobilize resources outside traditional taxation.

In this context, financial repression -most notably interest-rate controls that reduce the cost of domestic borrowing-emerges as a convenient quasi-fiscal tool.

To our knowledge, no previous research has examined credit deepening and financial sector development in oil-rich countries through the explicit channel of financial repression induced by fiscal dependence on NOC revenues. Our framework therefore connects strands of the literature that were previously treated separately -resource abundance, public-sector ownership, fiscal behavior, and financial repression- and provides empirical evidence using dynamic panel techniques and mediation analysis. This allows us to uncover a structural link between fiscal vulnerability in NOC-dependent economies and the long-run stagnation of private-sector credit.

The document is organized as follows, section two explains the empirical strategy, including data, methodology, sample, and the definition we use of fiscal dependence. Section three discusses the model specification and results of the econometric model and in section four the concluding remarks.

2.2 Empirical Strategy

2.2.1 Data

This study seeks to determine whether abundant oil revenues and national companies managing their exploitation stimulate financial repression, thereby negatively affecting financial development.According to the International Monetary Fund (IMF) Sahay et al. (2015), financial development is defined as a combination of depth (size and liquidity of markets), access (the ability of individuals to access financial services), and efficiency (the ability of institutions to provide financial services at low cost and with sustainable revenues, along with the level of activity of capital markets).

This definition reflects the complexity of financial development, which involves various aspects of credit intermediation. While using a simple depth indicator, such as the ratio of credit to the private sector to GDP, is limited, it has the advantage of being readily available over the study period. Despite its shortcomings, our analysis will use this ratio as a proxy measure of financial development, with data sourced from the World Bank's World Development Indicators (WDI).

We utilize an unbalanced panel of 90 countries over the period from 1973 to 2017. We take advantage of the database provided by Jafarov et al. (2019), which compiles information on the presence of interest rate controls (IRC) in lending and deposit markets. This qualitative index represents the significance of administrative or legal controls on interest rates, assuming four possible numerical values: zero (the strictest controls) to three (where banks are free to set their interest rates). IRC serves as the variable to account for financial repression. Interest rate controls impact the allocation of loanable funds; controls on lending rates hinder capital from being allocated to the most productive uses, while controls on deposit rates encourage savers to place their funds in informal financial systems or external assets. Generally, interest rate ceilings prevent a price-based allocation of funds (Montiel, 2011).

According to Jafarov et al. (2019), the global financial crisis of 2008-09 rekindled the debate on the role of government, prompting calls for increased regulation and supervision to strengthen the stability of the financial system. Conversely, the surge in government debt has revived discussions regarding the potential role of financial repression as a second-best solution to reduce debt burdens. Reinhart et al. (2011) suggest that the large public and private debts in advanced economies, combined with the perceived risks of currency misalignments and overvaluation in emerging markets facing capital inflows, have contributed to a resurgence of financial repression. This approach typically aims to provide cheap loans to companies and governments, reducing their repayment burdens by lowering returns to savers below the market rate.

To account for the relevance of the oil sector in each country, we use oil rents, defined as the value of crude oil production at world prices minus total production costs. This calculation involves estimating the price of oil barrels and subtracting average unit extraction costs. The resulting unit rents are then multiplied by the physical quantities extracted by each country to determine the rents for oil as a share of gross domestic product (GDP). In some countries, these earnings represent a significant portion of GDP, largely in the form of economic rents-revenues exceeding the cost of resource extraction.

Natural resources generate economic rents because they are not produced. When countries utilize these rents to support current consumption instead of investing in new capital to replace what is being depleted, they effectively borrow against their future.[6] This variable is expressed as a percentage of GDP and is sourced from the World Bank's World Development Indicators (WDI).

To establish the type of ownership of oil companies, we utilized the Natural Resource Governance Institute (NRGI) database. According to NRGI, National Oil Companies (NOCs)

[6]The World Bank, Metadata Glossary

produce 55% of the world's oil and gas. They dominate the production landscape in some of the most oil-rich countries, including Saudi Arabia, Mexico, Venezuela, and Iran, and play a central role in the oil and gas sector. However, the NRGI dataset only covers the period from 2011 to 2017. Therefore, it was necessary to supplement this information with data from national sources to identify which countries have NOCs.[7]

As for control variables in the model, we include a variable to account for institutional strength, using the Polity index[8] as a proxy for institutional quality. According to the literature Bhattacharyya and Hodler (2014), higher institutional strength fosters better conditions for financial development, as a greater degree of democracy enhances transparency and government accountability, thereby reducing financial repression. To control for the level of economic activity, we incorporate gross capital formation and final consumption expenditure as percentages of GDP, allowing us to estimate the impact of demand for loanable resources. In the interest rate control model, we use the logarithm of the Consumer Price Index (CPI), positing that rising inflation incentivizes governments to limit nominal interest rates to avoid higher financing costs, reflecting the fiscal dominance of monetary policy. Many developing countries have faced double-digit inflation rates, leading monetary authorities to intervene in real interest rates through rate controls, which contributes to financial repression (Namazi and Salehi, 2010).[9]. Additionally, we include dummy variables for region and time trends.

As control variables, particularly for the interest rate controls model, we incorporate oil prices, which reflect a different dynamic than oil rents. According to Mansour and Nakhle (2016), the relationship between governments and companies varies with oil prices, which serve as a trigger for modifications in the upstream fiscal regime. High oil prices typically lead to increased taxes, contract renegotiations, tougher regulations, and, in extreme cases, expropriation and nationalization, as host governments seek a larger share of the perceived higher profitability of the industry. Reactions among oil-producing countries range from straightforward tax rate increases to the implementation of new taxes and enhanced shares for national oil companies, and even the expropriation of assets. The price level significantly influences the bargaining power of each party at the negotiating table; when oil prices are high, governments often hold the upper hand, while falling prices tend to favor companies.

[7]From 1973 to 2017, nine countries changed their ownership structures. Austria, Bulgaria, France, Hungary, Romania, Spain, and the United Kingdom transitioned to private ownership. Argentina, Bolivia, and Russia changed from public to private ownership and then back to public ownership.

[8]A measure of political regime characteristics categorizing autocracies (-10 to -6), anocracies (-5 to +5), and democracies (+6 to +10), taken from the Center for Systemic Peace

[9]Consumption, gross capital formation, and CPI are taken from the World Bank's WDI

However, the response to declining prices is generally less visible and more erratic than that to rising prices (Mansour and Nakhle, 2016). The international oil prices are sourced from the Brent crude oil spot price series.

Table 2.1: **Descriptive statistics**

Variable	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
Credit as % of GDP (WDI)	3547	50.8304	42.4851	0.0555	233.211
Interest rate controls	3718	2.0126	1.2419	0	3
Oilrents as % of GDP (WDI)	3687	1.9891	4.7351	0	39.5580
National Oil Company (NGRI)	4050	0.3651	0.4183	0	1
Fiscal dependence index	2482	0.0059	0.0311	0	0.5000
log. CPI (WDI)	3631	3.1296	2.8123	-21.0658	13.7276
log. Oil price (BP)	4050	3.3556	0.7451	1.9509	4.7155
Polity (Center for Systemic Peace)	3757	3.6622	6.8228	-10	10
log. GDP-PC (WDI)	3739	13236.41	16821.71	164.3366	91565.73
log. consumption (WDI)	3606	78.6641	11.1091	11.6105	186.9121
log. FBK (WDI)	3665	23.9879	7.0957	-5.73974	89.3811

Note: This table reports summary statistics for the main variables used in the analysis. The sample includes country-year observations for macroeconomic and institutional indicators from the WDI, BP, and NGRI datasets. Interest rate controls are measured on a scale from 0 (strictest) to 3 (freest). Polity scores range from -10 (autocracy) to 10 (democracy). All monetary variables are in logs.

2.2.2 Fiscal dependence on oil revenues and control variables

According to our hypothesis, governments in countries with high oil rents and national oil companies have direct access to these revenues, granting them greater discretion in utilizing these resources. This situation encourages the emergence of rentier states, characterized by weak tax systems that depend heavily on oil taxes and indirect or implicit taxes across various sectors of the economy (Luong and Weinthal, 2010), including financial repression.

Governments often suppress the financial system to fund their quasi-fiscal activities. Consequently, rentier states with weak fiscal structures arise, leading to persistent fiscal deficits that compel governments to implement interest rate controls and other measures of financial repression that, in the long run, tend to diminish the development of the financial system.

To test this working hypothesis, it is essential to estimate the dependence of total government revenues on oil taxes. However, to the best of our knowledge, there is no comprehensive dataset detailing the magnitude of oil taxes as a portion of total government revenues. Instead, we found only partial information from various sources, including the World Development Indicators (WDI), the OECD, and the National Oil Companies (NOC) database.

To measure fiscal dependence, we developed a summary measure that averages oil rents and NOC transfers to governments. Oil rents are sourced from the World Bank's WDI, while NOC transfers come from the Natural Resource Governance Institute (NRGI). Both sources have limitations, the WDI lacks information on government revenues for nearly 40% of the panel data, and the NOC transfer data only covers the period from 2011 to 2017.

The *fiscal dependence index* is a weighted index composed of normalized indices for two dimensions: the significance of oil revenues to government revenues and NOC transfers to the fiscal budget. To construct the index, we first normalize each country's distance relative to the maximum distance found in the database. Each component's magnitude is then converted to a scale between 0 and 1 using the following formula:

$$I(X_{i,t}) = \frac{X_{i,t} - m}{M - m} \tag{2.1}$$

Where $I(X_{i,t})$ denotes the fiscal dependence index for each country i in year t; M and m represent the maximum and minimum values of $X_{i,t}$ across all observations, respectively. The term $X_{i,t}$ refers to the observed value of the variable for country i in year t. Finally, to construct the fiscal dependence index, we averaged the two components:

$$fdep = 0.5 * I(oil.rents/Gov.rev) + 0.5 * I(NOC.transfers/Gov.rev) \tag{2.2}$$

It should range from 0 (no fiscal dependence) to 1 (total dependence).

The fiscal dependence measure used in this study has limitations, particularly due to the lack of government revenue data from seven countries: Algeria, Ecuador, Hong Kong, Nigeria, Pakistan, Venezuela, and Vietnam. Notably, five of these countries have significant oil rents and national oil companies. While the absence of data from these countries may weaken the indicator, it remains sufficient to test the research hypothesis.

2.2.3 Methodology

This research aims to determine whether the combination of national oil companies and fiscal dependence on oil rents affects financial development. The study uses a large sample of 90 countries over a 45-year period. This analysis relies on financial indicators such as bank credit to the private sector and interest rate controls. Monetary and financial indicators exhibit inertia, meaning that variables in this sector tend to remain relatively unchanged over time (Mlachila and Ouedraogo, 2020). This inertia arises because central bank decisions depend on information about the state of the economy, along with delays in the transmission of monetary policy. From the perspective of financial institutions, factors such as asymmetric information, risk aversion, and the effects of banking regulations -particularly regarding solvency and provisioning- contribute to the persistence of financial indicators like bank lending.

To account for the inertia in interest rate controls and bank credit to the private sector, we employ dynamic panel data analysis. This approach allows us to capture the impact of lagged endogenous variables and the unobservable fixed effects of the countries in our sample. The dynamic model estimates the effects of interest rate control and bank credit based on their lagged values and a set of control variables.

$$y_{i,t} = \alpha y_{i,t-1} + \beta \chi_{i,t-1} + \eta_i + \epsilon_{i,t}; i = 1, .., N; t = 1, ...T \tag{2.3}$$

In this specification, $y_{i,t}$, denotes the dependent variable for unit i in period t, representing either the level of interest rate controls (IRC) or the change in credit to the private sector. The vector $\chi_{i,t-1}$ contains explanatory variables, including contemporaneous and lagged values. The term η_i captures unobserve, time-invariant individual heterogeneity, while $\epsilon_{i,t}$ denotes the idiosyncratic error term .

Endogeneity may arise from several sources. First, the individual-specific effect may be correlated with the regressors, $E(\eta_i \mid \chi_i) \neq 0$. Second, η_i is also likely to be correlated with the lagged dependent variable, $E(\eta_i \mid y_{i,t-1}) \neq 0$. Third, contemporaneous or lagged covariates may be correlated with the idiosyncratic error term, $E(\epsilon_{i,t} \mid \chi_i) \neq 0$ for for t $\leq$ s. Additional endogeneity concerns include unobservable variables and potential reverse causality among the right-hand side variables.

Inference issues also arise when the number of time periods T is small, leading to finite-sample bias in coefficient estimation. Conventional fixed or random effects estimators are therefore biased and inconsistent in this setting (Bun et al., 2013). As a result, it has become standard to employ Instrumental Variables (IV) methods or the Generalized Method of Moments (GMM), which yield consistent estimates when T (T, i.e., years) is finite and the cross-sectional dimension N (N, i.e., countries) is large. According to Bond (2002) and Baltagi and Baltagi (2008), GMM is appropriate when ($N \geq T$), as in this study. Furthermore, Labra Lillo and Torrecillas (2018) emphasize that dynamic panel methods address individual heterogeneity and allow the use of multiple instruments to mitigate endogeneity.

Two main GMM approaches are available. The first, difference GMM (Arellano and Bond, 1991), uses lagged levels as instruments for equations in first differences. The second, system GMM (Arellano and Bover, 1995), combines the difference equations with additional moment conditions in levels, using lagged differences as instruments. The latter improves efficiency and reduces finite-sample bias (Bond, 2002). The augmented system GMM estimator of Blundell and Bond (1998) has been widely adopted, with Monte Carlo evidence supporting its performance (Roodman, 2009). Given the presence of country-specific effects and a lagged dependent variable, we adopt the system GMM estimator.[10]

When selecting GMM estimators to address endogeneity arising from simultaneity bias and omitted variables, it is essential to acknowledge the specific challenges inherent to dynamic panel data models. One key concern with the system GMM approach is instrument proliferation. An excessive number of instruments can lead to overfitting, weakening the Hansen test and increasing the risk of biased estimates. To mitigate over-identification, we restrict the instrument count by limiting the lag depth of the dependent variable to one (Roodman, 2009) and reducing the instrument set accordingly.

Following de Mendonça and Barcelos (2021), we maintain the ratio of the number of instruments to the number of cross-sectional units below one. The validity of the instruments is assessed using the Hansen test for over-identifying restrictions, while the Arellano–Bond test for serial correlation ensures the absence of second-order autocorrelation in the first-differenced residuals. We also verify that the number of cross-sectional units exceeds the number of instruments to safeguard against overfitting and weak identification.

For the empirical analysis, it is essential to test for the presence of panel unit roots. Given that our dataset spans a 45-year interval, it is important to consider the serial correlation

[10] `xtabond2` implements both difference and system GMM estimators in one- and two-step variants. While two-step estimators are asymptotically more efficient, their standard errors tend to be downward biased (Arellano and Bond, 1991; Blundell and Bond, 1998). To address this, `xtabond2` applies the finite-sample correction proposed by Windmeijer (2005), which often makes the two-step robust estimator more efficient than its one-step counterpart, especially in system GMM (Roodman, 2009).

patterns in the panel, which may include both short-memory and persistent components. These patterns can lead to inconsistencies in pooled estimators in dynamic heterogeneous panel models. The main advantage of using panel unit root tests is their significantly greater power compared to standard time-series unit root tests in finite samples (Taylor and Sarno, 1998).

(Im et al., 2003) propose a testing procedure that utilizes a standardized t-bar test statistic based on the augmented Dickey-Fuller statistics averaged across groups Bornhorst and Baum (2007). [11] We employ IPS, incorporating a constant and a time trend in the specification due to the inertia of the time series. An important advantage of IPS is its applicability to unbalanced data panels, such as our dataset, which includes a moderate number of cross-sectional groups over a long time period. Additionally, it is particularly useful for our dynamic heterogeneous panel data as it allows for heterogeneity across countries, including individual-specific effects and unique patterns of residual serial correlations.

Subsequently, we conducted a marginal effects analysis to assess whether the ownership of oil companies adversely affects financial development, controlling for the fiscal dependence of government revenues on oil rents. The partial effect measures the change in the conditional mean of the dependent variable associated with a change in one of the regressors. In a linear regression model, the marginal effect corresponds to the estimated slope coefficient (Cameron, 2005). Our focus is on the marginal effect of a change in ownership structure (a categorical variable) from 0 to 1 on the conditional mean of financial development, holding the other variables constant. For a dichotomous regressor, the marginal effect is the difference in the adjusted predictions between the two categories-in this case, public versus private ownership of oil companies. We compute average marginal effects ($\widehat{\text{AME}}$) using a variance-covariance matrix corrected for finite-sample bias. The mean partial effect of ownership structure is expressed as:

$$\widehat{\text{AME}}_{\text{ownership}} = \frac{1}{N} \sum_{i=1}^{N} \left[\hat{y}(x_i,\ \text{ownership} = 1) \ - \ \hat{y}(x_i,\ \text{ownership} = 0) \right] \tag{2.4}$$

A negative and statistically significant value of $\widehat{\text{AME}}$ would indicate that public ownership of oil companies is associated with lower levels of financial development, after accounting for fiscal dependence on oil rents and other controls.

To complement the identification of the causality of the proposed institutional arrangement

[11] The Im, Pesaran, and Shin test for unit roots, denoted as IPS, assumes individual unit root processes and has the null hypothesis that all panels contain unit roots.

on financial development, we conduct a mediation analysis[12] This approach decomposes the total effect of the mix of oil company (NOC) ownership and large oil rents on financial development (FD). Following Dippel et al. (2020), we separate the total effect into the indirect effect—the portion transmitted via the mediator variable, interest rate controls (IRC) -and the direct effect, which captures the impact not operating through IRC. This implies that the combined presence of NOCs and large oil rents influences financial development both indirectly, through interest rate controls, and directly, via other channels.

The magnitude of the indirect effect indicates the extent of mediation through the relevant mediator variables. With complete mediation, the total effect of an independent variable on a dependent variable is transmitted entirely through one or more mediator variables. In this case, the independent variable has no direct effect on the dependent variable; rather, its entire effect is indirect. In contrast, with partial mediation, an independent variable has both direct and indirect effects on a dependent variable. The direct effect is not mediated, while the indirect effect is transmitted through one or more mediator variables Edwards and Lambert (2007).

This path analysis will support the findings obtained from the marginal effects and verify whether the interaction between fiscal dependence and domestic ownership of firms (treatment) exerts a direct effect on financial development (outcome), as well as an indirect effect through interest rate controls. The magnitude of the indirect effect indicates the extent of mediation through the relevant mediator variables.

2.2.4 Sample

Jafarov et al. (2019) estimated the losses caused by interest rate controls (financial repression) on economic growth. For this purpose, they updated the database developed by Abiad et al. (2009), which included information on different dimensions of financial repression. We utilized this update to build our own database, which contains information on 90 countries on an annual basis, covering the period from 1973 to 2017.

In the database, 41 countries (46% of the sample) are either non-oil or only marginal oil producers, and most of them do not possess proven oil reserves.[13] The remaining 49 countries

[12] This refers to the transmission of the effect of an independent variable on a dependent variable through one or more other variables.

[13] Among the non-oil countries with proven reserves, Italy holds the largest share, ranking 47th worldwide according to British Petroleum and the U.S. Energy Information Administration (EIA).

are oil producers. Within this group, 37 nations operate through national oil companies. Among these, 18 major producers generate oil rents that equal or exceed 3% of GDP.

We hypothesize that countries with oil rents, public companies for the exploitation of hydrocarbons, and a weak tax system characterized by fiscal dependence on oil revenues negatively impact the development of their financial systems. For this reason, we focus on countries in the sample that have oil revenues and national oil companies. Since fiscal dependence is not a directly available variable, we approximate it using the fiscal dependence index.

2.2.5 Model specification

To assess the impact of the described institutional arrangement on financial development, we investigate whether this environment is associated with the implementation of interest rate controls. Specifically, we explore the interaction of these variables jointly: countries with oil rents, national oil companies, and fiscal dependence on oil revenues are more likely to implement interest rate controls, resulting in their banking systems granting lower credit compared to countries that lack these characteristics. According to Jafarov et al. (2019), financial repression reduces the return on savings, leading to financial disintermediation. By weakening price signals, it distorts the allocation of investment, thereby reducing the rate of return. A ceiling on loan interest rates benefits selected borrowers at the expense of depositors, who receive lower rates on their deposits. This constitutes a quasi-fiscal operation that effectively taxes depositors while subsidizing selected borrowers.

The empirical strategy consists of a first step involving the estimation of two dynamic panel data models, with one dependent variable representing interest rate controls and the other representing the change in credit to the private sector as a share of GDP. In both models, we use the interaction of oil company ownership, oil revenues, and fiscal dependence as the main independent variables in the regression, although the control variables differ between the two models. Both estimations aim to determine whether the specified conditions favor the imposition of interest rate controls by governments, thereby endogenizing the decision to implement financial repression measures. In the second model, we not only examine the effect of the interaction on the variation of credit to the private sector but also study the impact of interest rate controls on countries' financial development. Subsequently, we perform marginal effects analysis and mediation analysis to provide further evidence of the causal relationships.

To perform the dynamic panels, we first check the stationarity of the variables in the models. Credit to the private sector, which accounts for financial development, exhibits unit roots when the variable is taken in levels; however, in the first difference, we reject the null hypothesis of non-stationarity at the 1 percent level. Furthermore, we find that both the oil price level and the Consumer Price Index (CPI) are stationary. However, we were unable to apply the IPS test for the logarithm of gross capital formation, consumption expenditure, polity, oil rents, and IRC, as not all groups had sufficient observations.

Model for Interest rate controls

$$\begin{aligned} IRC_{i,t} = \alpha + \beta_1 IRC_{i,(t-1)} + \beta_2 NOC_{i,t} + \beta_3 oilrent_{i,t} + \beta_4 depf_{i,t} + \beta_5 (NOC_{i,t} \cdot depf_{i,t}) \\ + \beta_6 (NOC_{i,t} \cdot oilrent_{i,t}) + \beta_7 (depf_{i,t} \cdot oilrent_{i,t}) + \beta_8 (NOC_{i,t} \cdot depf_{i,t} \cdot oilrent_{i,t}) \\ + \beta_9 polity_{i,t} + \beta_{10} lnoprice_{i,t} + \beta_{11} X_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (2.5)$$

In this specification, the dependent variable $IRC_{i,t}$ represents the level of interest rate controls in country i at time t. The model includes a lagged dependent variable $IRC_{i,(t-1)}$ to account for persistence over time. The key independent variable $NOC_{i,t}$ is a binary indicator equal to 1 if a national oil company is present, and 0 otherwise. Fiscal dependence on oil revenues is captured by the variable $depf_{i,t}$, while $oilrent_{i,t}$ measures oil rents as a percentage of GDP. The specification includes several interaction terms, among National Oil Companies, the fiscal dependence index and oil rents. The model also controls for political regime characteristics through $polity_{i,t}$, and for external price effects with the log of oil prices $lnoprice_{i,t}$. The vector $X_{i,t}$ includes additional controls such as time trends, regional fixed effects, the difference in the logarithm of gross capital formation and final consumption expenditure (as a percentage of GDP), and the logarithm of the consumer price index (CPI). Finally, $\varepsilon_{i,t}$ denotes the standard error term.

This specification includes oil prices as an explanatory variable. Notably, this variable exhibits a low correlation with oil rents among major oil producers. In fact, the correlation coefficient between oil prices and oil rents as a percentage of GDP for oil-abundant countries is 0.176.

Higher oil prices encourage host governments to demand a greater share of the industry's increased profitability through taxes or contract re-negotiations (Mansour and Nakhle, 2016). This increase in tax revenues reduces the need to raise indirect taxes on the financial system by using interest rate controls. Conversely, low oil prices decrease government oil revenues, leading to greater fiscal pressures that compel governments to implement financial repression measures.

Additionally, oil rents are a long-term characteristic that influences a country's productive structure and, consequently, the development of its financial system. In this context, oil prices act as a lever that triggers governments' short-term financial needs and drives the implementation of financial repression measures.

Model for private credit as percentage of GDP

In this context, the financial motivations of governments to implement financial repression by manipulating interest rates lead to financial underdevelopment. To test this hypothesis, we employ the following model:

$$\Delta Credit_{i,t} = \alpha + \beta_1 \Delta Credit_{i,(t-1)} + \beta_2 NOC_{it} + \beta_3 oilrent_{it} + \beta_4 depf_{it} + \beta_5 (NOC_{it} * depf_{it}) + \beta_6 (NOC_{it} * oilrent_{it}) + \beta_7 (depf_{it} * oilrent_{it}) + \beta_8 (NOC_{it} * depf_{it} * oilrent_{it}) + \beta_9 IRC_{i,t} + \beta_{10} \Delta lfbk_{i,t} + \beta_{11} d1974 + \beta_{12} X_{it} + \varepsilon_{it} \quad (2.6)$$

In this dynamic panel model, the dependent variable $\Delta Credit_{i,t}$ measures the change in domestic credit to the private sector as a percentage of GDP for country i in year t. The specification includes a lagged dependent variable, $\Delta Credit_{i,(t-1)}$, to capture persistence in credit dynamics. The variable $NOC_{i,t}$ is a binary indicator equal to 1 if a national oil company is present, and 0 otherwise. The model incorporates $oilrent_{i,t}$, representing oil rents as a percentage of GDP, and $depf_{i,t}$, an index capturing fiscal dependence on oil revenues. To assess the conditional relationships between these factors, the model includes two-way and three-way interaction terms among National Oil Companies, the fiscal dependence index and oil rents. The model also controls for institutional and macroeconomic factors. Specifically, $IRC_{i,t}$ reflects the degree of interest rate controls, and $\Delta lnfbk_{i,t}$ captures the change in the logarithm of gross capital formation as a percentage of GDP. A time dummy, $d1974$, is included to control for global shocks beginning in that year. The vector $X_{i,t}$ includes instrumental variables such as country-specific trends, regional dummies, and the political regime indicator (*polity*). Finally, $\varepsilon_{i,t}$ denotes the standard error term.

As a second step, we apply a test to assess the marginal effect of fiscal dependence on oil revenues regarding the control of interest rates and the deepening of credit relative to GDP in countries with national oil companies. As Cameron (2005) note, the marginal effect most often measures the impact on the conditional mean of y resulting from a change in one of the regressors, X_k. This marginal effect illustrates how the probability of implementing interest rate controls changes depending on whether the ownership structure is private or state-owned, while controlling for fiscal dependence on oil rents.

In the third step, we apply a mediational analysis. The basic mediational framework involves a three-variable system in which an initial independent variable influences a mediational variable, which, in turn, affects an outcome variable (Baron and Kenny, 1986). In our case, we test the proposed causal mechanism in which the interaction of government revenues, dependent on high oil revenues, and the presence of national oil companies hinders financial development through interest rate controls applied to the banking system. The mediational analysis aims to determine whether the relationship between the initial variable and the outcome is due, wholly or in part, to the mediator (Krull and MacKinnon, 2001). A variable is generally accepted to lie on the causal path if it is measured after the cause and before the effect and if its inclusion in the regression reduces the size of the presumed causal variable's coefficient Baron and Kenny (1986).

2.3 Results and Discussion

2.3.1 Model for Interest rate controls

Table 2.2 presents the estimation results for the dynamic panel analysis aimed at explaining interest rate controls. This analysis is based on the lagged dependent variable, the institutional arrangement of oil companies, and incorporates oil prices and the political environment as additional exogenous variables.

Table 2.2: `IRC specifications`

Interest rate control (IRC)	**Model A**	**Model B**	**Model C**	**Model D**	**Model E**	**Model F**
IRC lagged	0.938***	0.191	0.189	0.164	0.313**	0.251**
	(0.016)	(0.119)	(0.116)	(0.131)	(0.127)	(0.124)
National oil company			0.261	0.459*	0.933***	0.752**
			(0.087)	(0.084)	(0.082)	(0.112)
Oil rents				-0.065	-0.013	-0.300
				(0.056)	(0.029)	(0.565)
Fiscal dependence					-2.643	92.584
					(1.661)	(141.92)
NOC × oil rents						0.347
						(0.680)
NOC × fiscal dependence						-92.236
						(141.80)
Oil rents × fiscal dependence						15.014
						(29.241)
NOC × oil rents × fiscal dependence						-16.286
						(29.541)
Observations	3699	3626	3441	3427	2334	2334
Countries	90	89	89	89	82	82
Number of instruments	68	68	70	70	70	70
AR(2) p-value	0.630	0.418	0.290	0.287	0.990	0.548
Hansen p-value	0.044	0.059	0.072	0.077	0.117	0.072
Instruments per country	0.76	0.76	0.79	0.79	0.85	0.85

Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: The table reports results from system GMM regressions of interest rate control (IRC) on oil-related and fiscal variables. All models include lagged IRC and fixed effects. Models B to E sequentially add controls for the presence of a national oil company (NOC), oil rents, and fiscal dependence. Model F includes their interaction terms. Control variables include the log of consumption, the log of fixed capital formation, and time fixed effects.

Statistical tests do not invalidate the econometric method, as the null hypotheses of the Hansen and AR(2) tests are not rejected. The significance of the coefficient associated with the lagged interest rate control (IRC) underscores the inertia present in these controls, thereby justifying the use of dynamic panel data.

To assess the influence of fiscal dependence on interest rate controls in countries characterized by oil revenues and public oil companies, this analysis considers both direct impacts and various interactions, which are evaluated through regression analysis. Consequently, to determine the overall effect, it is imperative to evaluate the marginal effect of fiscal dependence in relation to interest rate controls, taking into account whether the oil companies are privately or publicly owned (Table 2.3). We specify distinct sets of effects to be estimated for countries with National Oil Companies and those without. The average marginal effect serves as an estimator of the average impact based on the ownership status of the oil company. Marginal effect tests are conducted using the observed values of oil rents at their means.

Table 2.3: **Interest Rate Controls: Marginal Effects**

over: NOC	dy/dx	z	Pr > z	Oil rent mean
Not-state owned	95.845	0.66	0.508	0.217
State-owned	-2.233	-2.22	0.026	2.029

Note: The table reports the marginal effects of fiscal dependence on oil revenue at the mean value of oil rents, across different ownership types of National Oil Companies (NOCs). Estimates are derived from models of IRC. Standard errors are clustered at the country level.

The results indicate that countries with national oil companies tend to impose more controls on interest rates. When the IRC variable approaches zero, it reflects a situation where the tightest controls on rates are enforced. The estimated coefficient is negative and significant at the 5% level, suggesting that higher fiscal dependence correlates with the application of tighter interest rate controls.

Regarding the explanatory variables in the dynamic panel data, both political factors and oil prices are found to be positive and significant. Thus, we interpret that more democratic countries tend to implement fewer interest rate controls, while higher oil prices increase government revenues and reduce the need to seek alternative funding sources.

2.3.2 Model for private credit as percentage of GDP

The dynamic panel analyzes the change in credit to the private sector as a percentage of GDP, based on the lagged dependent variable and the institutional arrangement of the oil companies. Independent variables include interest rate controls, the change in the logarithm of gross capital formation, and a dummy variable for the year 1974. In that year, international oil prices experienced an atypical increase (over 250% per year) due to the oil embargo imposed by Saudi Arabia, Iran, Iraq, the United Arab Emirates, Kuwait, and Qatar, which began at the end of 1973. The results are presented in Table 2.4.

Table 2.4: Change in Credit as % of GDP (GMM specifications)

Change in domestic credit	**Model A**	**Model B**	**Model C**	**Model D**	**Model E**	**Model F**
Change in cred. lagged	-0.351***	0.446	0.699*	0.782*	0.740**	0.775**
	(0.065)	(0.365)	(0.384)	(0.413)	(0.323)	(0.330)
National Oil Company			7.418**	4.124	8.802**	10.315*
			(2.953)	(3.983)	(4.426)	(5.323)
Oil rents				0.993	-0.202	7.986
				(0.879)	(0.469)	(9.358)
Fiscal dependence					-32.558**	-376.26
					(12.980)	(2671.71)
NOC * oil rents						-8.223
						(9.342)
NOC * fiscal dependence						340.808
						(2669.18)
Oil rents * fiscal dependence						-463.45
						(415.72)
NOC * oil rents * fiscal dependence						463.25
						(416.39)
Hansen (Prob > chi2)	0.266	0.010	0.528	0.436	0.328	0.321
AR(2) (Prob > z)	0.001	0.419	0.743	0.543	0.404	0.382
Instruments	71	71	71	71	71	71
Observations	3420	3348	3348	3320	2289	2289
Countries	88	87	87	87	80	80
No. of instr./No. of cross-sections	0.81	0.82	0.82	0.82	0.89	0.89

Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: The table reports results from system GMM regressions of the change in domestic credit (Ddcred) on oil-related variables, fiscal dependence, and interest rate control (IRC). All models include the lagged dependent variable and fixed effects. Models B to E sequentially introduce the presence of a national oil company (NOC), oil rents, and fiscal dependence. Model F incorporates their interaction terms. Control variables include the log of fixed capital formation and time fixed effects. The model uses GMM-style instruments for the lagged dependent variable and fiscal dependence, and standard IVs for interactions between time and structural dummies. Robust two-step standard errors are reported.

Statistical tests validate the econometric method, as the null hypotheses of the Hansen and AR(2) tests are not rejected. The significance of the coefficient associated with lagged credit emphasizes the inertia present in this financial indicator. Regarding the explanatory variables, fewer interest rate controls have a positive effect on credit deepening, while gross capital formation and the dummy variable are also positive and significant. Once again, it is essential to apply marginal effects tests to assess changes in credit depth concerning fiscal dependence by dividing the sample based on the ownership of oil companies (Table 2.5).

Table 2.5: **Change in Credit: Marginal Effects**

y: Change in private credit as percentage of GDP				**Obs.** 2334
w.r.t.: fiscal dependence on oil revenue				*at mean oil rent*
over: NOC	**dy/dx**	**z**	**Pr > z**	**Oil rent mean**
Not-state owned	-472.974	2696.03	0.861	0.209
State-owned	-35.849	14.814	0.016	2.059

Note: Table reports marginal effects of fiscal dependence on oil revenue at the mean value of oil rent, for different ownership types of National Oil Companies (NOC). Estimates are derived from models of ΔCredit/GDP. Standard errors clustered at the country level.

Figure 2.1: Mediation diagram: NOC + oil rents (treatment) → Interest Rate Controls (IRC, mediator) → credit growth (outcome), with paths a, b, c (dashed, total effect), and c' (direct effect). The indirect effect is $a \times b$, representing the portion of the effect of NOC + oil rents on credit growth transmitted through IRC. The direct effect is c', and the total effect satisfies $c = c' + ab$.

Evidence from applying this test indicates that countries with fiscal dependence on oil revenues and national oil companies exhibit lower levels of financial development, as measured by credit deepening. The results of the marginal effects tests-both for the use of interest rate controls and for the growth of the credit share of GDP-show that fiscal dependence on oil revenues in countries with national oil companies is associated with a higher prevalence of interest rate regulations and lower credit growth.

2.3.3 Mediation analysis

The third stage of the empirical strategy involves applying mediation tests for panel data. The motivation for conducting this exercise is to disentangle the channels through which the combination of National Oil Companies (NOCs) and oil rents influences financial outcomes. In particular, we seek to identify whether this interaction is systematically associated with the use of interest rate controls (IRC). Such controls may temporarily stimulate credit growth in the short run by artificially lowering borrowing costs, but over time they tend to distort market signals, constrain financial intermediation, and ultimately reduce credit expansion. Mediation analysis therefore provides a suitable framework to capture both the immediate and the longer-term effects of resource dependence and state ownership on financial development, allowing us to distinguish between direct effects and those operating through financial repression mechanisms.

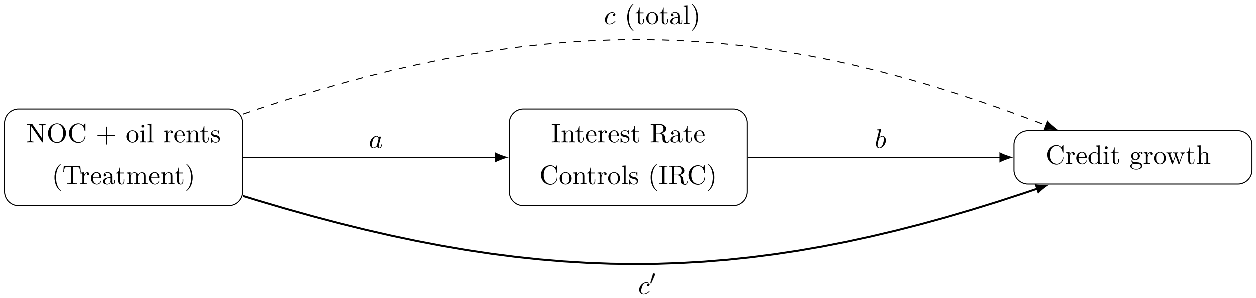


Figure 2.2: Mediation diagram: NOC + oil rents (treatment) → Interest Rate Controls (IRC, mediator) → credit growth (outcome), with paths a, b, c (dashed, total effect), and c' (direct effect). The indirect effect is $a \times b$, representing the portion of the effect of NOC + oil rents on credit growth transmitted through IRC. The direct effect is c', and the total effect satisfies $c = c' + ab$.

We apply the approach adapted from Krull and MacKinnon (2001), which relies on estimating three equations: (1) the dependent variable, credit growth, regressed on the independent variable, defined as the interaction between NOC presence and oil rents; (2) the mediator variable, interest rate controls (IRC), regressed on the same independent variable; and (3) credit growth regressed simultaneously on both the mediator variable (IRC) and the independent variable (NOC + oil rents). In this framework, the portion of the effect of the exogenous variable that is transmitted through IRC is identified as the indirect effect, while the portion that flows directly to credit growth is the direct effect. The total effect corresponds to the sum of these two components.

A mediation analysis is conducted using a mixed-effects regression model to examine the relationship between the independent variable—the interaction between fiscal dependence and the presence of a National Oil Company (NOC)—the mediator, interest rate controls (IRC), and the dependent variable, the credit growth rate. The interaction term is not a significant predictor of credit growth (c path), but it is a significant predictor of interest rate controls (a path), indicating that as fiscal dependence increases, the likelihood of imposing interest rate controls also rises. Moreover, the effect of IRC on credit growth is significant (b path). Taken together, these results support the mediation hypothesis, suggesting that IRC play a crucial role in transmitting the effect of fiscal dependence on credit growth.

In summary, while fiscal dependence does not directly affect credit, it significantly influences interest rate controls, which in turn affects the growth rate. The mediation analysis indicates that IRC accounts for around 20% of the total effect of fiscal dependence on credit. The ratio of the indirect effect to the direct effect is approximately 0.25, suggesting that the indirect effect is about 25% of the direct effect.

Table 2.6: **Mediation Analysis**

Analysis Component	**Coefficient**	**Std. Error**	**z-value**	**p-value**	**95% Conf.**
Equation 1 (c_path)					
Direct Effect of IV on Ddcred	8.24	5.99	1.38	0.169	[–3.50, 19.98]
Equation 2 (a_path)					
Effect of IV on IRC	1.67	0.81	2.06	0.040	[0.08, 3.27]
Equation 3 (b_path & c_prime)					
Effect of IRC on Ddcred	0.91	0.18	5.16	0.000	[0.57, 1.26]
Direct Effect (c_prime)	6.02	5.98	1.01	0.314	[–5.69, 17.73]
Summary of Effects					
Total Effect (c_path)	8.24				
Indirect Effect	1.53				
Proportion of Total Effect	20.24%				
Ratio of Indirect to Direct Effect	0.25				
Ratio of Total to Direct Effect	1.25				

Note: The table presents results from a mediation analysis of the effect of the independent variable (IV) on the change in domestic credit (Ddcred) through the mediator interest rate control (IRC). Confidence intervals are based on robust standard errors.

2.4 Discussion

Our findings reveal important policy implications for oil-rich countries. When governments decide to retain control of the oil industry, often the largest or one of the largest sectors in the economy, they typically establish a National Oil Company (NOC) and design institutional arrangements that channel oil rents to the rest of the economy. While this model allows states to capture and redistribute resource wealth, it also creates a vulnerability. When fiscal needs exceed the revenues provided by oil rents, governments often resort to financial repression measures. A prominent example is the use of interest rate controls (IRC) to direct credit toward quasi-fiscal activities.

Although such interventions may provide short-term liquidity and stimulate credit growth, they distort saving incentives and undermine the efficiency of financial intermediation. Over the long run, these distortions constrain credit expansion and weaken the financial system's ability to support sustained economic growth. Beyond the scope of this research, there are additional adverse consequences. Monetary policy becomes less effective in containing inflation, and the use of negative real interest rates can actually spur inflationary pressures. Moreover, financial repression tends to encourage capital flight, as domestic returns become lower or even negative, and it discourages foreign direct investment. These mechanisms have been documented extensively in the literature, from the early analyses of McKinnon (1973) and Cole and Shaw (1974) to subsequent empirical work (see, e.g., Giovannini (1985); Abiad et al. (2009);Jafarov et al. (2019)). The combined effect is to reduce both domestic and external sources of finance, making it more difficult for these economies to sustain growth.

Governments should avoid financial repression as a means of financing quasi-fiscal activities. Building transparent and broad-based tax systems, supported by stabilization or sovereign wealth funds, provides a more sustainable path to fiscal stability. In this way, credit markets can remain deep, resilient, and capable of supporting long-term growth without the distortions created by financial repression. A similar pattern is highlighted by Reinhart et al. (2011), who document how financial repression has historically been employed as a tool for managing fiscal pressures and public debt, often at the expense of financial development and long-term growth. In oil-rich economies that directly manage the oil industry via a national oil company (NOC), the short-term benefits of financial repression are outweighed by long-term costs—namely weaker credit markets and slower investment and growth.

2.5 Conclusions

In this paper, we hypothesize that oil-producing countries that manage their oil business through national companies may experience high fiscal dependence on these revenues, which encourages them to employ various mechanisms to finance public spending through specific measures of financial repression, such as interest rate controls. This proposed arrangement acts as an underlying mechanism that weakens credit expansion in the banking system because credit is not allocated efficiently, and depositors receive lower returns than they would in the absence of interest rate restrictions.

To study this hypothesis, we utilized the database on interest rate controls developed by Jafarov et al. (2019). By applying dynamic panel data analysis, along with marginal and mediation effects tests, we obtained empirical evidence that countries with national oil companies and governments dependent on oil revenues are more likely to implement interest rate controls. This, in turn, inhibits private credit growth and constrains the development of the financial system.

The results obtained provide an alternative explanation for the financial curse by endogenizing the application of financial repression within the institutional framework that characterizes countries with national oil companies and a high fiscal dependence on oil revenues. National oil companies are often viewed as sources of revenue for the state, which limits their ability to develop the investment plans necessary to maintain their competitiveness in the international oil market.

In this context, an important economic policy implication emerges. Resource-rich countries that rely predominantly on revenues generated by oil companies have fewer incentives than their non-oil counterparts to establish a fiscal system based on direct, transparent, and broad-based taxation.

Moreover, this overdependence on oil rents undermines fiscal discipline and increases vulnerability to external shocks, often compelling governments to resort to financial repression. To mitigate these risks, the development of a fiscal system less dependent on oil revenues becomes essential. In particular, the creation of sovereign wealth or stabilization funds—governed by clear rules for channeling excess revenues during boom periods and transparent mechanisms for withdrawals during downturns—could contribute to stabilizing fiscal resources. Thus, by reducing revenue volatility and the temptation to interfere in financial markets, such an approach would foster greater macroeconomic stability and stimulate long-term financial and economic development.

Future research should examine how these dynamics evolve under different external and institutional conditions. The effects identified in this study may be amplified during periods of low oil prices, when more dependent countries are compelled to resort to financial repression as a substitute for lost revenues. Investigating the role of price volatility in shaping the incentives for financial repression would therefore add important insights. Another relevant dimension concerns institutional quality and regime type, since weak institutions or autocratic governments may be more prone to employ repression as a policy tool. In addition, further research could explore in greater detail how financial repression undermines the effectiveness of monetary policy, both in stabilizing inflation and in sustaining credit markets. Collectively, these extensions would deepen the understanding of how resource dependence and institutional arrangements interact to shape long-term financial development.

Finally, it is important to note that a limitation of this research is the estimation of fiscal dependence. In the case of some countries with high oil revenues, it was not possible to obtain data on public revenues, which could impact the estimates made, although it is unlikely to change the overall conclusion.

3. Fossil-Fuel Abundance and greenhouse gases Emissions: Can Financial Development Contribute to Breaking the Carbon Curse?[1]

3.1 Introduction

Climate change poses an unprecedented challenge for humanity, threatening ecosystems, livelihoods, and economic stability. The United Nations has consistently associated global warming with rising temperatures and more frequent extreme weather, and with soil erosion, biodiversity loss, and sea-level rise.[2] Tackling these impacts requires both mitigation—such as boosting energy efficiency and transitioning to renewables—and adaptation policies, including climate-resilient infrastructure. Both strategies demand substantial financial resources, especially in resource-rich nations where reliance on fossil fuels complicates the green transition.

Johnsson et al. (2018) argue that fossil-fuel abundance hampers compliance with warming targets, in line with the carbon-curse hypothesis of Friedrichs and Inderwildi (2013). Easy access to fossil fuels discourages investment in decarbonisation and crowds out cleaner alternatives. Many such countries also subsidise fossil-fuel consumption. Khan et al. (2022) provide evidence that natural-resource abundance is positively correlated with carbon-emission intensity.[3]

In this context, understanding the role of the financial system—particularly in fossil-fuel-rich countries—is key. Addressing climate change involves promoting renewable energy, improving energy efficiency, and reforestation, as well as enhancing infrastructure and agricultural resilience. All these initiatives require substantial funding. Yet many fossil-fuel-rich countries suffer a *financial curse*

[1]I thank the participants of the 1st Congress of the Latin American Association of Environmental and Resource Economists (LAERE, Bogotá, 2025), Dr. Leonardo Bonilla for his comments at the VI National Colloquium of Doctoral Students in Economics (Medellín, 2023), and colleagues at the Universidad del Rosario seminars for their valuable feedback. This paper has also been accepted for presentation at the 19th Environment for Development (EfD) Annual Meeting (2025).

[2]United Nations (2023), *Climate action*. `https://www.un.org/en/climatechange`

[3]Climate change is primarily driven by the accumulation of greenhouse gases (GHGs) from burning fossil fuels. Between 1990 and 2019, the top GHG-emitting countries accounted for over 80%, 90%, and 95% of the world's oil, gas, and coal production, respectively, underscoring the link between fossil-fuel production and CO_2 emissions.

(Beck, 2011), whereby their financial systems extend less credit than those of resource-poor nations.[4] Taken together, the financial and carbon curses suggest that resource-rich economies often display underdeveloped finance and higher emissions per unit of output.

The relationship between financial development and emissions is theoretically ambiguous. One strand finds that deeper finance can expand fossil-fuel technologies and durable-goods consumption, raising GHG emissions in both advanced and emerging economies (Sadorsky, 2010; Dogan and Turkekul, 2015; Shahbaz et al., 2013; Bekhet et al., 2017; Cetin et al., 2018; Al-Mulali et al., 2015; Jiang et al., 2019; Bui, 2020). Another strand shows that finance can enable environmental improvements by easing investment in renewables and sustainable practices,[5] lowering emissions (Piñeiro Chousa et al., 2017; Saidi and Mbarek, 2016; Shahbaz et al., 2013; Dogan and Seker, 2016; Zafar et al., 2022; Dasgupta et al., 2001; Islam et al., 2013; Martin et al., 2021). A third group finds no significant relationship (Ozturk and Acaravci, 2013; Dogan and Seker, 2016; Charfeddine and Kahia, 2019). These mixed findings motivate our research questions: (i) Does financial development influence *carbon intensity*? (ii) Does its impact differ with a country's stance on fossil-fuel subsidies? (iii) Which financial-system components are most effective at reducing emissions? Throughout the paper, "carbon intensity" denotes greenhouse-gas emissions per unit of GDP, with emissions expressed in CO_2-equivalent kilotonnes (kt); that is, CO_2e/GDP.

Guided by empirical evidence, we adopt the working assumption that financial development facilitates structural transformation towards services and low-carbon technologies, thereby reducing carbon intensity (Du et al., 2012; Okamoto, 2013; Aghion et al., 2018; Tian et al., 2019; Zhao et al., 2020; Ren et al., 2020; Ma et al., 2022; Ebeling, 2022). This reallocation improves capital allocation to renewables, promotes green R&D, and fosters entrepreneurship and diversification, with stronger effects where environmental governance is robust. However, the decarbonising potential of finance is curtailed by fossil-fuel subsidies, which distort price signals by artificially lowering the cost of carbon-intensive energy.

We interpret fossil-fuel consumption subsidies as a revealed-preference signal of low climate-policy stringency. When policy holds end-user fuel prices below a reference price that reflects full supply costs, the effective carbon price falls; relative prices favour carbon-intensive uses; and credit and investment tilt away from low-carbon assets. Consequently, in subsidising economies

[4]Explanations include: (i) the concentrated structure of oil-rich economies exposes them to terms-of-trade shocks, raising risk premia (Hausmann and Rigobon, 2003); (ii) Dutch-disease effects shift resources toward non-tradables, lowering productivity growth and credit (Benigno and Fornaro, 2013); (iii) misuse of windfalls for consumption smoothing discourages financial development (Gylfason and Zoega, 2001); and (iv) weak contract-enforcement institutions, undermined by rent-seeking and corruption, impede finance (Bhattacharyya and Hodler, 2014).

[5]Public markets require periodic disclosures (e.g., ESG), with the environmental pillar assessing alignment with low-carbon targets.

the decarbonising role of financial development is attenuated—damping the greening channel—and carbon intensity tends to be higher, *ceteris paribus.*

To address our research questions, we assemble a dynamic panel covering the 45 largest GHG emitters (in CO_2-equivalent) over 1990–2019, which together account for more than 90% of global GHG emissions.[6] Nearly all of these countries are significant fossil-fuel producers; within this group we can identify sub-samples that differ in their decarbonisation stance, particularly regarding fossil-fuel subsidies. To address endogeneity, we employ the two-step system GMM estimator of Blundell and Bond (1998), suitable given the inertia observed in emissions and financial indicators (Mlachila and Ouedraogo, 2020).

Our findings indicate that, in countries without fossil-fuel subsidies and with more advanced structural transformation towards services, financial development contributes to the decoupling of economic growth from GHG emissions. Moreover, when disaggregating financial development, we find that *financial markets* exert the strongest influence in reducing GHG intensity per unit of GDP.

We contribute to the finance–environment literature by explicitly incorporating fossil-fuel subsidies and structural transformation. This helps explain prior mixed results; financial development need not inherently raise or lower emissions and its impact depends on complementary policies and economic structure. Policy implications follow. Environmental protection measures should accompany financial-sector development to reduce GHG emissions effectively. In resource-rich economies, shallow finance already limits the ability to shift away from fossil dependence; this challenge is compounded where subsidies persist, entrenching a high-carbon development path and constraining the financing of sustainable transformation.

The document is organized into four sections: an introduction; an explanation of the data and technique utilized in section two; a presentation of the results in section three; and a conclusion in the final section.

[6] Definition follows the World Bank WDI. Total GHG emissions (kt CO_2e) include CO_2 excluding short-cycle biomass burning (agricultural-waste and savanna burning) but including other biomass burning (forest fires, post-burn decay, peat fires, and decay of drained peatlands), plus all anthropogenic CH_4, N_2O, and F-gases (HFCs, PFCs, SF_6).

3.2 Data and Methodology

3.2.1 Data

The dependent variable is the GHG intensity of GDP, defined as the logarithmic difference between greenhouse-gas emissions and real GDP, i.e., $I_{GHG,it} \equiv \log(\text{GHG}_{it}) - \log(\text{GDP}_{it})$, where GHG denotes total greenhouse-gas emissions expressed as CO_2-equivalent (kt CO_2e), sourced from the World Development Indicators (WDI). Emissions include those from fossil-fuel combustion (oil, coal, and gas), biomass (e.g., wood and waste), and industrial processes such as cement production.[7]

The main explanatory variable is financial development, measured using the IMF's composite Financial Development Index. This index addresses the limitations of single indicators by capturing both financial institutions and financial markets across three key dimensions, *depth*, which refers to the size and liquidity of financial systems; *access*, reflecting the ability of individuals and firms to obtain financial services; and *efficiency*, which gauges the capacity of institutions to provide services at low cost and with sustainable revenues, as well as the level of capital market activity. Developed by Sahay et al. (2015), this multidimensional framework offers a comprehensive and internationally comparable measure of financial system development. Financial institutions include banks, insurers, mutual funds, and pension funds, while financial markets comprise equity and bond markets. The index ranges from 0 to 1, with higher values indicating more developed financial systems.

To account for potential heterogeneity in the relationship between financial development and our outcome of interest, we also include a measure of economic structure. Specifically, we use the share of value added by the services sector in GDP, which reflects the extent of structural transformation and the economy's orientation toward less carbon-intensive activities. To capture structural heterogeneity in the effect of financial development, we include the share of value added by the services sector in GDP. This variable reflects the extent of economic transformation and is used both as a control and as an interaction term to explore moderating effects.[8]

In addition to the main explanatory variables, the model includes control variables commonly used in the environmental economics literature, such as trade openness, renewable energy consumption, and the global energy price index. Trade openness—measured as trade in goods and services as a share of GDP—is incorporated as a structural determinant of emissions. Openness affects carbon

[7]Totals are expressed in CO_2-equivalent (CO_2e). GHG (kt CO_2e) comprises CO_2 excluding short-cycle biomass burning (e.g., agricultural-waste and savanna burning) but including other biomass burning (e.g., forest fires, post-burn decay, peat fires, and decay of drained peatlands), plus all anthropogenic CH_4, N_2O, and F-gases (HFCs, PFCs, SF_6).

[8]The services sector is typically less carbon-intensive and more innovation-driven, potentially reinforcing the greening effect of finance.

intensity through scale, composition, and technology-transfer channels (Antweiler et al., 2001) (Copeland and Taylor, 2004) (Grossman and Krueger, 1993), all of which evolve gradually and reflect a country's long-term integration into global markets. Given these slow-moving characteristics, and considering that the specification already includes other institutional and structural controls, trade openness is unlikely to adjust contemporaneously in response to short-run changes in carbon intensity.

Renewable energy consumption—expressed as a share of final energy use—is included to capture the effective energy mix within the economy. Consumption, rather than production, is employed because it more accurately reflects the degree to which renewable sources substitute for fossil fuels in meeting domestic energy needs. Countries may produce renewable energy but export part of it, or conversely, rely heavily on imported fossil fuels; therefore, consumption provides a more precise measure of the energy mix relevant for carbon intensity outcomes. The global energy price index, sourced from the Federal Reserve Bank of St. Louis, is included to capture international fuel price dynamics. This index reflects benchmark energy prices in nominal U.S. dollars and proxies external cost pressures that influence fossil fuel use. To mitigate concerns related to reverse causality or contemporaneous feedback effects, all control variables are lagged by one period in the empirical specification.

Foreign direct investment (FDI), measured as a share of GDP, is used as an external instrumental variable in the dynamic panel model. FDI is associated with technology transfer, managerial efficiency, and improvements in financial and productive systems, and its influence on carbon intensity operates indirectly through these structural channels. Once these mechanisms are accounted for in the specification, FDI is plausibly exogenous to short-term changes in emissions. Finally, the empirical model includes regional fixed effects and a linear time trend to account for unobserved heterogeneity across countries and global structural changes over time.

In our framework, the subsidy indicator serves as a revealed-preference measure of climate-policy stringency. When governments shield households from higher fuel prices rather than preserve carbon-consistent price signals, they reveal low policy stringency, artificially cheap fossil energy skews credit and investment toward carbon-intensive activities and weakens the decarbonising role of financial development. Where such subsidies are absent and effective climate incentives are maintained, relative prices favour efficiency and low-carbon alternatives, and finance is more likely to support structural transformation toward services and cleaner technologies. We use this criterion to split the sample into countries that *subsidise* and those that *do not subsidise* fossil-fuel consumption.

Data on fossil-fuel consumption subsidies are drawn from the International Energy Agency (IEA) and are available annually since 2010.[9] The IEA applies the *price-gap* approach, comparing average

[9]International Energy Agency, Fossil fuel consumption subsidies—methodology and data access at `https://www.iea.org/topics/energy-subsidies`.

end-user prices with reference prices that reflect full supply costs. A subsidy is recorded when the end-user price falls below the reference level.[10] The approach captures both explicit budget outlays and implicit support. In fuel-exporting economies that sell domestically below the reference price, the subsidy is implicit and recorded as an opportunity cost equal to forgone rent after adjusting for transport and distribution. In net-importing economies, measured subsidies may be explicit budget expenditures or implicit, and many countries combine both channels.

Price-gap estimates identify only interventions that push final consumer prices below competitive benchmarks. They do not include upstream or production subsidies, preferential tax treatments that do not lower end-user prices, or support for research and development. As a result, the figures understate total fossil-fuel support. This limitation can be more pronounced when international prices are high and volatile, since governments often shield consumers—widening the observed gap even when measures are temporary.

For empirical implementation, the IEA time series begin in 2010. For the years prior to 2010, we assume that countries identified as subsidizing consumption in 2010 also maintained subsidies in the earlier period, while countries without subsidies in 2010 are assumed not to have subsidized consumption before that year. These classification rules allow the construction of a consistent indicator for whether each country maintained fossil-fuel consumption subsidies during the pre-2010 period. To preserve coverage over 1990–2019, we construct a time-invariant policy-stance proxy that equals one if a country records a strictly positive IEA consumption-subsidy value in any year between 2010 and 2019, and zero otherwise. This binary classification is then applied to the full panel and summarizes whether an economy systematically tolerated end-user fossil-energy prices below reference levels, signalling a weak climate-policy environme

[10] Subsidy = (Reference price − End-user price) × Units consumed.

Table 3.1: **Descriptive statistics**

Variable	**Source**	**obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Carbon intensity (GHG, log CO_2e - log GDP)	WDI	1350	5.896	1.007	4.089	9.450
Financial development index (IFS-IMF)						
Financial development index	IFS-IMF	1320	0.434	0.239	0.000	0.967
Financial institutions index		1320	0.467	0.247	0.000	0.978
Depth		1320	0.333	0.296	0.000	1.000
Access		1320	0.399	0.295	0.000	0.900
Efficiency		1320	0.586	0.132	0.000	0.905
Financial markets index		1320	0.386	0.256	0.000	0.949
Depth		1320	0.363	0.244	0.000	0.943
Access		1320	0.317	0.226	0.000	0.900
Efficiency		1320	0.492	0.368	0.000	1.000
Services, value added (share of GDP)	WDI	1240	0.532	0.114	0.109	0.794
Industry (incl. construction), value added	WDI	1248	0.326	0.115	0.122	0.867
Fossil-fuel subsidies (dummy)		1350	0.599	0.490	0.000	1.000
GDP (const. 2015 USD)	WDI	1304	26.729	1.389	26.784	30.623
Population (millions)	WEO	1324	10.820	1.208	7.520	14.159
Renewable energy (% of energy use)	WDI	1350	0.156	0.189	0.000	0.887
Trade (share of GDP)	WDI	1288	0.638	0.364	0.000	2.204
Global energy price index	FRED	1233	117.2	65.5	37.2	232.5
Political system	CSP	1298	3.867	7.052	−10	10

Note: This table presents descriptive statistics for the main variables used in the analysis. Financial development indicators are sourced from the IMF's Financial Development Index database. Other data sources include the World Bank, IEA, FRED, WEO, and CSP datasets. All variables are expressed in consistent units as used in the regressions.

3.2.2 Methodology

Given the persistent nature of both carbon intensity and financial development indicators, a dynamic panel data approach is warranted. Inertia is a defining characteristic of climate, ecological, and socio-economic systems, as highlighted by the Intergovernmental Panel on Climate Change (IPCC).[11] Stabilizing CO_2 concentrations requires sustained reductions in net global emissions, meaning that current emission levels and trends are closely linked to past trajectories (IPCC, 2023b). Similarly, financial development exhibits considerable persistence, shaped by structural factors such as regulatory frameworks, asymmetric information, and risk aversion, which limit abrupt changes in financial deepening. These dynamics justify the use of a model that accounts for lagged effects when assessing the relationship between financial development and carbon emissions.

The relationship between carbon intensity, the services sector, and financial development may be subject to endogeneity caused by reverse causality, measurement errors, and omitted variable bias (Haq et al., 2018). These issues undermine the reliability of pooled OLS, fixed-effects, and random-effects estimators. To address this, we employ dynamic panel GMM techniques, which control for both unobserved heterogeneity and endogeneity by incorporating lagged endogenous variables as instruments.

We adopt the two-step System GMM estimator developed by Arellano and Bover (1995) and extended by Blundell and Bond (1998), which improves efficiency over the difference GMM estimator (Arellano and Bond, 1991). As noted by Bond (2002), System GMM reduces finite-sample bias, especially when the number of cross-sections (N) exceeds the number of time periods (T)—a condition satisfied in our dataset. Although the two-step estimator is asymptotically more efficient, its standard errors are often biased downward. To address this, we apply the Windmeijer (2005) finite-sample correction to the two-step covariance matrix, improving the reliability of inference (Roodman, 2009).

We also take measures to prevent instrument proliferation, which can overfit endogenous variables and weaken the Hansen test of instrument validity. Following de Mendonça and Barcelos (2021), we restrict the lag structure and ensure the number of instruments remains lower than the number of cross-sectional units. Instrument validity is assessed using the Hansen test of over-identifying restrictions, where failure to reject the null suggests that instruments are valid. Additionally, we test for serial correlation in the error term using AR(2) tests.

To assess stationarity, we perform panel unit root tests. For most variables, we use the (Im et al., 2003) (IPS) test, which is suitable for unbalanced panels and allows for cross-sectional heterogeneity. For the politics variable, we use Fisher-type unit root tests, which aggregate p-values from individual ADF or PP tests. All variables used in our regressions are found to be stationary.

[11]The IPCC is the United Nations body responsible for assessing the science of climate change.

To estimate the dynamic relationship between carbon intensity, financial development, and structural transformation, we employ the two-step System GMM estimator. This approach controls for endogeneity and omitted variable bias by combining equations in levels and first differences. The model includes a lagged dependent variable to capture inertia in emissions intensity, treated as endogenous and instrumented using its own lagged values, following the Arellano and Bover (1995) and Blundell and Bond (1998) framework.

We use foreign direct investment (FDI) as a percentage of GDP as an external instrument. FDI is widely recognized as a conduit for technology transfer, managerial know-how, and productivity-enhancing innovations, and it plays an important role in shaping the structural composition of economies. Its capacity to support cleaner production processes depends critically on domestic conditions—particularly the depth and efficiency of the financial system, the absence of fossil-fuel consumption subsidies, and the degree of structural transformation reflected in the size of the service sector. As documented in the literature, FDI inflows are associated with improvements in financial systems and the diffusion of more advanced, often greener, technologies. In this context, FDI affects carbon intensity only indirectly, through these structural and financial channels, and not through an immediate impact on emissions. Given that these mechanisms are explicitly controlled for in the empirical specification, FDI is plausibly exogenous to short-term fluctuations in carbon intensity, which supports its use as an external instrument.

It is also included interaction terms between time and regional dummies to control flexibly for unobserved regional trends. Robust standard errors are reported to account for heteroskedasticity and serial correlation.

3.2.3 Model specification and empirical strategy

The dynamic panel model used to explore the effects of financial development on the carbon intensity of GDP is as follows:

The dynamic panel model used to explore the effects of financial developmen t on the GHG intensity of GDP is:

$$\begin{aligned} \Delta I_{GHG,i,t} \;=\; & \alpha + \beta_1\, \Delta I_{GHG,i,t-1} + \beta_2\, Fd_{i,t} + \beta_3\, Services_{i,t} \\ & + \; \beta_4 \left(Fd_{i,t} \times Services_{i,t}\right) + \beta_5\, \Delta renew_{i,t-1} + \beta_6\, \Delta \ln GEPI_{i,t-1} \\ & + \; \beta_7\, \Delta trade_{i,t-1} + \beta_8\, X_{i,t} + \varepsilon_{i,t}\,, \end{aligned} \tag{3.1}$$

In equation (3.1),the dependent variable, $\Delta I_{GHG,i,t}$, is the change in GHG intensity (CO_2e/GDP). captures the change in GHG intensity of GDP, measured as the difference between the logarithm of total CO_2 equivalent emissions and the logarithm of real GDP for country i at time t. The key explanatory variables include the financial development index ($Fd_{i,t}$) and the value added by the service sector as a share of GDP ($Services_{i,t}$), along with their interaction term ($Fd_{i,t} \times Services_{i,t}$), which tests whether the impact of financial development on emissions depends on the structure of the economy. The model also controls for the one-period lag of the dependent variable, reflecting dynamic adjustment. Additional controls include the change in renewable energy consumption ($\Delta renew_{i,t-1}$), the change in the logarithm of the global energy price index ($\Delta \ln GEPI_{i,t-1}$), and the change in international trade ($\Delta trade_{i,t-1}$). The vector $X_{i,t}$ includes time trends, regional fixed effects, and foreign direct investment as a share of GDP. The error term is denoted by $\varepsilon_{i,t}$. The model is estimated over a panel of 45 countries from 1990 to 2019, with i indexing countries and t denoting time.

We begin by regressing the change in GHG intensity on the service-sector share and financial development for the full sample. In a second step, we include an interaction term between financial development and the service-sector share to assess whether their combined effect influences carbon intensity. Next, we split the sample into non-subsidizing (environmentally proactive) countries and subsidizing countries. Then, estimate the model for each sub-sample. Subsequently, we perform several tests to ensure the robustness of the results, and we ultimately repeat the process for the sub-samples using other financial development metrics.

To further examine the channels through which financial development affects carbon intensity, we sequentially replace the aggregate financial development index ($Fd_{i,t}$) in Equation (3.1) with each of its institutional and market-based components. Specifically, we estimate the model using the sub-indices for financial institutions, including access, depth, and efficiency, followed by separate estimations incorporating the corresponding components for financial markets. This approach allows us to disentangle the individual effects of different dimensions of financial development and to assess whether specific institutional or market features are more influential in moderating carbon emissions. In each case, we retain the interaction term with the service-sector share to evaluate how the structure of the economy shapes the environmental impact of each financial component.

3.3 Baseline results, the role of Financial Development and the Service Sector in Carbon intensity

The outcomes of the baseline model are presented below. First, we run the panel for the entire sample, both with and without the interaction between value-added services and financial development. Next, we divide the sample into nations that support fossil fuel consumption and those that do not [12]

Table 3.2: **Effects of Financial Development and Services on Carbon intensity**.

	(1) Full sample	(2) With interaction term	(3) Do not subsidize fossil-fuels	(4) Subsidize fossil-fuels
Dependent variable: Carbon intensity (GHG, CO_2e/GDP)				
Services	0.221	0.338**	−0.00885	0.566
	(0.160)	(0.169)	(0.243)	(0.507)
Financial development	−0.054	0.271	0.939***	0.680
	(0.054)	(0.345)	(0.336)	(1.000)
Services × Financial dev.	–	−0.513	−1.168***	−1.427
		(0.523)	(0.441)	(1.935)
Observations	1,019	1,019	428	591
Number of id	41	41	17	24
Number of Instruments	15	15	11	15
AR(2)	0.026	0.0213	0.292	0.329
Hansen	0.006	0.0022	0.758	0.0529
N° instr. / cross-sec	0.37	0.37	0.65	0.63

Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: Estimates are based on two-step system GMM regressions. Columns (3) and (4) report the core results from the split-sample analysis, which explores the moderating role of financial development in the relationship between services and carbon intensity. The results suggest that a structural shift toward services significantly reduces carbon intensity—but only when accompanied by deeper financial systems, and primarily in countries that do not subsidize fossil fuels.

The first column of Table 3.2 shows that, for the entire sample of countries, neither the service

[12] Annex A.2 (p. 118) presents the triple-interaction model using fossil-fuel subsidies as an explanatory variable. The objective is to isolate the marginal impact of moving from non-subsidizing to subsidizing economies. This pooled specification is more restrictive, as it constrains all remaining coefficients to be equal across the two groups. The results (Table 6.10) show that the coefficient on *Finance* × *Services* × *Subsidies* is not statistically significant on average. However, the marginal effects reveal meaningful heterogeneity. In subsidizing economies, financial development reduces carbon intensity only when the service share is large.

sector nor financial development alone significantly affects emissions. In the full sample (Column 2), the interaction term between services and financial development is negative, yet statistically insignificant. However, more revealing insights emerge when the sample is split according to a country's environmental stance. The third column focuses on environmentally friendly countries, shows that the interaction term has a statistically significant and negative effect on carbon emissions per unit of GDP. This supports the hypothesis that financial development can facilitate structural shifts toward less carbon-intensive sectors, particularly services, and foster the adoption of greener technologies. Conversely, the last column, examines countries that subsidize fossil fuels and are less environmentally inclined, shows a smaller and statistically insignificant interaction coefficient. This suggests that in such contexts, financial development has a more muted effect on reducing emissions—consistent with the view that fuel subsidies weaken the incentives for green structural transformation.

The results in Column (3) offer compelling evidence in support of the hypothesis that financial development strengthens the environmental benefits of structural economic transformation. Specifically, the interaction term between the service sector share and financial development is negative and statistically significant at the 1% level, with a coefficient of -1.168. This implies that in countries that do not subsidize fossil fuels, the expansion of the service sector is associated with a substantial reduction in carbon intensity-but only when accompanied by a more developed financial system. The large magnitude of the coefficient suggests that well-developed financial systems play a catalytic role in enabling the service sector to contribute meaningfully to decarbonization.

The *de facto* stance of fossil fuel–rich countries on climate change can often be inferred from their subsidy policies. As shown in our results, many governments continue to subsidize fossil fuel prices, often to shield consumers from international price volatility.[13] Our hypothesis is that when a country deliberately maintains end-user fossil fuel prices below the international benchmark—estimated by the IEA—the primary objective is not to reduce GHG emissions or carbon intensity, but rather to protect domestic consumers from global price fluctuations. Subsidy policy thus provides a concrete and observable metric through which to assess the credibility of a country's environmental commitments. According to IMF estimates, fossil fuel subsidies represented 7.1 percent of global GDP in 2022,[14] underscoring the scale of the political economy challenge.

Building on this, the results presented in Columns (3) and (4) of Table 3.2 suggest a deeper structural trade-off linked to what can be termed a carbon curse. Resource-rich countries [15] that contributes little to global CO_2 emissions, often face considerable fiscal constraints when attempting to scale back fossil fuel extraction or investments, as revenues from oil, gas, and coal remain vital for

[13]Subsidies are explicit when fuel prices fall below costs, and implicit when they ignore environmental externalities.

[14]IMF (2023).

[15]Such as Pakistan, Nigeria, Colombia, and Egypt each one contribute less than 1% to global CO_2 emissions

public finances and macroeconomic stability. In these contexts, efforts toward low-carbon transitions must navigate not only market distortions caused by subsidies, but also institutional rigidities and fiscal dependencies embedded in the resource-based growth model.

Our regression findings indicate that financial development and structural transformation-proxied by a shift toward the service sector- are significantly associated with lower carbon intensity only in countries that do not maintain fossil fuel subsidies. This underscores the dual function of subsidies, beyond distorting price signals, they reflect deeper institutional and fiscal lock-ins that hinder economic diversification. These dynamics are consistent with the framework of Ploeg (2011), who argues that resource abundance, when coupled with weak institutions, perpetuates ineffective policies and rent-seeking, thereby entrenching carbon-intensive development paths and delaying structural change.

These results reinforce our theoretical expectations. While fossil fuel production tends to access financing relatively easily (Beck and Poelhekke, 2023), the service sector often faces credit constraints that hinder its ability to modernize and invest in renewable energy—especially in economies with entrenched fossil-fuel subsidies. These financial barriers pose a major obstacle to the green transition (Mukhtarov et al., 2022; Wang et al., 2021; Yang et al., 2022).Directing financial resources toward climate-friendly initiatives requires a well-developed financial system capable of identifying and funding viable low-carbon projects. Empirical evidence suggests that financial development plays a key role in driving structural economic transformation—through mechanisms like creative destruction and industrial upgrading—which in turn contribute to lower pollution levels (Du et al., 2012; Zhao et al., 2020; Aghion et al., 2018; Okamoto, 2013; Tian et al., 2019; Ebeling, 2022; Ren et al., 2020; Ma et al., 2022). As financial systems mature, they tend to support the expansion of the service sector, helping economies reduce emissions during structural change. This effect is likely to be stronger in countries with explicit climate policies. By contrast, in fossil fuel-dependent economies—where polluting industries dominate and structural change has stalled (Herrendorf et al., 2014)—financial development has a more limited environmental impact.

3.3.1 Exploring Alternative Financial Development Metrics

To refine our understanding of the baseline results, we follow Ma et al. (2022) and decompose financial development into its institutional[16] and market dimensions,[17] assessing their depth, access, and efficiency. This disaggregated approach allows us to identify which financial system features most effectively support structural transformation and emissions reduction, particularly in non-subsidizing countries.

[16]Financial institutions include banks, insurance companies, mutual funds, and pension funds.
[17]Financial markets include stock and bond markets

Over the past thirty years, the global financial system has undergone significant changes, leading to the consolidation of sophisticated financial firms, including insurance companies, investment banks, mutual funds, pension funds, venture capital firms, and many other non-bank financial institutions that play crucial roles. Concurrently, financial markets have expanded, enabling individuals and companies to diversify their savings (Svirydzenka, 2016). Companies can raise capital through wholesale money markets, bonds, and stocks. However, this access is restricted if a significant portion of the population and firms cannot utilize large financial systems, limiting their potential contribution to economic growth if these systems are shallow and inefficient.

Table 3.3, displays the results for the group of nations that do not subsidize fossil fuel consumption. The financial institutions indicator is used in the first column, while the indicators for financial institution access, depth, and efficiency are used in the following three columns. The financial markets indicator is used to display the results in Column 5,and Columns 6 through 8 employ the financial markets' access, depth, and efficiency measures.

All interaction terms between financial development and the service sector are negatively associated with carbon intensity, but statistical significance emerges only for indicators linked to financial markets—particularly the overall market development index and market access. Notably, the interaction between services and the financial markets index exhibits the strongest effect in the entire analysis, with a coefficient of –2.479, significant at the 1% level. This result suggests that well-functioning and accessible market-based finance, when coupled with a robust service sector, plays a pivotal role in decarbonizing economic activity. In contrast, financial institutions and their subcomponents -access, depth, and efficiency- show no statistically significant effects and consistently smaller magnitudes. One potential explanation lies in the limited traceability of green lending during the study period, due to the lack of standardized green taxonomies or climate-related financial disclosures. Without clear taxonomies, regulatory incentives, and climate-aligned risk assessments, financial institutions may fall short in channeling financial resources toward low-carbon transitions. Bridging this gap could significantly enhance their capacity to support structural transformation and sustainable development.

Table 3.3: **Financial Institutions and Markets Indexes in Non-Subsidizing Countries**

Panel A: Financial Institutions Indexes

VARIABLES	(1) Fin. Instit.	(2) Access	(3) Depth	(4) Efficiency
Services	−0.0744	−0.109	0.204	1.624*
	(0.403)	(0.172)	(0.338)	(0.857)
Financial ind. (i)	0.359	0.216	0.548	0.892
	(0.323)	(0.292)	(0.334)	(0.883)
Services × Fin. ind.	−0.392	−0.186	−0.788	−2.074
	(0.520)	(0.468)	(0.541)	(1.486)
Observations	428	428	428	428
Number of id	17	17	17	17
Number of instruments	11	11	11	11
AR(2)	0.120	0.232	0.295	0.0441
Hansen	0.595	0.682	0.584	0.996
N° instruments / cross-sec	0.65	0.65	0.65	0.65

Panel B: Financial Markets Indexes

VARIABLES	(5) Fin. Markets	(6) Access	(7) Depth	(8) Efficiency
Services	0.123	0.416**	0.462	0.615
	(0.297)	(0.203)	(0.334)	(0.389)
Financial ind. (i)	1.831***	0.962***	0.658	0.644**
	(0.699)	(0.298)	(0.827)	(0.319)
Services × Fin. ind.	−2.479***	−1.517**	−1.049	−0.980
	(0.861)	(0.384)	(1.127)	(0.552)
Observations	428	428	428	428
Number of id	17	17	17	17
Number of instruments	11	11	11	11
AR(2)	0.343	0.273	0.394	0.209
Hansen	0.999	0.660	0.565	0.527
N° instruments / cross-sec	0.65	0.65	0.65	0.65

Note: Estimations are based on system GMM using robust standard errors clustered by country. All models include time fixed effects. Standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 3.4 reports the estimates for countries that subsidize fossil fuels. In this subsample every interaction term between financial development indicator and the service-sector share carries the expected negative sign, yet none is statistically significant. The absence of significance reinforces the notion that fossil-fuel subsidies blunt the ability of finance and services to catalyse a low-carbon transition.

Table 3.4: **Financial Institutions and Markets Indexes in Subsidizing Countries**

Panel A: Financial Institutions Indexes

VARIABLES	(1) Fin. Instit.	(2) Access	(3) Depth	(4) Efficiency
Services	0.133	0.171	0.071	0.409
	(0.128)	(0.131)	(0.066)	(0.303)
Financial ind. (i)	0.0671	0.246	−0.058	0.371
	(0.224)	(0.233)	(0.188)	(0.271)
Services × Fin. ind.	−0.164	−0.535	−0.065	−0.667
	(0.381)	(0.451)	(0.290)	(0.542)
Observations	591	591	591	591
Number of id	24	24	24	24
Number of instruments	15	15	15	15
AR(2)	0.428	0.460	0.446	0.801
Hansen	0.212	0.343	0.247	0.095
N° instruments / cross-sec	0.63	0.63	0.63	0.63

Panel B: Financial Markets Indexes

VARIABLES	(5) Fin. Markets	(6) Access	(7) Depth	(8) Efficiency
Services	0.365**	0.164	0.115	0.201
	(0.174)	(0.161)	(0.099)	(0.160)
Financial ind. (i)	0.486	0.316	0.112	0.239
	(0.316)	(0.301)	(0.205)	(0.206)
Services × Fin. ind.	−1.006	−0.606	−0.228	−0.499
	(0.628)	(0.627)	(0.372)	(0.397)
Observations	591	591	591	591
Number of id	24	24	24	24
Number of instruments	15	15	15	15
AR(2)	0.315	0.985	0.471	0.152
Hansen	0.531	0.132	0.171	0.278
N° instruments / cross-sec	0.63	0.63	0.63	0.63

Note: Estimations are based on system GMM using robust standard errors clustered by country. All models include time fixed effects. Standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

When energy prices are kept artificially low through fossil fuel subsidies—common in resource-rich countries—the relative returns on green investments diminish. As a result, even deeper financial systems may fail to allocate sufficient credit toward decarbonization. This finding supports our hypothesis that economies dependent on fossil-fuel production -often marked by less developed financial sectors- devote fewer resources to climate-friendly initiatives and, consequently, face greater difficulties in decoupling emissions from economic growth. These broad-based subsidies, aimed at suppressing fuel prices below international benchmarks, offer an objective metric of a country's stance on climate action.

3.4 Robustness checks

To probe the robustness of the baseline estimates-derived with the composite financial development index-we run a focused set of sensitivity checks that all retain this index as the core financial variable. First, we reclassify countries by the presence of a national oil company rather than by fossil-fuel-subsidy status (Table 3.5). Second, we replace the composite index with a credit-depth proxy (domestic credit to the private sector) while keeping the remainder of the specification unchanged. Third, we swap the original instrument (FDI inflows) for the Polity score to address potential endogeneity. Finally, we alter the dependent variable in two ways-per-capita CO_2 emissions and absolute CO_2 emissions relative to GDP-rather than GHG emissions in CO_2-equivalent terms. These exercises, reported in Table 3.6 and Table 3.7, are designed to verify that the main results are stable across alternative country classifications, financial-depth metrics, instruments, and emissions definitions, while keeping the composite financial development index at the centre of the analysis.

To shield citizens from the instability of global pricing, nations that manage the fossil fuel industry through national enterprises typically provide subsidies for fuel consumption, whereas those without such companies do not.[18] Economies centered on the production of these commodities often feature large national corporations and subsidies for hydrocarbon consumption. This classification is sourced from the Natural Resource Governance Institute.

[18]In our sample, 25 out of the 27 countries that subsidize fossil fuels have a national company (NC), highlighting a strong institutional overlap between state ownership and continued fossil-fuel support

Table 3.5: **Results for Carbon intensity by National Companies**.

	(1) Full sample	(2) With interaction term	(3) Do not subsidize fossil-fuels	(4) Subsidize fossil-fuels
Dependent variable: Carbon intensity (GHG, CO_2e/GDP)				
Services	0.126	0.338**	1.021***	0.463**
	(0.157)	(0.166)	(0.296)	(0.214)
Financial development	−0.0592	0.344	0.607*	0.330
	(0.0623)	(0.247)	(0.349)	(0.372)
Services × Financial dev.	–	−0.615*	−1.192***	−0.695
		(0.362)	(0.434)	(0.542)
Observations	993	993	354	639
Number of id	40	40	14	26
Number of Instruments	16	16	10	16
AR(2)	0.0684	0.0167	0.0574	0.0600
Hansen	0.0056	0.0102	0.666	0.0333
N° of instruments / cross-sec	0.40	0.40	0.71	0.62

Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: Estimates are based on two-step system GMM regressions. Columns (3) and (4) present the core results from the split-sample analysis by the presence of national oil companies. The interaction between financial development and the service sector is significant and negative in countries without national companies, suggesting that financial depth enhances the decarbonization potential of structural transformation. This moderating effect appears weaker and statistically insignificant in countries with national companies, possibly due to entrenched fossil-fuel interests or weaker financial-market mechanisms.

Table 3.5 reports the regression results for carbon intensity, distinguishing between countries with and without national companies involved in managing the fossil fuel sector. In Column (3), the interaction term between services and financial development is -1.192 and statistically significant at the 1% level, indicating a strong moderating effect. This suggests that for countries with higher levels of service sector output, the marginal effect of financial development on carbon intensity becomes substantially more negative. This reinforces the idea that structural transformation is a critical condition for unlocking the environmental benefits of financial development. In contrast, Column 4 (countries with NCs) shows a smaller, statistically insignificant effect of the interaction. This suggests that in subsidizing countries, even a larger service sector does not significantly amplify the decarbonizing effect of financial development.

To further validate the robustness of our findings, Table 3.6 focuses exclusively on non-subsidizing countries and presents four complementary specifications. In Column (1), the financial development index is replaced by credit to the private sector—a narrower proxy that emphasizes the role of financial institutions while excluding financial markets. Column (2) substitutes foreign direct investment with the political system as an alternative measure of institutional quality. In Column (3), we re-specify the dependent variable using per-capita CO_2 emissions instead of carbon intensity. Finally, Column (4) employs a variant of the carbon intensity measure defined as the difference between the logarithm of CO_2 emissions and the logarithm of GDP (i.e., excluding non-CO_2 greenhouse gases).

Table 3.6: **Results for Carbon intensity in Non-Subsidizing Countries.**

	(1) Domestic credit to private sector	(2) Polity as control variable	(3) CO_2 emissions per capita	(4) Carbon intensity (only CO_2 emissions)
Dependent variable: Carbon intensity (cols. 1–2)				
Services	0.170	0.187	0.480	0.305
	(1.011)	(0.539)	(0.456)	(0.272)
Credit	0.00749	–	–	–
	(0.00636)			
Services × Credit	-0.0152	–	–	–
	(0.0144)			
Financial development	–	1.141**	0.611***	1.029***
		(0.539)	(0.216)	(0.257)
Services × Financial dev.	–	-1.427*	-1.022***	-1.431***
		(0.762)	(0.387)	(0.376)
Observations	362	412	430	428
Number of id	17	17	17	17
Number of Instruments	11	11	11	11
AR(2)	0.106	0.162	0.135	0.0852
Hansen	0.409	0.268	0.836	0.915
N° of instruments / cross-sec	0.65	0.65	0.65	0.65

Standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Note: Note: Estimates are based on two-step system GMM regressions for a subsample of countries that do not subsidize fossil fuels. Column (1) includes a credit variable and its interaction with services to assess an alternative proxy for financial depth. Column (2) introduces a political control (System polity) while reverting to the financial development index. Columns (3) and (4) change the dependent variable to CO_2 emissions per capita and CO_2-based carbon intensity, respectively. The interaction between financial development and services is consistently negative and statistically significant across these specifications, reinforcing the moderating role of financial depth in enhancing the decarbonization effect of structural transformation toward services.

The decoupling between CO_2 emissions and GDP growth in nations that do not subsidize fossil fuels is attributed to the relationship between the size of the service sector and the development of the financial system. This finding remains statistically significant when using a political system measure, examining the influence on per capita emissions, or adjusting carbon intensity based solely on CO_2 emissions. However, when using credit to the private sector (column 1), the result is not statistically significant. This discrepancy may be explained by the fact that, during the examined period, the growth of green credits issued by financial institutions has not yet reached the levels traded through green bonds in financial markets. Furthermore, there is no appropriate taxonomy to classify loans granted to green initiatives related to the energy transition during the study period.

The results obtained for countries that have consistently announced their commitment to protecting the environment and do not subsidize fossil fuel use, support the hypothesis that the development of the financial system can effectively reduce pollution, particularly when these countries have advanced their structural change toward the service sector.

In countries that subsidize fossil fuel consumption, the combined effect of financial development and the service sector lowers CO_2 emissions, although the effect is not statistically significant (Table 3.7). However, the expansion of service-sector firms in these countries is constrained by limited credit availability, high financial costs, and underdeveloped, illiquid financial markets. Moreover, the abundance of fossil fuels reduces the perceived risk of fossil fuel–related activities, resulting in a disproportionate allocation of credit toward polluting sectors. This finding is consistent with Beck (2011). As a result, the growth of the service sector is stifled, and value added by carbon-intensive industries increases. These dynamics contribute to what is known as the *carbon curse*. In such contexts, the financial system's capacity to decouple economic growth from emissions is significantly diminished.

Table 3.7: **Results for carbon intensity in Subsidizing Countries**.

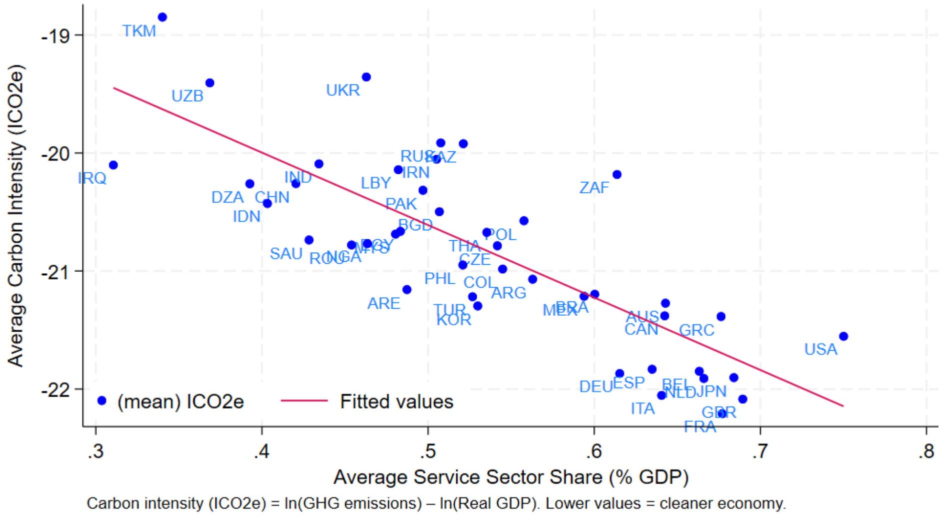
	(1) Domestic credit to private sector	(2) Polity as control variable	(3) CO_2 emissions per capita	(4) Carbon intensity (only CO_2 emissions)
Dependent variable: Carbon intensity (cols. 1–2)				
Services	0.0397	0.425	0.127	0.235
	(0.199)	(0.495)	(0.348)	(0.469)
Credit	-0.000950	–	–	–
	(0.00184)			
Services × Credit	0.00148	–	–	–
	(0.00304)			
Financial development	–	0.571	0.331	0.463
		(1.087)	(0.734)	(0.760)
Services × Financial dev.	–	−1.160	−0.681	−0.944
		(1.981)	(1.157)	(1.491)
Observations	476	570	612	591
Number of id	24	24	25	24
Number of Instruments	15	15	15	15
AR(2)	0.318	0.332	0.101	0.217
Hansen	0.268	0.0843	0.398	0.0557
N° of instruments / cross-sec	0.63	0.63	0.60	0.63

Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

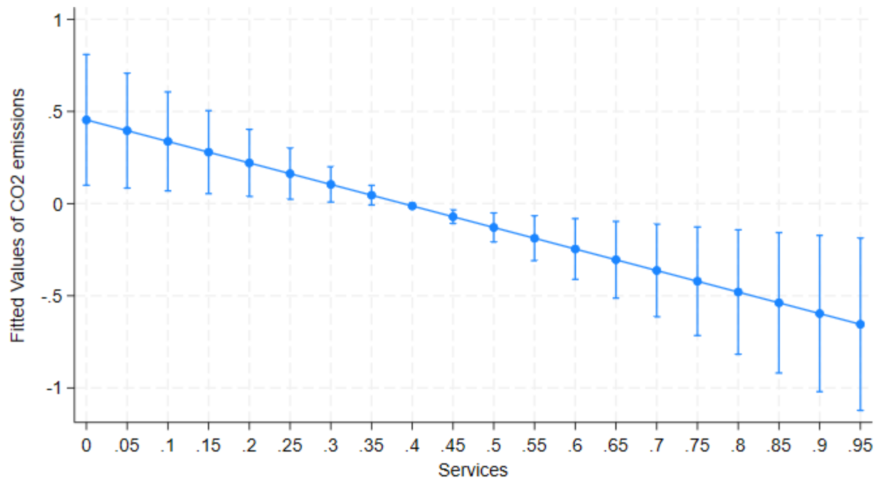
Note: Note: Estimates are based on two-step system GMM regressions for a subsample of countries that subsidize fossil fuels. Column (1) includes a credit variable and its interaction with services to assess an alternative proxy for financial depth. Column (2) introduces a political control (System polity) while reverting to the financial development index. Columns (3) and (4) use CO_2 emissions per capita and CO_2-based carbon intensity, respectively, as dependent variables. The interaction between financial development and services is consistently negative but not statistically significant across these specifications, reinforcing the idea that in countries subsidizing fossil fuels, deeper financial systems do not have a discernible effect on emissions.

3.4.1 Discussion

The interaction estimates shows that the environmental payoff of finance depends on economic structure. In particular, the partial effect of financial development on carbon intensity, becomes more negative as the service-sector share rises. Figure 3.1a provides a descriptive backdrop, country averages shows a negative association between carbon intensity (CO_2e/GDP) and the size of the services sector. Figure 3.1b then formalises this pattern using predictive margins, showing that the finance–environment relationship improves monotonically with the service share.



(a) **Carbon intensity vs. service-sector share (country averages).** Each point is a country mean over 1990–2019. Carbon intensity = GHG emissions (CO_2e) per unit of GDP. A fitted line is shown; lower values denote a cleaner economy.



(b) **Predictive margins of financial development across service-sector shares.** Fitted values with 95% CIs from linear combinations of interaction coefficients. Dependent variable: carbon intensity (GHG, CO_2e/GDP).

Figure 3.1: **Services, finance, and carbon intensity.** Panel (a) shows the stylised fact; Panel (b) reports model-based predictive margins.

Note. (i) Panel (a) is descriptive; margins include controls and fixed effects. (ii) The price-gap metric captures only consumer-price support; upstream/production subsidies are omitted. (iii) Interaction magnitudes are scale-dependent; we report predictive margins and simple slopes with CIs.

These results imply that structural transformation towards services is not merely a correlate but a conditioning factor. For a given increase in financial development, the reduction in GHG intensity is larger in more service-oriented economies. By contrast, fossil-fuel consumption subsidies weaken this channel by distorting relative prices, lowering the effective carbon price, and steering credit towards carbon-intensive activities, thereby raising GHG intensity. The policy implication is straightforward. Deepening market-based finance and increasing climate-policy stringency—including the phase-out of fuel subsidies—work as complements; together they expand the service share and lower GHG emissions.

The marginal effect of finance on carbon intensity changes sign at a threshold. While its precise value is model-specific, the predictive margins in Figure 3.1b indicate that economies with larger service sectors experience a larger reduction in GHG intensity from deeper finance. This pattern is consistent with channels operating through capital reallocation, lower financing costs for clean technologies, and knowledge-intensive services that foster process and product innovation. Policywise, removing fuel-price distortions and deepening market-based finance are complementary, together they strengthen the decarbonising role of finance by aligning price signals with structural change.

3.5 Conclusions

This study advances the debate on the environmental payoff of financial development by showing that its synergy with an expanding service sector can lower the carbon intensity of growth -but only where fuel-price distortions have been removed. Using panel data from 45 high-emitting countries, we find that in the absence of fossil fuel subsidies, more developed financial systems—when paired with a growing service sector—are associated with a significant reduction in carbon emissions per unit of GDP. This suggests an emerging decoupling of economic growth from CO_2 emissions.

A well-developed financial system—characterized by a diverse range of institutions, markets, and instruments—plays a catalytic role in enabling structural transformation. It does so by facilitating investment in low-carbon technologies, modernizing production processes, and reallocating resources toward less carbon-intensive sectors. However, financial development alone is not sufficient. Its effectiveness depends critically on a supportive policy environment and a meaningful shift in economic structure toward services and other clean-growth sectors.

By contrast, fossil fuel–dependent economies with shallow financial systems and persistent subsidies face entrenched structural barriers to decarbonization. These distortions hinder the ability of financial markets to efficiently mobilize and allocate capital toward sustainable technologies, thereby limiting progress toward environmental goals. Notably, such countries account for 60% of the top emitters in our sample, highlighting how widespread these vulnerabilities are. This is especially relevant given the mounting risks posed by climate-related events—such as rising temperatures, sea level rise, and extreme weather events.

Our findings highlight that financial markets, in particular, are pivotal in reducing carbon intensity by mobilizing long-term financing for clean investments. Yet, financial institutions such as banks and insurers also have an essential role to play in supporting the green transition, especially in economies where financial markets remain underdeveloped.

Policy implications are clear, governments must prioritize building inclusive and efficient financial systems. This includes fostering financial innovation, expanding access to credit and capital, and ensuring a competitive financial environment. Just as importantly, fossil fuel subsidies should be phased out, and policymakers should refrain from using distortive instruments -such as interest rate caps or directed lending mandates- that compromise financial sector efficiency. Achieving climate goals will require coordinated efforts to align financial sector development with structural and environmental reforms.

Future work should use the IEA price-gap series while expanding to alternative datasets and subsidy metrics—including upstream/production support—exploit policy reforms for identification, and employ loan-level data to uncover micro-mechanisms in capital reallocation and clean-technology adoption. It should also examine heterogeneity by income group, institutional quality, energy mix, and exposure to global energy prices, and assess international spillovers.

4. Financial Development Under Climate Stress: Evidence from Extreme Weather Events

4.1 Introduction

Climate change exerts wide-ranging environmental and social pressures that are reshaping economic and institutional dynamics. Rising temperatures, accelerating biodiversity loss, more frequent extreme weather events (EWEs), and sea-level rise disrupt ecosystems and threaten critical resources. These shifts heighten food- and water-insecurity, health risks, and forced migration, disproportionately harming vulnerable populations (Diffenbaugh and Burke, 2019; CRED, 2020). The unequal burden also fuels social tensions and governance challenges—particularly in fragile or resource-dependent states (Koubi, 2019).

Recent data from the National Oceanic and Atmospheric Administration rank 2024 as the warmest year on record (global series since 1850) (NOAA, 2025). Higher temperatures depress labour productivity, damage capital, and lower total-factor productivity (Henseler and Schumacher, 2019; Orlov et al., 2021). While this gradual, systemic dimension of climate change unfolds, an acute pattern is evident in the rising incidence of EWEs.[1] Localized yet costly, EWEs disrupt production, raise prices, and cause widespread social hardship (Torsten Ehlers and Shim, 2025).

The IPCC (2023a) projects that the frequency, severity, and co-occurrence of extreme weather events (EWEs) will rise non-linearly, intensifying systemic fragilities. These risks are particularly relevant for financial system resilience, which varies significantly across income levels. Low- and middle-income countries (LMICs) face greater exposure due to limited adaptive capacity, weaker infrastructure and institutions, a heavier reliance on climate-sensitive agriculture, and constrained fiscal space—all of which hinder effective adaptation (Noy, 2009; Fankhauser and McDermott, 2014; Schlenker and Lobell, 2010; Kahn, 2005; Dell et al., 2014; Rezai et al., 2025). As a result, financial disruptions triggered by EWEs tend to be deeper and longer-lasting in these contexts. For example, Thailand's 2011 floods reduced GDP by approximately 10% and drove equity indices down by 30% within 40 trading days (Suntheim and Vandenbussche, 2020). Similar patterns have been observed in other emerging economies (Botzen et al., 2019; Chakrabarti et al., 2023; Quante et al., 2024; Fuje, 2023), whereas advanced economies tend to experience more contained and short-lived effects (Altin, 2024; U-Din et al., 2022). Income level thus shapes both exposure and absorptive capacity,

[1] The UN Climate Centre (2020) reports an 83% increase in the number and severity of climate-related disasters between 1980-1999 and 2000-2019.

primarily through the quality of adaptive infrastructure. Empirical evidence confirms that adaptive capacity increases with income (Ferreira, 2024).

Although the environmental and macro-economic costs of EWEs are well documented, their systemic implications for finance merit closer scrutiny. Frequent disasters elevate non-performing loans and erode banks' liquidity and solvency (Klomp, 2014). Banks reduce lending in affected areas (Rajan and Ramcharan, 2023), face higher defaults, and exit markets where they lack local presence (Gallagher and Hartley, 2017). Mortgage lenders price in climate risk (Nguyen et al., 2022), and equity markets register negative abnormal returns after EWEs (Lanfear et al., 2019; Jiang et al., 2019). Regulators warn that climate-driven shifts in EWE patterns pose escalating threats to global financial stability (Mandel et al., 2021; Chabot and Bertrand, 2023).

Beyond climate shocks, financial systems also face a rising incidence of unexpected disasters from various sources. Armed conflicts, civil unrest, global epidemics, and geophysical disasters all pose significant risks (Mamonov et al., 2023). Events such as earthquakes, volcanic eruptions, and tsunamis can destroy infrastructure, disrupt markets, and trigger sudden fiscal pressures (Sawada and Shimizutani, 2008; Horvath, 2021). Among these threats, those associated with climate change introduce an intensifying layer of weather-related shocks whose increasing frequency and cumulative impacts may amplify financial instability—even when individual events appear short-lived.

EWEs therefore represent a critical source of physical risk. They damage capital, disrupt supply chains, and increase uncertainty about future losses-altering risk perceptions, curbing investment, and potentially triggering financial contagion (Batten et al., 2016). Approximately 70% of weather-related losses are uninsured (IAIS, 2018), eroding the balance sheets of households, firms, and governments, while insured losses strain insurers' and reinsurers' capital.

The transmission channels differ across the two pillars of finance. Financial institutions—particularly banks—are more exposed to localized credit, liquidity, and operational risks due to their reliance on physical infrastructure and close ties to small and medium-sized enterprises (SMEs) (OECD, 2024; NGFS, 2020). Insurers likewise face rising liabilities (P. Grippa and Suntheim, 2019), while financial shocks can propagate through credit, market, liquidity, and underwriting channels.[2](FSB, 2025); Financial markets, while generally more diversified and responsive via price signals, can amplify volatility and trigger capital flight—especially in fragile contexts (Lanfear et al.,

[2]Climate-related risks operate through financial stability channels: credit (when EWEs reduce borrowers' capacity to repay debts or impair banks' ability to recover non-performing loans), market (a decline in financial asset values, including the potential for sudden and severe price adjustments where climate risks are not yet priced in), liquidity (as banks' access to stable funding may diminish due to shifting market conditions), and operational (arising from heightened legal and regulatory compliance challenges for climate-sensitive businesses). Additionally, insurance sector stress may intensify-particularly in structurally vulnerable economies.

2019; Altin, 2024; Jiang et al., 2019). Disentangling these dimensions is essential, particularly in low- and middle-income countries (LMICs), where institutional depth and market liquidity are often limited.

A well-functioning and resilient financial system is crucial for post-disaster recovery. Advanced economies benefit from robust infrastructure, greater institutional capacity, and diversified structures, enabling quicker rebounds (Bangalore et al., 2015; Kahn, 2005; Fomby et al., 2011). Low-income countries, by contrast, endure more prolonged disruptions due to higher sectoral exposure, limited fiscal space, and weaker institutions (Loayza et al., 2012; Löscher and Kaltenbrunner, 2022; Torsten Ehlers and Shim, 2025). Many LMICs confront an adaptation deficit (Fankhauser and McDermott, 2014; Tol and Yohe, 2007; Barr et al., 2010), and climate disasters can reduce banks' capital-adequacy ratios (FISMA, 2024), underscoring the urgency of financial resilience.

Theoretical predictions on the effects of natural disasters on growth and financial development are mixed (Cavallo et al., 2013; Horvath, 2021; Ferreira, 2024). Neoclassical growth models suggest that disasters can temporarily boost growth by displacing economies from their steady states (recovery-to-trend hypothesis). Schumpeterian models propose that destruction may trigger reinvestment and technological upgrading (creative-destruction hypothesis). In contrast, AK-type models predict lasting negative effects due to capital loss and scale inefficiencies (no-recovery hypothesis) (Cavallo et al., 2013; Ferreira, 2024). Similarly, the impact on financial development is ambiguous. Disasters may deepen financial systems by expanding credit and stimulating reconstruction (Melecky and Raddatz, 2014). However, government spending, public loan programs, and foreign aid may crowd out private credit (Melecky and Raddatz, 2014). Financial institutions often tighten lending in response to heightened risk (Klomp and Valckx, 2014), and in financially underdeveloped economies, credit constraints further hinder investment in new capital (McDermott et al., 2013). Given these conflicting mechanisms, the net effect remains an empirical question.

This study investigates the impact of fifteen extreme weather events on financial systems, asking: (i) Do these events affect financial development differently depending on a country's income level? and (ii) Are financial institutions or markets more vulnerable? We combine EM-DAT disaster data with IMF financial-development indices (Sahay et al., 2015), which capture institutional and market dimensions and outperform single-metric proxies. Causal effects are estimated with the staggered difference-in-differences (DiD) framework of Callaway and Sant'Anna (2021). Extreme events are defined as the top decile by population affected (McDermott et al., 2013).Accordingly, the final set of affected countries under study constitutes a balanced sample across income levels and geographic regions. Among the extreme weather events considered, droughts account for 60%, floods for 20%, winter storms for 13%, and tropical cyclones for 7%.

We hypothesize that extreme weather events (EWEs) depress financial development more severely in low- and middle-income countries (LMICs), with the largest impacts transmitted through financial institutions. Our cross-country evidence, based on globally comparable indices and a robust identification strategy, advances the climate-finance literature beyond micro or single-country analyses and offers insights for adaptation policy and financial stability oversight.

Identification relies on the assumption of conditional parallel trends, supported by the quasi-random timing of EWEs and the use of income- and region-restricted control groups. We implement the staggered difference-in-differences estimator proposed by Callaway and Sant'Anna (2021), which accommodates variation in treatment timing, heterogeneous effects, and dynamic responses. Country and year fixed effects absorb unobserved heterogeneity, while macroeconomic controls—such as GDP growth, inflation, and trade openness—help mitigate confounding. We allow treatment effects to vary by income level, generating group-time average treatment effects ($ATT(g, t)$) that preserve heterogeneity while enabling aggregation into overall estimates.

The document is organized as follows. After the introduction, Section 2 describes the empirical strategy, including the data, identification approach, and model specification. Section 3 presents the baseline results, while Section 4 discusses the robustness checks. Section 5 offers a broader discussion of the findings, and the final section presents the conclusions.

4.2 Empirical Strategy

4.2.1 Data and Sample

To conduct the quantitative analysis, this study relies on the Emergency Events Database (EM-DAT), compiled by the Centre for Research on the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain. EM-DAT provides global coverage from 1900 to the present and includes standardized information on disaster-related fatalities, the number of individuals affected, and estimates of economic damages. An event is included in the database if it meets at least one of the following criteria: (i) ten or more people reported killed; (ii) one hundred or more people reported affected; (iii) a declaration of a state of emergency; or (iv) a formal request for international assistance.

Economic-loss figures in EM-DAT should be interpreted with caution because there is no single, standardised protocol for collecting post-disaster damage data (McDermott et al., 2013). The database draws on diverse sources—UN agencies, national and sub-national governments, NGOs, insurers, research institutes, and the press—and data gaps are common (EM-DAT, 2023). Missing values arise from technological limits on hazard monitoring, methodological difficulties in valuing damage, and uneven reporting practices across (and within) countries (Jones et al., 2023). Reported losses typically rely on preliminary, unadjusted figures from local authorities that may be incomplete or inflated in the immediate aftermath. Moreover, because monetary estimates lean heavily on insurance data, losses are usually understated in developing countries, where insurance penetration is lower (Horvath, 2021). The recorded magnitude of damages therefore tends to rise with GDP per capita—high-income countries both incur larger absolute losses and document them more thoroughly (Botzen et al., 2019).

Due to inconsistencies in how countries report monetary damages, this study relies on physical impact measures, which are more appropriate for international comparisons. Following Cavallo et al. (2013) and Horvath (2021), physical indicators—such as the number of people killed or affected—are generally more accurately recorded, particularly in low-income countries, and offer greater cross-country comparability than value-based metrics. LMICs, in particular, tend to have weaker infrastructure and limited adaptive capacity, which increases their vulnerability to extreme weather events and raises the likelihood of higher fatality rates. However, disaster-related fatalities are also shaped by a range of socio-economic factors—including institutional quality, public health systems, and emergency response capacity—that vary widely across countries (Kellenberg and Mobarak, 2008). As a result, datasets on natural disasters include relatively few fatal events, especially in high-income countries, which can introduce selection bias when fatalities are used as the primary measure of disaster severity.

To mitigate endogeneity concerns associated with using fatalities as a proxy for disaster severity—particularly due to their correlation with institutional capacity—this study relies on the share of the population affected, calculated relative to the previous year's population. Disasters can have significant social and economic impacts through evacuations, temporary displacement, disruption of essential services, food insecurity, and increased morbidity (EPA, 2024; Bell et al., 2018; McDermott et al., 2013). A high proportion of the population affected typically indicates that the event was either severe in intensity, widespread in scope, or both (McDermott et al., 2013).

The definition of extreme weather events lacks a universally accepted empirical threshold. Table 4.1 reviews some prevailing methodologies in the literature, which differ based on metrics such as death tolls, affected populations, or economic damages.

Table 4.1: **Definitions of EWEs in Selected Studies**

Study	**Some definitions of EWEs**	**Notes / Context**
Horvath (2021)	Events with $\geq$ 100 fatalities	Focus on effect of natural catastrophes on financial depth in EMDEs
McDermott et al. (2013)	Top 10% of events by population affected	Argues for physical measures over monetary loss in cross-country analyses
Klomp and Valckx (2014)	Events causing economic damage > 1% of GDP	Examines macroeconomic effects of natural disasters
Berlemann and Wenzel (2018)	EM-DAT criteria; matched by disaster type	Studies long-run effects on financial development
Fomby et al. (2011)	EM-DAT database events by disaster category	Looks at post-disaster dynamics in banking crises
P. Grippa and Suntheim (2019)	Conceptual framing (no strict threshold)	Climate-related financial stability risks and transmission channels
Amirkhani et al. (2022)	Country-year averages of weather fatalities	Global analysis of 77 countries (1999-2018)
Cavallo et al. (2023)	Events ranked by mortality; robustness check using physical intensity	Estimates growth losses post-disaster; finds stronger impacts for developing countries
EM-DAT (CRED)	$\geq$ 10 deaths, or $\geq$ 100 people affected, or state of emergency	Standard in disaster economics and development literature
Munich Re(*)	$\geq$ 1000 deaths or injured, or $\geq$ 100000 people affected, or damages $\geq$ USD 1 billion	Standard in disaster economics and development literature

(*) Münchener Rückversicherungs-Gesellschaft

Source: Author's own elaboration.

This study defines extreme weather events using the formula proposed by McDermott et al. (2013):

$$\text{Extreme Weather Event}_{it} = \frac{\sum_j Affected_{it,j}}{Population_{i,t-1}} > \text{90th percentile} \tag{4.1}$$

where the numerator represents the total number of people affected by all disaster events j in country i during year t, and the denominator is the population of country i in the previous year.

An event is classified as extreme if this ratio exceeds the 90th percentile of the global distribution. Following Cavallo et al. (2013), this percentile-based threshold is used to capture large-scale disasters from a global perspective, thereby enhancing cross-country comparability. We adopt this global benchmark rather than a country-specific rule—such as two standard deviations above a nation's historical mean—because the latter may label events as *extreme* within a local context, even when their severity is relatively modest by global standards.

The analysis spans 1991–2021 and covers countries with populations exceeding three million. From an initial pool of 6,171 events—each affecting more than 1,000 people—we excluded observations lacking consistent data on financial-development indicators or key macroeconomic covariates. The final treatment sample comprises fifteen extreme weather events in which the share of affected individuals exceeds 2.68 percent of the respective country's population, corresponding to the 90th-percentile cutoff of the global distribution. These events were retained because complete and reliable data are available. For the never-treated control group, all countries lie below the 25th percentile of the distribution—none has ever recorded an event in which even 1 percent of the population was affected. The resulting treated group includes two high-income countries (Europe and North America), five upper-middle-income countries (Europe, Latin America, and Asia), five lower-middle-income countries (Africa and Asia), and three low-income countries (Africa).[3]

As covariates in the baseline model, we include real GDP per capita growth, trade openness (measured as the trade-to-GDP ratio), and inflation—sourced from the World Development Indicators (WDI). These variables help control for key macroeconomic conditions that may independently influence financial development. GDP growth captures the overall economic environment at the national level; since EWEs are typically localized, their direct impact may not significantly alter aggregate growth. Including GDP growth therefore helps isolate the specific effects of climate shocks from broader economic trends. Trade openness reflects the degree of international integration, which may affect financial deepening through increased exposure to foreign capital and financial services. Inflation serves as a proxy for macroeconomic stability, as persistently high inflation can distort financial intermediation and erode trust in domestic financial markets.

Altogether, this set of macroeconomic fundamentals enables us to identify the distinct impact of EWEs on financial systems while maintaining a parsimonious and policy-relevant model. Unlike firm- or balance sheet–based approaches, our framework relies on publicly available aggregate data,

[3]Income levels are defined according to the World Bank's country classification system.

making it feasible for cross-country analysis and comparative research.

For robustness checks, we also incorporate the share of agriculture in GDP (WDI) to proxy for the structure of the economy, particularly its dependence on climate-sensitive sectors. In addition, we include a political characteristics variable from the Center for Systemic Peace to capture institutional quality and regime type, which may influence the credibility of financial institutions and the state's ability to respond to shocks. Together, these covariates help mitigate omitted variable bias and strengthen the identification of the causal effect of EWEs on financial development.

4.2.2 Identification Strategy: Staggered DiD and the Callaway–Sant'Anna Estimator

This study leverages the quasi-random timing of EWEs as exogenous shocks, creating a natural experiment setting conducive to causal inference. Given the variation in treatment timing across countries and years, a staggered Difference-in-Differences (DiD) approach is employed, following the framework developed by Callaway and Sant'Anna (2021). This estimator computes group-time average treatment effects ($\text{ATT}_{g,t}$), thereby accommodating treatment effect heterogeneity and allowing for the analysis of dynamic post-treatment responses. The Callaway–Sant'Anna estimator is particularly suited to this context, as it accounts for treatment effect heterogeneity and avoids biases found in traditional two-way fixed effects models under staggered treatment timing (Goodman-Bacon, 2021). This estimator produces group-time average treatment effects ($\text{ATT}_{g,t}$), capturing variation in treatment timing and enabling the analysis of dynamic responses over time. The outcomes of interes are measured annually, facilitating an assessment of both immediate and medium-term impacts.

Identification rests on three key assumptions: (i) the Stable Unit Treatment Value Assumption (SUTVA), which rules out interference between units; (ii) the no-anticipation assumption, ruling out behavioral changes in anticipation of treatment; and (iii) the parallel trends assumption, which posits that, in the absence of treatment conditional on a set of covariates, treated and control units would have followed similar outcome trajectories Baker et al. (2025). Pre-treatment dynamics are inspected through event-study specifications to assess the plausibility of this assumption.

To mitigate potential bias from time-varying confounders, the model includes relevant macroeconomic covariates and exploits the exogeneity of disaster timing. Furthermore, to strengthen the overlap in covariate distributions and improve comparability, the sample is stratified by income level and geographic proximity Baker et al. (2025).

The treatment group consists of countries that experienced at least one extreme weather event falling within the top 90th percentile of severity (in terms of population affected), while the control group includes countries never exposed to such events. By comparing changes in financial development indicators across treated and untreated countries before and after exposure, this strategy estimates the causal effect of EWEs on financial systems. The dynamic nature of the estimator allows exploration of temporal patterns in the effects, shedding light on both short-run disruptions and medium-term adaptation processes.

4.2.3 Model specification

We estimate the causal impact of EWEs on financial development using a staggered Difference-in-Differences approach. Given the quasi-random timing of EWE shocks, this method fits our context well. Following Callaway and Sant'Anna (2021), we estimate group-time average treatment effects ($\text{ATT}_{g,t}$), capturing both dynamic and timing-related heterogeneity.

The outcome equation is based on a difference-in-differences (DiD) framework, which compares changes in financial development indices between treated and control countries before and after exposure to extreme weather events (EWEs). This approach allows us to estimate the causal impact of EWEs on financial development. Our baseline specification follows:

$$y_{it} = \alpha_i + \delta_t + \sum_{g} \sum_{t \geq g} \mathbb{1}\{G_i = g\} \cdot \mathbb{1}\{t \geq g\} \cdot ATT(g,t) + X_{it}'\beta + \varepsilon_{it} \tag{4.2}$$

Where y_{it} denotes the financial development index for country i in year t. The IMF's Financial Development Indexes, developed by Sahay et al. (2015), offer a comprehensive measure of financial system development, covering both institutions (e.g., banks, insurers) and markets (e.g., equities, bonds). Ranging from 0 to 1, higher values indicate greater financial development. [4] Country fixed effects (α_i) control for time-invariant heterogeneity, while year fixed effects (δ_t) capture global shocks common to all countries. The term $ATT(g,t)$ captures the average treatment effect for the group of countries first exposed to an extreme weather event in year g, evaluated in year t. The indicators function $\mathbf{1}\{G_i = g\}$ and $\mathbf{1}\{t \geq g\}$ identify units treated in year g and their post-treatment periods. X_{it} is a vector of time-varying covariates (e.g., GDP growth, trade openess and inflation), and ε_{it} is the idiosyncratic error term.

[4] The Financial Development Index captures the multidimensional nature of financial systems by aggregating indicators of depth, access, and efficiency across both financial institutions (e.g., banks, insurers, pension funds) and financial markets (e.g., equity and bond markets). It is constructed using a three-step process: (i) winsorization (the transformation of statistics by limiting extreme values in the statistical data to reduce the effect of possibly spurious outliers) and normalization of variables using a min–max approach; (ii) aggregation into sub-indices for each dimension; and (iii) a weighted linear combination of sub-indices, with weights derived from principal component analysis to reflect each indicator's contribution to overall variation (Svirydzenka, 2016)

To isolate the treatment effect, we control for macroeconomic variables that are both theoretically grounded and empirically associated with financial development. These include real GDP per capita growth, trade openness, and inflation. These channels are essential, as extreme weather events are known to depress short-term economic growth (Cavallo et al., 2023; Kotz et al., 2022), [5] and might generate inflationary pressures (Mongelli et al., 2022; Ciccarelli et al., 2023; Kunawotor et al., 2021). Each of these outcomes can affect credit availability, banking stability, and overall financial system performance (Bordo and Rousseau, 2011; Rani and Kumar, 2018; Farhat, 2023).

We stratify the sample by income level and region to enhance comparability and address potential lack of covariate overlap between treated and control units. Standard errors are clustered at the country level to account for serial correlation within units.

Following Callaway and Sant'Anna (2021) and the broader discussion in Baker et al. (2025), we refrain from interpreting long-run ATT estimates as strictly causal. Over time, general equilibrium effects may emerge—such as international spillovers, cross-country policy diffusion, or sectoral shifts—which can violate the Stable Unit Treatment Value Assumption (SUTVA) and bias the estimated treatment effects.[6] These indirect pathways, while relevant, fall outside the scope of our immediate causal claims.

4.3 Results

Using the methodology developed by Callaway and Sant'Anna (2021), we examine the response of the financial development index to extreme weather events. The specification includes key macroeconomic controls -GDP per capita growth, the inflation rate, and a measure of trade openness- to account for time-varying confounders that may influence financial development outcomes.

Our empirical strategy assesses the impact of extreme weather shocks on three indexes, the aggregate financial development index, the financial institutions development index, and the financial markets development index. We begin by estimating the average treatment effects (ATT) for the full sample of fifteen countries affected by these disasters, and subsequently restrict the analysis by excluding high-income countries to explore heterogeneity across income groups.

[5]While their medium-to long-term effects are heterogeneous and less well understood (Horvath, 2021; Insaidoo et al., 2025; Kaushik et al., 2024), disrupt trade(Osberghaus, 2019; Mohan, 2023)

[6]General equilibrium effects refer to economy-wide repercussions that arise when an extreme weather event impacts multiple markets and sectors simultaneously. These include indirect consequences such as supply chain disruptions, labor displacement, sectoral shifts in demand, capital reallocation, and responses from governments or international aid. Over longer horizons, these dynamics can confound the estimation of treatment effects by introducing channels of influence not directly attributable to the initial shock (Baker et al., 2025; Sun and Abraham, 2021).

The analysis focuses on a two-year post-treatment window, where period zero denotes the year in which country i first experiences the shock and enters the treated group. We employ a staggered Difference-in-Differences framework with annual panel data to estimate dynamic treatment effects. To capture the most immediate and policy-relevant responses—while minimizing the risk of confounding from longer-run structural adjustments—we concentrate on short-run dynamics within this window. This strategy aligns with the identification approach proposed by Sant'Anna and Marcus (2020), which emphasizes the importance of temporally precise treatment windows in staggered adoption designs. (Appendix tables present estimates using a five-year post-treatment window for the baseline model and robustness checks.)

Across all specifications, we assess pre-treatment dynamics by plotting event-time coefficients up to two years before the first extreme weather event. The estimates for these pre-event periods are statistically indistinguishable from zero (as indicated by the blue bars in the figures), providing support for the parallel trends assumption and suggesting no evidence of anticipatory behavior.

We then examine the trajectory of financial development from two years before to two years after the onset of the shock. In the year of the event (period 0), we observe a negative, though statistically insignificant, impact on the Financial Development Index. The estimated effects remain negative in the following two years, but none reach conventional levels of statistical significance—highlighting that, while the direction of impact is consistent, the short-run effects may be modest or heterogeneous across countries.

Table 4.2 and Figure 4.1, present results from the staggered difference-in-differences specification. Each column reports the Callaway and Sant'Anna ATT estimates and their corresponding standard errors for the global financial development index, the financial institutions index, and the financial markets index. Across all specifications, we observe small negative effects. However, none of the point estimates are statistically significant at the 10% level, suggesting that EWEs may exert limited short-term influence on financial development when averaged across the full sample.

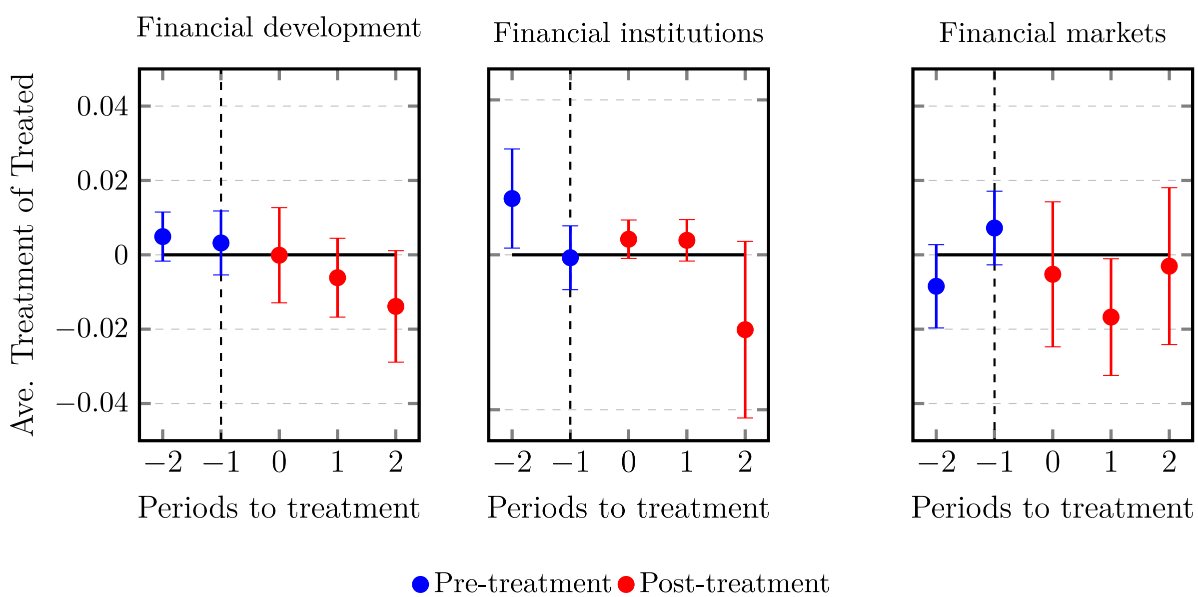
Table 4.2: **All Treated Countries**

	Financial Develop.	**Financial Instit.**	**Financial Mrkt**
Post * Treated	-0.007	-0.005	-0.008
	(0.012)	(0.007)	(0.018)
Mean Dep. Var.	0.298	0.350	0.235
SD Dep. Var.	0.242	0.224	0.270
Observations	702	702	702

$^{(*)}$ $p < 0.10$

Note: This table reports average treatment effects on the treated (ATT) for all countries affected by extreme weather events. The dependent variables are the IMF's Financial Development Index (column 1), Financial Institutions Index (column 2), and Financial Markets Index (column 3), each scaled between 0 and 1. 'Post * Treated' is an interaction term indicating post-treatment years for treated units. All models include country and year fixed effects and control for GDP per capita growth, trade openness, and inflation. Standard errors are reported in parentheses.

Figure 4.1: **Dynamic effects of EWEs on financial outcomes.**



Note: Each panel shows dynamic average treatment effect on the treated (ATT) estimates for overall financial development (left), financial institutions (center), and financial markets (right). The horizontal axis reports periods relative to treatment ($t = 0$). Blue dots represent pre-treatment periods; red dots indicate post-treatment periods. Vertical bars show 95% confidence intervals. The vertical dashed line marks the last period without treatment. Estimates are based on the staggered difference-in-differences method developed by (Callaway and Sant'Anna, 2021).

As illustrated in Figure 4.1, the analysis of fifteen extreme weather events reveals a negative impact on financial development, financial institutions, and financial markets. Although the estimated effects are predominantly negative in the post-treatment periods, none reach conventional levels of statistical significance. Notably, the adverse impact appears to intensify over time, suggesting a delayed transmission of shocks to the financial sector.

While the treatment effects are not statistically significant, their economic magnitude is nontrivial. For instance, an estimated average treatment effect on the treated (ATT) of -0.007 corresponds to a 2.3% decline relative to the sample mean of the financial development index, highlighting the potential for EWEs to disrupt financial performance, in the short term. These temporal lags likely reflect the time required for physical and economic damages to materialize into measurable disruptions in credit markets, institutional balance sheets, and investment behavior.

Economic activity is a key structural determinant of financial development. As national income rises, financial systems expand, credit institutions proliferate, financial instruments diversify, and markets deepen and modernize. Consequently, high-income countries exhibit significantly higher levels of financial development (Beck T and Levine, 2009). In our dataset, their Financial Development Index values are more than twice those of upper-middle-income countries, the next highest group. This disparity suggests that financial resilience to EWEs likely varies with income. According to the World Bank's classification, high-income countries—defined by gross national income per capita above a specified threshold—are generally better equipped to absorb and recover from disaster-related shocks due to better infrastructure, stronger institutions, and greater fiscal capacity. To explore this heterogeneity, we re-estimate the results excluding high-income countries from the sample. This adjustment yields a more homogeneous group of low- and middle-income countries (LMICs), allowing for a clearer identification of EWEs effects on more vulnerable financial systems.

Estimates using the Callaway and Sant'Anna method confirm that the assumptions of parallel trends and absence of anticipation effects hold in this context. In the year of the event, a slight negative impact on the financial development index is observed. This effect becomes statistically significant in the following year and intensifies two years after the shock.

Table 4.4 and Figure 4.2 present the estimated coefficients and standard errors from the Callaway and Sant'Anna approach for the Financial Development Index, the Financial Institutions Index, and the Financial Markets Index. In this subsample—excluding high-income countries—the Financial Development Index declines by an average of 7.3%, while the Financial Institutions Index falls by 7.1%, [7] underscoring the considerable vulnerability of financial systems in lower- and middle-income contexts to EWEs. The results point to a statistically significant negative effect, particularly

[7] Each percentage is estimated by dividing the $Post \times Treated$ coefficient by the mean of the dependent variable

Table 4.3: **Financial Development by Income Group and Treatment Status**

Income Group	**Full Sample**			**Treated**			**Not-treated**		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
High income	0.695	0.211	124	0.622	0.255	62	0.768	0.119	62
Upper-middle	0.307	0.152	307	0.264	0.186	152	0.348	0.093	155
Lower-middle	0.188	0.114	307	0.169	0.140	153	0.206	0.077	154
Low	0.088	0.030	186	0.100	0.020	93	0.075	0.033	93
Total	0.275	0.228	924	0.248	0.228	460	0.302	0.224	464

Author's own calculations.

Note: This table reports summary statistics for the Financial Development Index by income group and treatment status. The index ranges from 0 to 1 and is sourced from the IMF's Financial Development database. "Treated" refers to country-years affected by extreme weather events; "Not-treated" includes unaffected country-years. Mean, standard deviation (SD), and number of observations (N) are reported for each subgroup.

Table 4.4: **Low- and Middle-Income Countries (LMICs)**

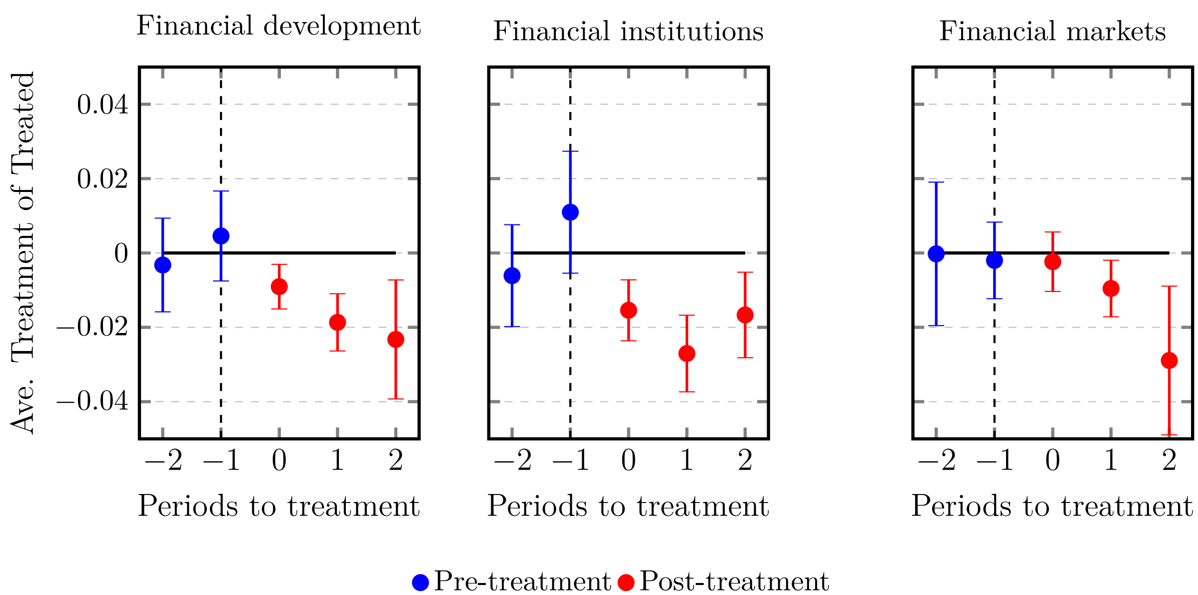
	Financial Dev.	**Financial Instit.**	**Financial Mrkt.**
Post × Treated	-0.017*	-0.020**	-0.014
	(0.009)	(0.008)	(0.011)
Mean Dep. Var.	0.234	0.280	0.179
SD Dep. Var.	0.154	0.137	0.192
Observations	550	550	550

** $p < 0.05$, * $p < 0.10$

*Note:*This table reports average treatment effects on the treated (ATT) for low- and middle-income countries only. The dependent variables are the IMF Financial Development Index, Financial Institutions Index, and Financial Markets Index, each scaled between 0 and 1. The interaction term 'Post × Treated' indicates post-event years for countries affected by extreme weather events. All models include country and year fixed effects and control for GDP per capita growth, trade openness, and inflation. Standard errors are in parentheses.

concentrated in financial institutions, which appear more exposed to the disruptions triggered by climate shocks.

Figure 4.2: **Dynamic Effects of EWEs on Financial Outcomes in LMICs.**



Note: This figure displays dynamic treatment effects of extreme weather events (EWEs) on financial development, financial institutions, and financial markets in low- and middle-income countries (LMICs). Estimates correspond to group-time average treatment effects (ATTs) computed using the staggered difference-in-differences estimator of Callaway and Sant'Anna (2021). Markers indicate estimated coefficients, with blue (red) denoting pre-treatment (post-treatment) periods. Vertical bars represent robust standard errors clustered at the country level. The vertical dashed line marks the last period without treatment. Results suggest a gradual decline in financial development and financial institutions post-EWE, while financial market effects appear more volatile.

The findings highlight significant heterogeneity in the financial consequences of EWEs across countries at different income levels. While high-income countries exhibit greater resilience, the effects in low- and middle-income economies are notably more severe and persistent. This divergence likely stems from structural disparities in infrastructure, institutional capacity, and the depth and efficiency of financial systems across income groups.

In LMICs the lack of resilient infrastructure, combined with underdeveloped financial systems [8], hampers swift recovery and amplifies the adverse impacts of climate shocks. The empirical analysis confirms this pattern, when the full sample—including high-income countries—is considered, the

[8] When the combined size of banks, other financial institutions, and financial markets in a country is relatively small compared to its economic output, and the financial system offers a narrow range of services characterized by low financial inclusion, difficult access, and high costs for users, it is considered underdeveloped Demirgüç-Kunt and Levine (2001).

average treatment effects are small and statistically insignificant. However, upon restricting the sample to LMIC economies, the estimated coefficients grow in absolute magnitude and become statistically significant, particularly for the financial institutions index.

This asymmetry is consistent with differences in adaptive capacity and macro-financial buffers. High-income countries typically possess deeper, more diversified financial systems supported by strong regulatory frameworks and countercyclical policy tools. In contrast, many developing economies are characterized by high informality, limited insurance coverage, concentrated banking sectors, and weaker fiscal space. As a result, EWEs in these contexts are more likely to disrupt credit provision, erode asset quality, and impair intermediation, amplifying their macro-financial consequences.

4.4 Robustness checks

Robustness checks are essential diagnostic tools for evaluating the reliability of estimated relationships. Their primary objective is to assess the sensitivity of empirical findings to plausible changes in model specifications and sample composition (Angrist and Pischke, 2009; Cameron, 2005). By systematically varying these elements, robustness analyses help address concerns related to endogeneity, omitted variable bias, functional form misspecification, and sample heterogeneity.

First, we extend the baseline specification by incorporating additional control variables. We account for the economic structure by including the share of value added by agriculture, and we capture political institutions using the Polity index as a proxy for regime characteristics. These variables aim to reflect institutional and sectoral vulnerabilities that may influence a country's exposure and response to climate-related shocks. Finally, we restrict the sample to countries that experienced the most severe extreme weather events—those in the 95th percentile of the affectedness distribution—to examine whether treatment effects vary with event intensity. Together, these robustness checks deepen our understanding of the underlying mechanisms and bolster the credibility and generalizability of our findings.

4.4.1 Controlling for economy's structure

The effects of EWEs are likely to be more pronounced in countries where agriculture accounts for a larger share of economic activity. Acute climate shocks—such as floods, droughts, and extreme heat—disproportionately affect agricultural production, leading to reduced output and heightened economic vulnerability. Globally, droughts and extreme heat have been shown to reduce cereal production by 9–10% between 1964 and 2007, driven by both diminished harvested areas and lower yields, particularly during drought episodes [9] (Lesk et al., 2016). To explore this potential source of heterogeneity, we replicate the baseline estimation strategy by first analyzing the full sample of affected countries, and then re-estimating the model after excluding the two high-income countries. This two-step approach allows us to assess whether the estimated treatment effects differ systematically across income levels, potentially reflecting structural differences in agricultural dependence and adaptive capacity.

Table 4.5: **Adding Agriculture (as % of GDP) as Covariate**

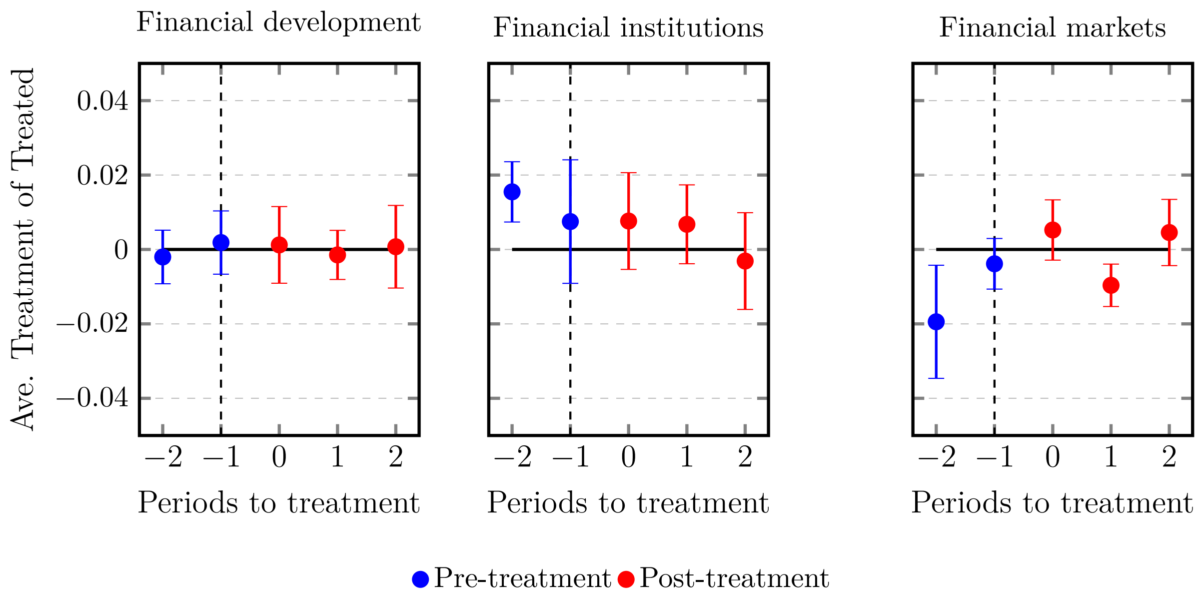
	Financial Dev.	**Financial Inst.**	**Financial Mrkt.**
Post $\times$ Treated	0.000	0.004	-0.003
	(0.009)	(0.014)	(0.007)
Mean Dep. Var.	0.305	0.352	0.247
SD Dep. Var.	0.242	0.221	0.273
Observations	659	659	659

** $p < 0.05$, * $p < 0.10$

Note: This table presents ATT estimates from models that include agricultural value added (as a percentage of GDP) as an additional covariate. The dependent variables are the IMF's Financial Development Index, Financial Institutions Index, and Financial Markets Index. The interaction term 'Post $\times$ Treated' captures the post-event effect of extreme weather events on treated countries. All models also control for GDP per capita growth, trade openness, and inflation, and include country and year fixed effects. Standard errors are reported in parentheses.

[9] In our dataset, 60% of the extreme weather events recorded were droughts.

Figure 4.3: **Dynamic effects of EWEs on financial outcomes with agriculture**



Note: This figure presents dynamic treatment effects of extreme weather events (EWEs) on financial development, financial institutions, and financial markets, controlling for the agricultural share in GDP. Estimates are based on the staggered difference-in-differences estimator by Callaway and Sant'Anna (2021), using group-time average treatment effects (ATTs). The inclusion of agriculture accounts for sectoral exposure to climate risks. Blue (red) markers denote pre-treatment (post-treatment) periods, with vertical bars showing robust standard errors clustered at the country level. The vertical dashed line marks the last period without treatment. Results suggest muted post-event effects once agricultural dependence is controlled for.

The results from the full sample do not reveal a statistically significant relationship between EWEs and overall financial system development. For financial institutions specifically, the estimates indicate a positive but non-significant effect. In certain contexts, post-disaster reconstruction efforts and targeted aid flows may contribute to credit expansion, enhance financial inclusion, or catalyze institutional innovation—particularly when government or donor responses are well-coordinated and timely. However, on balance, the evidence points to no consistent or robust impact of extreme weather events on financial development at the aggregate level.

However, when the analysis is restricted to LMICs, a more pronounced and statistically significant negative impact emerges across financial development indicators. Notably, the Financial Institutions Index shows a sustained decline lasting up to two years after the shock, indicating heightened vulnerability in these economies' financial infrastructure. Although there are initial signs of recovery beyond this period, the effect remains persistent in the short run. In contrast, the Financial Markets Index does not exhibit statistically significant changes, suggesting a relative degree of resilience or insulation from climate-related shocks in capital markets, compared to banking and institutional finance.

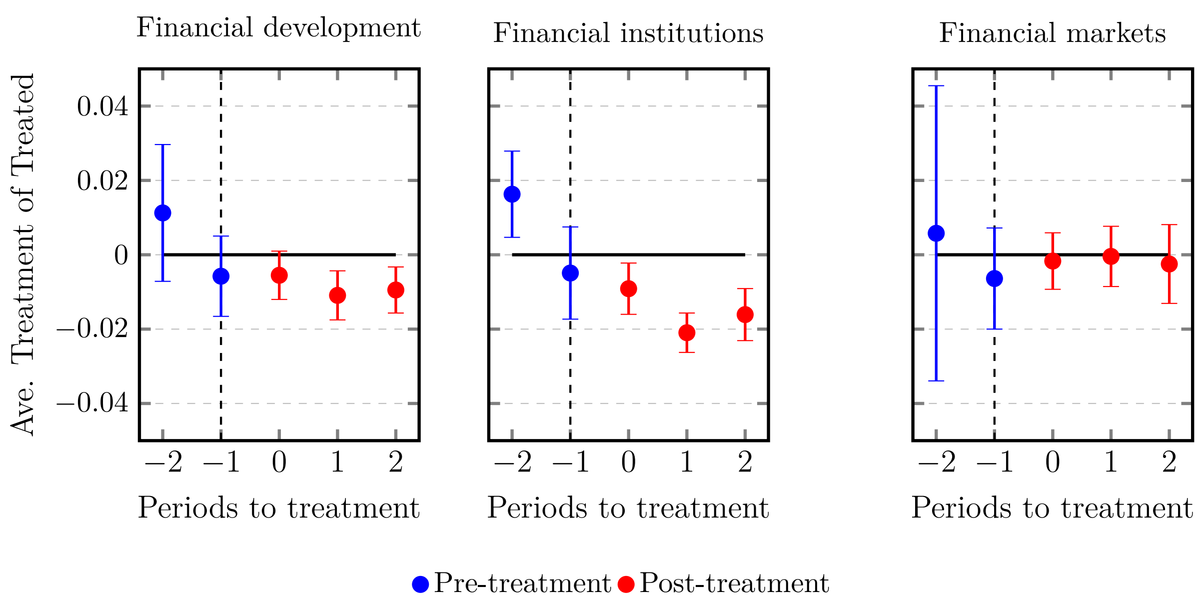
Table 4.6: **Adding Agriculture (as % of GDP) as Covariate in LMIc**

	Financial Development	Financial Institutions	Financial Markets
Post × Treated	-0.009	-0.015**	-0.002
	(0.006)	(0.006)	(0.008)
Mean Dep. Var.	0.240	0.284	0.187
SD Dep. Var.	0.155	0.139	0.194
Observations	517	517	517

** $p < 0.05$, * $p < 0.10$

Note: This table presents ATT estimates for low- and middle-income countries, including agricultural value added (as a percentage of GDP) as an additional control variable. The dependent variables are the IMF's Financial Development Index, Financial Institutions Index, and Financial Markets Index, all scaled from 0 to 1. The interaction term 'Post × Treated' captures the post-event effect of extreme weather events. All models control for GDP per capita growth, trade openness, and inflation, and include country and year fixed effects. Standard errors are reported in parentheses.

Figure 4.4: **Dynamic effects of EWEs with agriculture as covariate in LMICs**



Note: This figure illustrates the dynamic effects of extreme weather events (EWEs) on financial development, financial institutions, and financial markets in low- and middle-income countries, controlling for the agricultural share of GDP. Estimates are derived from the staggered difference-in-differences method by Callaway and Sant'Anna (2021), reporting group-time average treatment effects (ATTs). Including agriculture accounts for sectoral climate sensitivity, particularly relevant in LMICs. Dots represent coefficient estimates with 95% confidence intervals based on country-clustered standard errors. The vertical dashed line marks the last period without treatment. Results suggest that, even after accounting for agricultural exposure, EWEs exhibit significant and persistent negative effects, particularly on financial institutions.

Our results indicate that in Low- and Medium-income countries with larger agricultural sectors, EWEs have a significant and adverse impact on the financial system—particularly on financial institutions, which experience the strongest negative effects in the year following the event. In contrast, financial markets appear to be largely unaffected by such climatic shocks. These findings suggest that the physical damages caused by EWEs may destroy capital and impair the capacity to provide financial services in affected areas, with effects that are both significant and persistent in the years that follow. This evidence aligns with previous research showing that natural disasters weaken financial institutions in developing economies through asset destruction, increased credit risk, and disruptions in service delivery (Klomp, 2014; Hosono et al., 2016).

4.4.2 Democratic Institutions as a Proxy for Institutional Resilience

The impact of EWEs on financial system development may depend on the institutional quality of the affected country. Democratic institutions—characterized by stronger accountability, greater transparency, and more inclusive policy frameworks—are generally better equipped to mobilize resources and coordinate effective disaster responses (Robinson and Acemoglu, 2012; Persson and Tabellini, 2009; Marshall and Gurr, 2021; Finnegan, 2022). To explore this potential source of heterogeneity, the baseline specification is extended by incorporating a binary variable indicating whether a country operates under a democratic regime. This indicator is based on the Polity index, which ranges from -10 (hereditary autocracy) to +10 (full democracy). Countries with a Polity score above zero are classified as democracies (democracy = 1), while those with scores below zero are categorized as autocracies (democracy = 0).

We replicate the baseline estimation strategy in two steps. First, we estimate the model using the full sample of affected countries to capture general patterns. Second, we re-estimate the model excluding the two high-income countries to focus on low- and middle-income contexts, where institutional constraints and climate vulnerability are typically more pronounced. This two-tiered approach enables a more nuanced understanding of the moderating role of institutional quality in shaping financial resilience to EWEs.

Table 4.7 and Figure 4.5 report the results for all treated countries, while Table 4.8 and Figure 4.6 focus on the subset of LMICs. In both cases, the models control for the democracy dummy.

For all treated countries, the estimates—though statistically insignificant—reveal a negative impact of extreme weather events on overall financial development and financial markets. Interestingly, financial institutions display a positive response, potentially reflecting more effective post-disaster policies and support mechanisms under democratic regimes. These findings suggest that democratic institutions may help buffer financial systems against the adverse effects of climate shocks.

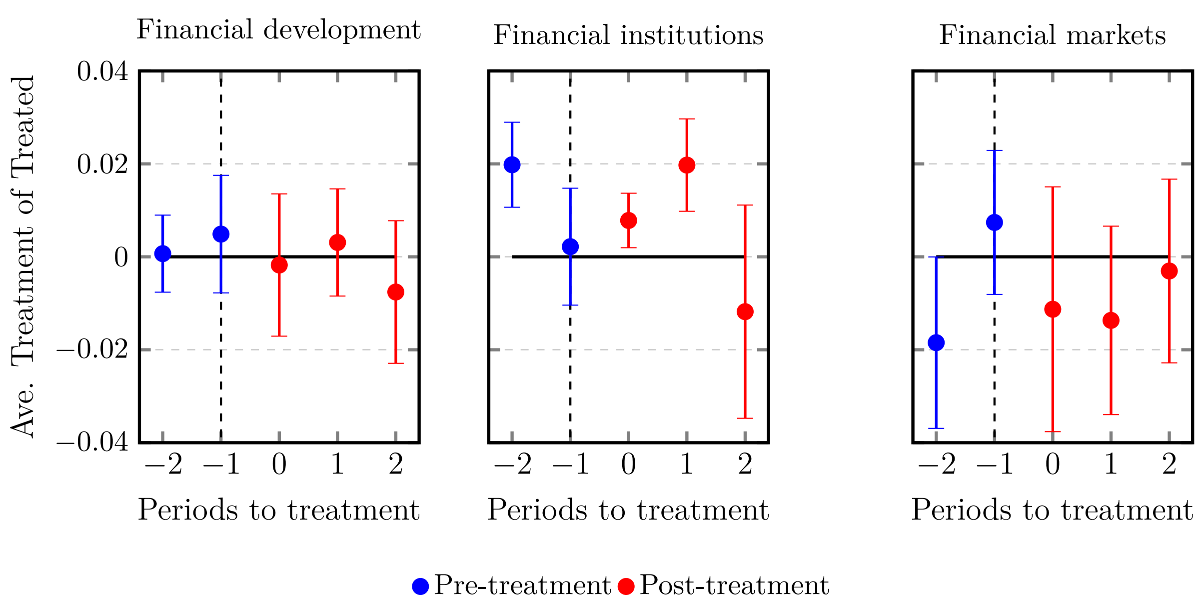
Table 4.7: **All Countries: Democracy Dummy (Polity)**

	Financial Development	Financial Institutions	Financial Markets
Post × Treated	-0.002	0.005	-0.009
	(0.013)	(0.011)	(0.022)
Mean Dependent Variable	0.296	0.344	0.236
Standard Deviation	0.242	0.224	0.270
Observations	613	613	613

** $p < 0.05$, * $p < 0.10$

Note: This table reports average treatment effects on the treated (ATT) for all treated countries including a democracy dummy. The dependent variables are the IMF Financial Development Index, Financial Institutions Index, and Financial Markets Index, each scaled between 0 and 1. The interaction term 'Post × Treated' indicates post-event years for countries affected by extreme weather events. All models include country and year fixed effects and control for GDP per capita growth, trade openness, inflation and a democracy dummy based.

Figure 4.5: **Dynamic effects of EWEs with Democracy as covariate**



Note: This figure presents the dynamic effects of EWEs on financial outcomes, controlling for democracy. The panels display the average treatment effects on the treated (ATT) across three dimensions: overall financial development, financial institutions, and financial markets. Estimates are derived from an event-study specification that includes GDP growth, trade, inflation, and a democracy dummy as covariates. Blue dots represent pre-treatment periods, red dots represent post-treatment periods. Vertical bars denote 95% confidence intervals, the dashed vertical line marks the last period without treatment, and the solid horizontal line indicates the zero-effect benchmark.

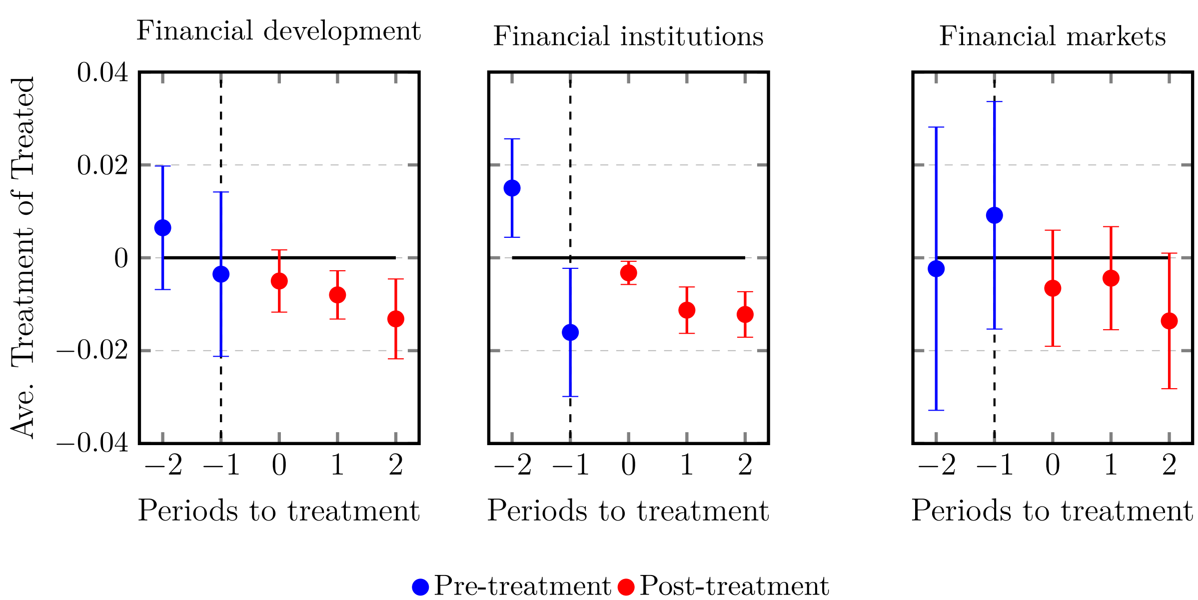
Table 4.8: **LMICs: Democracy Dummy (Polity)**

	Financial Development	**Financial Institutions**	**Financial Markets**
Post × Treated	-0.009	-0.009***	-0.008
	(0.006)	(0.002)	(0.012)
Mean Dependent Variable	0.226	0.272	0.171
Standard Deviation	0.148	0.134	0.185
Observations	424	424	424

** $p < 0.05$, * $p < 0.10$

Note: The table reports ave. treatment effects on the treated (ATT) for LMICs only. The dependent variables are the IMF Financial Development Index, Financial Institutions Index, and Financial Markets Index, each scaled between 0 and 1. The interaction term 'Post × Treated' indicates post-event years for countries affected by extreme weather events. All models include country and year fixed effects and control for GDP per capita growth, trade openness, inflation and a democracy dummy.

Figure 4.6: **Dynamic effects of EWEs with Democracy as covariate in LMICs**



Note: This figure shows the dynamic effects of EWEs on financial outcomes in LMICs, controlling for democracy. Each panel represents the ATT over time for financial development, institutions, and markets, respectively. Estimates are derived from an event-study specification that includes GDP growth, trade, inflation, and a democracy dummy as covariates. Blue dots represent pre-treatment periods, red dots represent post-treatment periods. Vertical bars denote 95% confidence intervals, the dashed vertical line marks the last period without treatment, and the solid horizontal line indicates the zero-effect benchmark.

The estimates indicate that democracy, even in low and middle income-countries, reduces the negative impact of extreme weather events on financial institutions by more than half relative to the baseline model (from -7.1% to -3.3%). In contrast, no statistically significant effects are observed on overall financial development or financial markets. These findings suggest that democratic institutions may contribute to greater stability and resilience within the financial sector in the face of climate-related shocks.

4.4.3 Focusing on most severe events: 95th percentile threshold

As an additional robustness check, we restrict the analysis to extreme weather events falling within the 95th percentile of the disaster severity distribution. This subsample captures the twelve most severe events in the dataset, including cases from two high-income, seven middle-income, and three low-income countries. By focusing on the most intense episodes, this approach allows us to assess whether the financial system responses observed in the baseline are driven primarily by the most disruptive shocks, thereby enhancing the robustness of the estimated treatment effects.

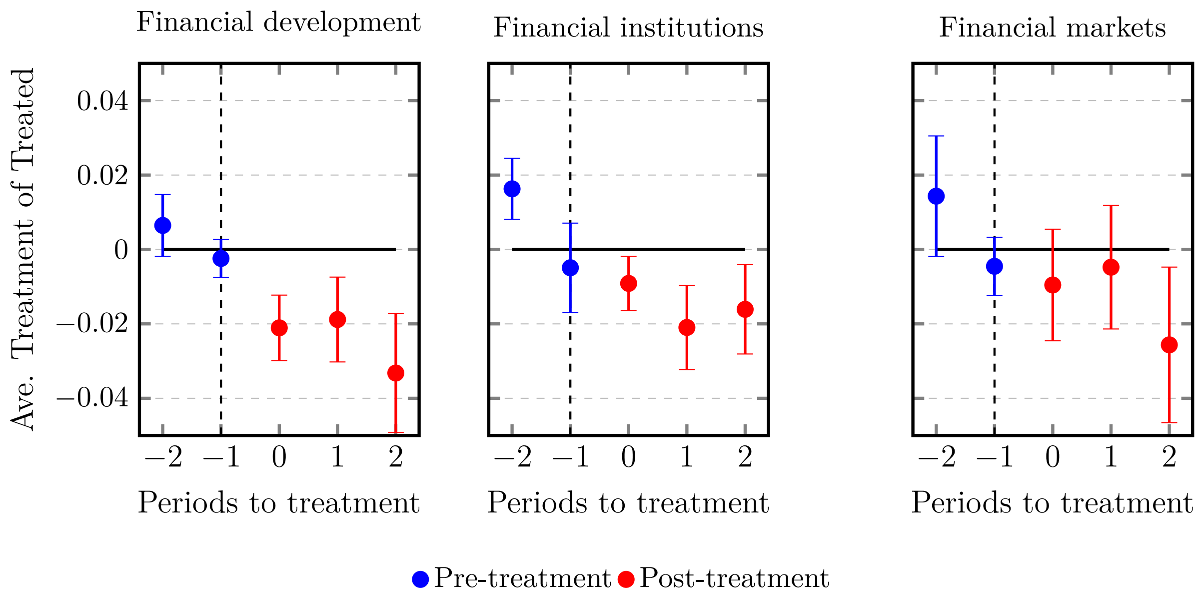
Table 4.9: **Treated countries in the top 95th percentile**

	Financial Development	**Financial Institutions**	**Financial Markets**
Post × Treated	-0.024**	-0.013	-0.034**
	(0.006)	(0.009)	(0.016)
Mean Dep. Var.	0.316	0.365	0.254
SD Dep. Var.	0.256	0.234	0.288
Observations	549	549	549

** $p < 0.05$, * $p < 0.10$

Note: This table presents ATT estimates for treated countries for countries in the top 95th percentile. The dependent variables are the IMF's Financial Development Index, Financial Institutions Index, and Financial Markets Index, each scaled from 0 to 1. 'Post × Treated' indicates post-event years for treated units. All models control for GDP per capita growth, trade openness and inflation, and include country and year fixed effects. Standard errors are reported in parentheses.

Figure 4.7: **Dynamic effects of EWEs on financial outcomes in the 95th percentile**



Note: This figure presents the dynamic effects of EWEs on financial outcomes, focusing on the most severe events—those in the 95th percentile of the affectedness distribution. The panels display the average treatment effects on the treated (ATT) across three dimensions: overall financial development, financial institutions, and financial markets. Estimates are derived from an event-study specification, with blue dots representing pre-treatment periods and red dots representing post-treatment periods. Vertical bars denote 95% confidence intervals, the dashed vertical line marks the las period without treatment, and the solid horizontal line indicates the zero-effect benchmark. The results suggest that the financial sector experiences more pronounced negative effects when exposed to high-intensity EWEs.

Table 4.9 and and Figure 4.7 presents average treatment effects on the treated (ATT) for countries exposed to extreme weather events in the top 95th percentile of severity. The results indicate that high-intensity climate shocks are associated with a statistically significant decline of 0.024 points in the overall Financial Development Index and 0.034 points in the Financial Markets sub-index. These effects correspond to reductions of approximately 7.6% and 13.4% relative to their respective sample means. In contrast, the coefficient for Financial Institutions is negative but not statistically significant. However, the analysis shows that adverse impacts on financial institutions emerge with a one-year delay, becoming significant in the period following the event. This pattern suggests a lagged institutional response to severe climate shocks.

This exercise, unlike previous ones, highlights the heightened vulnerability of financial markets to high-severity weather shocks. The results suggest that as EWEs become more intense, they can exert destabilizing effects on financial markets. The litearture has shed light on some channels, such as, declining investor confidence, tightening liquidity conditions, and increased capital outflows in the aftermath of such events (Klomp and Valckx, 2014; Battiston et al., 2017). These dynamics reflect the higher sensitivity of market-based finance to uncertainty and severe climate shocks. This result aligns with prior research showing that financial markets are particularly susceptible to climate-related shocks due to their sensitivity to investor sentiment, liquidity conditions, and capital flow dynamics .

In this specification, high-income countries are retained to ensure proper representation of the upper tail of the severity distribution. Their inclusion helps preserve sufficient variation and temporal coverage, as these countries often constitute early and well-documented cases of severe events. Excluding them significantly reduces the number of treated observations with valid pre-treatment data, thereby limiting the estimation of dynamic effects and weakening identification in event-study analyses.

4.5 Discussion

Given conflicting theoretical predictions, the question of whether and how extreme weather events (EWEs) affect financial development remains an empirical one (Cavallo et al., 2013; E. Cavallo and Acevedo, 2022). Overall, our results consistently indicate that EWEs hinder the development of financial systems, with particularly pronounced effects in low- and middle-income countries (LMICs). However, as event severity increases, the negative impact extends to high-income countries as well. Across our baseline specifications and robustness checks, estimated declines in financial institutions indexes are consistently negative and statistically significant. Notably, the largest reduction is observed in the Financial Markets Index in response to the most severe events.

In the baseline specification, exposure to extreme weather events (EWEs) is associated with declines across all financial development indices, although these effects are not statistically significant. However, when we account for income heterogeneity by excluding high-income countries, we observe statistically significant negative effects on financial development—particularly through the financial institutions channel. In low- and middle-income countries (LMICs), the estimated average reduction in the Financial Development Index is approximately 7.3%, while financial institutions decline by 7.1% and financial markets by 7.8%. Although the effect on markets is not statistically significant, the overall pattern suggests that, even after controlling only for macroeconomic fundamentals, EWEs exert a substantial adverse impact on financial systems in more vulnerable economies. The heightened sensitivity of financial institutions may reflect limited physical resilience, weaker regulatory capacity, or lower adaptive infrastructure in LMICs.

When controlling for the share of agriculture in GDP, the estimated effect of EWEs on financial development weakens, particularly for the aggregate Financial Development Index. In economies where agriculture constitutes a significant share of output and employment, weather-related dis-

Table 4.10: **Summary of Results**

	Baseline	**Agriculture**	**Polity**	**95th Percentile**
All Treated				
Financial Development	-2.3%	0.0%	-0.7%	-7.6%**
Institutions	-1.4%	1.1%	1.4%	-3.6%
Markets	-3.4%	-1.2%	-3.8%	-13.4%**
LMICs				
Financial Development	-7.3%*	-3.8%	-4.0%	–
Institutions	-7.1%**	-5.3%**	-3.3%***	–
Markets	-7.8%	-1.1%	-4.7%	–

*** $p < 0.1$,** $p < 0.05$, * $p < 0.10$

Note: Each percentage is estimated by dividing the Post×Treated coefficient by the mean of the dependent variable.

Author's own elaboration.

ruptions may have a more direct impact on credit flows and the performance of banking systems. Interestingly, in this specification, financial institutions exhibit a small positive coefficient, although it is not statistically significant—potentially reflecting compensatory fiscal or credit policies in agrarian economies. However, when accounting for income disparities, we find that EWEs reduce all financial development indicators in LMICs. Financial institutions in these countries experience a 5.3% decline, underscoring the compounding effects of structural economic exposure and limited adaptive capacity. These results highlight the importance of sectoral composition—particularly the prominence of agriculture— as a key channel through which climate shocks generate financial system stress.

We expected that more democratic institutions would be better positioned to mobilize effective policy responses and accelerate post-disaster financial recovery. The inclusion of the democracy dummy supports this hypothesis, as it attenuates the estimates from the baseline model and reinforces earlier findings. Democracies appear more capable of coping with the adverse effects of EWEs, as they typically offer a more robust and responsive framework for managing such shocks. By fostering citizen participation, accountability, and access to information, democratic regimes are more likely to deploy resources efficiently and coordinate timely disaster responses, thereby addressing the needs of their populations and strengthening societal resilience.

When the analysis is restricted to countries affected by the most severe events—those in the 95th percentile of the disaster severity distribution—the estimated impacts become substantially larger. The Financial Development Index declines by 7.6% and the Financial Markets Index by 13.4%, with both effects statistically significant. These magnitudes point to systemic stress following high-intensity shocks, likely driven by disruptions in investor confidence, capital outflows, and tightening liquidity conditions. Interestingly, while financial institutions also exhibit a negative effect, the most pronounced vulnerability emerges in market-based financial structures, underscoring the amplifying role of disaster severity in shaping climate–finance dynamics.[10]

4.6 Conclusion

The increasing frequency of EWEs underscores the need to understand their broader economic impacts—particularly on financial systems. This study explores how such events influence financial development by examining fifteen major episodes, each in the top decile of climate-related disasters by population affected. Employing the staggered Differences-in-Differences estimator by Callaway and Sant'Anna (2021), we estimate dynamic treatment effects while addressing identification assumptions. The quasi-random timing of shocks, alongside the confirmation of parallel trends and non-anticipation in our baseline, supports the credibility of our approach.

Our findings reinforce growing evidence that EWEs negatively affect financial development. However, these impacts are heterogeneous. They are particularly pronounced in LMICs, especially those with large agricultural sectors. As the severity of events increases, negative effects extend to high-income countries—most notably in financial markets. These patterns likely reflect structural vulnerabilities such as weak institutional capacity, limited financial buffers, fragile infrastructure, and client migration from affected areas—all of which erode the stability of financial systems.

A positive takeaway from our findings is that democratic institutions appear to mitigate the negative impacts of extreme weather events. Democratic accountability, when aligned with climate goals, can foster more effective organizational structures and responses to such shocks. Our results suggest that democratic regimes significantly reduce the decline in financial system performance—particularly in the development of financial institutions, where the negative effect is reduced by more than half. This contrast implies that autocratic regimes, which may lack the same level of coordination and responsiveness, are more vulnerable to the financial consequences of climate-related disasters.

As global temperatures rise—and with them the frequency and intensity of climate events (IPCC, 2023a)—both financial institutions and markets are increasingly exposed to systemic risks. These

[10]In this specification, high-income countries were not excluded from the sample, as doing so would substantially reduce the number of treated observations with valid pre-treatment data. Their inclusion ensures proper representation of the upper tail of both the income and disaster severity distributions.

include the destruction of capital, declines in labor productivity and diminished investor confidence. The transmission of these shocks through the financial system highlights the urgency of building resilience before the next wave of climate-related disruptions.

Our findings highlight the need for policies that strengthen financial systems' ability to withstand climate shocks. Beyond investing in resilient infrastructure and clean energy, governments should avoid repressive financial policies and instead promote financial inclusion, digital infrastructure, and climate insurance to support financial development.

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5. A.1: Oil Abundance, National Oil Companies and Financial Repression

Table 5.1: National Oil Companies

Code	Country	NOC	Ave. oil rents (% of GDP)	Ave. credit (% of GDP)
ALB	Albania	Albpetrol (*)	2.95	21.21
ARG	Argentina	YPF	2.39	18.67
AZE	Azerbaijan	SOCAR	21.34	13.32
BGD	Bangladesh	Petrobangla	0.04	21.60
BGR	Bulgaria	Bulgargaz (*)	0.04	46.22
BOL	Bolivia	YPFB	3.15	35.60
BRA	Brazil	Petrobras	1.05	52.24
CHN	China	CNOOC/CNPC/PetroChina/Sinopec	3.02	97.39
CIV	Côte d'Ivoire	Petroci	1.02	26.35
CMR	Cameroon	SNH	4.27	16.30
COL	Colombia	Ecopetrol	3.52	33.42
DNK	Denmark	Orsted	0.55	91.66
DZA	Algeria	Sonatrach	19.12	30.91
ECU	Ecuador	Petroamazonas / Petroecuador	8.94	18.90
EGY	Egypt	EGPC	11.06	31.68
GHA	Ghana	GNPC	0.72	8.49
IDN	Indonesia	Pertamina	7.02	30.85
IND	India	ONGC	1.01	32.24
JAM	Jamaica	PCJ	0.00	25.59
KAZ	Kazakhstan	KazMunayGas	12.95	29.00
KEN	Kenya	National Oil Kenya	0.00	23.35
MEX	Mexico	Pemex	4.58	20.97
MOZ	Mozambique	ENH	0.11	16.85
MYS	Malaysia	Petronas	5.41	95.37
NGA	Nigeria	NNPC	13.41	9.40
NOR	Norway	Equinor	4.90	74.52
PER	Peru	Perupetro	2.25	21.55
PHL	Philippines	PNOC	0.09	30.90
RUS	Russia	Gazprom/Rosneft	8.05	31.08
THA	Thailand	PTT	0.53	91.50
TUN	Tunisia	ETAP	5.64	60.62
TZA	Tanzania	TPDC	0.00	9.18
UKR	Ukraine	Naftogaz	0.52	36.40
UZB	Uzbekistan	Uzbekneftegaz (*)	2.67	–
VEN	Venezuela	PDVSA	18.19	31.23
VNM	Vietnam	PetroVietnam	4.11	65.31
ZAF	South Africa	Petro SA	0.04	105.01

* Not in the NOC database.

Source: Companies in the National Oil Company Database.

Table 5.2: **Im, Pesaran and Shin (IPS) and Fisher Panel Unit-Root Tests**

Variable	**Statistic**	**p-value**	**Nº of panels**
Im, Pesaran and Shin (IPS) unit-root test			
Credit as % of GDP	-0.9189	1.0000	89
Δ Credit as % of GDP	-11.5847	0.0000	89
log(Oil price)	-3.0671	0.0000	90
log(FBK)	-2.3825	0.0000	89
log(Consumption)	-2.1355	0.0000	89
Fisher unit-root test			
Oil rents as % of GDP			82
Inverse chi-squared	523.7715	0.0000	
Inverse normal	-13.7991	0.0000	
Inverse logit	-14.4403	0.0000	
Modified inv. chi-squared	18.3259	0.0000	

Note: Table reports results from Im, Pesaran and Shin (IPS) and Fisher-type unit-root tests. The null hypothesis is that all panels contain a unit root. The IPS test shows that log of oil price, log of FBK (gross fixed capital formation), and log of consumption are stationary in levels. Credit as a percentage of GDP is non-stationary, but its first difference is stationary. Fisher-type tests for oil rents strongly reject the unit root null.

Table 5.3: **Interest Rate Controls (IRC) Model**

	Coefficient
Lagged IRC	0.231***
	[0.075]
National Oil Company (NOC)	-0.124
	[0.164]
Oil rents	29.596
	[56.886]
Fiscal dependence	52.354
	[82.161]
NOC × Oil rents	-9.127
	[24.393]
NOC × Fiscal dependence	-141.367**
	[63.951]
Oil rents × Fiscal dependence	-5.884
	[11.863]
NOC × Oil rents × Fiscal dependence	-28.258
	[12.341]
Polity	0.078***
	[0.019]
Log(GDP pc)	0.011
	[0.018]
Constant	0.237
	[0.235]
Observations	2214
Countries	68
No. of instruments / groups	0.85
AR(2) p-value	0.271
Hansen p-value	0.425

Note: Two-step System GMM estimates of interest rate controls (IRC), scored from 0 (strictest) to 3 (most liberalized). The model includes interactions between NOC presence, oil rents, and fiscal dependence. Year and country fixed effects included. Robust standard errors clustered at the country level are in brackets.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$

Table 5.4: **Determinants of Credit Growth – Interaction Model**

Change in Domestic Credit (Ddcred)	**Model with Interactions**
Change in Credit (lagged)	0.775**
	(0.330)
NOC	10.315*
	(5.323)
Oil rents	7.986
	(9.358)
Fiscal dependence	-376.260
	(2671.71)
NOC × Oil rents	-8.223
	(9.342)
NOC × Fiscal dependence	340.808
	(2669.18)
Oil rents × Fiscal dependence	-463.450
	(415.72)
NOC × Oil rents × Fiscal dependence	463.250
	(416.39)
IRC	7.895***
	(1.693)
Δln(FBK)	81.005**
	(32.339)
D1974 (year dummy)	248.804***
	(58.063)
Constant	-24.193***
	(5.094)
Hansen p-value	0.321
AR(2) p-value	0.382
Instruments	71
Observations	2289
Countries	80
No. of instruments / cross-sections	0.89

Note: The dependent variable is the annual change in domestic credit to the private sector. The model includes interaction terms between oil rents, national oil company (NOC) presence, and fiscal dependence on oil revenues to assess their combined effect on financial repression. Estimated via two-step system GMM with country-clustered robust standard errors. All models include time fixed effects. Standard errors in parentheses.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$

6. A.2: Fossil-Fuel abundance and CO_2 emissions

Table 6.1: **Correlation Matrix**

	Carbon intensity	Renew. energy	Energy price index	Trade	Services	Fin. dev.	FDI
Carbon intensity	1.0000						
Renew. energy	0.0502	1.0000					
Energy price index	-0.1620	-0.0706	1.0000				
Trade	-0.0373	-0.0078	-0.0220	1.0000			
Services	-0.7503	-0.1521	0.1149	-0.0143	1.0000		
Financial dev.	-0.7422	-0.2493	0.1955	0.0154	0.7209	1.0000	
FDI	-0.0991	-0.1396	0.0822	0.0522	0.0908	0.1188	1.0000

Note: This table presents the pairwise correlation coefficients among the main variables used in the analysis. Values closer to 1 or −1 indicate stronger positive or negative linear relationships, respectively. Carbon intensity is measured as CO_2 emissions per unit of GDP. Financial development corresponds to the IMF index. Correlations are based on unbalanced panel data for the period 1990–2019.

Table 6.2: **Panel Unit Root Tests**

Im, Pesaran and Shin (IPS) unit-root test			
Variable	**Statistic**	**p-value**	**N° of panels**
log. population	-3.4469	0.1462	45
Renewable energy	-0.7910	1.0000	45
d.Renewable energy	-4.9545	0.0000	45
Value-added services	-1.9664	0.0053	44
d.log. global eneregy price index	-4.6759	0.0000	45
Trade as share of GDP	-5.2391	0.0000	44
CO_2 equivalent emissions	-0.1856	1.0000	44
d.CO_2 equivalent emissions	-5.0808	0.0000	44
Foreign direct investment	-2.7837	0.0000	45
Carbon emissions per-capita	-1.1335	0.9996	45
d.Carbon emissions per-capita	-4.9970	0.0000	45

Working hypothesis

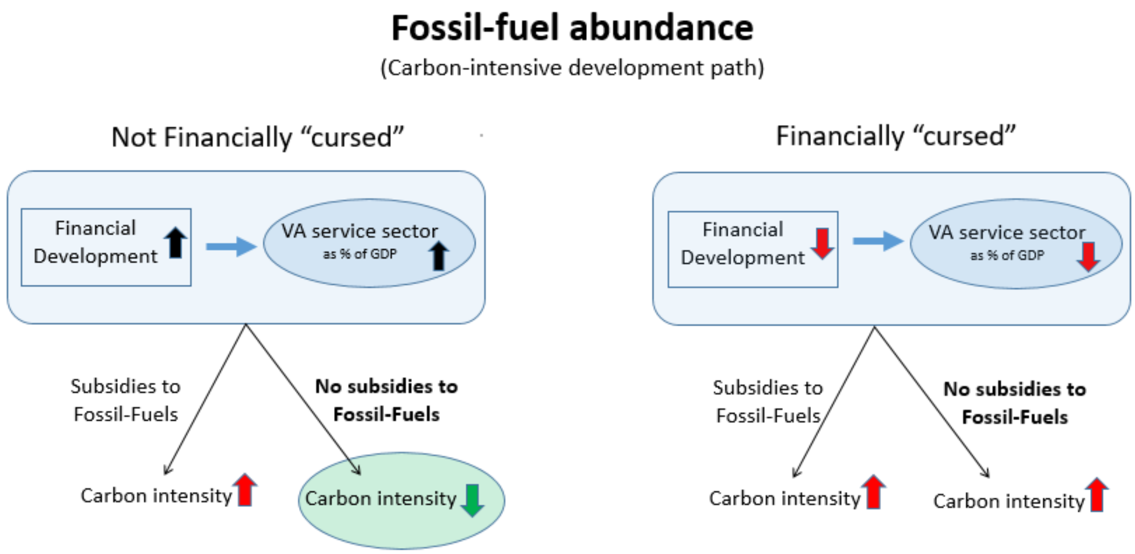


Figure 6.1: **Financial development index composition**

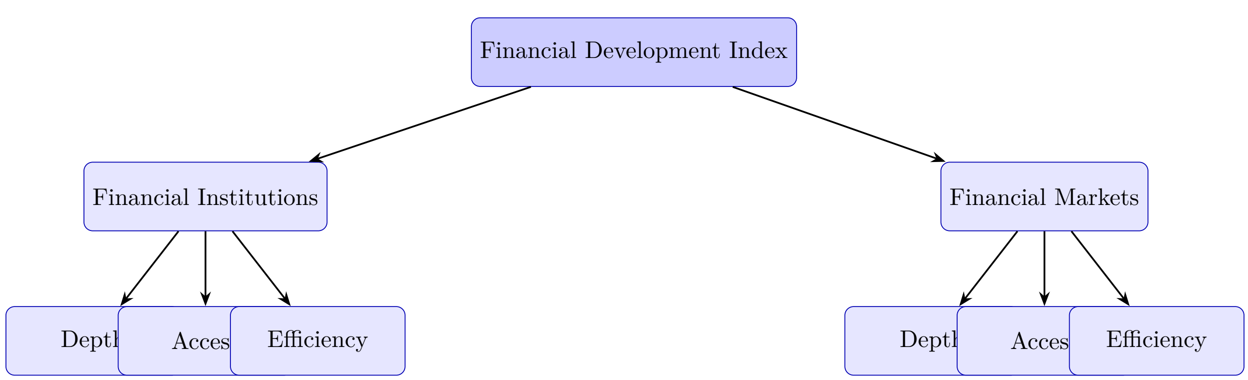


Figure 6.2: **Structure of the Financial Development Index (adapted from Sahay et al., 2015)**

Table 6.3: **Financial development indexes in the sub-samples**

	Do not subsidize fossil-fuels *18 countries*	**Subsidize fossil-fuels** *27 countries*
Financial development index	**0.603**	**0.317**
Financial institutions index	**0.656**	**0.336**
Financial markets index	**0.529**	**0.288**

Source: IMF, IEA and WDI.

Note: The financial development index is 90% higher in countries that do not subsidize fossil fuels compared to those that do. The financial institutions index is 95% higher, and the financial markets index is 84% higher in countries without fossil fuel consumption subsidies (n=1320).

Table 6.4: **Baseline results – impact of Financial Development and Services on Carbon intensity**

Dependent variable:	Change in carbon intensity			
	(1) Full sample	(2) w/ interaction	(3) No subsidies	(4) Subsidies
Change in carbon intensity lag	-0.890^{***}	-0.724^{***}	-0.816^{***}	-0.677^{***}
	(0.274)	(0.233)	(0.246)	(0.242)
Services	0.221	0.338^{**}	−0.00885	0.566
	(0.160)	(0.169)	(0.243)	(0.507)
Financial development	−0.054	0.271	0.939^{***}	0.680
	(0.054)	(0.345)	(0.336)	(1.000)
Services x financial development	–	−0.513	-1.168^{***}	−1.427
		(0.523)	(0.441)	(1.935)
Lag growth rate renewable energy use	−3.712	−3.611	−2.506	−4.857
	(2.953)	(3.030)	(1.752)	(3.207)
Lag growth rate global energy price index	0.055	0.140	0.0377	0.120
	(0.158)	(0.116)	(0.148)	(0.146)
Lag change in trade	0.273	0.116	-1.653^{***}	0.0938
	(0.391)	(0.379)	(0.484)	(0.421)
Constant	0.138^{*}	-0.208^{**}	−0.137	0.0842
	(0.00916)	(0.0995)	(0.113)	(0.272)
Observations	1,019	1,019	428	591
Number of id	41	41	17	24
Number of Instruments	15	15	11	15
AR(2)	0.026	0.0213	0.292	0.329
Hansen	0.006	0.0022	0.758	0.0529
N° of instruments / cross-sec	0.37	0.37	0.65	0.63

Robust standard errors in parentheses

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: Estimates are based on two-step system GMM regressions. Columns (3) and (4) report split-sample estimates for countries with and without fossil fuel subsidies. The interaction between services and financial development is negative and statistically significant only in countries that do not subsidize fossil fuels, indicating that deeper financial systems can amplify the carbon-reducing effect of structural shifts toward services—but only in contexts where price signals are not distorted by energy subsidies. The lack of significance in subsidizing countries suggests that artificially low energy prices reduce the relative attractiveness of green investments, weakening the financial system's ability to support decarbonization. All models include time fixed effects.

Table 6.5: **Effect of financial development and services by national companies**

VARIABLES	(1) Full sample	(2) With interaction	(3) Not NC's	(4) With NC's
Change in carbon intensity lag	-0.625^{***}	-0.661^{***}	-0.635^{***}	-0.680^{***}
	(0.134)	(0.135)	(0.129)	(0.221)
Lag growth rate global energy price index	0.110	0.120	0.136	−0.00510
	(0.128)	(0.0991)	(0.121)	(0.191)
Lag change in trade	−0.228	−0.391	-2.424^{***}	0.308
	(0.338)	(0.387)	(0.825)	(0.546)
Services	0.126	0.338^{**}	1.021^{***}	0.463^{**}
	(0.157)	(0.166)	(0.296)	(0.214)
Financial development	−0.0592	0.344	0.607^{*}	0.330
	(0.0623)	(0.247)	(0.349)	(0.372)
Services x financial development	–	-0.615^{*}	-1.192^{***}	−0.695
		(0.362)	(0.434)	(0.542)
Observations	993	993	354	639
Number of id	40	40	14	26
Number of Instruments	16	16	10	16
AR(2)	0.0684	0.0167	0.0574	0.0600
Hansen	0.00577	0.0102	0.666	0.0333
N° of instruments / cross-sec	0.40	0.40	0.71	0.62

Robust standard errors in parentheses

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: Estimates are based on two-step system GMM regressions. Columns (3) and (4) present results from the split-sample analysis based on the presence of national companies (NCs). The interaction between financial development and services shows a negative and statistically significant effect on carbon intensity only for countries without NCs. This suggests that in the absence of state-dominated extractive sectors, financial systems and service-sector expansion are more effective in reducing emissions. In contrast, countries with NCs—often characterized by resource dependence and weaker institutional frameworks—exhibit no significant interaction effects, reinforcing the idea that state control in resource sectors may constrain financial sector alignment with low-carbon structural transformation.

Table 6.6:

Results examining the impact of domestic credit on carbon intensity

VARIABLES	(1) Full sample	(2) With interaction	(3) No subsidies	(4) Subsidize fossil-fuels
Change in carbon intensity lag	-0.352	-0.335	-0.759	-0.167
	(0.386)	(0.436)	(0.567)	(0.444)
Lag growth rate renewable energy use	-1.221	-0.107	-3.465	0.444
	(2.022)	(3.639)	(3.697)	(2.006)
Lag growth rate global energy price index	0.132	0.149	-0.425^{*}	0.0750
	(0.111)	(0.142)	(0.226)	(0.186)
Lag change in trade	-1.279^{**}	-1.229^{*}	-1.492	-0.648
	(0.523)	(0.668)	(1.709)	(0.635)
Services	0.214^{*}	0.268^{*}	-0.0327	0.0397
	(0.115)	(0.150)	(0.879)	(0.199)
Credit	-0.000372^{*}	0.000337	0.00749	-0.000950
	(0.000195)	(0.00139)	(0.00636)	(0.00184)
Services x Credit	–	-0.00111	-0.00979	0.00148
		(0.00220)	(0.0101)	(0.00304)
Constant	-0.125^{**}	-0.158^{*}	-0.0725	-0.0319
	(0.0624)	(0.0836)	(0.477)	(0.106)
Observations	838	838	362	476
Number of id	41	41	17	24
Number of Instruments	15	15	11	15
AR(2)	0.196	0.219	0.127	0.318
Hansen	0.115	0.136	0.270	0.268
N° of instruments / cross-sec	0.37	0.37	0.65	0.65

Robust standard errors in parentheses

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: Estimates are based on two-step system GMM regressions. In this specification, the composite financial development index is replaced with domestic credit to the private sector, which serves as a narrower proxy for the role of financial institutions. The results reveal no statistically significant interaction effects between credit and services in reducing carbon intensity—neither in the full sample nor across the subsidy-based subsamples. This suggests that financial institutions alone, without the broader support of market mechanisms or policy alignment, may be insufficient to drive structural decarbonization. The lack of significant effects may also reflect the limited targeting of credit toward green investments during the study period.

Table 6.7: **Regression results examining the impact of Financial Development and Services on CO_2 emissions per-capita**

Dependent variable: CO_2**e. per capita**				
	(1) Full sample	(2) w/ interaction	(3) No subsidy	(4) Subsidy
CO_2 emissions per capita lag	-2.041***	-1.955***	-1.231***	-1.602***
	(0.361)	(0.347)	(0.314)	(0.542)
Services	0.185	0.307	0.480	0.127
	(1.183)	(1.130)	(0.456)	(1.495)
Financial development	-0.868	0.342	0.611***	0.331
	(0.532)	(0.379)	(0.216)	(0.734)
Services × Financial dev.	-	-0.597	-1.022***	-0.681
		(0.540)	(1.082)	(1.157)
Lag growth rate renewable energy use	-11.85***	-10.448***	-6.827***	-8.312***
	(2.545)	(2.563)	(1.638)	(3.882)
Lag change in trade	0.072	0.046	0.482	1.062***
	(0.136)	(0.109)	(0.350)	(0.356)
Lag growth rate global energy price index	0.410	0.592	0.084	0.396
	(0.560)	(0.121)	(0.693)	(0.425)
Constant	-0.591	-0.151*	-0.088	-0.207
	(0.591)	(0.088)	(0.235)	(0.204)
Observations	1,042	1,042	430	612
Number of IDs	42	42	17	25
Number of Instruments	15	15	11	15
AR(2)	0.021	0.031	0.135	0.101
Hansen	0.336	0.397	0.836	0.398
N° of instruments / cross-sec	0.36	0.36	0.65	0.6

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: Estimates are based on two-step system GMM regressions. In this specification, the dependent variable is redefined as CO_2 emissions per capita rather than carbon intensity. Results confirm the baseline findings: the interaction between financial development and the service sector is associated with a statistically significant reduction in emissions, particularly in countries that do not subsidize fossil fuels. These effects reinforce the importance of complementary structural change and financial development to achieve emissions mitigation. The per capita approach further underscores how financial and sectoral dynamics influence the individual-level environmental footprint.

Table 6.8: **Regression results examining the impact of Financial Development and Services on carbon intensity as the difference between CO_2 emission (instead of GHG emissions in kt. of CO_2) and GDP**

	(1)	(2)	(3)	(4)
Dependent variable:	Carbon intensity (only with CO_2 emissions)			
Change in carbon intensity lag	-0.704***	-0.508	-0.686***	-0.612*
	(0.221)	(0.329)	(0.211)	(0.330)
Services	0.120	0.251	0.305	0.325
	(0.270)	(0.238)	(0.295)	(0.469)
Financial development	-0.0456	0.329	1.029***	0.463
	(0.0921)	(0.381)	(0.257)	(0.760)
Services × Financial dev.	-	-0.566	-1.431***	-0.944
		(0.532)	(0.611)	(1.010)
Lag growth rate renewable energy use	-3.488	-0.944	-3.057**	-0.968
	(2.321)	(3.861)	(1.547)	(3.919)
Lag growth rate global energy price index	0.129	0.152	0.0223	-0.117
	(0.135)	(0.111)	(0.151)	(0.853)
Lag change in trade	-0.389	0.408	-1.934**	0.168
	(0.344)	(0.426)	(0.301)	(0.430)
Constant	-0.0775	-0.165	-0.272**	-0.124
	(0.108)	(0.121)	(0.137)	(0.226)
Observations	1,019	1,019	428	591
Number of IDs	41	41	17	24
Number of Instruments	15	15	11	15
AR(2)	0.0749	0.164	0.0.0852	0.217
Hansen	0.0099	0.0076	0.915	0.0056
N° of instruments / cross-sec	0.37	0.37	0.65	0.63

*** p<0.01, ** p<0.05, * p<0.1

Note: This table replicates the baseline model using an alternative measure of carbon intensity, computed as the ratio between CO_2 emissions and GDP. The results confirm the robustness of our main findings: the interaction between financial development and the service sector remains negatively associated with carbon intensity, and it is statistically significant in countries that do not subsidize fossil fuels (column 3). This reinforces the hypothesis that deeper financial systems enhance the decarbonization potential of structural economic shifts—particularly when market signals are not distorted by subsidies. The negative and significant coefficient of the trade variable in column 3 also suggests that more open economies may better facilitate the diffusion of cleaner technologies and practices.

Table 6.9: **Regression results replacing FDI by Polity, as instrumental variable**

VARIABLES	(1) Full sample	(2) Full sample with interaction	(3) Do not subsidize fossil-fuels	(4) Subsidize fossil-fuels
Change in carbon intensity lag	-0.931^{***}	-0.741^{***}	-1.278^{***}	-0.692^{**}
	(0.282)	(0.322)	(0.495)	(0.286)
Services	0.203	0.223	0.187	0.425
	(0.165)	(0.164)	(0.539)	(0.495)
Financial development	−0.046	0.131	1.141^{**}	0.681
	(0.057)	(0.357)	(0.521)	(1.000)
Services × Financial dev.		−0.254	-1.427^{**}	1.160
		(0.421)	(0.762)	(1.981)
Lag growth rate renewable energy use	−3.256	−3.144	-5.885^{**}	0.342
	(2.804)	(2.721)	(3.064)	(4.357)
Lag growth rate global energy price index	0.045	0.088	0.0839	0.175
	(0.131)	(0.140)	(0.186)	(0.191)
Lag change in trade	−0.154	−0.423	−0.289	0.028
	(0.412)	(0.618)	(0.195)	(0.402)
Constant	−0.134	−0.152	−0.295	−0.236
	(0.085)	(0.094)	(0.269)	(0.276)
Observations	982	982	412	570
Number of ID	41	41	17	24
Number of Instruments	15	15	11	15
AR(2)	0.078	0.024	0.162	0.332
Hansen	0.084	0.026	0.268	0.084
N° of instruments / cross-sec	0.37	0.37	0.65	0.63

Notes: Robust standard errors in parentheses.

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: This table tests the robustness of the baseline specification by replacing foreign direct investment (FDI) with a political institutional quality index (Polity) as the instrumental variable. The main results remain consistent: the interaction between financial development and the service sector continues to show a negative association with carbon intensity, although statistical significance is lost. Notably, the coefficients remain economically meaningful and stable in sign, especially for countries without fossil fuel subsidies (column 3). The validity of the alternative instrument is supported by favorable Hansen statistics.

Table 6.10: **Triple interaction model**

Dependent variable: Carbon intensity	
Services	−1.119
	(1.988)
Financial development	1.725
	(1.579)
Services × Financial dev.	−1.389
	(2.261)
Subsidies	−0.626
	(1.145)
Services × Subsidies	2.294
	(2.284)
Financial dev. × Subsidies	−0.0497
	(1.734)
Services × Financial dev. × Subsidies	−2.045
	(2.823)
Observations	1,019
Number of id	41
Number of Instruments	15
AR(2)	0.225
Hansen	0.935
N° of instruments / cross-sections	0.37

Standard errors in parentheses
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 6.10 adds a three-way interaction (Financial Development × Service Share × Fuel Subsidies). The triple-interaction coefficient is not statistically significant, indicating no clear average effect. In other words, we cannot conclusively say that the impact of financial development on carbon intensity differs by both service-sector size and subsidy status simultaneously. However, examining marginal effects yields insight that in countries with fuel subsidies, financial development tends to reduce carbon intensity only when the service sector is sufficiently large. Our calculations show that for subsidizing countries with a below-average service share (0.47 in our sample), higher financial development is actually associated with higher carbon intensity. It is only above an approximate threshold of 0.6 service share that financial development begins to lower emissions. By contrast, in non-subsidizing countries, the marginal effect of financial development on carbon intensity becomes increasingly negative as the share of services rises. These patterns are consistent with our hypothesis, in the sense that financial development mitigates emissions by promoting the service economy, but this benefit emerges primarily when the economy is already service-oriented. In heavily industrialized, subsidy-supporting economies, financial development alone may reinforce carbon-intensive growth unless accompanied by a strong service sector.

Table 6.11: **Conditional means of service sector share (`vaserv`) by fossil fuel subsidy status (`ysub`)**

ysub	Mean	Std. Err.	95% Conf. Interval
0 (No subsidies)	0.619	0.0036	[0.612, 0.626]
1 (Subsidies)	0.474	0.0035	[0.467, 0.481]

Note: Based on 1,240 observations. `vaserv` is the share of services in GDP.

Other annexes

Production-based CO_2 emissions is the amount of CO_2 emitted in a particular country. Consumption-based CO_2 emissions are adjusted for trade and reflect CO_2 emissions related to goods and services consumed in a particular country (Emenekwe et al., 2023). Countries with a large trade deficit, usually have lower production CO_2 emissions than consumption. Since the 1980s, richer countries have experienced a period of deindustrialization (a decline in manufacturing industries) and a large current account deficit, especially a deficit in the import of goods. Therefore, CO_2 from production emissions is lower than CO_2 emissions relating to consumption. On the other hand, net exporters of manufactured goods, have higher levels of CO_2 from production than domestic consumption.

6.0.1 CO_2 emissions and fossil-fuel production

Table 6.12: **Annual Average Indicators (1990–2019)**

Country	GHG emissions* (kt of CO_2 eq.)	Petroleum*(%)	Coal* (%)	Gas* (%)
China	7,517,282	4.7	36.8	1.8
United States	6,312,413	12.6	16.4	23.3
Russian Federation	2,349,118	10.6	6.9	21.3
India	2,132,260	1.0	7.0	0.7
Japan	1,257,730	1.0	1.7	2.0
Germany	938,570	0.2	3.8	0.7
Brazil	862,412	2.4	0.4	0.3
Indonesia	714,016	1.6	3.6	2.2
Canada	651,509	3.9	0.7	5.7
Iran	637,842	4.7	0.9	7.0
United Kingdom	631,488	2.4	0.7	2.6
Australia	568,895	6.0	7.2	1.9
Mexico	567,408	3.8	0.2	1.2
Korea, Rep.	541,108	3.0	3.4	0.4
France	481,028	0.6	0.0	0.1
Italy	480,622	0.2	0.9	0.6
Saudi Arabia	466,897	12.4	0.0	2.0
South Africa	452,322	0.2	3.9	0.0
Ukraine	400,765	0.1	3.0	0.1
Poland	375,795	0.0	3.0	0.2
Spain	341,866	0.0	0.3	0.0
Venezuela	329,757	3.3	0.1	0.9
Turkiye	326,590	0.1	1.1	0.7
Argentina	315,567	0.9	0.0	1.1
Thailand	300,315	0.3	0.3	0.6
Pakistan	281,871	0.1	0.1	0.5
Nigeria	253,218	2.1	0.0	0.7
Kazakhstan	245,473	1.4	1.6	0.6
Egypt	236,957	1.0	0.0	1.6
Netherlands	199,896	0.1	0.0	3.3
Malaysia	199,824	0.9	0.0	1.4
Vietnam	199,712	0.3	0.4	0.4
Algeria	191,047	2.0	0.0	2.6
Iraq	177,512	2.7	0.1	1.0
Uzbekistan	170,743	0.1	0.1	2.0
UAE	157,886	3.5	0.0	1.3
Colombia	151,334	0.8	0.9	0.6
Philippines	150,826	0.3	0.0	0.3
Bangladesh	141,256	0.0	0.0	0.0
Czechia	139,184	0.2	0.6	0.2
Romania	128,981	0.2	0.6	0.3
Belgium	125,984	0.1	0.0	0.2
Turkmenistan	111,300	0.2	0.0	1.9
Libya	110,779	1.7	0.0	0.3
Greece	105,238	0.0	1.0	0.0

Note: GHG data from WDI; fossil fuel production shares from EIA. (* as % of world production)

7. A.3: Financial development under climate stress

Table 7.1: **Descriptive Statistics by Treatment Status**

Panel A: Full Sample	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Financial Development	924	0.275	0.228	0.000	0.926
Financial Institutions Index	924	0.331	0.212	0.000	0.959
Financial Markets Index	924	0.209	0.256	0.000	0.933
Growth of GDP per capita	900	-0.00085	0.0571	-0.612	0.179
Openness to Trade	913	0.618	0.339	0.0017	2.204
Inflation	883	0.132	0.327	-0.064	3.878
Agriculture (% of GDP)	882	15.68	11.96	0.833	57.24
Polity Index	824	3.42	5.29	-8	10
Panel B: Control Group (Treated = 0)					
Financial Development	464	0.302	0.224	0.000	0.926
Financial Institutions Index	464	0.339	0.216	0.000	0.959
Financial Markets Index	464	0.254	0.246	0.000	0.894
Growth of GDP per capita	450	-0.0038	0.0497	-0.383	0.127
Openness to Trade	459	0.535	0.195	0.164	1.157
Inflation	443	0.148	0.323	-0.003	3.878
Agriculture (% of GDP)	444	13.79	10.09	1.49	56.54
Polity Index	420	2.26	5.58	-7	10
Panel C: Treated Group (Treated = 1)					
Financial Development	460	0.248	0.228	0.000	0.921
Financial Institutions Index	460	0.322	0.208	0.000	0.910
Financial Markets Index	460	0.254	0.246	0.000	0.894
Growth of GDP per capita	450	0.0021	0.0636	-0.612	0.179
Openness to Trade	454	0.702	0.424	0.0017	2.204
Inflation	440	0.115	0.331	-0.064	3.748
Agriculture (% of GDP)	438	17.59	13.34	0.833	57.24
Polity Index	404	4.63	4.69	-8	10

Note: Summary statistics are reported for the full sample, as well as for the control and treated groups separately. Political regime quality is measured using the Polity index.

Table 7.2: **Selected EWEs in countries with more than 3 million people = 6171**

(a) Percentile - 90th = 2.687%

Income level	Country	Disaster	Treatment Year	Ratio affected (%)
High	CZE	Riverine flood	2013	12.37
	USA	Blizzard/Winter storm	2016	26.50
Upper middle	GEO	Drought	2000	16.74
	DOM	Riverine flood	2016	26.83
	PRY	Drought	2012	23.82
	MYS	Drought	2014	7.30
	LBN	Blizzard/Winter storm	2015	15.94
Lower middle	IND	Drought	2002	27.80
	KGZ	Drought	2009	37.60
	MMR	Tropical cyclone	2008	5.00
	AGO	Drought	2012	7.56
	SEN	Drought	2011	6.78
Low	BDI	Drought	2005	30.19
	BEN	Riverine flood	2010	9.06
	MLI	Drought	2011	22.54

Table 7.3: **Summary Statistics for *Ratio of population Affected* (%)**

Statistic	Value	Description
Observations (N)	6,171	Total number of observations
Mean	1.575	Average percentage affected
Standard Deviation	6.459	Dispersion in the data
Minimum	0.000004	Smallest observed value
Maximum	113.932	Largest observed value
Skewness	8.951	Asymmetry of distribution
Kurtosis	110.112	Peakedness of distribution
Percentiles		
1%	0.0003	
5%	0.0011	
10%	0.0026	
25%	0.0100	
50% (Median)	0.0667	
75%	0.4788	
90%	2.6871	
95%	7.3497	
99%	30.1945	

Table 7.4: **Panel Unit Root Test**

Im, Pesaran and Shin (IPS) unit-root test			
Variable	**Statistic**	**p-value**	**N° of panels**
log. GDP-pc	-1.2539	0.995	30
d.log. GDP-pc	-4.0801	0.0000	30
Trade as share of GDP	-1.9538	0.0093	30
log.CPI	-4.5493	0.0000	30
log. agriculture as share of GDP	-2.318	0.001	30

Note: Financial development indexes and Polity are categorical variables.

7.0.1 Institutional resilience and Regime Type

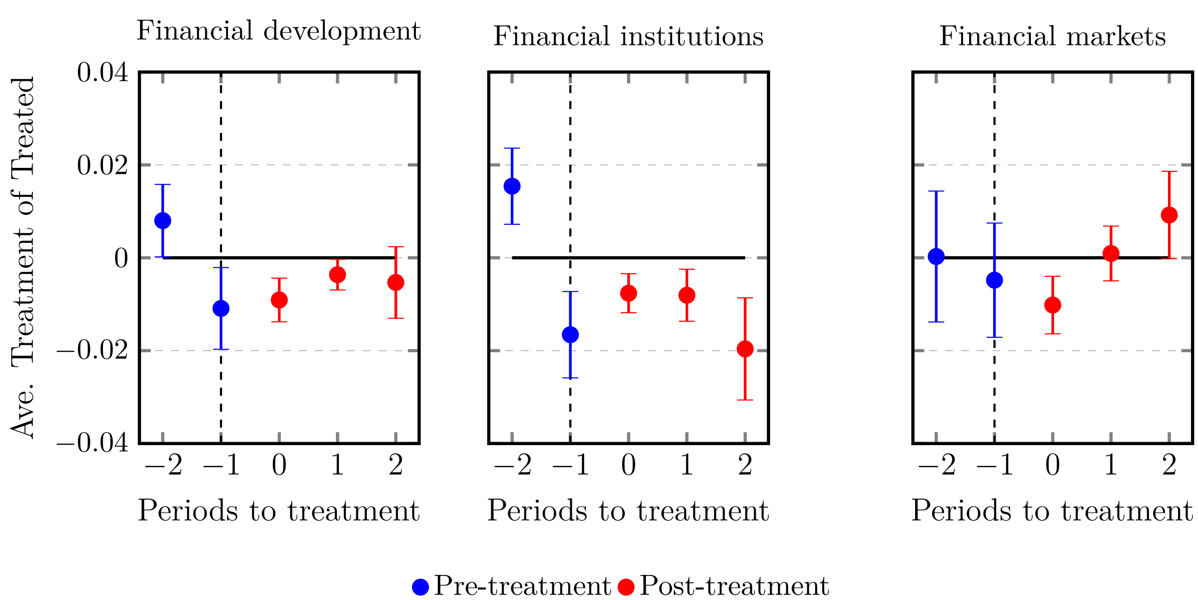
Table 7.5: **All Treated Countries Adding Polity as Covariate**

	Financial Development	Financial Institutions	Financial Markets
Post × Treated	-0.006*	-0.012**	-0.000
	(0.003)	(0.009)	(0.006)
Mean Dep. Var.	0.300	0.342	0.247
SD Dep. Var.	0.244	0.223	0.272
Observations	614	614	614

** $p < 0.05$, * $p < 0.10$

Note: This table presents ATT estimates for all treated countries, including the Polity score (ranging from –10 to +10) as a control variable for political regime type. The dependent variables are the IMF's Financial Development Index, Financial Institutions Index, and Financial Markets Index, each scaled from 0 to 1. 'Post × Treated' indicates post-event years for treated units. All models include country and year fixed effects and control for GDP per capita growth, trade openness, inflation, and political regime. Standard errors are reported in parentheses.

Figure 7.1: **Dynamic effects of EWEs including polity system**



Note: This figure shows the dynamic effects of EWEs on financial outcomes across three indexes: financial development, financial institutions, and financial markets. Estimates are derived from an event-study specification incorporating the Polity as a control to account for regime characteristics. Dots represent the average treatment effect on the treated (ATT) for each period relative to the treatment event. Blue dots denote pre-treatment periods, and red dots denote post-treatment periods. Vertical lines indicate 95% confidence intervals. The vertical dashed line marks the last period without treatment.

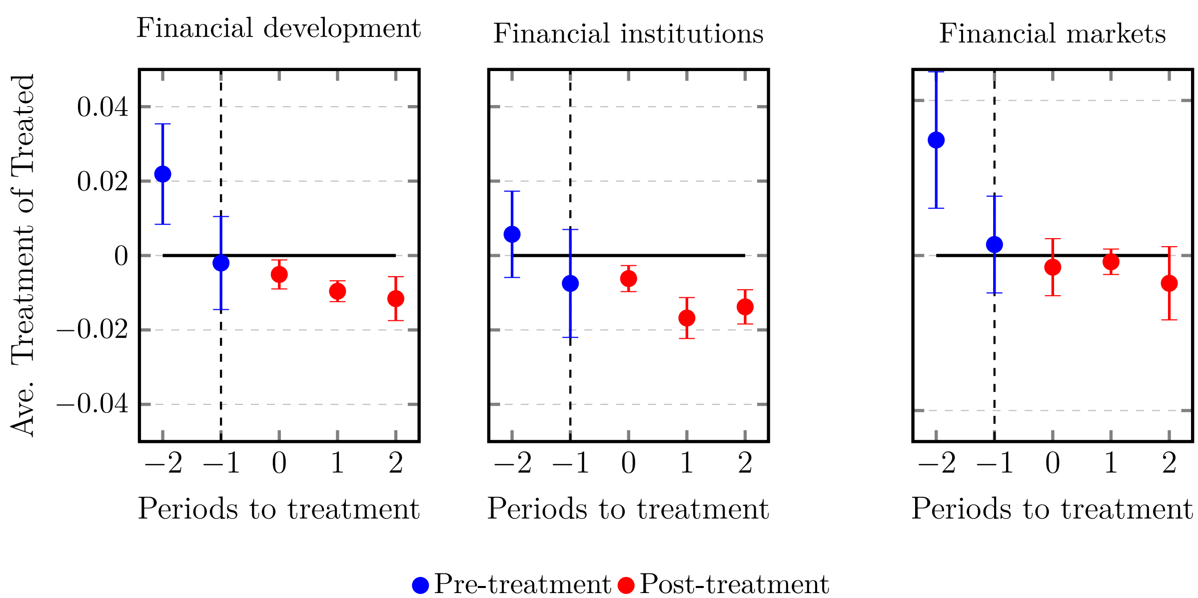
Table 7.6: **Adding Polity as covariate in LMICs**

	Financial Development	**Financial Institutions**	**Financial Markets**
Post × Treated	-0.009***	-0.012***	-0.005
	(0.003)	(0.009)	(0.007)
Mean Dep. Var.	0.221	0.266	0.168
SD Dep. Var.	0.148	0.134	0.184
Observations	458	458	458

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

Note: This table presents ATT estimates for treated countries, excluding high-income economies, and includes the Polity2 score as a covariate to account for political regime type. The dependent variables are the IMF's Financial Development Index, Financial Institutions Index, and Financial Markets Index, each scaled from 0 to 1. 'Post × Treated' indicates post-event years for treated units. All models control for GDP per capita growth, trade openness, inflation, and political regime, and include country and year fixed effects. Standard errors are reported in parentheses.

Figure 7.2: **Dynamic effects of EWEs including polity system in LMICs**



Note: This figure displays the dynamic effects of EWEs on three dimensions of financial development: overall financial development, financial institutions, and financial markets. The analysis controls for political regime characteristics via the Polity index. Each dot represents the average treatment effect on the treated (ATT) for a given period relative to the treatment. Blue dots indicate pre-treatment periods, and red dots indicate post-treatment periods. Error bars represent 95% confidence intervals. The vertical dashed line marks the last period without the treatment window, and the solid horizontal line indicates zero effect. When accounting for political regime characteristics, financial institutions in LMICs emerge as the most affected dimension of the financial system in the wake of EWEs.

Table 7.5 and Figure 7.1 present the results for all treated countries, controlling for regime type. The estimates reveal a negative impact on financial development and financial institutions, both of which become statistically significant, while the effect on financial markets remains statistically insignificant. These findings suggest that—even after accounting for institutional quality—extreme weather events exert a modest but measurable adverse effect on financial development, particularly through financial institutions. The estimated decline of 3.5% in the financial institutions index highlights the sector's vulnerability to climate-related shocks.

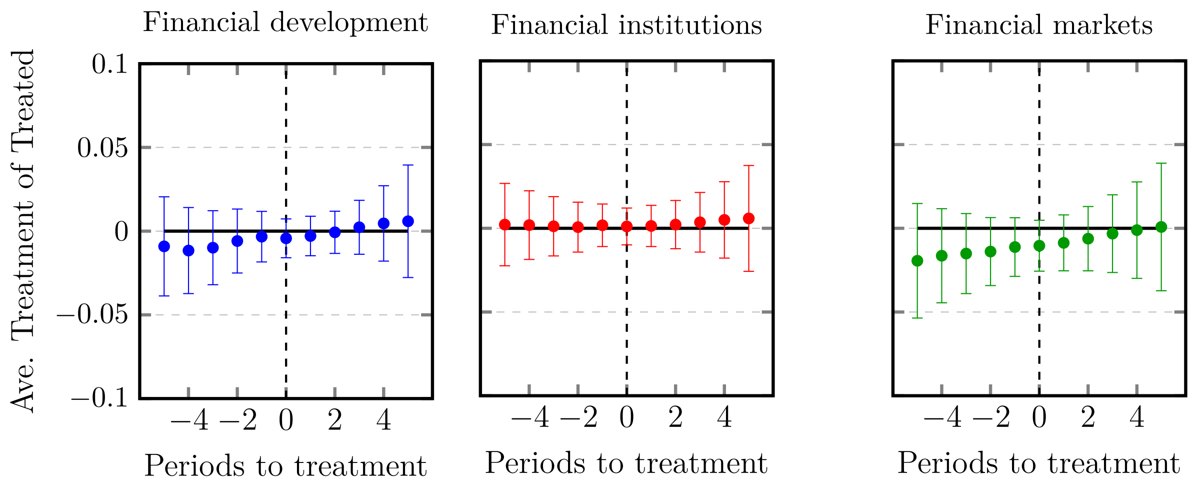
We then repeat the strategy of excluding high-income countries from the sample while incorporating the political system variable. Table 7.6 and Figure 7.2 report the results. When high-income countries are excluded, the estimated negative effects become stronger and reach higher levels of statistical significance. The findings indicate a persistent decline in the financial development and financial institutions indices up to two years after the event. This reinforces the notion that institutional resilience is more variable—and generally weaker—among lower-income countries, making their financial systems more vulnerable to the adverse impacts of EWEs.

7.0.2 Alternative post-treatment windows

To assess the temporal robustness of the findings, we extend the post-treatment window to five years. This approach allows us to examine whether the observed impacts on financial development are delayed or amplified over a longer horizon. The extended windows yield qualitatively similar patterns, in the sense that, the estimated treatment effects remain negative but are largely statistically insignificant. These findings suggest that, while extreme weather events may exert downward pressure on financial development indicators, their short- to medium-term impacts are limited in both magnitude and precision. Importantly, the parallel trends assumption continues to hold across all specifications, reinforcing the credibility of the identification strategy.

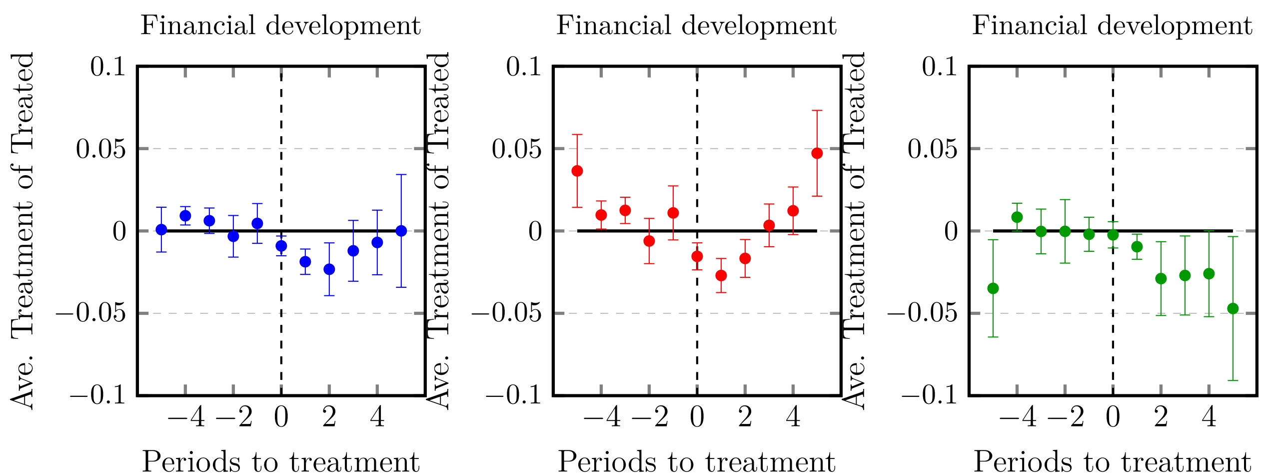
- Baseline model: Figures 7.3 and 7.4
- Robustness checks with agriculture as covariate: Figures 7.5 and 7.6
- Robustness checks with democracy as covariate: Figures 7.7 and 7.8
- Robustness checks with 95th-percentile of EWEs distribution: Figure 7.9

Figure 7.3: **Baseline results for all treated countries: dynamic Effects of EWEs on Financial Outcomes (5-year window)**



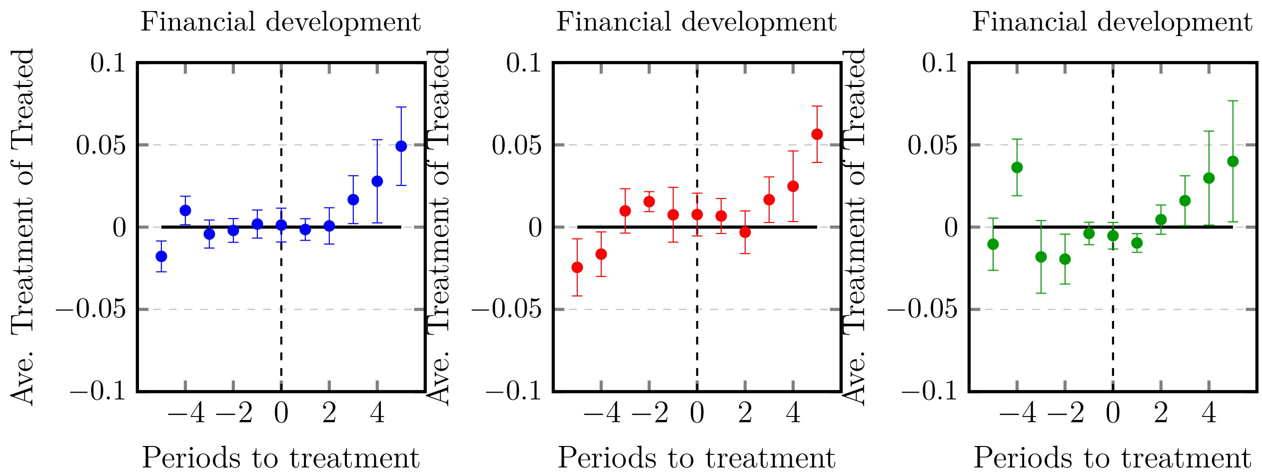
Note: Estimates represent the average treatment effect on the treated (ATT) using a five-year window around the occurrence of extreme weather events. Confidence intervals are based on robust standard errors. Each panel corresponds to a different dimension of financial development: overall financial development (left), financial institutions (center), and financial markets (right).

Figure 7.4: **Baseline results for LMICs: dynamic effects of EWEs on Financial Outcomes (5-year window)**



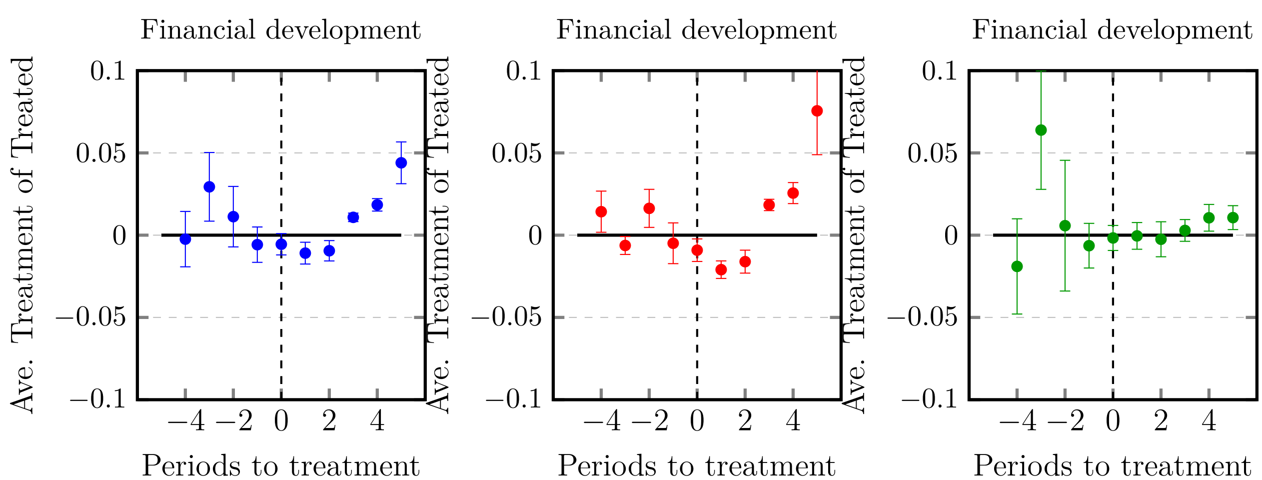
Note: Average treatment effects on the treated (ATT) over a five-year window around extreme weather events. Vertical bars represent 95% confidence intervals using robust standard errors. Each panel corresponds to a distinct financial dimension.

Figure 7.5: **Dynamic Effects of Extreme Weather Events on Financial Outcomes (with Agriculture as Covariate)**



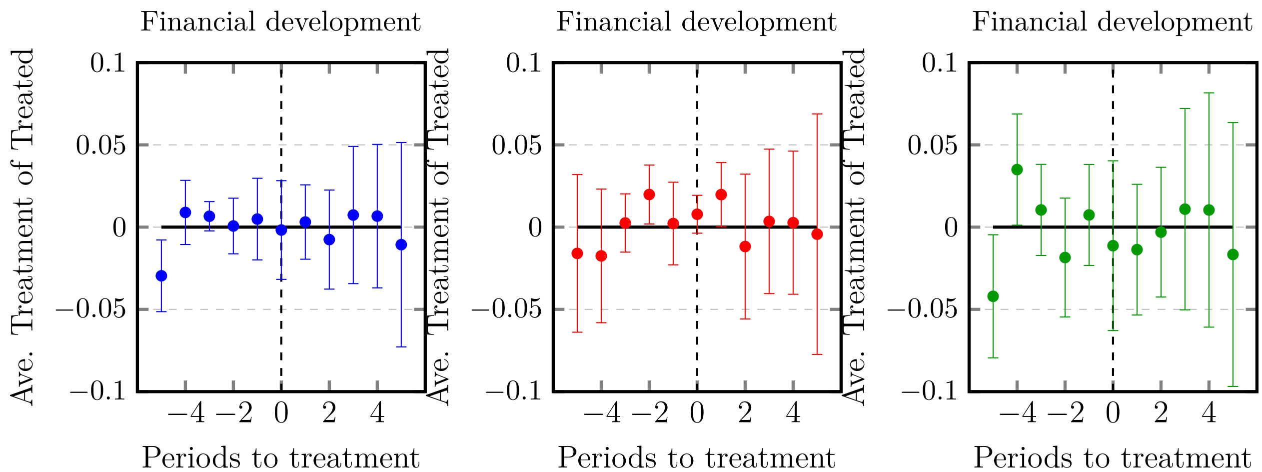
Note: ATT estimates from an event-study specification including agricultural value added as a covariate. Error bars represent 95% confidence intervals using robust standard errors. Panels display effects on financial development (left), institutions (center), and markets (right).

Figure 7.6: **Dynamic Effects of Extreme Weather Events on Financial Outcomes in LMICs (with Agriculture as Covariate)**



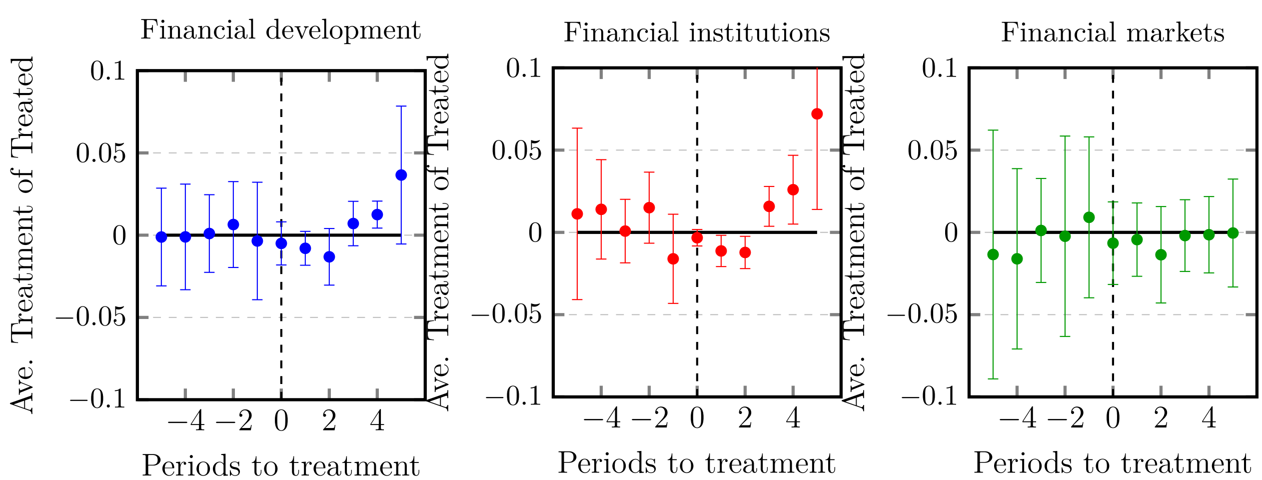
Note: ATT estimates from an event-study specification for low- and middle-income countries, including agricultural value added as a covariate. Error bars represent 95% confidence intervals using robust standard errors. Each panel shows dynamic effects on financial development (left), institutions (center), and markets (right).

Figure 7.7: **Dynamic Effects of Extreme Weather Events on Financial Outcomes (with Democracy as Covariate)**



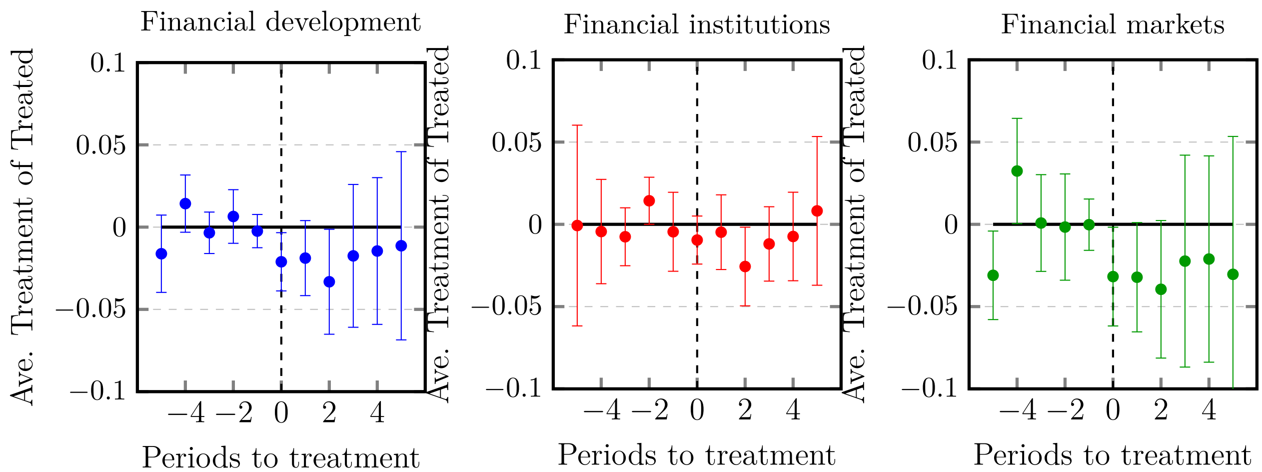
Note: ATT estimates from an event-study specification for all-treated countries, adding a dummy variable for democracy (equal to 1 if a country is democratic) as covariate. Error bars represent 95% confidence intervals using robust standard errors. Each panel shows dynamic effects on financial development (left), institutions (center), and markets (right).

Figure 7.8: **Dynamic Effects of Extreme Weather Events on Financial Outcomes in LMICs (with Democracy as Covariate)**



Note: ATT estimates from an event-study specification for low- and middle-income countries, using democracy, economic growth, trade, and inflation as covariates. Error bars represent 95% confidence intervals using robust standard errors. Each panel shows dynamic effects on financial development (left), institutions (center), and markets (right).

Figure 7.9: **Dynamic Effects of Most Severe Extreme Weather Events (95th Percentile)**



Note: ATT estimates from an event-study specification for countries exposed to the most severe extreme weather events (above the 95th percentile of the distribution). Covariates include democracy, economic growth, trade, and inflation. Error bars represent 95% confidence intervals using robust standard errors.