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Regional aspects of financial development and renewable energy: A cross-sectional study in 214 countries

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Abstract

Renewable energy is one of the most promising technologies for developing sustainable energy systems. This paper presents empirical evidence on the finance-green energy nexus. We use an extensive database on financial development (depth, access, efficiency, stability) from 1960 to 2017 for 214 countries, providing the first, to our knowledge, comprehensive empirical investigation on all four dimensions. We show macroeconomic and energy development conditions (public/social awareness and willingness, policy and legal framework, fossil fuels orientation, energy sector competition) are crucial to leverage financing and improve financing conditions for renewable energy entrepreneurs. Our empirical findings show that the financial system in East Asia and the Pacific is a significant constraint for investments in sustainable technologies. The cost of capital and debt, as well as the cost of equity and assets, for green investors, is commonly 30% higher than for non-green investors. Our findings support the crowding-in effect for South Asia. Here we supply empirical knowledge on the policymakers' and investors (governments, institutions, markets) goals, policies, and instruments targeting green financing and sustainable development.

Keywords: Green energy, renewable energy, sustainable development, green finance, resource curse

1. Introduction

An unconventional set of policies is needed to meet the Paris agreement goals. Investment policy on renewable energy should attract diverse investors to foster competition and reduce financing costs (Egli et al., 2019). Financing conditions (cost of debt, equity, cost of capital) on renewable energy technologies, facing high upfront costs, impair financial support on renewable energy projects as vital. They studied 133 representative photovoltaic and onshore wind projects in Germany over the last 18 years. Research by (Egli et al., 2018) shows financing conditions have improved significantly. However, micro-level data studies (Kempa et al., 2021) identify changes in the stringency of environmental policies and the growth of the financial sector, particularly financial institutions, as crucial to the energy

transition. Poor financial supporting approach and instruments to firms competing in low-carbon markets facing (supply and demand factors) - higher operating risks, transaction costs, low funding level, imperfect competition, not transparent tax-subsidy scheme, and extended risk exposure limits investments in renewable energy firms and industries (**Falcone et al., 2018; Mazzucato and Semieniuk, 2018; Liu et al., 2019; Agliardi and Agliardi, 2019; Barua and Chiesa, 2019**). Investments in renewable energy require special financing and structuring efforts due to their limited financial viability and increased risk profile (**Lindlein and Mostert, 2005**). To achieve such a comprehensive socio-technological transition, finance must be reintroduced into science and technology policies, which lay the foundations for a sustainable financial system (**Falcone et al., 2018**).

Fossil fuel technology remains highly attractive to financial institutions. The Bank's extensive financial support amounts to \$3.8 trillion in fossil fuel cycle companies between 2016 and 2020. However, the link between financial development and renewable energy consumption remains unexplained. Previous study results on the issue are mixed both on the micro and macro level. Also, a gap in the literature remains since the last researcher focused on a country case, a small, primarily regional sample, and a specific aspect of financial development and renewable energy link. Here we use 31 indicators covering all aspects of financial development, not just one as in past studies; (1) financial depth, (2) financial access, (3) financial efficiency, and (4) financial stability. Our research is the first comprehensive study on all financial development dimensions and their impact on renewable energy consumption. We use a large sample of 214 countries to study the regional aspects of financial development and renewable energy from 1960 to 2017. Data are constrained to 2017 due to the survey method connections as explained in **Beck et al. (1999, 2000a), Beck and Demirguc-Kunt (2009), Čihák et al. (2012)** and **Demirgüç-Kunt et al. (2013)**.

We aim to study the link between financial development and renewable energy, addressing several research objectives. First, one considers financial development a necessary but insufficient condition for the energy transition. Our second objective is to study the importance of financial intermediation for renewable energy consumption growth. Third, we consider fossil fuel subsidies a significant constraint to renewable energy use and consumption. Finally, financial literacy, as in the economic growth model, profoundly impacts investors' confidence and expectations of renewable investments and green growth.

We formulate our research hypotheses as; (1) financial development is a necessary but not sufficient condition for energy transition, (2) financial intermediation is crucial for renewable energy consumption growth, (3) fossil fuel subsidies decrease the use of renewable energy, (4) financial institutions and markets demonstrate a low level of green financial literacy, resulting in a restricted investor pool and low investor confidence in green investments.

Our data panel is unbalanced because observations for all variables listed in the sample data are unavailable from surveys conducted in all countries and periods. Therefore, before constructing the regression model, we examine the data for dependence across sections and stationarity. We use the (**Pesaran, 2015**) test for cross-section dependence and second-generation panel unit root tests (**Bai and Ng, 2004; Moon and Perron, 2004; Breitung and Candelon, 2006; Gengenbach et al., 2009; Pesaran, 2004, 2007**). The model we use for testing our hypotheses against the data is the Driscoll-Kraay two-way fixed effect technique (**Driscoll and Kraay, 1998**). Evidence supports our study's arguments for the Driscoll-Kraay approach (**Hoechle, 2007; Reed and Webb, 2010**).

This work significantly contributes to the field of energy transition and green growth. In addition, the present study is expected to contribute to our understanding of the importance of financial intermediation for renewable energy investments and demand growth.

This article is organized as follows: the introduction section provides a perspective on the importance and the problem addressed in the study. The literature review introduces leading scientific publications in financial development and renewable energy. Section three explains the data we used to study the link between financial development and renewable energy and how the problem was studied. The results section supplies empirical evidence (knowledge) by testing our research hypothesis against the data. Discussion sections highlight our results and how they relate to the original question or the objectives outlined in the study. It explains how the data support our hypotheses, consistency with other investigators, and the research's weaknesses and discrepancies. The conclusion section demonstrates our research advances in green financing beyond the current level of knowledge.

2. Literature review

Climate change is a leading global socio-economic issue. The Paris Agreement (**United Nations, 2015**) course was set to address it. Change in the economic structure and transition to low-carbon economies (as any growth model) requires specific conditions (**Piggot et al., 2018; Walton, 2018; Keen, 2020; Trippel, 2020**). Decarbonization requires moving away from fossil fuel growth to green growth. That is the only feasible course of action to meet Paris Agreement targets by 2030 (already heavily challenged). Motivating research by **Egli et al. (2018)** finds financial conditions (cost of debt, cost of equity, and cost of capital) crucial for renewable energy technology adoption. Financial markets, as their study show, are essential factors for the low-carbon energy transition in Germany from 2000-2017. Higher green technology adoption costs, debt margin for renewable and non-renewable energy firms, and high-rise default risk (data for 26 countries from 1996 to 2018) are tightly linked to environmental policy use and financial sector development (**Egli et al., 2019; Kempa et al., 2021**). More advanced financial systems improve financial conditions for investing in renewable energy technology, driving green growth. Financial systems characteristics (depth, access, efficiency, stability) appear crucial for financing renewable energy investments (**Lindlein and Mostert, 2005; Čihák et al., 2012, 2013**).

A report from International Renewable Energy Agency (IRENA) (2020) shows significant sources for renewable energy investments (2017–2018) were project developers (152 bn US\$), commercial financial institutions (67 bn US\$), national development financial institutions (35 bn US\$), corporate actors (24 bn US\$), households (22 bn US\$). A large part of the total renewable energy investments is financed through equity investments (91 bn US\$) and debt (91 bn US\$). Project financing debt with (107 bn US\$) and equity (32 bn US\$) are necessary financial instruments in renewable energy finance. Primarily, funds for financing renewable energy investments come from private money-project developers (56%) and private financial institutions (25%). The majority of the investments were realized in East Asia and the Pacific (107 bn US\$), Western Europe (51 bn US\$), and the Americas (88 bn US\$). Renewable energy consumption largely depends on regulatory impact (feed-in-tariff/premium payment, electric utility quota obligations/renewable portfolio standard, net metering, biofuels obligation/mandate, heat obligation/mandate, tradable renewable energy certificate), disposable green technology infrastructure, fiscal incentives, and public financing (capital subsidy, grant or rebate, investment or production tax credits, reduction in sales, energy CO₂, VAT or other taxes, energy production payment, public investment, loans or grants), for details see KPMG (2016). Therefore, learning in the financial and renewable energy industries is crucial (Egli et al., 2018).

In developing economies, the share of state-owned energy investments in renewables and energy efficiency on average reached 50% in 2020. The same share in advanced economies is below 10%. Green and credit financing instruments under carbon emission policy suppression and an incentive

market interest rate show positive effects on renewable energy financing (**An et al., 2021**). Setting up an efficient Green credit policy framework limits non-low-carbon firms financing conditions under firms' property rights and debt financing diversity (**Liu et al., 2019**). According to a study by **Li et al. (2020b)**, companies with a more sustainable green governance structure in Chinese firms meet fewer funding constraints. The requirement for a unique financial mix for renewable energy results from special supply-side conditions, demand-side restrictions, and limitations in the framework conditions (**Lindlein and Mostert, 2005**). Green supply chain financing can assist manufacturers facing capital constraints to improve micro and macro environmental sustainability and financing conditions (**Fang and Xu, 2020; Wu and Kung, 2020**).

Financing renewable energy technology through green bonds discount makes them an attractive investment. They are a cheaper source for funding green investments by lowering issuer credit risk (lower cost of capital) and providing hedging against assets volatility and tax policy changes (**Agliardi and Agliardi, 2019; Azhgaliyeva et al., 2019; Barua and Chiesa, 2019; Heine et al., 2019; Li et al., 2020a,b; Maltais and Nykvist, 2020; Tu et al., 2020; Hyun et al., 2021**). Green bonds' attractiveness for financing renewable investments is contrasted by fossil fuel subsidies distorting energy prices under profit maximization, driving firms' to remain carbon fuel-intensive (**Covert et al., 2016; Mundaca, 2017; Becker et al., 2018; Barua and Chiesa, 2019; Gençsü et al., 2020; Li et al., 2020a; Plantinga and Scholtens, 2021; Cojoianu et al., 2021**). National and multinational development finance agencies (like China) significantly invest in green innovation (technology and management). It is a form of green subsidy to low-carbon committed firms to expand their financing sources. Green innovation and green labeling encourage both low-carbon and high-carbon firms to think and manage 'green' by getting generous green subsidies from the government (**Cui and Huang, 2018; Zhang et al., 2020; Chen and Zhang, 2021; Wang et al., 2021**). Green credits, supplied by partners investors, and financial institutions, backed up with long-term state financing schemes for green technology, are becoming a future significant green financing source (**Amran et al., 2018; Grilli et al., 2018; Mazzucato and Semieniuk, 2018; Yoshino et al., 2019**). Governments, multilateral and national development financial institutions, commercial banks, institutional investors, private equity, and venture capital play a significant role in financing the renewable energy sector. Sources, intermediaries, and financial instruments used to finance green innovation significantly differ across countries and regions (**Bobinaite and Tarvydas, 2014; Dörry and Schulz, 2018; Falcone et al., 2018; Halstead et al., 2019; Heine et al., 2019; Semieniuk and Mazzucato, 2019; Yoshino et al., 2019**). The literature lacks a comprehensive empirical study on the financial system's role in energy transition across countries, regions, and income levels. Previous works deal with the issue of green financing (financing conditions) at the micro (firm-level), case studies (one country), or regional level (European Union). Even so, such studies are focused on a particular aspect of financing renewable energy — cost of equity, capital, debt, subsidies, learning process in the green energy industry, green innovation, green financial instruments, and sources. Previous studies are also limited in time (no long time-series studies) and sample (no comprehensive panel time-series studies).

Table 1 lists the empirical studies on the link between financial intermediation and renewable energy consumption.

We find empirical evidence to support a causality link between finance (financing conditions) and green energy. Financing conditions mirroring countries' financial systems (financial institutions and financial markets) have implications for the energy transition. Countries with a developed financial system can supply a special financial instruments mix needed for renewable energy (green) investments and innovation.

3. Data and method

To study the importance of financial development on energy transition, we use a global sample of 214 countries/regions from 1960 to 2017 (**Beck et al., 2000a, 1999; Beck and Demirguc-Kunt, 2009; Čihák et al., 2012; Demirgüç-Kunt et al., 2013**). The dataset's time series properties limit our sample. Data from the World Bank database are available only in 2017. However, the panel time series data are available from 1960, assuring robust estimation, so data limitation to the end of 2017 (survey 2019) does not present severe limitations to our study. Following the investigation of **Beck et al. (2000b), King and Levine (1993) and Levine et al. (2000)**, we are interested in studying the link between financial intermediation (finance, financial development) and renewable energy use (energy transition). Our hypothesis states financial intermediation is necessary but not a sufficient condition for the energy transition. Here we explore if the hypothesis of financial intermediation as an essential condition for energy transition holds. To this end, we use the extensive database on financial structure with data from 1960 to 2017 for 214 countries and World Bank World Development Indicator Database (<https://databank.worldbank.org/source/world-development-indicators>).

Table 1 Literature summary on financial intermediation and renewable energy link.

Study	Design	Method	Sample	Findings
Abbasi and Riaz (2016)	Examines the impact of economic and financial growth on carbon emissions in a developing nation.	An augmented VAR approach	Pakistan 1970–2011	Financial growth does not contribute to the reduction of CO2 emissions; rather, it increases them.
Acheampong et al. (2020)	Impact of financial industry growth on carbon dioxide emissions	Instrumental variable generalized method of moment	83 countries 1980–2015	The overall development of the financial market and its sub-indicators have no direct effect on carbon emission intensity.
Ahmad et al. (2022)	Examines the impact of financial development, human capital, and institutional quality on the ecological footprint of emerging countries.	Cross-sectional autoregressive distributed lag (CS-ARDL)	17 emerging countries 1984–2017	Human capital, institutional quality moderates the statistically substantial positive effect of financial development on environmental quality.
Al Mamun et al. (2018)	Financial markets, innovations and cleaner energy production in OECD countries.	Mean group (MG) based on the assumption of the common correlated effect pooled (CCEP).	25 Organization for Economic Co-operation and Development (OECD) countries	Financial intermediation, especially commercial banking, increases the quantity of non-hydropower renewable energy (RE) produced, such as wind, solar, geothermal, and biomass.
Anwar et al. (2022)	Explores the impact of urbanization, renewable energy consumption, financial development, agriculture, and economic growth on CO2 emissions.	FMOL and DOLS	15 Asian economies 1990–2014	Long-term environmental degradation is caused by urbanization, financial development, and economic growth.
Baloch et al. (2019)	Researching the effect of economic growth on ecological footprint.	Driscoll-Kraay panel regression model	59 Belt and Road countries 1990 to 2016	The data indicate that economic growth increases ecological footprint.
Brunnschweiler (2010)	Finance for renewable energy: an empirical analysis of developing and transition economies.	Panel analysis	119 non-OECD countries for 1980–2006	Financial intermediation, especially commercial banking, increases the quantity of renewable energy (RE) produced, especially non-hydropower RE such as wind, solar, geothermal, and biomass.
Çetin et al. (2022)	Using financial development-CO2 emissions to study environmental degradation.	Dumitrescu-Hurlin panel bootstrap causality, AMG method	18 upper-middle-income countries, 1990–2018	One-way causality runs from renewable energy consumption to CO2 emissions. A bidirectional causality is observed between financial development and CO2 emissions.
Doytch and Narayan (2016)	An examination of the influence of sectoral FDI on industrial renewable and nonrenewable energy consumption.	Blundell–Bond dynamic panel estimator	74 countries for the period 1985–2012	Financial services FDI discourages the use of nonrenewable industrial energy.
Fakher et al. (2021)	This study examines how financial development affects economic growth and environmental quality.	System Generalized Method of Moment	OPEC and OECD countries, 2010–2019	Financial growth causes environmental damage.
Fareed et al. (2022)	Explore the relationship between financial inclusion and CO2 emissions and ecological footprint.	Method of Movements Quantile Regression	Eurozone 1995 to 2018	The results indicate that financial inclusion contributes to environmental degradation in the Eurozone.

Source: Authors' research.

For financial intermediation, we use variables covering (1) financial depth, (2) financial access, (3) financial efficiency, and (4) financial stability.

Table 1 (continued).

Study	Design	Method	Sample	Findings
Ji and Zhang (2019)	To what extent does financial development contribute to renewable energy growth and upgrading the energy structure in China?	Vector autoregressive model (VAR)	China	Financial development is crucial and accounts for 42.42 percent of the variance in renewable energy growth.
Kim and Park (2016)	Financial development and deployment of renewable energy technologies.	Panel analysis	30 countries	In nations with developed financial markets, renewable energy sectors that rely heavily on external financing grow disproportionately more quickly.
Mosleh et al. (2022)	Evaluating the impact of globalization, energy use, and financial growth on Japan's CO2 emissions.	Autoregressive Distributed Lag (ARDL)	Japan 1990–2019	Japan's CO2 emissions have increased due to the usage of fossil fuels, economic growth, and financial development.
Nguyen et al. (2021)	Examining the influences of financial development and institutional quality on energy consumption.	Dynamic two-step system GMM estimations	Sample of 112 countries between 2002 and 2014	In a weak institutional framework, financial development increases per capita energy use. In a well-developed institutional environment, it decreases it.
Paramati et al. (2017)	The effects of stock market growth and renewable energy use on CO2 emissions: Evidence from G20 countries.	FMOLS, short-run dynamic bivariate panel causality	G20 countries	Long-term CO2 emissions are linked to stock market capitalization, FDI inflows, and renewable energy consumption.
Pham (2019)	The impact of financial development on renewable energy innovation.	Panel data	22 OECD countries	Financial development plays a crucial role in the development of both biomass and non-biomass renewable technologies.
Shahbaz et al. (2021)	Study the impact of financial development on renewable energy consumption in 34 developing countries with upper middle incomes from 1994 to 2015.	Fully-Modified OLS (FMOLS) approach	34 upper middle income developing countries	The demand for renewable energy increases, and greenhouse gases decreases with financial development.
Wang et al. (2020)	The impact of green finance on inclusive economic growth from 2005 to 2019.	Spatial econometric analysis	31 provinces in China	Green finance is an essential method for promoting inclusive economic growth.
Xu et al. (2020)	Comprehensive Meta-Analysis	Comprehensive Meta-Analysis	30 empirical studies, sample size 62051	There is a significant positive correlation between green finance and enterprise green performance.
Ye et al. (2022)	Examines the effects of green financial development, including green credit, green investment, and green securities, as well as corporate social responsibility.	Autoregressive distributed lag and error correction	Pakistan 1976–2020	Green credit, green investment, and green securities, as well as CSR reporting and economic growth, were found to have a significant positive relationship with renewable energy investment.
Zhang et al. (2021)	Exploring the investment and financing behavior changes of enterprises and environmental impacts of the green credit policy.	Difference-in-difference (DID) model	945 A-share listed companies and 30 provinces in China 2004–2017,	The green credit policy improves the quality of the environment by influencing corporate financing and investment.

We study the link between financial intermediation in overall (all financial structure indicators) and a specific financial intermediation dimension (depth, access, efficiency, stability) with renewable energy use. The dependent variable is the renewable energy measured as — renewable power is based on gross generation from renewable sources, including wind, geothermal, solar, biomass and waste, and not accounting for cross-border electricity supply, Terawatt-hours (Dale, 2022; Energy Agency, 2021). The list of selected nations/regions and variables can be found in Tables A1 and A2 of the Appendix.

In this study, we address this gap using data from the Global financial development database of 1960-2017 on 214 economies, The Financial Structure database, The World Bank database, The AMECO database, and The World Intellectual Property Organisation database. Our research here reports

empirical evidence on the financial system development (financing conditions) causal link with renewable energy and; the finance-green energy nexus. Here we use renewable energy indicators over thirty-one financial development and structure indicators for 214 countries, providing the first comprehensive empirical investigation on the finance-green energy link to our knowledge. Here we study the impact of a change in financial institutions and markets' depth, access, efficiency, and stability on investments in renewable energy.

Three time-varying control variables are included to adjust for the omitted variable bias, making our conclusions more logical and plausible. However, explanatory factors are the primary focus of this study. A study of the relevant research found that numerous national/regional macro-level factors may influence green energy use. Therefore, the control factor indicators we evaluate are per capita *GDP*, energy intensity, and innovation (patent), all of which have been extensively studied and confirmed in the literature (**Del Rio and Kiefer, 2022; Ohler and Fetters, 2014; Yu et al., 2022**).

Our data panel is unbalanced since all variables listed in the sample data observations are not available from surveys across all countries and times. Before setting up the regression model, we test data for cross-section dependence and stationarity. We use the (**Pesaran, 2015**) test for cross-section dependence and second-generation panel unit root tests (**Bai and Ng, 2004; Breitung and Candelon, 2006; Gengenbach et al., 2009; Moon and Perron, 2004; Pesaran, 2007, 2004**). We do not list the test results here due to space publication limits (available upon request). Both individual intercepts and trends are performed. All constructed variables are stationary, as the tests prove.

The final step is the optimal estimate from the pooled *OLS*, *FE*, and *RE* estimators.

The findings of the F (Chow), Breusch-Pagan LM, and Hausman tests are not listed here. The null hypothesis for the F (Chow) (**Chow, 1960**) and Breusch-Pagan LM test

Breusch and Pagan (1979) Suggests the pooled *OLS*. The statistical outcomes of all three models reject the null hypothesis at the 1% significance level. In other words, the study's panel estimations do not apply to the pooled *OLS*. The Hausman test compares, in addition, the appropriateness of the *FE* and *RE* estimators. The findings show the former is superior due to the rejection of the null hypothesis of *RE*. In the subsequent stage, the model is estimated using the Driscoll-Kraay two-way fixed effect technique (**Driscoll and Kraay, 1998**). Country/region- and time-specific disturbances are under control under these conditions. Other possible estimation techniques in the state of the unbalanced panel and cross-sectional dependence could also be applied. Moreover, arguments favoring the Driscoll-Kraay approach are substantiated (**Hoechle, 2007; Reed and Webb, 2010**).

Our estimation model takes the form,

$\ln\text{renewables}_{it}$

$$= \alpha + \beta_{\text{lgdppc}} \cdot \text{lgdppc}_{it} + \beta_{\text{lpatot}} \cdot \text{lpatot}_{it} + \beta_{\text{lintensity}} \cdot \text{lintensity}_{it} + \beta_{\text{finandev}} \cdot \text{finandev}_{it} + \epsilon_{it} \quad (1)$$

with $i = 1, \dots, 214$ denotes the country, and $t = 1, \dots, 58$ is the year and disturbance term ϵ_{it} .

$\ln\text{renewables}$ as dependent variable measures renewable energy consumption in terawatt-hours. lgdppc present GDP per capita in constant 2010 US\$. lpatot express number of total patents in the region. CO_2 intensity is listed as lintensity measured in kg per kg of oil equivalent energy use. Variable finandev for each region is expressed as different proxy measures for regions' level of financial development. All variables are expressed in natural logarithm form. The variable finandev measures the impact of financial development across 31 variables we use as a proxy to evaluate financial

development's impact on renewable resource use. Variables are defined in Table 2 in the appendix. Following the research in **Table 1**, we want to conduct a comprehensive study on the link between financial development and renewable energy.

Hypothesis 1. Financial development is a necessary but not sufficient condition for the energy transition.

Hypothesis 2. Financial intermediation is crucial for renewable energy consumption growth.

Hypothesis 3. Fossil fuel subsidies decrease the use of renewable energy.

Hypothesis 4. Financial institutions and markets demonstrate a low level of green financial literacy, resulting in a restricted investor pool and low investor confidence in green investments.

We set and estimated a separate regression model for each region sample to get regression results. A summary of regression results is provided in the appendix online due to the length of the tables.

4. Results

4.1. East Asia and the Pacific

The financial system in East Asia and the Pacific is a significant constraint for investments in renewable energy technologies. Our empirical results (Table A3) show that the region has not yet transitioned to the green growth model. Fossil fuels (oil, gas, and coal-fired electricity generation) represented 73.8% of the total electricity generation capacity in 2015. Green investments are focused mainly on solar and wind energy potential, with other green technology lagging (Egli et al., 2019).

Financial investors have high expectations of renewable energy investments resulting in a negative link between bank return on assets (lroa) and renewable energy in use. For a 1% increase in the bank ROA, renewable energy use falls by -0.11%. Equity investors show risk aversion to renewable energy investments resulting from opinion divergence on appropriate business and investment models, project impact and expected returns, and investment payback period. Empirical evidence supports this by finding no statistically significant link between renewable energy consumption and return on equity. Financial institutions and markets show a low level of financial learning resulting in a limited spectrum of investors and low investors' confidence supporting the thesis of financial learning. Our study results prove it since we find no statistically significant link between financial institutions, market equity indicators, and renewable energy consumption. To improve equity financial conditions, policymakers could use state 'green' banks to support renewable energy investments and attract private investors (crowding-in effect) - (0.28 lzscore impact).

The cost of debt measured by real interest rate (lrate) shows a negative elasticity coefficient of -0.19. A rise in the market real interest rate by 1% results in a higher cost of debt for renewable energy investments reducing renewable energy consumption by 0.19%. Debt financing shows a positive and statistically significant impact on renewable energy consumption but is limited in size. For a percent increase in public bond market capitalization (lpubond), renewable energy consumption rise by 0.38%. Attracting international investors and financing (international debt issue - lintldebt) have a positive and limited impact on green energy consumption. The elasticity coefficient is just 0.38 for a 1% rise in

international debt securities (*IDS*) issued outside the local market. Loans from non-resident banks (increase by 1%) drive renewable energy consumption by +0.31%.

Here we measure the impact of the cost of capital on renewable energy consumption using the real internal rate of return (*lirr*). The elasticity coefficient is negative -1.68, meaning a 1% increase in the real internal rate of return renewable energy use decreases by -1.68%. The substantial and statistically significant effect supports the thesis that investors expect unrealistic returns on renewable energy investment projects. A rise in the economy's real internal rate of return discourages investors from investing in the green industry. Increasing liquidity in the financial sectors (*llgdp*) stimulates green investments and rising renewable energy consumption. For a 1% increase in financial system liquid liabilities, renewable energy consumption rise by 0.78%. A percent increase in the central bank assets (*lcbagdp*), deposit money banks assets (*ldbagdp*), and banks deposits to *GDP* (*lbdgdp*) results in renewable energy consumption growth by 0.19%, 0.44%, and 0.72%. Output rise followed by liquidity rise in the financial system positively impacts renewable energy consumption. Conversely, a 1% increase in deposit money banks' assets aside from the output rise will result in a significant drop (-2.22%) in renewable energy consumption. Banks, in times of increasing liquidity (deposit money), invest in fossil energy industries to seize the opportunity to make large expected profits.

Financial markets have a positive but limited effect on renewable energy use, with a stock market turnover ratio (*lssturnover*) of 1%, resulting in a 0.17% increase in renewable energy consumption. Output size measured as *GDP* per capita shows the most significant impact on renewable energy consumption. For a 1% increase in *GDP* per capita (*lgdppc*), renewable energy consumption rise on average by 4.01%. Policymakers in the region understand they can maximize the economic benefits of the transition to sustainable energy. Benefits depend on many enabling factors, including a diverse economy and sufficient market capacity to absorb job creation opportunities, as well as training and training that contribute to developing a skilled and versatile workforce. Economic growth also depends on increasing investments in renewable energy without reducing investment in other sectors of the economy (Egli et al., 2018).

The empirical evidence on the impact of fossil fuel subsidies on renewable energy use is mixed. As a proxy for fossil fuel subsidies, we use data on CO₂ intensity (*lintensity*). CO₂ intensity is expected to fall if fewer subsidies are available. The impact of subsidies on renewable energy consumption is negative and statistically significant, varying across estimated models from -0.93% to -2.97%. Thus, fossil fuel subsidies harm renewable energy consumption. Post-tax subsidies (in % of the *GDP*, 2016) level in the region is high, with China at 14.91%, Thailand at 9.71%, and Mongolia at 32.3%. Green technology development and installation costs are high, measured by (*lpatot*), the number of patent applications (resident and non-resident). There is a negative link between the number of patent applications and renewable energy consumption, with an average impact of -0.26% for a 1% increase in the total number of patent applications.

Besides a few improvements in financing conditions, financial development in the region is still a limiting factor for energy transition and renewable energy consumption's more significant rise.

4.2. Europe and Central Asia

Financial development in Europe and Central Asia supports renewable energy investments to achieve the energy transition (Table A4). Unlike in East Asia and the Pacific, policymakers are more open to the change to sustainable energy and development benefits. As a result, the region has moved to energy transition and green growth models. Electricity production from oil, gas, and coal sources (% of total)

was 49% compared to 75% in East Asia and the Pacific in 2015. Our empirical results here show macroeconomic and energy development conditions (public/social awareness and willingness, policy, legal framework, fossil fuels orientation, energy sector competition) are crucial to leverage financial development and improve financing conditions for renewable energy entrepreneurs.

Policy and legal framework reward renewable energy investors, thanks to explicit energy transition policy targeting, driving green technology adoption, and the levelized costs of electricity down. A broad financing policy mix is available to green investors making investments in the green industry easier. The cost of debt, equity, and capital plays an essential role in the green market. Still, financial institutions, markets, equity, and debt investors, development banks, and governments are open to the idea and benefits of investing in renewable energy. Equity and debt investors are open to renewable energy investments but careful about collateral, tenure, hedging costs, financial literacy (learning), expected returns, financial assets supply, banking system liquidity, and financial markets stability. Investors are driven by the same equity and debt finance determinants as traditional investments, but in the case of green investments, their reactions are more sensitive (elastic). For a 1% increase in the bank's return on equity, investors will search for more traditional investment forms driving renewable energy use down by -0.30% (*lroe*). Almost the same reaction holds for banks' return on assets with an elasticity coefficient of -0.24 (*lroa*). Change in market real interest rate impact on renewable energy consumption is statistically significant only at 10% with an elasticity coefficient of -0.13 (*lzscore*). Commercial private equity funds and investors are highly sensitive to volatility in the real internal rate of return (*lirr*). With an increase in (*lirr*) of 1%, investors look for more traditional investments demanding too high returns on green investments. That results in renewable energy consumption dropping by -1.56%.

A rise in financial assets (deposit money bank assets, *ldbacba*) positively affect renewable energy investments. For a 1% increase in bank assets, renewable energy consumption rise by 1.72%. A surge in deposit money bank assets to GDP (*ldbogdp*) will have the same positive effect but slightly lower (1.01%). The impact of rising financial assets in other financial institutions is positive but limited to 0.25% (*loafgdp*). Here we see private credit by deposit money banks and other financial institutions are a significant financial source for renewable energy. An increase in private credit by 1% results in a 1.16% rise in renewable energy use in the region. Financial assets increase by 1% due to bank deposits to GDP (*lbdgdp*) rise will drive up demand for renewable energy by 1.60%. An increase in the financial system's liquidity also reroutes investors toward green investments raising renewable energy consumption by 0.41%. Financial system efficiency (overhead costs - *loverhead*) and banks' net interest margin (*linetmargin*) have a negative but limited impact on renewable energy consumption. Increasing banks' overhead costs destimulate renewable energy use by -0.34%. A rise in the bank's net interest margin (rising costs of debt, credit spread) causes a drop in renewable energy use by -0.19%.

Life insurance firms are not particularly interested in green financing. For a 1% increase in the life insurance premium volume to GDP (*linslife*) only 0.24% will be placed in the renewable energy industry. Financial markets also show a limited connection to green investments and industry. Rising stock market capitalization to GDP (*lstmktcap*) by 1% will drive renewable energy use down by -0.20%. Conversely, a percent increase in the stock market turnover ratio (*lssturnover*) causes renewable energy consumption to rise by 0.17%.

Debt financing in the region shows a positive link to renewable energy investments. A percent increase in private bond market capitalization to GDP (*lprbond*) results in a rise of 0.17% in renewable energy use. Loans from non-resident banks to GDP (*lintledebt*) positively impact renewable energy consumption. International investors look optimistic about financing the green industry in the region. A percent increase in international debt securities will increase renewable energy consumption by

0.45%, while a rise in offshore bank loans (*lnrbloan*) will drive up green energy use by 0.31%. Offshore bank deposits (*loffdep*) do not find their way to green investments, driving green energy use down by -0.28%.

Renewable energy investments in the region are highly affected by the growth model in use and fossil fuels subsidy policies. Policymakers in the region recognize and understand opportunities to maximize the benefits of the green energy transition. Consequently, the average elasticity coefficient to a percent rise in the real *GDP* per capita (*lgdppc*) for renewable energy consumption is 6.53%. In addition, policymakers and investors recognize favorable economic growth trends to stimulate investments in the green industry, expecting future economic growth, profits, and welfare returns. Thus, economic growth encourages renewable energy consumption to a significant extent (elasticity coefficient 6.53).

Fossil fuel subsidies remain a critical determinant of the green energy transition. Our empirical results show that fossil fuel subsidies measured as (*lintensity*) cause an average drop in renewable energy use of -1.55% for a percent increase in (*lintensity*). Here we can observe that Europe and Central Asia financing development improves green investments, having a sizeable and statistically significant impact on renewable energy use in the region.

4.3. Latin America and the Caribbean

The financial development of Europe and Central Asia supports the investments in renewable energy necessary to achieve the transition in the energy sector (**Table A5**). More like the condition in Europe and Central Asia, policymakers in Latin America and the Caribbean have become more receptive to sustainable energy and development benefits. The region is progressing in terms of energy transition and sustainable growth models. Oil, gas, and coal-fired electricity generation (a percentage of the total) was 44% in 2015. Financial development supports favorable green financing conditions (better than East Asia and the Pacific and less fortunate than Europe and Central Asia). Public/social awareness and willingness, policy and legal framework, the orientation of fossil fuels, and competition in the energy sector give positive support to renewable energy entrepreneurs. The support is significant, but not as in Europe and Central Asia.

Policymakers, financial institutions, markets, and debt and equity investors appreciate the opportunity to return to green investments but still with significant risk perception. Increasing banking sector profitability (a 1% increase in bank *ROA* - *lroa*, and *ROE* - *lroe*) positively affects renewable energy consumption. Improving the health conditions of the banking sectors is a sign that institutional and private investors hedging on green investments is declining, so they turn more to green industry financing. A percentage increase in bank *ROA* increases renewable energy consumption by 0.28%, and for *ROE*, the growth is 0.25%. The elasticity effects are not significant but are positive and statistically significant.

Regarding the real internal rate of return dynamics (*lirr*), investors, like in other world regions, show unrealistic expectations of the expected real internal rate of green investments. Thus, increasing real internal return by 1% discourages institutional and private investors, resulting in a drop of -1.56% in renewable energy use. The effect is, on average, like the registered effect in the other two previous regions. An increase in financial sector liquid liabilities signals investors on positive liquidity trends to direct part of planned investments to renewable energy (0.77% increase in renewable energy use of a 1% rise in *lgdp*). The same effect is visible for an increase in deposit money bank assets to *GDP* (*ldbagd*) with an elasticity coefficient of 0.58. A rise in other financial institutions' assets (*loafgdp*)

is statistically significant at 10%, with an elasticity coefficient of 0.09. More private credit extended to the non-financial private sector positively impacts renewable energy consumption (elasticity coefficient 0.34). Deposit growth (*lbdgdp*) increases renewable energy use by 0.86% for a 1% increase in bank deposit to *GDP* ratio. A rise (1%) in the absolute value of liquid liabilities (*ll_usd*) impact is positive, increasing renewable energy consumption by 0.45%.

Worsening in the financial sectors (rising costs, profit decline, interest rate margin volatility) affects the financing condition for green investments, resulting in a negative impact on renewable energy use. For example, an increase in (overhead - 10% significance level) banks' overhead costs (1%) decreases investments in the green industry, resulting in a decline of -0.56% in green energy consumption. In addition, worsening the banks' position (bank cost to income ratio -*lcostinc*) results in crowding out institutional and private investments in the green industry by a significant -2.08%. We observe the same negative effect (limited in scale - *lnetintmargin*) for a 1% increase in banks' net interest margin, driving renewable energy consumption down by -0.27% (10% significance level).

Insurance companies funding green investments have a positive but limited effect (elasticity coefficient 0.49 for *linslife*). Financial markets are linked to renewable energy consumption, but the link is not supportive. Stock market capitalization increase supports a rise in renewable energy use by 0.37% (*lstmktcap*). However, the rising stock market turnover ratio (*lssturnover*) and the number of listed companies (*l listo_pc* - per 10.000 population) hurt green investments. The increasing stock market turnover ratio decreases green investments and energy use by -0.30%. The negative effect of several listed companies reduces renewable energy use by -1.49%. Equity investors will likely search for fossil fuels equity investments over renewable energy equity investments. Debt financing in private (*lprbond*) and public bond financing (*lpubond*) as supportive financing sources for green investments has positive but limited effects (elasticity coefficients 0.15 and 0.17). International debt financing as a source of renewable energy financing has a positive but limited impact on scale. Financing green investments through a rise in international debt securities (*lintldebt*) by 1% will increase renewable energy consumption by 0.20%. Loans from non-resident banks made available to green entrepreneurs will increase renewable energy use by 0.18% for a 1% increase (*lnrbloan*). An increase in offshore bank deposits harms renewable energy consumption since they are unavailable to green investors (*loffdep*). Net remittance inflows as a share of *GDP* (*lremit*) support green investments with a limited scale effect (elasticity coefficient 0.29).

Energy transition in the region is still on the move. There is insufficient public and private awareness of the benefits of the energy transition, making financial institutions and markets risk-averse to green investments. Investment in renewable energy in the region is strongly affected by the growth model in use and subsidy policies on fossil fuels. Subventions for fossil fuels remain essential to the transition to green energy. According to the results, economic growth significantly stimulates renewable energy use. The empirical results of the study show subsidies for fossil fuels cause an

4.4. The Middle East and North Africa

The development of the Middle East and North Africa region relies heavily on fossil fuels with a low energy transition level (**Table A6**). Fossil fuel energy sources (oil, gas, and coal-fired electricity generation) accounted for 89.4% of the total electricity production in 2015. However, policymakers' orientation and public awareness of the importance of energy transition and sustainable development of the regions are still missing. To provide renewable energy in the *MENA* region, fundamental market and pricing reforms are required, leading to different energy sources in each domestic market. Barriers to renewable energy transition here include sustained regional consumption of fossil fuels, electricity,

and domestic fossil fuels pricing mechanism, energy market control (privatization), fiscal and regulatory framework for renewable energy markets and lack of a clear policymakers decision statement to replace the fossil fuel growth model with a green growth one.

As expected, our empirical findings show that financing conditions in the *MENA* region exemplify a hostile renewable energy financing policy. Financial institutions and markets show high-risk aversion, unrealistic assets, and equity returns on renewable energy investments pushing out the renewable energy market for private and public investors. Green entrepreneurs face unfavorable renewable energy targets, a regulatory policy (tariff/premium payments, a quota on electricity use, biofuels and heat obligation, tradable renewable energy certificate, tendering), fiscal incentives, and public financing (subsidies, grants, tax credits, carbon taxes, tax benefits, energy production payment, green public investments, loans).

An increase in financial system liquidity (assets or debts) has only a negative impact on renewable energy consumption in the region. Improvement in the banking sector condition (*lzscore*) destimulates investors in the green industry, driving renewable energy consumption down by -2.19% for a percentage increase in the banking system z-score. The region's debt financing (cost of debt) shows a negative link to renewable energy investments (*lrate*). Increasing the real interest rate harms renewable energy use (-0.26% for a 1% increase in *lrate*). Rising banks' overhead cost (*loverhead*) drives renewable energy consumption down by -1.51%, crowding out public and private investments in the green sector. Debt financing rise (*lbdgdp* 1% rise) makes more financial assets available for investing in the green industry, resulting in a 1.26% increase in renewable energy use. The same holds for the liquid liabilities (*ll_usd*) with an elasticity coefficient of 0.91. Growth in liquid liabilities over the GDP growth rate hurts investors in green energy (higher opportunity costs of green investments), causing renewable energy to fall by -2.35% for a percentage increase in (*llgdp*). International debt financing sources harm renewable energy, decreasing by -0.23% for a percentage rise in (*lintldebt*) and -0.96 for (*loffdep*).

Investing in renewable energy in the region is directly linked to how growth is pursued and the type of fossil fuel subsidies implemented. Policymakers do not get green energy transition opportunities and do not know how to maximize their benefits. There is a significant relationship between the percent rise in the real *GDP* per capita (*rgdppc*) and the elasticity coefficient of renewable energy consumption, so the average elasticity coefficient to a percent rise in the real *GDP* per capita (*rgdppc*) is 13.46 percent. Based on this fact, the energy transition in the *MENA* region could speed up convergence rapidly (catching up with the rest of the world) if only policymakers acknowledge the potential benefits they could get from the transition to green growth. Trade-off costs on energy transition in terms of opportunity costs (lost *GDP*) for a 1% increase in renewable energy consumption is only -0.06%. Thus, the costs of energy transition in the *MENA* region are small, but policymakers and investors seem unaware of them. Therefore, the negative impact of fossil fuel subsidies is high (*lintensity*) with an average elasticity coefficient of -3.38. Adverse financing conditions also constrain green innovations. A percentage increase in (*lpatot* - new patents granted are 'non-green' patents since investors are not willing to support riskier 'green patents') drives renewable energy use down by -1.41% in the region.

4.5. North America

In 2015, fossil fuels (oil, gas, and coal-fired electricity generation) accounted for 60.8 percent of total power consumption in the region (**Table A7**). Green investors have access to various financing options, investing in green industries easier. Financial institutions, markets, equity, and debt investors, development banks, and governments are all open to the concept and benefits of investment in

renewable energy. However, investors are cautious about collateral, tenure, hedging costs, expected returns, supply of financial assets, liquidity in the banking system, and stability in the financial markets.

Financing conditions favor green entrepreneurs but are less favorable than Europe and Central Asia. Cost of equity (*lroe*), assets financing (*lroa*), and cost of capital (*lirr*) have no significant (no statistical significance) effect on institutional and private investors' choice to invest in the green industry. The rising cost of debt (*lrate*) destimulates green energy use by -0.19 (*limited effect*). Green investments and energy transition in the region depend mainly on the value of financial assets. The increasing value of financial assets due to an increase in liquid liabilities (*llgdp*) and deposit money bank assets (*ldbogdp*) positively affect renewable energy consumption. The elasticity coefficient for (*llgdp*) is 1.33, with a financial assets increase of 1%, raising renewable energy consumption by 1.33%. The same effect holds for (*ldbogdp*) with an elasticity coefficient of 1.46, with renewable energy consumption rising by 1.46% for a percent increase in deposit money bank assets). As a result, investors are more willing to finance green projects and support green entrepreneurs with more available assets. The same fact is proved for (*loafgdp*) with other financial institutions' assets increasing renewable energy consumption (elasticity coefficient 0.99). An increase in financial assets reduces the financing gap for green investments. Banks and other financial investors foresee a rise in financial assets as a profit opportunity to direct investments in the green sector. The impact varies across debt financing indicators, close to the unit elasticity. A rise in private credit by deposit money banks (*lpcrdbogdp*) encourages green investments and renewable energy use by 1.34% for a percent increase in (*lpcrdbogdp*). The impact is like the increase in private credit by deposit money banks and other financial institutions (*lpcrdbogf*) with an estimated parameter of 1.26% for a percentage increase in the credit volume. Deposits as a source for green debt financing show a positive effect close to unit elasticity. Estimated parameters are (*lbdgdp*) 0.96% and (*ll_usd*) 0.99%, showing an increase in bank deposits and liquid liabilities, and renewable energy use is close to 1%.

Life insurance funds do not show interest in investing in the green industry, and projects harm renewable energy consumption when life insurance premium volume increases (*linslife*). The adverse effects equal -0.98% for a percentage rise in (*linslife*). Financial markets show interest in investing in green projects. However, the effect is limited in scale, with financial markets investing more in green projects resulting in renewable energy increases. A percentage increase in the stock market total value traded (*lstvaltraded*) renewable energy rises by 0.30% and 0.36% for a stock market turnover ratio (*lstturnover*) increase.

Green bonds (public and private) are critical financial sources for green regional investments. An increase in private bond market capitalization (*lprbond*) by 1% increases investments in the green industry and, thus, renewable energy use by 1.35%. Public bonds (*lpubond*) also attract private and institutional investors (crowding-in effect) to invest in the green sector, increasing renewable energy consumption by 1.05%. However, international investors and associated financial assets have a negative impact on renewable energy consumption. The inflow of loans from non-resident banks (*lintldebtnet*) is directed to fossil fuel investments, resulting in renewable energy use declining by -0.35%. Offshore bank loans relative to *GDP* (*lnrbloan*) have the same effect with an elasticity coefficient of -0.35. The impact of the offshore bank deposits increase is close to (*lintldebtnet*) and (*lnrbloan*) with an estimated elasticity coefficient of -0.29.

We observe a significant positive link between renewable energy use and real *GDP* per capita (*lgdppc*). The average elasticity coefficient is 2.05, with an increase in renewable energy by 2.05% for a percentage increase in (*lgdppc*). The result is expected under energy transition dynamics in the region, with green growth accounting for a significant share of the total real *GDP* per capita growth. With the financing supply mix available to green entrepreneurs, green investments result in a higher

green technology adoption rate with an average elasticity coefficient of 0.81. Fossil fuel subsidies are the main limiting factor to energy transition in the region. A fact is that renewable energy in use drops by -7.59% for a percentage increase in CO₂ intensity (caused by a fossil fuel subsidy increase). Fossil fuel subsidies are a significant obstacle to energy transition in North America.

4.6. South Asia

South Asia is dominantly based on fossil fuel growth and development. In 2015, fossil fuels (oil, gas, and coal-fired electricity generation) contributed 80.0 percent of the region's total electricity consumption. However, policymakers' orientation and public awareness of the critical nature of energy transition and regional sustainability are still insufficient. Renewable energy provision in the region will require fundamental market and pricing reforms leading to diverse energy sources within the national markets. Barriers to renewable energy transition in this region include sustained regional consumption of fossil fuels, electricity, and domestic pricing mechanisms for fossil fuels, energy market control (privatization), a fiscal and regulatory framework for renewable energy markets, and a lack of a clear decision to abandon the fossil fuel growth model. The region's financial development and financing conditions mirror the above limitations (**Table A8**).

The Association of Southeast Asian Nations (*ASEAN*) is moving toward a green paradigm by investing in renewable energy infrastructure, reflecting both governments' efforts to reduce carbon emissions and the lower costs associated with technology and economies of scale. Institutional and private investors in the region are aware of the government's commitment to the energy transition, which results in a crowding-in investment effect in the green industry. The area is developing a global renewable energy capacity program. The renewable energy construction program in the region planned for the 2021-2030 period amounts to approximately 40.000 US\$ million. Such a program will give a substantial crowding-in push to green investments in the area. Our empirical study results support the crowding-in effect for South Asia. Volatility in equity costs drives green investments in the region. A percentage rise in the cost of equity (*lroe*) stimulates banks and other financial institutions to advance funds for green investments, resulting in a 1.53% increase in renewable energy use. The same holds for asset financing, with a 1% increase in (*lroa*) and a 1.22% (elasticity) increase in renewable energy consumption. Financial liquidity improvement (rise in liquid liabilities in the financial system - *ll_usd*) by 1% has the most significant impact on renewable energy use. For a 1% increase in financial system liquidity, renewable energy consumption decreases by a substantial -3.72%, with funds going to non-green investments. Banking system concentration in the region has a similar effect, with a 1% increase in concentration leading to a -3.58% drop in renewable energy consumption. Big banks in the area generally do not prefer to do business with green firms and investors.

In summary, financial conditions in South Asia are not favorable for green entrepreneurship and green investments. Policymakers are not yet willing to opt for an energy transition with a financial system supporting the same policy, generally avoiding financing green investors and firms.

4.7. Sub-Saharan Africa

Fossil fuel energy sources accounted for 64.1% of the total electricity production in 2015 in Sub-Saharan Africa. The entire energy transition supporting scheme has raised six billion US\$ since 2003. Although policymakers and the public are generally aware of the region's climate change challenges, awareness of energy transition necessity is still lacking (**Table A9**). Renewable energy consumption

share in total final energy consumption (2015) was 70.1%. The cost of equity shows a limited impact on renewable energy (-0.102). The profitability and soundness of the financial system banking system and dynamics in the central bank referent interest rate do not change financing conditions for green investments (-0.123). The cost of capital measured by (*lirr*) shows a positive and significant impact on renewable energy. They have an estimated elasticity coefficient of 1.91, displaying investors' readiness to financially support green investments with (*lirr*) rise making them more attractive for investing. An increase in liquid liabilities (*llgdp*) in the region goes for companies' debt repayment and improving liquidity position to green investments. A negative elasticity coefficient of -5.212 shows a drop in renewable energy consumption for a percentage increase in liquidity is high. Banks are also more open to green investments. Deposit money bank assets (including central bank assets) increase (*ldbacba*). For a percentage increase in deposit money banks, renewable energy use increased by 24.62%. Thus, favorable deposit money bank asset conditions stimulate green investments in the region. The same holds for deposit money bank assets increase (*ldbagd*) with an elasticity coefficient of 5.35. An increase in system liquidity allows money to find its way to national development banks willing to finance green investments. Central bank assets' impact on green investments is significant but minor, with an elasticity coefficient <1 (*lcbagd*).

An increase in other financial institutions' assets (*loafgdp*) also stimulates green investments with an estimated elasticity of 1.827. Dominating form to support green financing is private credit by deposit money banks (*lpcrdbgd*) with an elasticity coefficient of 4.458. Taking into account also other financial institutions ready to help green investing lowers the elasticity coefficient to 2.418 (*lpcrdbogdp*). An increase in bank deposits (*lbgdp*) is necessary for growth in green financing support with an elasticity of 9.816. Banking system concentration (*lconcentration*), overhead costs (*loverhead*), life insurance premium (*linslife*), and net interest margin (*lnetintmargin*) show only a minor impact on green financing with an elasticity coefficient <1 or close to one.

The same holds for financial market conditions with a stock market capitalization (*lstmktcap*) elasticity coefficient of 2.16 and total value traded (*lstvaltraded*) of 0.858. Stock market turnover (*lssturnover*) shares the same impact (elasticity 0.809). Public listed companies show aversion to green financing with a negative elasticity coefficient (-2.26) that can also be seen on the private bond market (*lprbond*) with an elasticity of -1.13. National development banks and public bond markets are more open to green investors. Public bond market capitalization increase leads to a rise in renewable energy use (elasticity 1.861) backed by international debt issues (elasticity $lntldebt = 0.875$). International financial support to green financing is limited with ($lnrbloan = 0.883$) loans from non-resident Bank, offshore bank deposits ($loffdep = 0.393$), and remittance inflows ($lremit = 0.895$) having only a minor impact on renewable energy use in the region.

Patent and innovation show no link with renewable energy use supporting the assumption of weak nexus between financing conditions and green innovations (*lpatot*) with an average elasticity of -0.30. Fossil fuels financing support schemes destimulate green investments with a significant impact on renewable energy use. The effect is sizeable, with an average elasticity coefficient of -8.04. The negative impact of fossil fuels subsidies in green investments and renewable energy in use is 8.04% for a 1% increase in (*lintensity*). Fossil fuels subsidies set up a significant constraint for green investments in the region.

5. Discussion

Adverse socio-economic effects of climate change start to show significant negative impacts on output (*GDP*, which is even more damaging calculated using green *GDP* indicator), food prices, scarcity,

poverty, inequality, and unemployment. Technology is available to fight the problem, but we are missing the money to finance it. Banks and other financial institutions invest three times less in green investments. That leaves fossil fuel investments as preferred to green. Financial systems worldwide are not yet set up to provide the financing support needed to speed up the energy transition replacing old growth models with green growth. The reason is that financial institutions' profits are still the primary motivating factor. To move their attention from fossil to green investments, financial institutions demand an average return on investments 5%—10% higher than the average market ROI. The same holds for *ROE* and *ROA*, discouraging green technology and energy transition. Governments still promote policies favoring fossil fuels, supporting them, with subsidies being the primary constraint for the energy transition.

Financing conditions for green investments are limited and constrained by insufficient government support, sluggish green taxation introduction, and financial markets transferring the risks and uncertainty on green investors, resulting in high renewable energy and green infrastructure costs. The same conclusion can be found in the study of **Egli et al. (2019)**. As expected, renewable energy consumption depends on output (*GDP*) with elasticity coefficients ranging from 1.45 (North America) to 25.99 (Middle East). The elasticity coefficient between renewable energy and *GDP* varies across regions.

Green technology is necessary but not sufficient condition for the energy transition. Green financing conditions are. The cost of capital hurts green financing conditions in East Asia and the Pacific (-1.68), Europe and Central Asia (-1.56), and Latin America and the Caribbean (-1.56). In the Middle East, North Africa, North America, and South Asia, the cost of capital have no significant impact on green financing. The cost of capital positively impacts green financing (a rise in IRR increases green investments) only in Sub-Saharan Africa. Our results corroborate the results of **Egli et al. (2018, 2019)** and **Kempa et al. (2021)**.

The cost of debt has no significant impact on green investments in Europe and Central Asia, Latin America and the Caribbean, South Asia, and Sub-Saharan Africa. However, change in the cost of capital harms green financing in East Asia and the Pacific (-0.19), The Middle East and North Africa (-0.26), North America (-0.19) supporting (**Ameli et al., 2021; Kempa et al., 2021**).

Green bonds show potential promise for green investing, as our results show in line with (**Fatica and Panzica, 2021**). Green bonds issued by development banks and financial and non-financial institutions boost green investments, resulting in a rise in renewable energy use. A positive and significant effect on green producers through green bond channels is visible in East Asia and the Pacific (0.38), Latin America and the Caribbean (0.17), North America (1.05), and Sub-Saharan Africa (1.77). In other regions, the effects are minor and not statistically significant.

The cost of equity is also an essential determinant in green financing decisions. Banks and financial institutions expect a higher return on equity and assets for investing in green firms. That holds for Latin America, the Caribbean (0.28), and South Asia (1.53). For Europe and Central Asia, we register the opposite impact, with renewable energy use diminishing with a rise in *ROE* (-0.30) and *ROA* for East Asia and the Pacific (-0.11), Europe and Central Asia (-0.24), Sub-Saharan Africa (-0.09). On the other hand, a rise in *ROA* for banks stimulates green investments in Latin America, the Caribbean (0.25), and South Asia (1.22).

Stock markets' link to green financing is fragmented across regions. The link is insignificant in East Asia and the Pacific, The Middle East and North Africa, and South Asia. A strong positive effect of stock markets on green financing is present in Sub-Saharan Africa for stock market capitalization (2.16), stock market total value traded (0.83), and stock market turnover ratio (0.82). Stock market turnover ratio

change has a positive impact on renewable energy use also in East Asia and the Pacific (0.17), Europe and Central Asia (0.17), and North America (0.36). The turnover ratio impact on renewable energy is neutral in The Middle East, North Africa, and South Asia and harmful in Latin America and the Caribbean (-0.30).

Remittances do not significantly link renewable energy for regions except for Latin America and the Caribbean (0.29) and Sub-Saharan Africa (0.96). International financing (from non-resident banks) shows a limited impact on renewable energy use with East Asia and the Pacific (0.31), Europe and Central Asia (0.31), Latin America and the Caribbean (0.18), and Sub-Saharan Africa (0.85). International financing effect on renewable energy is not statistically significant in the Middle East, North Africa, and South Asia and harmful in North America (-0.35).

6. Conclusion

Empirical studies and articles on green financing are a critical gap in the literature on sustainable development, green growth, and energy transition. Policy agendas to fight climate change base their targets on green bonds, subsidies, financial learning in the green energy industry, and environmental taxation. They do not address the need for global financial system restructuring, a type of 'Green Bretton Woods'. Fighting climate change internationally with adequately designed and efficient policies is impossible without a worldwide financial system transitioning to green financing. Our study provides empirical evidence to support this thesis, studying 205 countries from 1960 to 2017. Climate deterioration cannot be stopped without full-scale financial system support for green investment essential for energy transition and green growth.

Our study shows that the cost of capital and debt, as well as the cost of equity and assets, for green investors is commonly 30% higher than for non-green investors. Such a fact is reflected in the higher required return on equity and assets' expected internal rate of returns on green investments. Banks and other financial institutions perceive high risk and uncertainty and are unwilling to take that chance. Instead, they finance fossil fuel investments with a sure profit and less risk and are backed by government support through subsidies. Financial learning in the green energy industry, green labels, and environmental taxes are necessary but not sufficient conditions to meet financial support for green energy industry needs. Financing costs for green investment must be drastically lowered. The only way is for the financial industry to restructure and transition to financing renewable energy investors by reducing information asymmetries, public opinion support, and setting a global financial 'green' system.

Modeling unbalanced panel data with long time series observation (many countries and time) post many challenges (heterogeneity, cross-sectional dependence, unit root, cointegration). Here we run 210 full regression models with Driscoll-Kraay standard errors to address the above limitations. Although regression with Driscoll-Kraay standard errors usually solves the issue, some other methods following contemporary techniques, including long-run effects in a large heterogeneous panel data model with cross-sectional dependence, can be applied to check the robustness of the results. Country and variable selection is limited by the available data from the databases at our disposal (research limitations). The sample can be extended using variables and data from commercial databases such as Datastream, Bloomberg, and Global financial data. Further studies on green energy financing should focus on other databases to improve the robustness of empirical results. However, our empirical results based on data at our disposal stand the rigor of statistical analysis.

We encourage future research to develop simulation and forecasting models for energy transition and climate change based on various green energy financing schemes. Standard models on energy transition instead include only macroeconomic variables without financial ones, or studies are delivered on a micro level. For a comprehensive analysis of green financing conditions' impact on renewable energy, micro and macro studies are necessary. They should include economic and financial variables since both are required pre-conditions for green investments.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.eap.2023.05.006>.

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