Master Thesis Economics and Business – Policy Economics

THE POLITICAL DETERMINANTS OF NON-HYDRO RENEWABLE ENERGY ADOPTION IN DEVELOPING COUNTRIES

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Abstract

This paper investigates the political and institutional determinants of non-hydro renewable energy (NHRE) adoption in developing countries. Based on the system GMM approach, it provides a panel data analysis on a sample of 77 low- and middle-income countries over the period 2001-2017. The analysis proceeds in a three-step approach that successively addresses (i) the effect of institutional quality, (ii) the role of government size, in particular its interaction effect with relevant political factors, and (iii) the extent to which the political determinants of NHRE are influenced by financial development and FDI inflows. The results corroborate prior findings by showing the presence of a "lobby effect" from conventional energy producers, and by confirming the positive impact of democracy and control of corruption on NHRE adoption. Interestingly, the results also suggest that financial development has an ambiguous effect on NHRE adoption: it has a significant positive effect on NHRE generation but seems to also enhance the lobby effect in fossil fuel-rich countries. The effect of Kyoto Protocol ratification negatively affects NHRE adoption when government size is small, but above a certain threshold for government size, Kyoto Protocol ratification increases NHRE adoption. Finally, a negative interaction effect between institutional quality and FDI inflows was found, which suggests that relatively good institutions might be a factor of attractivity for FDI in fossil-fuel-intensive industries.

Table of Contents

List of figures

List of tables

List of abbreviation

CSP: Concentrating Solar Power

EKC: Environmental Kuznet Curve

EU: European Union

FFB: Fossil Fuel-Based

FDI: Foreign Direct Investment

GHG: Green House Gas

LCOE: Levelized Cost of Energy

MENA: Middle East and North African

NPV: Net Present Value

NHRE: Non-Hydro Renewable Energy

SPV: Solar Photovoltaic

WACC: Weighted Average Cost of Capital

WGI: World Governance Indicator

1. Introduction

During the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris in 2015, nearly 200 countries agreed to maintain "the increase in the global average temperature to well below 2°C above preindustrial levels and to pursue efforts to limit the temperature increase to 1.5°C" (UNFCCC, 2015). Under current policies, global warming is expected to reach 3°C above preindustrial levels by the end of the century, and 2.8°C providing the respect of current pledges such as the Nationally Determined Contributions (Climate Action Tracker, 2020). The fossil fuel intensity of the energy sector makes it the primary source of anthropogenic greenhouse gas (GHG) emissions. As the global demand for energy continues to grow, many concerns have been expressed regarding the ability of our societies to meet this demand while remaining within the frame set by ecological objectives. The global primary energy demand rose by 2.3% from 2017 to 2018, which is near twice the average annual growth rate observed since 2010. This increase was mainly driven by the population growth and the economic development of developing countries. While energy use has been roughly constant during the last 10 years in OECD countries, it increased on average by 4.7% per annum in the rest of the world. Since 2011, and for the first time in history, the total annual energy consumption of non-OECD countries has exceeded that of OECD countries (see Fig. 1). Yet, per capita energy consumption remains three times superior in OECD countries (IEA, 2020). The decarbonization of the energy sector represents thus a pivotal element to align climate change mitigation and inclusive economic prosperity.

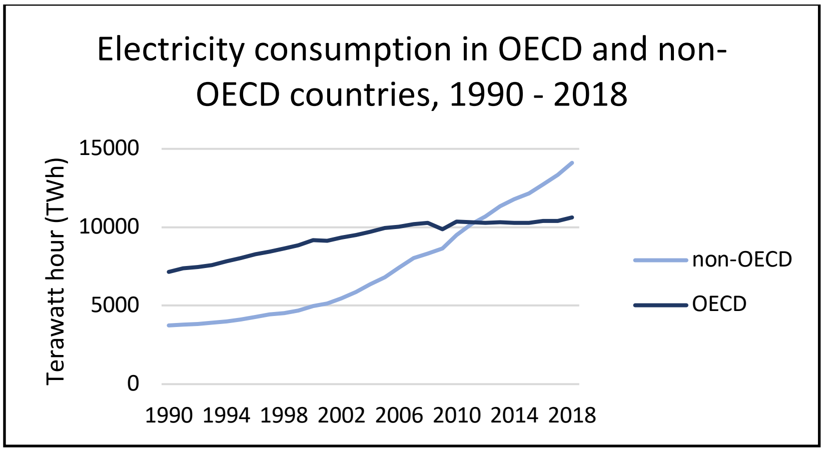

Fig. 1. Total electricity consumpion in OECD and non-OECD countries between 1990 and 2018. Source: Author's computation, based on IEA (2020)

Today, the lion's share of globally consumed power remains generated by fossil fuels (72% in 2018: IEA, 2020). Electricity generation from coal and gas continues to grow at a worrying pace, especially in developing countries (see Fig. 2). This persistence of fossil fuel can be partly explained by the fact that many low- and middle-income countries currently satiate their increasing demand for energy by investing in fossil-fuel-based (FFB) energy infrastructures (Bloomberg, 2019; IEA, 2020). This has developed in a context of relatively low prices of coal (Steckel et. al., 2015) and conducive business environment for investment in FFB projects (Coady et al, 2017; Sweerts et. al., 2019). Because of the long life-cycle of these infrastructures, important lock-in effects arise through capital stock inertia, further aggravating fossil-fuel dependence and future climate change mitigation costs (Bertram et al., 2015; Unruh, 2000; Schmidt et. al., 2017).

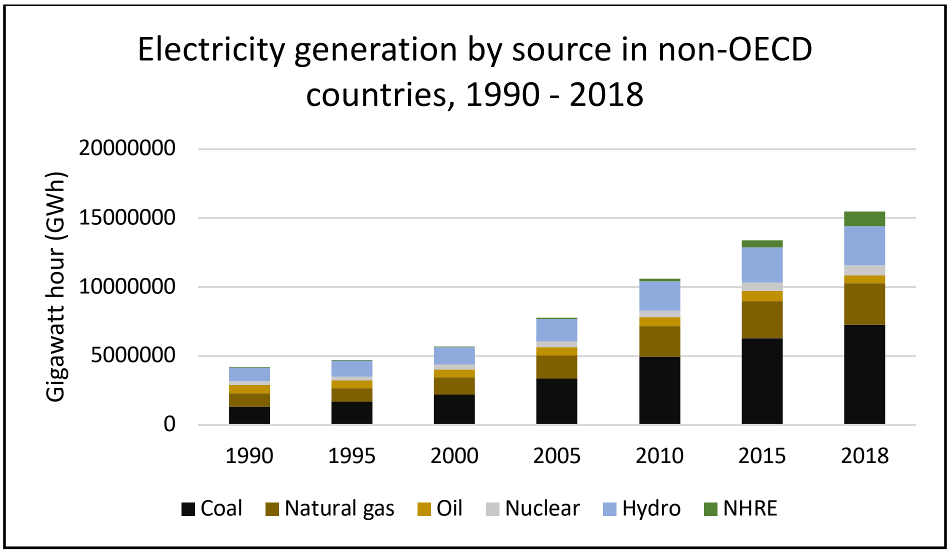

Fig. 2. Electricity generation by source in non-OECD countries between 1990 and 2018.
Notes: NHRE stands for non-hydro renewable energy which includes biofuel, geothermal, solar, wind and tide energy sources.
Source: Author's computation based on IEA (2020)

As environmental concern becomes more acute and cleaner energy technologies gain in maturity, there is a public momentum to trigger a transition toward a more sustainable global energy system. Over the past decades, non-hydro renewable energy (NHRE) technologies have gradually emerged as a sustainable alternative to fossil fuels. Between 2010 and 2019, the average energy generation cost of solar photovoltaic (SPV), concentrating solar power (CSP), and onshore wind fell by 82%, 47%, and 40%, respectively. More than half of the renewable energy capacity developed in 2019 has shown a lower generation cost than the new coal plants (IRENA, 2020). Hence, ensuring the decarbonization of the energy sector in developing countries will not only reduce GHG emissions in the short run. It might also allow these countries to skip dirty stages of energy development and directly “leapfrog” to more efficient and environment-friendly technologies (Amankwah-Amoah, 2015; Watson & Sauter, 2011).

The present paper empirically investigates the barriers and drivers of clean energy adoption in developing countries. In particular, it puts the emphasis on the political and institutional factors, and aims to shed light on the channels through which they operate. The analysis uses longitudinal data on 77 low- and middle-income countries for the period 2001-2017. Heterogeneity and endogeneity issues are addressed through the adoption of the system generalized method of moments (syst-GMM) strategy developed by Arellano and Bover (1995) and Blundell and Bond (1998). The analysis proceeds in a three-step approach that successively questions the role of institutional quality, the importance of government size (i.e. the volume of public expenses), and the interactions between the political environment and the main financing channels of NHRE.

This paper makes several new contributions. First, it analyses the determinants of NHRE adoption while using two dependent variables: the generation of NHRE per capita and share of NHRE in the total energy mix. These two variables are the most common measures of NHRE adoption in the literature and are often used to address the same issues. Exploring the predictors of these two measures enables to address two distinct questions: “What are the determinants of NHRE growth? “and “What increases the use of NHRE over conventional energy sources?”. Secondly, this paper measures institutional quality by using both specific and aggregate indexes. While the first step of the analysis addresses three particular dimensions of institutional quality: democracy, control of corruption, and political stability; the second and third steps use a single composite index of “overall institutional quality”[1]. The use of these two approaches and the comparison of their results gives useful insight to better understand the role of institutions in NHRE adoption in developing countries. Finally, in light of the literature review, this article posits that the effects of the political factors of NHRE adoption are likely to be affected by government size and the main financing channels of NHRE

[1] This composite index encompasses the six dimensions of institutional quality established by Kaufmann et. al. (2010): democracy, control of corruption, political stability, voice and accountability, regulatory quality, and government effectiveness.

projects: domestic credit and foreign direct investment (FDI). By testing for this, the analysis explores the empirical relevance of several interaction effects that, to my knowledge, have not been addressed by the literature yet.

The results of this study corroborate previous findings such as the presence of a lobby effect from the fossil fuel industry and the positive impact of democracy and control of corruption on NHRE adoption. The analysis has also brought light to interesting elements that have not been mentioned before in the literature. First, the results suggest that the development of domestic financial sectors has an ambiguous effect on NHRE. On the one hand, it has a direct positive effect on NHRE generation per capita. On the other hand, it seems to facilitate the presence of a lobby effect from the fossil fuel industry. Second, the presence of a negative interaction effect between institutional quality and FDI inflows suggests that good institutions might be a factor of attractiveness for FDI in carbon-intensive industries in developing countries. Finally, the results show a significant positive interaction effect between the ratification of the Kyoto Protocol and government size suggesting that high budgetary capacity and commitment toward climate change mitigation complement each other in the promotion of NHRE. All in all, these results glimpse intriguing dynamics between the political environment of developing countries and their level of NHRE adoption and draw some interesting avenues for future research.

The remainder of the paper is organized as follows. Section 2 presents an overview of the related literature to motivate the choices of the covariate implemented in the models. Section 3 describes the dataset, presents the econometric specifications, and introduces the empirical models and their underlying hypotheses. The results are reported and discussed in section 4. Section 5 concludes.

2. Literature review:

The number of studies addressing (NH)RE penetration in developing countries has grown substantially in the past decade. This can be attributed to the fact that NHRE technologies have attained a first order importance in national and international GHG mitigation strategies. Similar to this study, several papers have conducted econometric analyses to identify the drivers of RE or NHRE penetration. These papers consider a wide variety of determinants including macro-economic, demographic or environmental factors in their regression analysis. For instance, the impact of economic performance (Aspergis, 2011a, 2011b; Sadorsky, 2009a), air pollution (Nguyen & Kakinaka, 2019; Omri and Nguyen, 2014; Sadorsky, 2009b), trade (Amri, 2017; Wang & Zhang, 2020), oil price (Brini et. al., 2017; Sadorsky, 2009b), and urbanization (Wang, 2014; Yang et. al. 2016) have been widely studied.

To date, the question of the political and institutional factors of NHRE penetration has comparatively been neglected. The question of NHRE diffusion is however an intrinsically political issue. From a theoretical point of view, it features an important public good component leading to several positive externalities that are not directly priced by regular market dynamics (Borenstein, 2012). Conversely, FFB energy producers are often not held accountable for the environmental cost of their activity, and even sometimes benefit from large public subsidies (Coady et. al., 2017). Some authors have studied the political determinants of NHRE adoption by investigating which types of policies are the most efficient in fostering clean energy adoption (e.g. Kitzing et al., 2018; Polzin et. al., 2019; Reiche and Bechberger, 2004). These articles greatly contributed to understanding the barriers faced by environmental energy policies. By contrast, the present paper examines the aspects of the political environment[2] that favor NHRE adoption in developing countries – by making the implementation of such policies more or less likely to occur, and by influencing investment decisions of economic actors. This literature overview provides a rationale for the choice of the independent variables included in the empirical models presented in section 3.

2.1. Institutional quality

When addressing the features of the political environment, one the most frequently invoked topic in the literature is the quality of the political institutions. Measuring institutional quality is particularly challenging since this notion can be associated with various aspects of governance such as state efficiency, power, legitimacy or credibility (Alonzo & Garcimartin, 2013). Several datasets on institutional quality have been developed by institutions, companies and academics. These datasets include a wide variety of indexes measuring different dimensions of institutional quality. These indexes also differ by the methodology used in their computation, as well as the period and area they cover[3]. As a result, the proxies for institutional quality greatly differs across papers.

[2] The notion of "political environment" here refers to the quality of political institutions, the ideologies, and the distribution of the economic power between the public and private spheres which determine the orientation of public policies and the extent of their influence on the economy.

[3] For a presentation and comparison of many of these indexes see Kunčič (2014).

Some articles have assessed the impact of the institutions on environmental performance by running regressions analyses including multiple indexes of institutional quality as regressors. To study the institutional determinants of CO_2 emissions in European Union (EU) and Middle East and North African (MENA) countries, Abid (2017) built a model including four of the six World Bank governance indicators (WGIs) – control of corruption (CC), political stability (PS), government effectiveness (GE), and regulatory quality (RQ) – as covariates. His results suggest that these four dimensions of institutional quality have a significant negative effect on CO_2 emissions per capita in the EU, but no significant effect in MENA countries. Similarly, Akintande et. al (2020) used the same four indicators plus the rule of law (RL) indicator in their models to assess the impact of institutional quality on RE consumption in the five most populous African Countries (DR. Congo, Egypt, Ethiopia, Nigeria, and South Africa). They found that control of corruption, government effectiveness, political stability, and regulatory quality positively affect RE consumption, while rule of law seems to have a negative impact on RE consumption in these countries. As I will argue further down in this paper, the approach adopted by Abid (2017) and Akintande et. al (2020) raises an important methodological concern: The WGIs carry a high level of intercorrelation[4]. By combining them as regressors, one exposes the model to multicollinearity issues that undermine the statistical significance of the estimates (Allen, 1997).

In other studies, a wide definition of institutional quality was used by applying composite indexes, computed as the average value or sum of several indicators (e.g. Alonzo & Garcimartin, 2013; Osabuohien et. al. 2014; Sarkodie et. al., 2020). For instance, to study the institutional factors of CO_2 emissions in different regions and country income groups, Bhattacharaya et. al. (2017) measured institutional quality with the economic freedom index of Gwarthney et. al. (2008). This index builds on several sub-indices, such as government size, property rights, and business regulation. Bhattacharaya et. al. (2017) found a significant negative effect of institutional quality on CO_2 emissions in all income groups, Sub-Sahara African countries, and European and Central-Asian countries. However, no significant effect was found for MENA countries, nor for Sub-Asian countries. In another study using a composite measure, Uzar (2020) estimated the relationships between institutional quality and RE in 38 countries worldwide over the period 1990-2015. His measure of institutional quality

[4] See the correlation matrix of the WGIs in Table 2 – section 3

was built upon the international country risk guide (ICRG) database[5]. This measure accounts for corruption control, rule of law, bureaucratic quality, democracy, and government stability. The results indicated positive short- and long-run relationships between the quality of institutions and RE adoption.

Some articles have focused on specific dimensions of institutional quality. A large stream of papers has studied the relationship between institutions and RE under the democracy-environment nexus (e.g. Bernauer & Koubi, 2009; Chou et. al., 2020; Mak Arvin & Lew, 2011; Sequeira & Santos, 2018). It is commonly argued that more democratic regimes succeed better in preserving the environment because their population is more informed on environmental issues and more able to push for public action toward them (Farzin & Bond, 2006). Furthermore, non-democratic regimes are often characterized by an important concentration of wealth among the political elite. Such incurs disincentives for strict environmental policies because the cost of these policies will be disproportionally borne by this elite, while the benefit would be more equitably distributed within the population (Boyce, 1994; Uzar & Eyuboglu, 2019). Political systems where the median voters have the power – typically democracies (Black, 1948; Downs, 1957) – are thereby more likely to implement stricter environmental policies, and therefore, to adopt NHRE. Early studies working on global panel data have found that democracy tends to reduce air pollution (Pelligrini & Gerlagh, 2006) and strengthen environmental policies (Bernauer & Koubi, 2009). Working on a sample of 24 American countries, Chou et. al. (2020) found that democracy negatively impacts CO_2 emissions and improves energy efficiency. Similarly, Sequeira and Santos (2018) studied the relationship between democracy and the energy mix on a global sample. They found that the level of democratization has a strong positive effect on the share of NHRE in the energy sector. Their results are robust across three different measures of democracy used as predictors.

Another feature of institutional quality that is often cited as a factor of NHRE adoption is the level of corruption. It has been argued that corruptive practices within the state apparatus might result in low stringency of environmental policies (Damania et. al., 2003; Fredriksson & Neumayer, 2016) and weak enforcement of pre-existing environmental laws (Aklin et. al., 2014; Damania et. al., 2004; Sundström, 2013). Lopez and Mitra (2000) provide a theoretical framework to assess the impact of government corruption on air pollution under

[5] See https://www.prsgroup.com/explore-our-products/international-country-risk-guide/

the environmental Kuznets curve (EKC) assumption[6]. Their model predicts that government corruption delays the realization of the EKC turning point (i.e. the level of income at which a country starts to decrease its level of pollution) and sets it at a level of income that is above the social optimum. Sinha et. al. (2019) give some empirical support for this claim by studying the impact of public sector corruption on CO_2 emissions in the BRICS[7] and the Next-11 countries[8] for the period 1990-2017. Their results further suggest that, to a large extent, the environmental degradation that can be attributed to corruption involves the energy sector. In line with this, Cadoret and Padovano (2016) found that better control of corruption increased the share of RE in 26 EU countries, and Asante et. al. (2020) found corruption to be the most important barrier to RE development in Ghana.

Political stability is another aspect of institutional quality that is often mentioned as one of the main drivers of NHRE adoption in developing countries. Ragosa and Warren (2019) studied the impact of public interventions and business environment on foreign private investment in RE in developing countries. Performing a panel data analysis on a sample of 62 countries, they found that political stability enhances the efficiency of RE policies. From another perspective, a large corpus of papers has studied the determinants of (NH)RE penetration via investors survey analysis on the risk's drivers of RE investments. These papers have shown political stability to be one of the most critical elements in RE investment location decisions (Angelopoulos et. al., 2017; Criscuolo & Menon, 2015; Karneyeva & Wüstenhagen, 2017; Polzin et. al.,2019).

In some cases, the effect of institutional quality on the countries' environmental performance is shaped by the interaction among several institutional features. Fredriksson and Svenson (2003) presented a model in which the effect of government corruptibility is conditional to the level of political stability. Corruption reduces the stringency of environmental policy because it increases the likelihood of the government accepting bribes from polluting industries. On the other hand, political instability increases the probability of a

[6] The EKC hypothesis claims that there is an inverted U-shaped relationship between environment degradation and economic development: several indicators of environmental pollution depict positive relationship with economic development until the economy reaches a certain level of average income (the "EKC turning point"). Then, the relationship between income and pollution becomes negative (Arrow et. al., 1995).

[7] i.e. Brazil, Russia, India, China, and South Africa.

[8] The "Next-11" refer to the 11 countries that have been identified by Goldman Sachs in 2005 as the next emerging countries. This grouping comprises Bangladesh, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, Pakistan, the Philippines, Turkey and Vietnam.

political crisis (e.g. a putsch or a vote of non-confidence) that would overthrow the incumbent government and make the bribe ineffective. Hence, political instability (partly) offsets the negative effect of government corruption on environmental policy stringency by reducing the expected returns from bribes. Fredriksson and Svenson tested their predictions on 63 developed and developing countries. Their results are consistent with the model: the direct effect of both corruption and political instability on environmental policy stringency is negative and significant, while the interaction coefficient between them indicates a positive and significant effect. To date, no empirical work has been published on whether a similar offsetting effect of corruption vs. political instability exists for clean energy technologies in developing countries. The present paper will partly fill this gap by empirically exploring interactions between control of corruption and political stability on the adoption of NHRE in developing countries.

2.2. Lobby effect, climate commitment and government size

Besides the institutional framework, there are other aspects of the political environment that are likely to play a significant role in NHRE adoption in developing countries, such lobby effect from polluting industries, the level of commitment of the incumbent government toward climate change mitigation, and government size. These factors are not independent of the institutional framework discussed above, but they do not necessarily emanate from it and merit specific consideration.

It has been shown that lobbying effort from producers of incumbent technologies undermines the adoption of new technologies by encouraging institutional barriers to their diffusion (Comin & Hobijn, 2009). Damania and Fredriksson (2000) provided theoretical arguments that highlight a tendency of pollution-intensive industries to create lobbying coalitions against environmental regulations. Typically, the prospect of high environmental tax expenditures rises collusive profits and diminishes the incentive of polluting industries to freeride on rival firm lobby expenses. Hence, polluting industries are more likely to collude in order to lobby for lenient environmental standards. This is exacerbated for fossil fuel producers as they supply a strategic good that greatly affects the functioning of the economy; making it economically and politically costly for incumbent governments to promote energy sector diversification (Ahmadov & van der Borg, 2019; Lehmann et al., 2012). Some papers have shown that NHRE adoption occurs at a slower path in countries with a relatively high initial share of fossil fuels in their energy mix (Aguire & Ibikunle, 2014; Lin et. al. 2016; Marques et. al., 2010) or relatively high rents from oil, coal, and gas (Baldwin et. al., 2016; Johnsson et. al. 2019; Lin & Omoju, 2017; Ragossa & Warren,2019).

The political orientation of the incumbent government seems to also play an important role in RE diffusion. For instance, Chang and Berdiev (2011) and Potrafke (2010) showed that in OECD countries left-wing parties tend to relatively more regulate the energy markets. Biresselioglu and Karaibrahimoglu (2012) and Cadoret and Padovano (2016) found that Left and center-oriented parties in the EU are more likely to promote RE than right-wing parties. Other papers considered the countries' dedication toward environmental issues by looking at the formal commitments made on the international scene. Miyamoto and Takeuchi (2019) fund that countries that ratified the Kyoto Protocol contribute generally more to the development of RE technologies. This effect seems to be even stronger in countries with high emission mitigation targets. This is consistent with Popp et. al. (2011) and Brunnschweiler (2010) who found that the ratification of the Kyoto Protocol increased RE production in OECD and non-OCED countries, respectively.

Another element that seemed interesting to me to explore is the effect of government size. The term government size refers to the ratio between total public expenditure and the country's GDP (see e.g. Becker & Mullingan, 2003; Gali, 1994; Kau & Rubin 1981). It is generally used to proxy the budgetary power of a government. From another perspective, it can also constitute a proxy for the level of state involvement in the economy, and can thereby be interpreted as an indicator of ideology. From a theoretical point of view, arguments can be found in favor of a relationship between government size and NHRE adoption in either direction. On the one hand, an important branch of welfare and public economics presents the government as a provider of public good and a corrector of externalities (Pigou, 1920). Thus, it could be argued that government growth would result in more public action toward the environment, and thereby, increasing NHRE adoption. On the other hand, "big" governments are also sometimes associated with important bureaucratic inefficiencies (Niskanen, 1994) and the overrepresentation of the interests of a minor strain of the population (Olson, 1965) that would make the energy transition unlikely to happen. Empirical evidence on the matter also points in different directions. In some cases, it has been shown that government expenditure can complement private capital by enhancing its productivity (e.g. Lora, 2007; Blejet & Khan, 1986). Other papers have stressed the fact that excessive public investment generates market distortions and crowd-out private investments (Cavallo and Daude, 2011). Thus, although government size is likely to play a major role NHRE penetration, the nature of its effect is certainly conditional on many other political and economic factors. Some papers have looked at the relationship between government size and air pollution. Using a panel of 77 countries for the period 1980 – 2000, Halkos and Payzanos (2013) have identified a negative correlation between government spending and sulfur dioxide (SO_2) emissions – a component of air pollution generated by fossil fuel combustion. This is consistent with Islam and Lopez (2013) who found similar results using panel data from 50 US states between 1985 and 2008. Conversely, Bernauer and Koubi (2013) found the inverse relationship while working on 42 countries over the periods 1971-1996 and controlling for bureaucratic quality and corruption. To my knowledge, the empirical relationship between government size and NHRE adoption has not yet been addressed empirically. By implementing government size as explanatory variables, and considering its interaction effect with other factors, I intend to (partly) fill this gap.

2.3. Financial barriers

The Institute for Sustainability Leadership has estimated that investments in RE have to attain USD 900bn per year worldwide by 2030 to be consistent with the 2°C target fixed during the Paris agreement (ISL, 2016) for global warming. Such an objective involves substantive mobilization of private capital, especially given the high share of private financing generally observed in non-hydro RE projects[9]. However, NHRE technologies face important financial barriers that reduce their attractivity for investments and substantially limit their diffusion in developing countries. It is likely that a large part of the political and institutional effects on NHRE operate through the alleviation or the reinforcement of these barriers. Understanding them is thus essential to address the research question of this paper. Therefore, this subsection will be dedicated to explaining the main financial barriers of NHRE penetration, and how they might interact with the political environment.

Typically, investment decisions for energy projects are taken on the basis of their levelized cost of energy (LCOE) (Borenstein, 2012; Ondraczek et. al., 2015). The LCOE is an estimation of the cost per unit of output (energy) generated. It is a well-known metric,

[9] In 2015, 69% of new NHRE power plants have been commissioned by private sponsors (companies or households), while these figures is only equal to 39% for conventional power plants (fossil fuels, nuclear or hydro) source: IEA (2016)

commonly used by economists, policymakers and energy planners (UNDP, 2013). It is computed by dividing the net present value (NPV) of the life-cycle costs by the NPV of the total output generated:

$$LCOE_n = \frac{\sum_{t=0}^{T} \frac{C_t}{(1+r_n)^t}}{\sum_{t=0}^{T} \frac{Y_t}{(1+r_n)^t}} \qquad (1)$$

where:
$LOCE_n$ = The levelized cost of energy for project n
T = The economic lifespam of the project
C_t =The costs occurring in period t
Y_t =The energy output produced in period t
r_n =The weighted average cost of capital (WACC)

As shown in equation (1) , future costs and outputs are discounted at the weighted average cost of capital (WACC) expressed by the rate r_n . The higher the WACC, the more projects that have their costs occurring in late stages of their life cycle are cost-competitive. Fig.3. is based on Schmidt (2015). It reports the typical LCOE of five RE technologies (onshore wind, photovoltaic, concentrated solar power, small hydrological facilities, and biogas) and three FFB technologies (hard coal, natural gas, and diesel plants), as well as their relative cost components (see legend). For each technology the LCOE is reported assuming low (left-hand bar) and high (right-hand bar) WACC. Fig.3 shows that FFB technologies generate mainly operating and fuel costs. Because these costs are regularly spread across the life cycle of these infrastructures, they do not require important debt or equity emissions. The LCOE of these technologies is thereby weakly affected by WACC variations. Conversely, RE technologies are more capital intensive and require important initial investment (Egli et. al., 2018). Thus, financing costs (i.e. cost of equity and cost of debt) constitute a large portion of their total cost, which makes their LCOE very sensitive to WACC variations. For instance, according to Schmidt's (2014) calculations, the typical LCOE of on-shore wind technologies increases by 44% when switching from low (5% cost of debt and 10% cost of equity) to high (10% cost of debt and 18% cost of equity) WACC assumed. By contrast, the same figure is only equal to 7% for natural gas Technologies. Financing costs are generally larger in developing countries where the financial sector is less developed and investment risk higher. The limited penetration of NHRE in developing is thus likely to be linked to their particular cost structure and their resulting lack of financing. Identifying the way, the political determinants of NHRE adoption interact with these financial barriers might help to better understand the political and institutional mechanism at work behind NHRE adoption in developing countries.

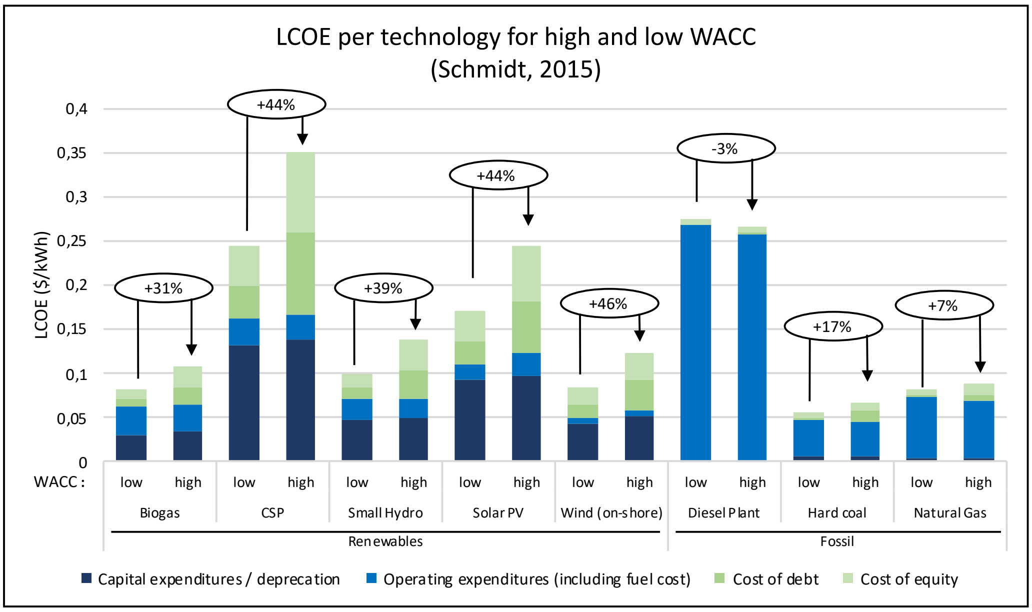

Fig. 3. The impact of a variation of financing costs on the levelized cost of energy
Note: The left bar for each technology represents the typical levelized cost of energy (LCOE) in USD (of 2012) per kilowatt-hour (kWh) assuming low weighted average cost of capital (WACC): 5% cost of debt and 10% cost of equity. The right bar for each technology represents the typical LCOE assuming high WACC: 10% cost of debt and 18% cost of equity. The different stack segments show the various cost components (see legend at the Figure bottom). Source: Schmidt (2015)

Some empirical works have shown that institutional factors influence the strength and the direction of the effect of financial variables on air pollution. Baksh et. al. (2020) used Syst-GMM estimations to study the moderating role of institutional quality – as measured by the WGIs – on the relationship between FDI inflows and CO2 emissions in 40 Asian countries. Their results suggest that good institutions tend to hamper the negative effect of FDI inflows on CO2 emissions. Working on a sample of 19 developing Asian countries, Huyn and Hoang (2019) state that, after crossing a certain threshold of institutional quality, the effect of FDI on air pollution switches from positive to negative values. Similarly, Abid (2017) found that the WGIs have a significantly negative interaction effect with FDI inflows and with financial development on CO2 emissions in EU and MENA countries.

To my knowledge, the empirical relevance of such interaction effects on NHRE adoption has not yet been investigated. However, there is good reason to believe that a conducive political environment might contribute to redirecting financial flows toward NHRE projects. Because of their sensitivity to interest rate variation, a reduction in investment risk due to better institutions might disproportionally benefit RE projects. Previous works have shown that good political institutions can reduce investment risk by bringing more political stability, propriety right enforcement, and bureaucratic efficiency (Aziz, 2018; Dutta & Roy, 2011, Yang et. al., 2018). Similarly, signs of awareness toward climate change mitigation such as the Kyoto Protocol ratification might increase the credibility of governments' commitment to maintaining favorable conditions for investment in RE. It has been shown that retroactive changes in environmental policies had a substantial negative effect on RE investments in many EU countries such as Greece (Eleftheriadis & Anagnostopoulou, 2015), Italy (Di Dio et. al., 2015), or Spain (De la Hoz et. al., 2016).

Furthermore, a conducive political environment might improve the financing conditions of NHRE by enhancing financial development. Any new technologies and infrastructural innovations such as in the energy sector are bound to have teething problems that further increase the technical and commercial risk associated with NHRE projects. Well-functioning financial institutions might allow to better ensure these risks. The underdevelopment of financial sectors in developing countries has been shown to considerably hamper the development of NHRE projects (Anton & Nucu, 2020; Brunnschweiler, 2010; Ji & Zhang, 2019). Several papers have shown the important role that the political environment, and in particular institutional quality, plays in the development of domestic financial sectors (e.g. Claessens & Laeven, 2003; Law and Azman-Saini, 2012).

Thus, evidence suggests that the combined effect of a conducive political environment and good financing conditions might favor the development of NHRE in developing countries. To test for this, the present paper includes an estimation of the interaction effects between the political variables of interest and the main financing channels for NHRE: FDI inflows and the domestic financial sector.

3. Data and Methodology

This paper aims to identify the political and institutional determinants of NHRE adoption in developing countries and to shed light on the underlying mechanisms driving them. In light of the literature review (see section 2), I identified several elements of the political environment that are likely to influence the level of NHRE adoption: institutional quality, climate commitment of the government, and potential lobby effects from the fossil fuel industry. I also hypothesized that the size of government plays a significant role in NHRE adoption, in particular by conditioning the effect of the other variables. Finally, as the development of NHRE project is highly dependent on their access to long-term and affordable finance, it appears relevant to test the extent to which the political determinants interact with the two main financial channels for NHRE, namely, the domestic financial markets and FDI inflows. All these aspects will be covered by this study. This section gives the material and method used in the analysis. It first presents the dataset and the variables (3.1.). Then, it provides some econometric specifications by introducing the syst-GMM approach and the related diagnostic tests (3.2.). Finally, it describes the empirical models and their underlying hypotheses (3.3.).

3.1. Dataset and variables

The analysis was performed on annual panel data on 77 low- and middle-income countries[10] for the period 2001-2017. Table 1 presents an overview of the sample composition by stating the regions and income levels considered. A complete list of the countries included in the sample is available in the appendix (see Table A 1). Throughout this paper, I will use the term "developing countries" to designate any country that is not classified as "high-income" countries by the World Bank. Depending on the models, the total number of observations ranged between 876 and 1014. This large sample provides statistical power but carries a large sample heterogeneity that has been addressed with adapted empirical methods (see subsection 3.2.)

Table 1 : Sample composition

Income groups / Regions	Low income	Lower middle income	Upper middle income	**Grand Total**
East Asia & Pacific		6	3	**9**
Europe & Central Asia		3	11	**14**
Latin America & the Caribbean	1	4	12	**17**
Middle East & North Africa		3	5	**8**
South Asia	1	3	1	**5**
Sub-Saharan Africa	8	11	5	**24**
Grand Total	**10**	**30**	**37**	**77**

Notes: The regions and income groups classification follow the World Bank standards.

[10] level of income is defined following the World Bank classification which divides world's economies into four income groups : low, lower-middle, upper-middle, and high-income countries. This classification is based on the gross national income per capita and is updated every year accounting for changes in interest rate. More details on the matter can be found on the World Bank website: https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2020-2021#:~:text=The%20World%20Bank%20assigns%20the,%2C%20and%20high%2Dincome%20countries.&text=In%20each%20country%2C%20factors%20such,growth%20influence%20GNI%20per%20capita.

The data on NHRE adoption are extracted from the electricity statistic database of the International Renewable Energy Agency (IRENA, 2020). They include electricity generation from wind, solar, biomass, geothermal, and marine energy sources. As in other studies (Lin & Omoju, 2017; Pfeiffer & Mulder, 2013) hydroelectricity have been removed from the analysis because its denomination of "clean energy" has been contested by several critics that pointed out the adverse effects of these technologies on natural ecosystems (Mattman et. al., 2016) and air pollution (Pacca, 2007). I used two different indicators for NHRE adoption: NHRE generation per capita expressed in gigawatt hour (GWh) (measure 1) and share of NHRE generation in total energy supply (measure 2). The choice of using both indicators as dependent variables is motivated by two reasons. First, measure 1 and measure 2 are both intensively used in the literature for the same purpose, namely, to measure NHRE adoption[11]. It seemed interesting to me to investigate whether the results significantly differ by interchanging both measures. Second, while the use of measure 1 will give insights on the determinants of NHRE growth, measure 2 will help to identify the factors that make NHRE more important relative to conventional energy sources. I consider that the use of both measures can lead to relevant insight for the design of clean energy policies in developing countries.

In this paper, the proxies for institutional quality are based on the WGIs from the World Bank (WGI, 2020). These indicators are computed following Kaufman et. al (2010). They are estimated in standard normal units ranging from approximately -2.5 to 2.5[12], where higher values mean higher performance. In total, there are six indicators that respectively capture control of corruption, governance effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability[13]. The WGIs are reference indexes of institutional quality. They have been used in numerous papers studying the institutional determinants of NHRE adoption in developing countries (e.g. Akintande et. al., 2020; Keeley

[11] Papers using share of (NH)RE: Adams & Acheampong (2019), Aguirre & Ibikunle (2014), Anton & Nucu (2020), Ito (2017), Lin et. al. (2016), Lin & Omoju (2017), Marques et. al. (2010)
Papers using generation of (NH)RE per capita: Brunnschweiler (2010), Pata (2018), Pffeiffer & Mulder (2013), Salim & Rafiq (2012), Sadorsky (2009a, 2009b)

[12] In extreme cases, the values can be lower than -2.5 or larger than 2.5. In this paper, I rescaled the WGIs by adding the constant 2.82 (as the smallest values observed was - 2.82) to each term in order to ensure that all observations depict a positive sign.

[13] The definition of each indicator can be found in the appendix (see Table A 2) and the documentation relative to the sources and methodology is available on the World Bank's website: See https://info.worldbank.org/governance/wgi/

& Ikeda, 2017; Ragosa & Warren, 2019). They are accessible opensource and have the advantage of offering a large and recent coverage (200 countries for the period 1996-2019). As shown by the correlation matrix in Table 2, some of the WGIs show a high level of intercorrelation. This Is particularly true for control of corruption (CC), government effectiveness (GE), regulatory quality (RQ), and rule of law (RL). As stated before, including variables that are too intercorrelated in a multivariate regression framework threatens the consistency of the estimates by incurring multicollinearity issues (Allen, 1997). Hence, in the first step of the analysis, the emphasis was put on the control of corruption, political stability, and voice and accountability (as a proxy for democracy). In addition to being the least intercorrelated, these three dimensions of institutional quality are also the most considered by the literature on the institutional determinants of NHRE adoption and environmental policy stringency (see section 2). As in Alonzo & Garcimartin (2013), the second and third steps of the analysis will only consider "overall institutional quality" through the inclusion of a composite index that is equal to the average value of the six WGIs.

Table 2 : Correlation matrix for the World Governance Indicators (WGIs) within the sample

Variables	CC	GE	PS	RQ	RL	VA
CC	1.00					
GE	0.82	1.00				
PS	0.48	0.44	1.00			
RQ	0.70	0.78	0.37	1.00		
RL	0.86	0.85	0.47	0.81	1.00	
VA	0.60	0.59	0.32	0.76	0.64	1.00

Notes: CC, GE, PS, RQ, RL and VA respectively stand for control of corruption, government effectiveness, political stability, regulatory quality, rule of law, and voice and accountability

The remaining independent variables used in this study come from the World Development Indicators database of the World Bank (WDI, 2020). Building on the most recent papers (Baldwin et. al., 2016; Lin & Omoju, 2017; Ragossa & Warren,2019), I included rents from fossil fuels (coal, natural gas, and oil) expressed in percentage of GDP to investigate for potential “lobby effects” from fossil fuel producers. In this case, the rent indicates the difference between the average cost of production (including taxes) and the selling price of the commodity[14]. Following classical economic theory, economic rents reflect inefficiencies and are thus efficient tax base (see e.g. Correia, 1996). The presence of high rents – and thus low taxation – from fossil fuels seems to be a good indicator of the weight of fossil fuel

[14] For sources and methodology of the computation of fossil fuels rents see World Bank (2011)

producer interests in the policy-making process. In the absence of a more accurate measure of climate commitment, and similarly to pre-existing studies (e.g. Aguire & Ibikunle, 2014; Brunnschweiler, 2010; Lin et. al., 2016), a dummy variable for the ratification of 1997's Kyoto Protocol is used as explanatory variable. This can also be seen as a way to evaluate the effectiveness of the said treaty, and more generally the relevance of the multilateral approach adopted in the promotion of NHRE at a global level. The analysis also aims to investigate the role played by government size in NHRE adoption. As in previous works (Becker & Mullingan, 2003; Gali, 1994; Kau & Rubin 1981), government size is expressed by the government final consumption expenditure as percentage of GDP. In order to investigate potential interaction effects between the political environment and financing channels of NHRE, two variables relative to the financing channels of NHRE are included in the analysis: net inflows of FDI and domestic credit to the private sector[15]. Both are expressed as percentage of GDP. The former is used as a proxy for the country's attractivity for private cross-border investments, and the latter is used to proxy the level of domestic financial sector development[16]. Finally, GDP per capita (in constant 2010 USD) and per capita CO_2 emissions from fuel combustibles (in thousands of tons) are used as control variables. Except for the Kyoto Protocol ratification and the rents from fossil fuels (because of their zero-values), all variables in the analysis are expressed under their logarithmic form. The descriptive statistics are reported in Table 3. An overview of all the variables including definitions, measurement units, and sources is available in the appendix (see Table A 2).

[15] Those are aggregate measures that are not specific the NHRE sector.

[16] Domestic credit to the private sector in percentage of GDP is commonly used as a proxy of financial development (e.g. Abid, 2017; Lin et. al., 2016; Lin & Omoju, 2017; Pata, 2018) and has been shown by Levine et. al. (2000) to be a reliable indicator of financial intermediary development

Table 3 : Descriptive statistics

Variable	Units	# Obs.	Mean	Std. Dev.	Min	Max
Dependent Variables						
NHRE per Capita (log)	GWh	1 149	-12.423	2.738	-23.270	-7.539
Share of NHRE (log)	% of total energy supply	1 149	-5.310	2.482	-15.744	-0.733
Independent Variables						
VA (log)	Relative points (0-5)	1 299	0.800	0.366	-0.533	1.379
CC (log)	Relative points (0-5)	1 300	0.774	0.230	0.093	1.395
PS (log)	Relative points (0-5)	1 294	0.729	0.492	-4.609	1.391
IQ (log)	Relative points (0-5)	1 294	0.804	0.252	-0.272	1.308
Fossil fuel rents	% of GDP	1 353	5.593	10.656	0.000	68.760
Kyoto	Binary dummy (0-1)	1 386	0.758	0.429	0.000	1.000
Public expenses / Government size (log)	% of GDP	1 325	2.564	0.385	-0.049	4.004
Domestic credit to private sector / Financial development (log)	% of GDP	1 149	3.285	0.886	-0.711	5.076
Net FDI inflows (log)	% of GDP	1 300	0.950	1.089	-6.684	4.009
Control Variables						
CO2 emissions per capita (log)	Thousands of tons	1 369	-9.078	1.298	-13.428	-6.523
GDP per capita (log)	Constant 2010 USD	1 367	7.670	1.001	4.921	9.684

Notes: The indication "log" under brackets indicates that the variable is expressed under its logarithmic form in the models and in the reported descriptive statistics. CC, PS, RQ, VA and IQ respectively stand for control of corruption, political stability, voice and accountability, and institutional quality.

3.2. Econometric specifications:

Similarly to many recent works in the related literature (e.g. Abid,2017; Bhattacharya et. al., 2017; Biresselioglu et. al., 2017; Omri & Nguyen, 2014), the empirical strategy of this paper relies on the two-step system GMM approach theorized by Arellano and Bover (1995) and developed by Blundell and Bond (1998). This method is of particular interest for analyzing dynamic panel data with a large number of groups (large N) and a limited number of observations (small T). Consistent with Roodman (2009), the *xtabond2* command in STATA is used. This allows to complement the regression with the Windmeijer (2005) finite sample correction of the standard error and to avoid instrument proliferation with the use of the *collapse* sub-option. By controlling for country-specific fixed effects, System GMM addresses sample heterogeneity. Under the underlying assumptions of overidentifying restrictions (i.e. validity of the instruments) and absence of serial correlation in the error term, System GMM also controls for other sources of endogeneity by instrumenting the lagged dependent variables with instruments that are uncorrelated to the fixed effect. The following subsection will be dedicated to explaining the method in detail.

3.2.1. Dynamic models and related assumptions

Let's consider the following dynamic model:

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2' X_{it} + \varepsilon_{it} \tag{2}$$

Where Y_{it} is the dependent variable, Y_{it-1} its associated lag, X_{it} is a set of explanatory and control variables, ε_{it} is the residual term, and the subscripts i and t are the related country and time indices. The error component (ε_{it}) is assumed to follow the following structure:

$$\varepsilon_{it} = \eta_i + u_{it} \tag{3}$$

$$E(\eta_i) = 0, \qquad E(u_{it}) = 0, \qquad E(\eta_i u_{it}) = 0 \tag{4}$$
$$For\ i = 1, \dots, n\ and\ t = 2, \dots, T$$

$$E(u_{it} u_{ij}) = 0 \tag{5}$$
$$for\ i = 1, \dots, n\ and\ t \neq s$$

The two components of the residuals η_i and u_{it} respectively denote the unobserved country-specific fixed effect and the idiosyncratic error. Equation (5) indicates that there is no autocorrelation in the idiosyncratic error. First differencing allows controlling for country-specific fixed effects η_i. The first-differenced version of equation (2) can be written as:

$$(Y_{it} - Y_{it-1}) = \beta_1 (Y_{it-1} - Y_{it-2}) + \beta_2' (X_{it} - X_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \equiv$$
$$\Delta Y_{it} = \beta_1 \Delta Y_{it-1} + \beta_2' \Delta X_{it} + \Delta u_{it} \tag{6}$$

Simple OLS estimation on equation (6) is still expected to lead to biased and inconsistent estimates because of the endogeneity problem embodied by the correlation between the change in idiosyncratic error Δu_{it} and the differenced lagged dependent variable ΔY_{it-1}. To solve this issue, Arellano and Bond (1991) suggest to instrument ΔY_{it-1} with its levels' lagged values Y_{it-1-s} (with $s > 0$). This is conventionally known as the "difference-GMM" estimator and requires an additional assumption ensuring the validity of the instrument:

$$E(Y_{it-1-s} \Delta u_{it}) = 0 \tag{7}$$
$$For\ t > 3\ and\ s > 0$$

Equation (7) implies sequential exogeneity – i.e. that current values of the regressors are not correlated with future idiosyncratic errors – and ensure the validity of the instruments. In theory, the instrument relevance is guaranteed by autoregressive path, but Blundell and Bond (1998) have shown that in the case of a persistent dependent variable Y_{it} and limited number of observations (small T), difference-GMM perform poorly because past levels constitute weak instruments for future changes. As an alternative, Arellano and Bover (1995) and Blundell and Bond (1998) developed the system GMM (syst-GMM) approach. It consists of estimating a system composed of two equations:

$$\Delta Y_{it} = \beta_1 \Delta Y_{it-1} + \beta_2' \Delta X_{it} + \Delta u_{it} \qquad (8)$$
$$Y_{it} = \beta_1 Y_{it-1} + \beta_2' X_{it} + \eta_i + u_{it} \qquad (9)$$

For the differenced equation (8), and similarly to difference-GMM, lagged values of the levels are used as instruments. For the level equation (9), instead of the regressor, it is the instrument that is differenced in order to make it independent from the fixed effects. Here again, the exogeneity of the instrument used for equation (8) has to hold:

$$E(\Delta Y_{it-s} u_{it}) = 0 \qquad (10)$$
$$For\ t > 3\ and\ \ s > 0$$

By introducing more instruments, System-GMM is expected to make the estimate more robust to the persistence of the dependent variable (Blundell & Bond, 1998).

3.2.2. Diagnostics

As stated before, two key conditions have to be met in order to ensure consistency of the System GMM estimator: the absence of serial autocorrelation in the idiosyncratic errors, see equation (5); and exogeneity of the instruments, see equations (7) and (10). Similarly to what has been done in previous papers (Bhattacharya et. al., 2017; Biresselioglu et. al., 2016; Omri & Nguyen, 2014) and consistent with Roodman (2009), two tests are performed. First, the Arellano-Bond tests for second-order autocorrelation, AR(2), are used to test of serial autocorrelation. AR(1) would be uninformative here because both Δu_{it} and Δu_{it-1} share the term u_{it} in their expression. First order-correlation in the differences is thus inherent to the model. By looking for second-order correlation in differences, the AR(2) test is used to track correlations between ε_{it-1} in $\Delta\varepsilon_{it}$ and ε_{it-2} in $\Delta\varepsilon_{it-1}$. In other words, the second-order correlation test in differences is used to track first-order serial correlation in levels. Secondly, the Hansen (1982) J-test of over-identifying restrictions test is used to test the validity of the instruments. Following the recommendations of Roodman (2009a, 2009b), unrealistically high p-values (close to, or equal to 1.000) for the Hansen J-test will be considered as a sign of instrument proliferation and failure in expunging their endogenous components. Together with AR(2) and J-test's p-values, the number of instruments used will be systematically reported in the results tables.

3.3. Empirical models and underlying hypotheses

The research strategy relies on a three-step approach. The first step investigates the role of institutions with a focus on the three dimensions of institutional quality that are the most invoked in the literature: democracy, corruption, and political stability. The second step of the analysis investigates the role of government size and its interaction with relevant political factors. Finally, the third step of the analysis looks at FDI and financial development as potential drivers of the effect of institutional and political variables on NHRE adoption. A graphical representation of the analytical framework is presented in Fig.4. Each model is estimated twice by alternatively using measure 1 (generation per capita) and measure 2 (share in the total energy generation) of NHRE adoption as dependent variable. All estimations are performed using the syst-GMM approach presented the subsection 3.2..

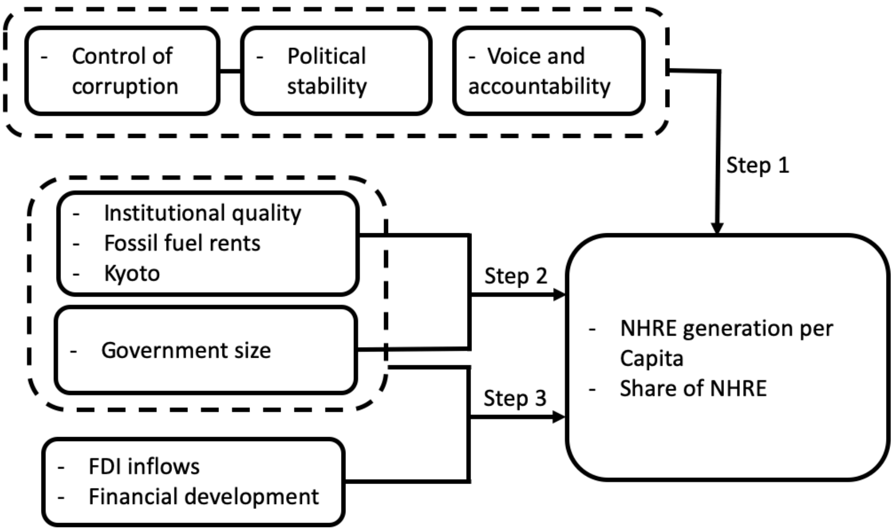

Fig. 4. Analytical framework

3.3.1. Step 1: Estimating the effect of three dimensions of institutional quality

The first step of the analysis focuses on the institutional determinants of NHRE. The analysis is restricted to three dimensions of institutional quality: control of corruption, political stability, and democracy (proxied by the voice and accountability index). The choice to focus on these three particular aspects of institutional quality is motivated by their preponderance in the related literature. They also have a comparatively low degree of intercorrelation among the WGIs (see Table 2), which minimizes the risk of multicollinearity. The first model is specified as follow:

$$Model\ 1:$$

$$lnY_{it} = \beta_1 lnY_{it-1} + \beta_2 lnCC_{it} + \beta_3 lnPS_{it} + \beta_4 lnVA_{it} + \beta_5' \boldsymbol{X}_{it} + \varepsilon_{it} \quad (11)$$

$$\boldsymbol{X}_{it} = (lnGDPpc_{it}, lnCO2_{it}, Year2001, \dots, Year2017) \quad (12)$$

The subscripts i and t respectively indicate the country and the year. The dependent variable lnY_{it} on the left-hand side of equation (11) expresses the level of NHRE adoption. The explanatory variables include the log value of the indexes for corruption control ($lnCC_{it}$), political stability ($lnPS_{it}$), and voice and accountability ($lnVA_{it}$). As common features for all the estimated models, the lagged value of the dependent variable (lnY_{it-1}) and a vector of control variables $\boldsymbol{X}_{it}$ are included as covariates. As shown in equation (12), $\boldsymbol{X}_{it}$ includes the log value of GDP per capita ($lnGDPpc_{it}$), the log value of per capita CO_2 emissions from fossil fuel ($lnCO2_{it}$), and a set of time dummies[17]. Finally, ε_{it} represents the error term. Based on previous work results (see subsection 2.1.), the underlying hypothesis is that the estimation of equation (11) to leads to significant and positive values for the coefficients β_2, β_3 and β_4.

Fredriksson and Svenson (2003) have provided theoretical and empirical arguments for a positive interaction effect between corruption and political instability on environmental policy stringency. Typically, political instability makes corrupt governments less likely to remain in power which reduces the incentive for polluting industry to bribe them. In the following model, I test whether the same mechanism can be observed while replacing environmental policy stringency by NHRE adoption, and by restricting the sample to developing countries only. In equation (13), model 1 is augmented by the inclusion of an interaction term between control of corruption and political stability:

$$Model\ 2:$$

$$lnY_{it} = \beta_1 lnY_{it-1} + \beta_2 lnCC_{it} + \beta_3 lnPS_{it} + \beta_4 (lnCC_{it} * lnPS_{it}) + \beta_5 lnVA_{it} + \beta_6' \boldsymbol{X}_{it} + \varepsilon_{it} \quad (12)$$

[17] The inclusion of time dummies makes the assumption of no autocorrelation in the idiosyncratic error more likely to hold.

Following the theoretical framework provided by Fredriksson and Svenson (2003), control of corruption would be less effective in fostering NHRE adoption if it is combined with greater political stability. Consequently, the estimated coefficient β_4 for the interaction term $(lnCC_{it} * lnPS_{it})$ is expected to be negative.

3.3.2. Step 2: The main political drivers and the effect of government size

The second step of the analysis aims to identify the main political determinants of NHRE adoption, and the extent to which their effects are conditioned by government size. The baseline model is presented in equation (13) and(14).

$$Model\ 3:$$

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2' \boldsymbol{Pol}_{it} + \beta_3' \boldsymbol{X}_{it} + \varepsilon_{it} \quad (13)$$

$$\boldsymbol{Pol}_{it} = (FFrent_{it}, Kyoto_{it}, lnIQ_{it}) \quad (14)$$

As shown in equation (14), $\boldsymbol{Pol}_{it}$ is a vector of explanatory variables including the rents from fossil fuels ($FFrent_{it}$), the ratification of the Kyoto Protocol ($Kyoto_{it}$), and the log value of the composite index for institutional quality (IQ_{it})[18] . Building on the literature, $FFrent_{it}$ is implemented to identify the potential presence of lobby effects from the fossil fuel industry on NHRE adoption. Based on the results of previous studies (Baldwin et. al., 2016; Lin and Omoju, 2017; Ragossa and Warren, 2019), a negative and statistically significant estimate is expected for the coefficient of $FFrent_{it}$. Conversely, a positive coefficient is generally estimated for the effect of Kyoto Protocol ratification (Aguire et Ibikunle, 2014; Brunnschweiler, 2010; Miyamoto & Takeuchi, 2019) and institutional quality (Uzar, 2020) on NHRE adoption. Hence, the hypothesis is to find statistically significant and positive estimates for $Kyoto_{it}$ and $lnIQ_{it}$.

In the following regressions, the baseline model is augmented to account for the direct and indirect effects of government size on NHRE adoption.

$$Model\ 4:$$

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2' \boldsymbol{Pol}_{it} + \beta_3 lnGov_{it} + \beta_4' \boldsymbol{X}_{it} + \varepsilon_{it} \quad (15)$$

[18] As stated in subsection 3.1., IQ_{it} is a composite index obtained by taking the mean value of all the rescaled WGIs. It accounts thus for control of corruption (CC_{it}), government effectiveness (GE_{it}), political stability (PS_{it}), regulatory quality (RQ_{it}), rule of law (RL_{it}), and voice and accountability (VA_{it}). Hence, $IQ_{it} = \frac{CC_{it}+GE_{it}+PS_{it}+RQ_{it}+RL_{it}+VA_{it}}{6}$

In equation (15), the log value of government size ($lnGov_{it}$) is implemented as explanatory variable. Theoretically, the government size can have either a positive or a negative effect on NHRE, as it is likely to be conditioned to many other factors. Hence, the hypothesized direct effect of government size on NHRE is ambiguous. Observing the way the other coefficients react to the inclusion of the variable $lnGov_{it}$ in the model, as well as the evolution of the estimated coefficient for $lnGov_{it}$ before (equation (15)) and after (equation (16)) the consideration of its interactions with the other variables of the model might provide useful insights to disentangle the complex effects of government size on NHRE.

Finally, I will also consider the interaction terms between $lnGov_{it}$ and the political variables included in vector $\boldsymbol{Pol}_{it}$. The related model is specified in equation (16).

$$Model\ 5:$$

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2' \boldsymbol{Pol}_{it} + \beta_3 lnGov_{it} + \beta_4'(lnGov_{it} * \boldsymbol{Pol_{it}}) + \beta_4' \boldsymbol{X}_{it} + \varepsilon_{it} \qquad (16)$$

The vector of coefficients β_4' in equation (16) incorporates the estimated interaction effects between $lnGov_{it}$ and the three political variables included in the vectors $\boldsymbol{Pol_{it}}$. These interaction effects have not been studied in previous empirical works and the theoretical arguments on the matter predict ambiguous effects. On the one hand, one could expect the interaction effect between $FFrent_{it}$ and $lnGov_{it}$ to be positive because a larger government might have more weight in the economy and thus be less vulnerable to pressions from private actors. On the other hand, following Olson's (1965) theory of "concentrated benefice and diffused costs", oversized governments create incentives for free-riding behaviors and lead to the overrepresentation of concentrated minor interests – e.g. those of monopolistic fossil fuel firms. Similarly, I also expect ambiguous interaction effects between IQ_{it} and $lnGov_{it}$. From one perspective, an oversized government might lead to bureaucratic inefficiency and hamper the (potential) positive effect of institutional quality on NHRE. Conversely, good institutions might strengthen the capacity of large governments to address climate change, and thus promote the development of NHRE adoption. Lastly, intuition suggest a positive interaction effect between $Kyoto_{it}$ and $lnGov_{it}$. Taking Kyoto Protocol ratification as a sign of government commitment toward climate change mitigation, signatory countries might succeed better in promoting NHRE if they have a large budgetary power, i.e. if they have a large government size.

3.3.3. Step 3: Political factors and the financing channels

We saw in the literature review that some of the most important barriers to NHRE adoption in developing countries relate to their particular cost structure and their resulting dependence on affordable financing conditions (see subsection 2.3.). Hence, it is likely that to a large extent, the political determinants of NHRE adoption operate through financial channels. This is what the third step of the analysis aims to test. Two financial variables are considered here: domestic credit provided to the private sector – as a proxy for financial development ($lnFD_{it}$) — and net inflows of FDI ($lnFDI_{it}$).

I first consider the following model:

$$Model\ 6:$$

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2 lnFD_{it} + \beta_3 lnFDI_{it} + \beta_4' \boldsymbol{X}_{it} + \varepsilon_{it} \tag{17}$$

This first model gives preliminary insights on the individual effect of these two financial variables on NHRE adoption without considering political variables yet. Several empirical studies have emphasized the critical driving role that financial development plays in NHRE penetration in developing countries (e.g. Brunnschweiler, 2010; Ji & Zhang, 2019). According to this hypothesis, I expect to find positive and significant estimates for β_2 in equation (17). However, the literature is less unanimous when it comes to estimating the relationship between FDI and NHRE adoption. Although FDI flows constitute an important source of financing for NHRE projects in developing countries (Keeley & Ikeda, 2017; Keeley & Matsumoto, 2018), they are also often pointed out to be a driver of the persistence of fossil fuel technologies (Lin et. al., 2016; Pfeiffer & Mulder, 2013). The question of the impact of FDI on RE development is often framed under the classical opposition between the "pollution haven" and the "pollution halo" hypotheses. The former states that, through FDI, developed economies tend to export their polluting industries to developing countries where environmental regulations are less stringent (Birdsall & Wheeler, 1993; Lucas et. al., 1992). In this case, FDI inflows are likely to promote the development of non-renewable energy-intensive infrastructures and hinder the development of NHRE. On the other hand, the pollution halo hypothesis states that FDI from developed to developing countries enhances RE adoption because it spreads human capital and contributes to the diffusion of cleaner and more efficient technologies (Asghari, 2013; Zarsky, 1999). Many empirical studies have been conducted on the matter, but they led to mixed and conflicting results[19].

In the following model (equations (18) and (19)), a stream of political explanatory variables is included in the regression:

$$Model\ 7:$$

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2 lnFD_{it} + \beta_3 lnFDI_{it} + \beta_4' \boldsymbol{Pol}_{it}^* + \beta_5' \boldsymbol{X}_{it} + \varepsilon_{it} \quad (18)$$

$$\boldsymbol{Pol}_{it}^* = (FFrent_{it}, Kyoto_{it}, lnIQ_{it}, lnGov_{it}) \quad (19)$$

As shown in equation (19), the variable $lnGov_{it}$ is now included along with $FFrent_{it}$, $Kyoto_{it}$, and $lnIQ_{it}$ in the vector of political variables $\boldsymbol{Pol}_{it}^*$**.** It will be interesting to observe the changes in magnitude, sign, and significance level of the different estimates between the equations (15), (16), and (18) to detect potential relationships between the different predictors.

While equations (17) and (18) addressed the direct effects of financial development and FDI inflows on NHRE adoptions, the following models look at the interaction effects between these two financial factors and the political variables of interest. Equations (20) and (21) respectively address the interactions for financial development and FDI inflows. The choice to build a specific model for each financial variable and its associated interaction terms is motivated by need to keep a reasonable number of covariates and thereby avoid instrument proliferation and multicollinearity issues.

$$Model\ 8$$

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2' \boldsymbol{Pol}_{it}^* + \beta_3 lnFD_{it} + \beta_4 lnFDI_{it} + \beta_5' (lnFD_{it} * \boldsymbol{Pol}_{it}^*) + \beta_6' \boldsymbol{X}_{it} + \varepsilon_{it} \quad (20)$$

$$Model\ 9$$

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2' \boldsymbol{Pol}_{it}^* + \beta_3 lnFD_{it} + \beta_4 lnFDI_{it} + \beta_5' (lnFDI_{it} * \boldsymbol{Pol}_{it}^*) + \beta_6' \boldsymbol{X}_{it} + \varepsilon_{it} \quad (21)$$

[19] For instance, Lin et. al. (2016), Solrarin and Pfeiffer & Mulder (2013) found a statistically negative relationship between NHRE and FDI inflows in China and developing countries, respectively. Akintande et. al.(2020) fund no significant impact of FDI inflows on RE in 5 African countries. Similarly Lin and Omoju (2017) fond insignificant estimate for the impact of FDI inflows on NHRE adoption in a sample of 46 developing and developed countries. Finally, working on a sample of 26 countries, Biresselioglu et. al. (2016) fund that FDI stocks positively affect installed wind energy capacity development.

The aim here is to investigate the moderating role played by financial sector development and FDI inflows on the political determinant of NHRE adoption. As this paper is the first to empirically investigate this, there is little material to hypothesize likely relationship these models might reveal.

A first educated guess is that financial development and large FDI attractivity would foster the dependence on FFB energy in countries that benefit from large domestic resources of fossil fuels. Typically, abundant fossil fuel resources still constitute an important financial windfall for these countries, which increases the short-term opportunity cost of a potential energy transition. Hence, it is likely that the mobilization of private capital in the energy sector in fossil fuel energy-rich countries would be essentially directed toward FFB technologies, as they have already reached a level of technical maturity and benefit from public subsidies that ensure a relatively safe return on investment. During the period 2016-2019, banks have provided nearly USD 2.7 trillion in financing for fossil fuels, with the volume of financing increasing every year since 2016 (RAN, 2020). Based on this argument, a negative interaction effect between $FFrent_{it}$ and the financial variables ($lnFD_{it}$ and $lnFDI_{it}$) might be found.

Conversely, the interaction effect between $Kyoto_{it}$ and the two financial variables is likely to positively affect NHRE. There are at least two reasons for this. Assuming that the ratification of the Kyoto Protocol is a sign of environmental awareness and climate commitment of a given country, one could expect better access to external founding – via better financial institutions or better FDI attractivity – to make this commitment more likely to be converted into investments in NHRE projects. Second, the Kyoto Protocol implemented a set of mechanisms – namely “flexible mechanisms” – allowing Annex 1 countries (i.e. developed countries) to achieve part of their reduction emission targets by investing in GHG emission mitigation projects in signatory developing countries. Hence, FDI inflows in countries that ratified the Kyoto Protocol are expected to be relatively more directed toward NHRE projects.

Previous empirical works have shown that the interaction effect between FDI and institutional quality on CO_2 emissions is significantly negative in EU (Abid, 2017), MENA (ibid.), and Asian countries (Huyn & Hoang, 2019; Bakhsh et. al., 2021). Furthermore, because institutional quality is one of the main levers for investment risk mitigation (Aziz, 2018; Dutta & Roy, 2011, Yang et. al., 2018) and because NHRE are particularly sensitive to investment risk (see subsection 2.3.), better political institutions are expected to provide a relatively advantageous investment environment for of NHRE projects. Hence, the estimated interaction effect between institutional quality and the two financial variables considered are expected to be positive

When considering the interaction effect between government size and the two financial variables on NHRE adoption, several scenarios appear credible. Assuming that governments generally favor NHRE development for their public good component, greater government size might lead to a greater capacity of governments to influence capital flows and redirect them toward NHRE projects. Conversely, if the government is associated with inefficiencies and concentrated private interests, large governments might fail in promoting NHRE and instead foster investments in fossil fuels. It is also possible that government expenses crowd out private investment, in which case government size and capital flows would behave as substitutes. In this case, government expenses for NHRE would disincentivize private investments in this sector. If significant estimates are found, a cross-analysis of the coefficients for the variables FD_{it}, FDI_{it}, $lnGov_{it}$, and their related interaction terms might help to disentangle the complex effects of government size and financial channels on NHRE.

4. Results and Discussion

This section presents and discusses the results from the models' estimation. Tables 3, 4, and 5 respectively show the results related to step 1, 2, and 3. The left-hand side of the tables reports the estimated coefficients for the predictors using per capita NHRE generation as dependent variable, while the right-hand side reports the estimates using the share of NHRE in total energy generation as dependent variable. At the bottom of each table, the p-values of the AR(2) tests and Hansen J-tests are presented. The non-rejection of the null hypothesis for both tests is consistent with the underlying assumptions of no serial autocorrelations and validity of the instruments, which suggests that the models are correctly specified.

4.1. Results: Role institutional quality

Table 4 : Results step 1

VARIABLES	NHRE generation per capita (log)		Share of NHRE generation (log)	
	(1) : Model 1	(2) : Model 2	(3) : Model 1	(4) : Model 2
Y (-1)	0.796***	0.797***	0.819***	0.829***
	(0.034)	(0.034)	(0.036)	(0.033)
lnVA	0.258*	0.248*	0.299**	0.270**
	(0.136)	(0.136)	(0.149)	(0.135)
lnCC	0.498*	0.767**	0.343	0.519*
	(0.281)	(0.339)	(0.283)	(0.281)
lnPS	-0.054	0.177	-0.045	0.119
	(0.061)	(0.194)	(0.053)	(0.153)
lnPS x lnCC		-0.364		-0.265
		(0.290)		(0.236)
lnCO2	0.124**	0.114**	0.006	-0.003
	(0.052)	(0.050)	(0.050)	(0.042)
lnGDPpc	0.056	0.072	-0.008	0.003
	(0.070)	(0.070)	(0.066)	(0.059)
Constant	-2.273**	-2.339**	-1.004	-1.396*
	(1.006)	(1.032)	(0.959)	(0.834)
Observations	1,014	1,014	1,014	1,014
Countries	77	77	77	77
Instruments	38	39	38	40
F-statistic	327.8	292.8	154.2	178.0
AR(2) p-value	0.497	0.486	0.483	0.474
J-test (p-value)	0.322	0.262	0.148	0.242

Notes: Robust standard errors with Windmeijer (2005) finite sample correction are in parentheses.
The superscripts *, **, and *** denotes 10%, 5%, and 1% level of significance, respectively.

The first step of the analysis (see Table 4) focused on the role of institutional quality in NHRE adoption in developing countries. In particular, the emphasis was placed on three particular dimensions of institutional quality: voice and accountability, control of corruption, and political stability. Two models were used in which these three dimensions of institutional quality were included as only explanatory variables. A significant positive relationship between the voice and accountability index (lnVA) and NHRE adoption was identified. This relationship was significant at a 10% level of confidence when NHRE generation per capita was used as dependent variable (columns 1 and 2), and at a 5% level of confidence when using the share of NHRE in the total energy mix as dependent variable (columns 3 and 4). This is consistent with Sequeira and Santos (2018) who found similar results with a sample composed of developing and developed countries. In line with other studies that have shown that democracy reduces GHG emissions (Chou et. al. 2020; Peligrini & Gerlagh, 2006) and increases the stringency of environmental policies (Bernauer & Koubi, 2009; Stadelmann & Castro, 2014), this study provides additional empirical evidence suggesting that the democratic framework pushes for greater consideration of environmental issues. Similarly, the results depict a positive relationship between control of corruption (lnCC) and the two dependent variables. This is consistent with Cadoret and Padovano (2016) and Asante et. al. (2020) who found that better control of corruption increases RE deployment in EU countries and Ghana, respectively. The presently estimated coefficients for control of corruption are higher in terms of magnitude, but one out of four estimates show no statistical significance (see Table 4, column 3). Conversely, and in contrast to Ragosa and Warren (2019), the present analysis found no evidence that political stability contributes to the development of NHRE in developing countries.

Building on the theoretical framework provided by Fredriksson and Svenson (2003), the interaction effect between control of corruption and political stability on NHRE adoption was tested in model 2 (see Table 4, columns 2 and 4). The estimates of the interaction terms are negative but not statistically significant (with p-values = 0.21 and 0.26 for columns 2 and 4, respectively). After the inclusion of the interaction term, the estimates for the direct effect of control of corruption on NHRE gained in both significance and magnitude, while the estimates for political stability remained non-significant but switched from negative to positive values. This was observed using both measure 1 (per capita) and measure 2 (share of total generation) of NHRE adoption as dependent variables. Taken together, these observations are in line with Fredriksson and Svenson's (2003) framework: there might be an offsetting effect between control of corruption and political stability. However, there is a clear lack of statistical significance in this last result. It should thus be considered with caution as no tangible empirical evidence validating the framework of Fredriksson and Svenson (2003) was fund here.

Steps 2 and 3 provided some additional insight on the impact of institutional quality on NHRE adoption. The models presented in Tables 5 and 6 estimated the effect of "overall institutional quality" through the inclusion of the composite index lnIQ in the regressions. This index encompasses the six dimensions of institutional quality as measured by the WGIs: control of corruption, political stability, governance effectiveness, regulatory quality, rule of law, and voice and accountability. Uzar (2020) used a similar multidimensional index and found a significant positive effect of institutional quality on RE consumption in a sample of 38 developed and developing countries. The results are less striking in the present paper:

Although the 12 estimated coefficients for lnIQ were positive, only one of them (see Table 5, column 1) was significant at a 10% level of confidence. Finally, some results from model 9 (see Table 6) suggests that institutional quality might significantly influence NHRE by changing the composition of FDI inflows, but these findings will be addressed in detail later in the discussion (subsection 4.3.).

4.2. Results: Main political determinants and government size

Table 5 : Results step 2

VARIABLES	NHRE generation per capita (log)			Share of NHRE generation (log)		
	(1) : Model 3	(2) : Model 4	(3) : Model 5	(4) : Model 3	(5) : Model 4	(6) : Model 5
Y (-1)	0.805***	0.806***	0.807***	0.821***	0.829***	0.829***
	(0.031)	(0.033)	(0.032)	(0.034)	(0.034)	(0.035)
FFrent	-0.015***	-0.015***	-0.050	-0.014***	-0.012**	-0.044
	(0.004)	(0.004)	(0.032)	(0.005)	(0.005)	(0.032)
lnIQ	0.334*	0.246	0.954	0.289	0.201	0.676
	(0.196)	(0.204)	(0.787)	(0.189)	(0.188)	(0.773)
Kyoto	0.116	0.153	-0.688**	0.126	0.148	-0.643*
	(0.103)	(0.112)	(0.337)	(0.105)	(0.108)	(0.359)
lnGov		0.097	-0.004		0.100	-0.047
		(0.084)	(0.189)		(0.077)	(0.203)
lnGov x FFrent			0.014			0.013
			(0.013)			(0.013)
lnGov x Kyoto			0.339**			0.322**
			(0.151)			(0.161)
lnGov x lnIQ			-0.292			-0.199
			(0.286)			(0.286)
lnCO2	0.122**	0.117**	0.111**	-0.003	-0.009	-0.016
	(0.049)	(0.052)	(0.048)	(0.045)	(0.047)	(0.045)
lnGDPpc	0.105	0.111	0.121*	0.050	0.051	0.064
	(0.066)	(0.070)	(0.068)	(0.064)	(0.065)	(0.065)
Constant	-2.074**	-2.366**	-2.315**	-1.464	-1.608	-1.418
	(0.959)	(1.067)	(1.048)	(0.949)	(0.991)	(1.072)
Observations	1,012	991	991	1,012	991	991
Countries	77	77	77	77	77	77
Instruments	38	39	42	38	39	42
F-statistic	296.8	343.7	281.9	154.9	147.3	159.8
AR(2) p-value	0.521	0.520	0.526	0.504	0.506	0.516
J-test (p-value)	0.391	0.354	0.393	0.249	0.197	0.163

Notes: Robust standard errors with Windmeijer (2005) finite sample correction are in parentheses. The superscripts *, **, and *** denotes 10%, 5%, and 1% level of significance, respectively.

The second step of the analysis (Table 5) focused on three political determinants of NHRE adoption (rents from fossil fuels, overall institutional quality, and Kyoto Protocol ratification) and their potential interactions with government size. In models 3 and 4, only the direct effects of the variables of interest were considered. The results revealed a highly significant negative relationship between rents from fossil fuels and the two measures of NHRE adoption. In particular, models 3 and 4 predict that a one percentage point increase in the portion of fossil fuel rent in GDP reduces NHRE generation per capita by 0.015%, and the share of NHRE by 0.012% to 0.014% (see Table 5, columns 1,2,4 and 5). This corroborates the presence of a "lobby effect" that undermines the development of NHRE in countries where the economic weight of the fossil fuel industry is too important (Aguirre and Ibikunle, 2014; Johnsson et. al., 2019; Marques et. al. 2010).

The comparison between models 3 and 4 shows that the inclusion of government size as explanatory variable does not significantly affect the estimated coefficient for fossil fuel rents. However, it is interesting to note that after the inclusions of the interaction terms between government size and the other variables of interest (model 5), the estimates for fossil fuel increases but lose significance (p-values = 0.13 and 0.17 for Table 5, columns 3 and 6 respectively). This, and the positive sign of the estimated interaction effect between fossil fuels rents and government size, suggests that the lobby effect in fossil-fuel-rich countries might be less important in countries with a relatively large government. Here again, the lack of significance calls for caution.

Little evidence was found in this study for a significant direct effect of government size on NHRE adoption: among the ten estimates, eight depicted a positive value, and only two of them were significant at a 10% level (see Table 6, columns 6 and 8). Similarly, ten out of twelve estimates for Kyoto Protocol ratification were positive, but none of them significant. This is in line with Pffeifer and Mulder (2013) and Lin and Omoju (2017) who claim that the effect of the Kyoto Protocol on NHRE is rather small or non-existent. However, this contradicts Aguirre and Ibikunle (2014), Brunnschweiler (2010), and Popp et. al. (2011) who found a significant positive relationship between the Kyoto Protocol ratification and the deployment of NHRE in developed and developing countries.

Interestingly, these results changed when considering the interaction effects between government size and the other variables of interest (model 5). Three notable observations can be reported. First, the coefficients for the direct effect of government size remain insignificant but switch from positive to negative values. Second, the variable Kyoto Protocol displays a strong, negative, direct effect on NHRE after the inclusion of the interaction terms. The coefficient is significant at a 5% level using NHRE generation per capita as dependent variable, and at a 10% level using the share of NHRE. Third, the interaction effect between Kyoto Protocol ratification and government size is positive and significant at a 5% level using the two measures of NHRE as dependent variable. These results suggest that Kyoto Protocol ratification and government size condition each other in the promotion of NHRE in developing countries. The effect of Kyoto Protocol ratification on NHRE adoption is negative until a certain threshold in government size is reached, but above this threshold, Kyoto Protocol ratification increases NHRE adoption. Hence, it seems that in order for the commitments in the reduction of GHG emissions made during the Kyoto Protocol to lead to an increase in the adoption of renewable energies, they must be combined with a significant degree of state involvement in the economy. Otherwise, these commitments might even have some adverse effects. This is an interesting result that would be worth addressing in future research.

4.3. Results: Political factors and the financing channels

Table 6 presents the results from the estimation of models 6,7, 8, and 9. These models were used for the third step of the analysis, addressing the financial determinants of NHRE adoption and their interactions with the political factors of interest. Model 6 (Table 6, columns 1 and 5) focused on the direct effect on NHRE adoption of the two financial variables of interest: financial development (lnFD) and FDI inflows (lnFDI). In model 7 (columns 2 and 6), the political variables from step 2 were included as covariates. Model 8 (columns 3 and 7) addressed the interaction effects between the political variables and financial development. And finally, model 9 (columns 4 and 8) addressed the interaction effect between the political variables and FDI inflows (lnFDI).

In general, the results in Table 6 report a positive and significant effect of financial development on NHRE generation per capita. Models 6 to 9 predict that an increase in financial development by 1% leads to an increase in NHRE generation per capita by 0.14% to 0.51% (see Table 6, columns 1 to 4). These results are in line with the literature (Anton & Nucu, 2020; Brunnschweiler, 2010; Ji & Zhang, 2019) and support the previously formulated argument that financial development fosters the deployment of the NHRE industry by facilitating access to long-term and affordable finance. When the share of NHRE is used as dependent variable, the estimated positive effect of financial development loses both in magnitude and significance (columns 5-8). In particular, only model 6 exhibits a significant estimate (column 5). Hence, while it seems that the development of the financial sector has a positive effect on the volume of NHRE produced in developing countries, it is less clear that it significantly increases the importance of NHRE over its fossil fuel-based competitors.

Table 6 : Results step 3

VARIABLES	NHRE generation per capita (log)				Share of NHRE (log)			
	(1) : Model 6	(2) : Model 7	(3) : Model 8	(4) : Model 9	(5) : Model 6	(6) : Model 7	(7) : Model 8	(8) : Model 9
Y (-1)	0.773***	0.801***	0.789***	0.783***	0.788***	0.805***	0.798***	0.787***
	(0.043)	(0.039)	(0.040)	(0.040)	(0.048)	(0.043)	(0.043)	(0.043)
lnFD	0.268***	0.140***	0.510*	0.142**	0.208**	0.072	0.311	0.079
	(0.078)	(0.051)	(0.258)	(0.054)	(0.079)	(0.056)	(0.256)	(0.054)
lnFDI	0.032	0.009	0.002	0.181	0.018	-0.010	-0.012	0.217
	(0.044)	(0.042)	(0.042)	(0.168)	(0.039)	(0.037)	(0.037)	(0.180)
FFrent		-0.015***	0.008	-0.015**		-0.014***	0.009	-0.013*
		(0.005)	(0.011)	(0.007)		(0.005)	(0.008)	(0.007)
lnIQ		0.082	0.695	0.292		0.199	0.727	0.408
		(0.219)	(0.651)	(0.268)		(0.221)	(0.585)	(0.247)
Kyoto		0.078	-0.277	0.012		0.120	-0.222	0.039
		(0.119)	(0.267)	(0.106)		(0.111)	(0.210)	(0.096)
lnGov		0.152	0.471	0.187		0.144*	0.303	0.193*
		(0.092)	(0.288)	(0.123)		(0.082)	(0.299)	(0.108)
lnFD x FFrent			-0.009**				-0.009***	
			(0.004)				(0.003)	
lnFD x lnIQ			-0.217				-0.200	
			(0.178)				(0.166)	
lnFD x Kyoto			0.118				0.114*	
			(0.077)				(0.062)	
lnFD x lnGov			-0.099				-0.050	
			(0.094)				(0.101)	
lnFDI x FFrent				-0.001				-0.002
				(0.003)				(0.003)
lnFDI x lnIQ				-0.220*				-0.242**
				(0.122)				(0.105)
lnFDI x Kyoto				0.136				0.138
				(0.097)				(0.084)
lnFDI x lnGov				-0.051				-0.065
				(0.072)				(0.076)
lnCO2	-0.076	0.016	0.014	0.021	-0.189*	-0.074	-0.087	-0.099
	(0.081)	(0.065)	(0.070)	(0.069)	(0.098)	(0.064)	(0.068)	(0.068)
lnGDPpc	0.318**	0.209**	0.242**	0.235**	0.227*	0.105	0.146	0.147
	(0.127)	(0.104)	(0.107)	(0.103)	(0.118)	(0.085)	(0.090)	(0.089)
Constant	-6.603***	-4.560**	-6.085***	-5.119***	-5.048**	-3.066**	-4.137**	-3.904**
	(2.172)	(1.750)	(2.271)	(1.780)	(2.048)	(1.378)	(1.876)	(1.560)
Observations	920	876	876	876	920	876	876	876
Countries	77	77	77	77	77	77	77	77
Instruments	38	42	45	45	38	42	45	45
F-statistic	197.1	259.1	242.0	209.8	75.65	116.4	122.1	132.8
AR(2) p-value	0.803	0.727	0.738	0.709	0.891	0.819	0.833	0.789
J-test (p-value)	0.564	0.513	0.507	0.596	0.321	0.479	0.522	0.484

Notes: Robust standard errors with Windmeijer (2005) finite sample correction are in parentheses. The superscripts *, **, and *** denotes 10%, 5%, and 1% level of significance, respectively.

Among the four models considered in Table 6, none estimates a significant direct effect of FDI inflows on NHRE in developing countries. This result challenges both the pollution halo and the pollution haven hypothesis. It is in line, however, with the recent findings of Lin and Omoju (2017) and Akintande et. al. (2020) who found that FDI stocks have no effect on both the share and the size of clean energy generation. But these findings are in contradiction with

Lin et. al. (2016), and Pfeiffer and Mulder (2013) who found that FDI inflows reduce the share of renewable energy in total electricity consumption in developing countries.

Consistent with what has been observed in Table 5, the estimations of models 7 and 9 suggest that there is a significant negative lobby effect from the fossil fuel industry on NHRE adoption (see Table 6, columns 2,4,7, and 9). These results were consistent between the two measures of NHRE adoption (per capita and share), and were of similar magnitude as the estimates generated by models 3 and 4 (see Table 5). However, the estimation of model 8 discloses interesting nuances. It reports a negative interaction effect between fossil fuel rents and financial development on NHRE adoption. This effect was observable using measures 1 and 2 of NHRE as dependent variables, and significant at a 5% and 1% level of confidence, respectively. Moreover, the estimated direct effect of fossil fuel rents became non-significant and positive after the inclusion of the interaction terms (see Table 6, columns 3 and 7). These results suggest that financial sector development plays a role in the negative relationship between fossil fuel rents and NHRE adoption. It might be the case that the development of domestic financial systems indirectly contributes to the persistence of fossil fuels by facilitating the emergence of lobby effects. This could also explain the observation made earlier, that the estimated positive direct effect of financial development is more pronounced on NHRE generation per capita than on the share of NHRE in the total energy mix.

In model 9, the interaction effects between FDI inflows and the political variables were estimated. The results report a negative interaction effect between FDI inflows and institutional quality on NHRE, significant at a 10% level of confidence for NHRE generation per capita and at 5% for NHRE adoption as a fraction of the total energy mix (see Table 6, columns 4 and 8). This goes against prior expectations as several studies reported that the combined effect of FDI and institutional quality tend to reduce CO_2 emissions in EU (Abid, 2017), MENA (Abid, 2017), and Asian countries (Huyn & Hoang, 2019; Bakhsh et. al., 2021). Moreover, given the high-risk sensitivity of NHRE projects, one would expect NHRE adoption to be higher in countries with high institutional quality where theoretically, the investment risk is lower. The fact that the opposite phenomenon was observed here casts doubts on the validity of this reasoning, at least for developing countries. The results rather suggest that relatively strong institutions in developing countries tend to attract FDI that increases the reliance on fossil fuel-based energy.

4.4. Results: Common features of the models

Table 7 presents a summary of the signs and the levels of significance of the estimates for the covariates that are common to all models, namely, the lagged dependent variables and the controls.

Table 7 : Summary of the results for the common features of the models

Variables	NHRE generation per capita (log)									Share of NHRE (log)								
Models:	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Y (-1)	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***	+***
lnCO2	+**	+**	+**	+**	+**	-	+	+	+	+	-	-	-	-	-*	+	+	+
lnGDPpc	+	+	+	+	+*	+**	+**	+**	+**	-	+	+	+	+	+*	+	+	+

Notes: + and – stand for positive and negative coefficients respectively. The superscripts *, **, and *** denotes 10%, 5%, and 1% level of significance, respectively.

All the estimates of the lagged dependent variables were positive and significant at a 1% level of confidence. The estimates ranged between 0.773 and 0.807 for NHRE generation per capita, and between 0.788 and 0.829 for the share of NHRE generation. This is consistent with previous observations made in developing (Anton & Nucu, 2020; Ito, 2017; Pfeiffer & Mulder, 2013) and developed countries (Biresselioglu et. al., 2016). It indicates the presence of a persistence effect in NHRE adoption: current levels of NHRE adoption are highly determined by past levels. These results are in line with the theoretical argument of positive reinforcement dynamics in NHRE technologies, as higher RE generation enables economies of scale and learning-by-doing mechanisms that enhance long-term penetration of NHRE (Aklin & Urpelainen, 2013).

The two control variables (per capita GDP and per capita CO_2 emissions) are outside the scope of this analysis, therefore they will only be briefly presented. Furthermore, their effects on NHRE have been largely documented in previous works (e.g. Aspergis, 2011a, 2011b; Sadorsky, 2009b; Nguyen & Kakinaka, 2019), and the present results are broadly consistent with them. For CO_2 emissions, models 1 to 5 predict a positive effect on NHRE generation per capita. These estimates are significant at a 5% level of confidence. They range between 0.111 and 0.124, which suggests that a 1% increase of per capita CO_2 emissions from fossil increases NHRE generation per capita by approximatively 0.12%. These results were not robust to the inclusion of the two financial variables in the models (see Table 5), nor to the use of the share of NHRE as dependent variable. The estimated effect of GDP per capita on NHRE adoption seemed generally positive: 17 out of 18 estimates depicted a positive sign. However, these estimates are only significant for models 5 to 9 with NHRE generation per capita as dependent variable, and for model 6 when using the share of NHRE as dependent variable. Taken together, the results suggest that CO_2 emissions and economic performance increase the amount of NHRE produced in developing countries. However, it is less clear whether or not these factors also significantly affect the importance of NHRE relative to conventional energy sources.

5. Conclusion

This paper addresses the political and institutional determinants of NHRE adoption in developing countries. It performs a panel data analysis on 77 low- and middle-income countries for the period between 2001 and 2017. The approach proceeded in a three-step analysis that sequentially assessed the role of institutions, the attenuating role of government size on relevant political factors, and the interactions between these political factors and the main financing channels. Together, these three steps constitute an exploratory analysis of the determinant of NHRE adoption, aiming to understand the effect of political and institutional factors and the underlying mechanisms that drive energy transition in the developing world.

The paper first highlights the complex nature of the relationship between institutions and NHRE adoption. It corroborates prior findings indicating a positive impact of democracy and control of corruption on NHRE. The presence of an offsetting effect between control of corruption and political stability cannot be statistically affirmed but is not rejected, suggesting that the impact of institutions on NHRE might be shaped by the interactions between several institutional features. The results further suggest that institutional quality indirectly affects NHRE adoption by modifying the composition of FDI inflows. In particular, it seems that relatively well-developed institutions in low- and middle-income countries attract FDI into fossil fuel intensive industries.

Another interesting result of the study is the ambiguous effect that domestic financial development has on NHRE. On the one hand, it seems to increase the NHRE generated per capita – presumably by enhancing access to long-term and affordable finance. On the other hand, it seems to reinforce the persistence of fossil fuels, which may involve lobby effects from conventional energy producers. Finally, the results show that Kyoto Protocol ratification and government size condition each other in the fostering of NHRE, whereby government must exceed a certain size to enable effective implementation of Kyoto Protocol. This suggests that the international climate commitments made by the states must be coupled with sufficient involvement of the governments in the economy to induce a significant increase in NHRE adoption.

The study has several limitations. In terms of uncertainty, the analysis carries the unknown errors associated with the approximation of the variables used. The World Government Indicators are useful to compare some aspects of institutional quality between the countries studied. However, they do not capture the institutional specificities of these countries. A similar remark can be made for the Kyoto Protocol ratification variable. While it reflects a formal multilateral engagement made by a state, it does not provide information on the extent to which this engagement is implemented in national law and taken seriously by incumbent governments. Furthermore, data limitations made it difficult to fully capture the factor relationships. This is particularly true for the financial variables used. Due to limited data availability, the present paper had to rely on an aggregated cross-sector measures of FDI and domestic credits. Having access to comprehensive data of the NHRE-specific credits and FDI would have enabled to quantify the contributions of the financial flows to NHRE development, and thereby to better assess how they interact with the political determinants of NHRE adoption. Finally, the measure of NHRE used in the paper does not account for off-grid renewable energy devices such as mini-grids and solar home systems. These technologies provide electricity to a considerable number of households, particularly in poor rural areas (IRENA, 2018).

Despite its limitations, this paper contributes to the emerging literature on the political determinants of NHRE adoption in developing countries by identifying general trends and outlining interesting avenues for future research.

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Appendix

Table A 1 : List of countries included in the sample

Country Name	Income Group	Region
Angola	Lower middle income	Sub-Saharan Africa
Albania	Upper middle income	Europe & Central Asia
Argentina	Upper middle income	Latin America & the Caribbean
Armenia	Upper middle income	Europe & Central Asia
Azerbaijan	Upper middle income	Europe & Central Asia
Benin	Low income	Sub-Saharan Africa
Bangladesh	Lower middle income	South Asia
Bosnia and Herzegovina	Upper middle income	Europe & Central Asia
Belarus	Upper middle income	Europe & Central Asia
Bolivia	Lower middle income	Latin America & the Caribbean
Brazil	Upper middle income	Latin America & the Caribbean
Botswana	Upper middle income	Sub-Saharan Africa
China	Upper middle income	East Asia & Pacific
Côte d'Ivoire	Lower middle income	Sub-Saharan Africa
Cameroon	Lower middle income	Sub-Saharan Africa
Democratic Republic of the Congo	Low income	Sub-Saharan Africa
Congo	Lower middle income	Sub-Saharan Africa
Colombia	Upper middle income	Latin America & the Caribbean
Costa Rica	Upper middle income	Latin America & the Caribbean
Dominican Republic	Upper middle income	Latin America & the Caribbean
Algeria	Upper middle income	Middle East & North Africa
Ecuador	Upper middle income	Latin America & the Caribbean
Egypt	Lower middle income	Middle East & North Africa
Eritrea	Low income	Sub-Saharan Africa
Gabon	Upper middle income	Sub-Saharan Africa
Georgia	Upper middle income	Europe & Central Asia
Ghana	Lower middle income	Sub-Saharan Africa
Guatemala	Upper middle income	Latin America & the Caribbean
Honduras	Lower middle income	Latin America & the Caribbean
Haiti	Low income	Latin America & the Caribbean
Indonesia	Lower middle income	East Asia & Pacific
India	Lower middle income	South Asia
Iran	Upper middle income	Middle East & North Africa
Jamaica	Upper middle income	Latin America & the Caribbean
Jordan	Upper middle income	Middle East & North Africa
Kazakhstan	Upper middle income	Europe & Central Asia
Kenya	Lower middle income	Sub-Saharan Africa
Cambodia	Lower middle income	East Asia & Pacific
Lebanon	Upper middle income	Middle East & North Africa
Libya	Upper middle income	Middle East & North Africa
Sri Lanka	Upper middle income	South Asia
Morocco	Lower middle income	Middle East & North Africa
Moldova	Lower middle income	Europe & Central Asia
Mexico	Upper middle income	Latin America & the Caribbean
North Macedonia	Upper middle income	Europe & Central Asia
Myanmar	Lower middle income	East Asia & Pacific
Montenegro	Upper middle income	Europe & Central Asia
Mongolia	Lower middle income	East Asia & Pacific
Mozambique	Low income	Sub-Saharan Africa
Mauritius	Upper middle income	Sub-Saharan Africa
Malaysia	Upper middle income	East Asia & Pacific
Namibia	Upper middle income	Sub-Saharan Africa
Niger	Low income	Sub-Saharan Africa
Nigeria	Lower middle income	Sub-Saharan Africa
Nicaragua	Lower middle income	Latin America & the Caribbean
Nepal	Low income	South Asia
Pakistan	Lower middle income	South Asia
Peru	Upper middle income	Latin America & the Caribbean
Philippines	Lower middle income	East Asia & Pacific
Paraguay	Upper middle income	Latin America & the Caribbean
Sudan	Lower middle income	Sub-Saharan Africa
Senegal	Lower middle income	Sub-Saharan Africa
El Salvador	Lower middle income	Latin America & the Caribbean
Serbia	Upper middle income	Europe & Central Asia
South Sudan	Low income	Sub-Saharan Africa

Togo	Low income	Sub-Saharan Africa
Thailand	Upper middle income	East Asia & Pacific
Tunisia	Lower middle income	Middle East & North Africa
Turkey	Upper middle income	Europe & Central Asia
Tanzania	Low income	Sub-Saharan Africa
Ukraine	Lower middle income	Europe & Central Asia
Uzbekistan	Lower middle income	Europe & Central Asia
Venezuela	Upper middle income	Latin America & the Caribbean
Vietnam	Lower middle income	East Asia & Pacific
South Africa	Upper middle income	Sub-Saharan Africa
Zambia	Lower middle income	Sub-Saharan Africa
Zimbabwe	Lower middle income	Sub-Saharan Africa

Table A 2 : Sources and definitions of the variables

	Definition	Source
Dependent Variables		
NHRE per Capita (GWh)	Per capita electricity generation in gigawatt hours (GWh) from Non-Hydro Renewable Energy. This definition includes wind, solar, geothermal and biomass technologies.	IRENA (2020)
Share of NHRE (%)	Share of non-hydro renewable energy in the total electricity generation.	IRENA (2020)
Explanatory Variables		
Control of Corruption (0 - 5)	Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Originally estimated in standard normal units ranging from approximately -2.5 (weak) to 2.5 (strong), the estimates have been rescaled by adding the constant 2.83 to each term (to avoid negative scores).*	WGI (2020)
Political Stability (0 - 5)	Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. Originally estimated in standard normal units ranging from approximately -2.5 (weak) to 2.5 (strong), the estimates have been rescaled by adding the constant 2.83 to each term (to avoid negative scores).*	WGI (2020)
Voice and Accountability (0 - 5)	Voice and accountability captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. Originally estimated in standard normal units ranging from approximately -2.5 (weak) to 2.5 (strong), the estimates have been rescaled by adding the constant 2.83 to each term (to avoid negative scores).*	WGI (2020)
Institutional Quality (0 - 5)	Indicators obtained by calculating the mean of the six world governance indicators: control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability. The estimates have been rescaled by adding the constant 2.83 to each term (to avoid negative scores). They approximatively range between 0 (weak) to 5 (strong) institutional quality. *	Author's computation using data from WGI (2020)
Kyoto	Dummy variable for Kyoto Protocol's ratification.	UNFCCC
Fossil Fuel Rents	Fossil fuel rents (% of GDP) obtained by summing the rents from coal, natural gas and oil.	Author's computation using data from WDI (2020)
Government Size	General government final consumption expenditure (% of GDP)	WDI(2020)
FDI	Foreign direct investment, net inflows (% of GDP)	WDI(2020)
Financial Development (log)	Domestic credit to private sector (% of GDP)	WDI(2020)
Control Variables		
CO2 intensity (log)	CO_2 emissions from fuel combustion (millions of tons)	CO2 Highlights, IAE(2019)
GDP per Capital (log)	Growth Domestic Product (constant 2010 US$) divided by total population	WDI(2020)

* Definition taken from the World Bank's website : https://info.worldbank.org/governance/wgi/Home/Documents