Title

Unpacking the determinants of cross-border private investment in renewable energy in developing countries

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Abstract

Private finance has emerged as a fundamental catalyst of the clean energy transition, an urgent and necessary step that must be taken in order to avert catastrophic climate change. Yet, private investment in renewable energy, although gaining momentum, remains limited in reaching some developing countries, where it is most needed. Previous research has provided some insights into the drivers and barriers faced by investors in this sector; however, these remain understudied in the context of developing country markets. This study contributes to this body of knowledge by systematically testing the effects that a variety of factors have on foreign investment in renewable power generation in developing countries, and by investigating how these effects may vary according to the source of finance. The determinants include the implementation of domestic renewable energy policies, the provision of international public finance and the wider business environment. Using panel data covering 62 countries over a 7-year period, this analysis relied on linear and logistic fixed effects models to determine what best explains the decision to invest and the volume of foreign private capital flows in the renewable energy sector. Results suggested that the provision of international public finance, regulatory support measures and feed-in tariffs, coupled with political stability, are strong drivers of cross-border investment in renewable energy in developing countries. Finally, evidence was presented that the effects of public interventions and business environment factors on investment may vary according to the source of finance, shedding light on the importance of breaking down investment flows to fully understand private financing decisions in renewable energy.

Key words:

- Renewable energy
- Developing countries
- Climate finance
- Private finance
- International public finance
- Climate change mitigation

1. Introduction

Human-induced global warming reached 1°C above pre-industrial levels in 2017 and the Intergovernmental Panel on Climate Change (IPCC) estimates that the world is on track for 3°C warming by 2100 (2018). Based on the current pledges (Nationally Determined Contributions) submitted by the 195 countries that have signed the 2015 Paris Agreement, the world is on track for 3.2°C, and heading for 3.4°C under current policies (Climate Action Tracker 2018). It is now recognised that, in order to avert the worst effects of climate change by limiting warming to 1.5°C, a shift towards cleaner production practices needs to occur on a global scale. Cleaner production is a term used by scholars and practitioners referring to a system in which waste and emissions are minimized, while the efficient use of energy and other resources is maximised (Fresner 1998). This paper contributes to the discussion of how to accelerate the transition towards cleaner production by focusing on the financial aspects of the decarbonisation of the energy system.

In view of the high costs associated with undergoing a global energy transition, private-sector finance has been identified as a fundamental catalyst of the shift towards renewable energy sources (IFC 2013; OECD 2015a). Strong investment in renewable technologies, such as solar photovoltaics and offshore wind power, has already resulted in significant cost reductions in some economies. For example, in the UK, the costs for future offshore wind capacity reduced by 47.2% between the 2015 and 2017 auction rounds, the costs of onshore wind by 50% since 2009 and those of solar cells by 80% since 2008 (BEIS 2017). Overall, global private investment in renewables is gaining momentum, having reached US $333.5 billion in 2017, the second highest figure ever (Louw 2018). This is promising in view of the falling capital costs for solar, the leading technology (Louw 2018). Nevertheless, to meet the 'well-below' 2°C goal set out in Paris, the Institute for Sustainability Leadership (ISL) estimates that investment in clean energy would need to reach US $900 billion per year by 2030 (2016). This would need to be undertaken in parallel with a reduction in fossil fuels investment, which still amounted to US $790 billion in 2017 (IEA 2018a). A seminal paper by McGlade and Ekins (2015) highlighted that globally, a third of oil reserves, half of gas reserves and over 80% of current coal reserves have to remain unused between 2010 and 2050 to prevent the 2°C goal being exceeded.

As for now, the investment gap in hence renewables persists, especially in less-advanced economies (Agbemabiese *et al*. 2018). In fact, private finance – the capital deployed by non-governmental entities (Haščič *et al*. 2015) – is asymmetrically allocated across countries, with many low-income economies failing to attract the much-needed capital to develop their renewable energy sector (FS-UNEP 2017; Atteridge 2011). This raises numerous concerns, as these markets require reliable and clean power sources to address increases in energy demand and carbon emissions, and in light of their fossil fuel resources coming under mounting pressure in the future (Sena and Ganguly 2017). As support from concessional and national public sources is limited in these countries, an involved private sector is crucial to paving the way for renewable energy penetration (Agbemabiese *et al*. 2018). Furthermore, renewable energy technologies constitute a substantial opportunity to reduce poverty and develop sustainably for many low-income economies, which are predicted to become seriously affected by climate change (Cancino *et al*. 2018). As such, renewable power generation has an important role to play in meeting the Sustainable Development Goals (SDGs).

Understanding the determinants of private finance is thus fundamental for monitoring the progress being made by domestic and international efforts to tackle climate change (Haščič *et al.* 2015). It lays the ground for future decision-making, informing the effective design of renewable energy policy and financial instruments to mobilise the highest degree of capital (OECD 2017). Nevertheless, this remains a surprisingly under-studied area of research, with a good section of relevant knowledge having been produced within the grey literature through international organisations, such as the OECD and Development Finance Institutions (DFIs) such as the World Bank Group.

Existing literature suggests two wide categories of determinants of foreign investment in renewable energy: while the first comprises of traditional factors shaping foreign investment, the second includes elements specific to renewable capital accumulation. Regardless of the underlying hypothesis, the former strand of literature has produced mixed results both in terms of the direction and significance of the investigated relationships (Keely and Ikeda 2017). Some point to macroeconomic factors as holding most explanatory power (Shamsuddin 1994; Chakrabarti 2001; Demirhan and Masca 2008), while others trace the roots of foreign investment decisions back to the institutional environment, such as the presence of political risk and corruption (Lucas 1990; Alfaro *et al*., 2008; Papaioannou 2009).

On the other hand, sector-specific literature finds that well-targeted public interventions are fundamental to attracting private finance in the renewable sector (Criscuolo and Menon 2014; Criscuolo *et al*. 2014; Keely and Matsumoto 2018). The term 'public interventions' is here used to refer to both domestic renewable energy policies (policies implemented by national governments to foster the diffusion of renewable technologies) and the provision of international public finance (capital flowing form national banks of developed economies and international development institutions towards developing countries). Domestic renewable energy policies have been found to play a crucial role in promoting increased renewable power generation, though some argue that their effect is conditional on the stage of development of the country (Baldwin *et al*. 2017; Romano *et al*. 2017) and subject to diminishing returns as the number of policies increases (Zhao *et al*. 2013). Furthermore, Haščič *et al*. (2015) show that, whilst domestic renewable energy policies are a strong determinant of renewable investment among advanced economies, the mobilisation effect of public finance is particularly large in the developing world. Finally, in line with that concerned with traditional determinants of foreign investment, sector-specific literature suggests that the overall quality of the investment environment is still an important factor affecting financing decisions in the context of renewable power generation (Ang *et al*. 2017; Reddy and Painuly 2004).

However, there remains a general scarcity of academic studies that systematically unpack the determinants of foreign capital investment in renewables in the context of developing countries. Previous literature has largely ignored how different factors vary in their effects on, first, the decision to invest and, second, the size of foreign capital flows. Further, the majority of existing studies use proxy dependent variables (e.g. electricity generation) rather than specifically addressing investment. Another important research gap is in the need to appropriately disentangle the implications of investors' heterogeneity for the allocation of foreign private capital in the renewable energy sector. Oversimplified frameworks largely overlook the variegated nature of renewable energy finance, which consists of a heterogeneous set of actors (Buchner *et al*. 2015) with different appetites for risk (Langiss 1996). With a few exceptions (Ghosh and Nanda 2010; Kalamova *et al*. 2011; Masini and Menichetti

2012; Mazzucato and Semieniuk 2018), previous literature has largely limited its focus to aggregate categories of 'public' and 'private' capital, failing to investigate the effects of various determinants on disaggregated categories of investors.

This paper aims to bridge the research gaps highlighted above through investigating the determinants of foreign investment in renewable power generation in developing countries by accounting for investor heterogeneity. As noted by Wüstenhagen and Menichetti (2012): "Thinking about ways to identify relevant investor segments may increase the efficiency and effectiveness of public policies to leverage private capital for the growth of the renewable energy market" (p.4). More specifically, it seeks to answer the following research questions:

- *How do public interventions and the wider investment environment affect foreign private capital flows into large renewable energy projects in developing countries?*

- *How do these factors interact with investor heterogeneity in terms of their effect on foreign investment in large renewable energy projects in developing countries?*

In doing so, this study employs a methodological approach comprised of linear and logistic fixed-effects models, which allows disentangling the effects of key explanatory factors on both the decision to invest and the amount of deployed finance. An original dataset is used, which was created by singling out relevant investment flows from Bloomberg New Energy Finance (BNEF)'s *Climatescope*, and by triangulating different databases to create a new set of renewable policies indicators.

2. Theoretical framework

Figure 1 summarises the chosen theoretical framework, containing the following three key explanatory factors: public interventions, the investment environment and investor heterogeneity. The term 'public interventions' is used here to refer to both domestic renewable energy policies and the provision of international public finance.

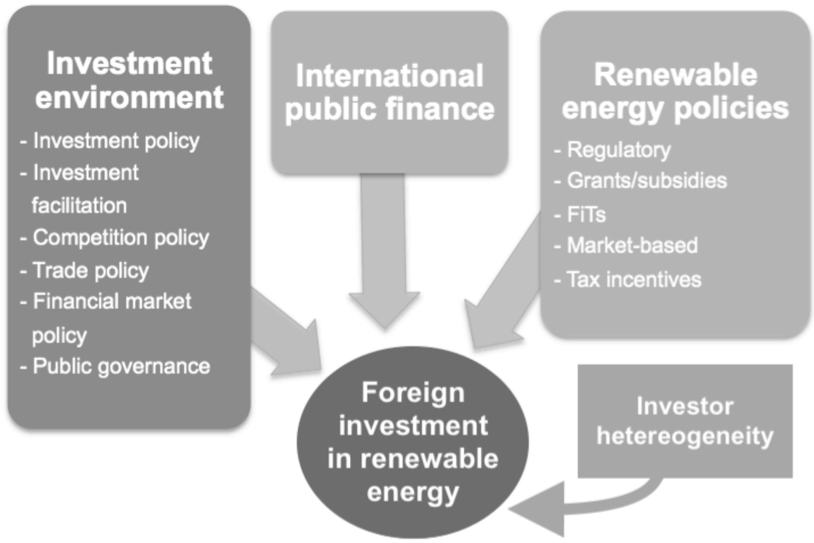

Figure 1 – *Theoretical framework for cross-border investment in renewable energy*

2.1 Public interventions

In-line with rational-choice tradition, it is assumed that private investors make their decisions based upon a weighing of the costs and risks on the one side, against expected financial return on the other side (Keely and Matsumoto 2018). Following this assumption, it is held that: "public interventions, in isolation or combination, directly or indirectly send signals, provide (dis)incentives, and/or extend financial support that can reshape both sides of the perceived risk/return equation" (Haščič *et al*. 2015, p. 17).

First, encouraging foreign investment in renewable-power technologies requires setting domestic renewable energy policies (Gambhir *et al*. 2014; Cárdenas-Rodríguez *et al*. 2014; Haščič *et al*. 2015). In particular, feed-in tariffs (FiTs) – through which a guaranteed price and a long-term purchase obligation are established for renewably produced electricity – are expected to be especially efficient in attracting investment in this sector (Eyraud *et al*. 2013; Cárdenas-Rodríguez *et al*. 2014). Similarly, subsidies and fiscal incentives are expected to have a positive effect, as they reduce investment costs (Romano *et al*. 2017; Baldwin *et al*. 2017). Furthermore, it is held that explicit carbon prices and market-based mechanisms (i.e. certificates or emissions trading schemes) do play a role in stimulating investment in renewable energy technologies (OECD 2013; Ecofys and World Bank 2016). However, their effect is predicted to be milder given that the portion of emissions not covered by explicit carbon prices is extremely high at the global level (over 85%), especially in less-developed economies (OECD 2015b). On the other hand, regulatory support policies are expected to be a strong driver of investment in this sector, which should benefit from easy access to grid infrastructure, clear technical standards, mandatory requirements, as well as auditing and monitoring (IEA 2018; Keeley and Ikeda 2017; Romano *et al*. 2017).

In addition to domestic renewable energy policies, this paper contends that the provision of international public finance plays a key role in mobilizing private finance towards renewable power generation. This claim is supported by previous research, which finds that this is particularly true in the context of developing countries that lack strong renewable energy policy frameworks (Hašćič 2015). This leads to the formulation of the following null hypothesis:

- $\mathbf{H0_1}$**:** Public interventions do not positively affect foreign investment into renewable power generation projects in developing countries.

2.2 Investment environment

For the conceptual framework on the investment environment, this study draws from the *Policy Guidance for Investment in Clean Energy Infrastructure* (OECD 2015c/d) and the *OECD Policy Framework for Investment* (PFI). The definition of the investment (or business) environment is as follows: the range of "policy fields critically important for improving the quality of a country's enabling environment for investment" (OECD 2015d, p.3).

Firstly, the adopted framework holds that public governance is a crucial determinant of foreign investment in renewable energy, which is undermined by an unstable, unaccountable and unpredictable government (Busse and Hefeker 2007; Alfaro *et al*. 2008; Komendantova *et al*. 2014). Secondly, investment policy is considered, which comprises of: "laws, regulations and policies relating to the admission of investors, the rules once established and the protection of their property" (OECD 2015d, p.23). In particular, it is contended that high regulatory quality (effective contract enforcement and dispute settlement) should result in a more attractive investment environment (Alfaro *et al*. 2008; Papaioannou 2009; Friebe 2014). Thirdly, the adopted framework suggests that investment facilitation is a fundamental ingredient, as it makes it easy for investors "to establish or expand their existing investments" (OECD 2015d; Ang *et al*. 2017; Gottfried *et al*. 2018). Research has in fact shown that administrative barriers such as time-consuming and convoluted processes for launching a business are important barriers to investment (Dumludag 2009; Reddy and Painuly 2004). Furthermore, "trade policies influence the size of markets for the output of firms and hence can shape foreign investment" (OECD 2015d, p.47). Academic research has established a link between trade openness and foreign direct investment (Jadhav 2012), which also holds in the context of renewable energy capital accumulation (Ang *et al*. 2017; Baldwin *et al*. 2017). Fourthly, it is held that a non-competitive environment discourages risk-taking and, thus, investment (OECD 2015d). Some studies have demonstrated that dependency of a country on fossil fuels results in less support for renewables due to the 'lobby effect' (Marques *et al*. 2010; Lin and Omoju 2017). Although some degree of market liberalisation has been occurring recently, many developing countries still display regulations accommodating monopoly or near-monopoly suppliers, which, it is argued, hamper the penetration of clean technologies (Sena and Ganguly 2017). Lastly, it is contended that financial market policy is essential to fostering investment in this sector (OECD 2015d). Previous studies have indeed found that a sound financial system has a strong effect on the shares of renewables in total energy supply (Lin and Omoju 2017), 'green' investment (Eyraud *et al*. 2013) and renewable energy investment (Ang *et al*. 2017). These findings lead to the formulation of the following null hypothesis:

- $\mathbf{H0_2}$**:** A sound investment environment does not positively affect foreign investment in large renewable energy projects in developing countries.

2.3 Investor heterogeneity

As a theory has not yet been developed on how different types of foreign private investors should vary in preferring particular public interventions or business environment characteristics, this research explores the hypothesis that they differ in their chosen destination according to the hosting country's investment environment, active domestic renewable energy policies and the level of international public finance provided. Accordingly, the following null hypothesis is formulated:

- $\mathbf{H0_3}$**:** The effect of renewable energy policies and the wider investment environment on foreign investment in large renewable energy projects in developing countries does not vary according to the investor type.

3. Research Design

3.1 Methodological approach

This section provides an overview the chosen research design, which relies on a deductive approach to theory development and large-number econometric analysis (Figure 2). Alternative methodologies have been used in the past; in particular, there exists a wide array of studies using qualitative approaches (Komendantova *et al*. 2012; Reddy and Painuly 2004). Though they are useful in explaining the motivations behind investors' choices within a specific context, qualitative studies suffer from important limitations such as small sample sizes and limited scope for generalisability (OECD 2017). On the other hand, large-N econometric techniques allow for more generalizable conclusions to be made and the isolation of the relationship between key variables through controlling a range of relevant factors (OECD 2017). Further, through the use of fixed effects in panel data (which involve using the subjects as their own controls), the problem of omitted variable bias is further reduced without the observation of some of the confounders (Stock and Watson 2015; Allison 2009; Allison 2005).

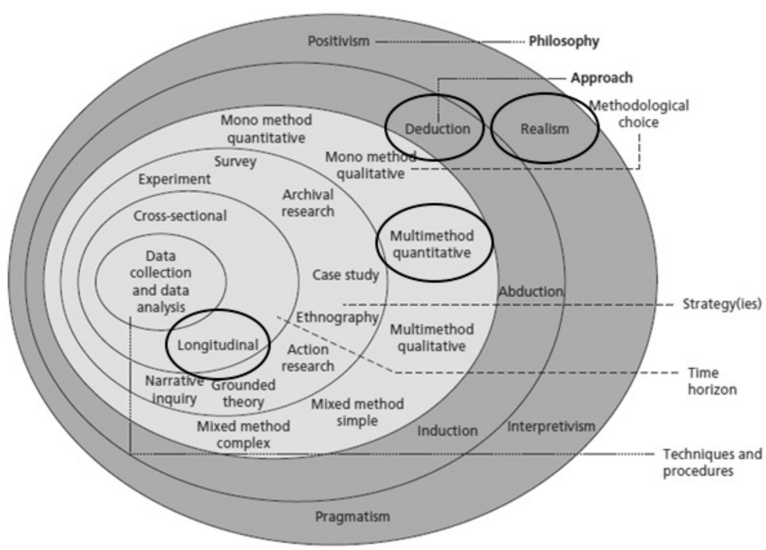

Figure 2 – *The research design mapped onto Saunders et al. (2016)'s Research Onion*

3.2 Data and variables

The approach employed involves combining datasets to account for the respective effect of the various explanatory factors. A full list of the variables included in the analysis is reported in the Appendix, along with their description and source. The data is available from 2008 to 2017 for 86 countries.

However, as some observations are lost due to missing variables, the final models include 7 years (2008-14) and 62 countries.

3.2.1 Dependent variables

The dataset for the dependent variables is constructed using Bloomberg New Energy Finance (BNEF)'s Climatescope database, which offers a comprehensive record of disclosed asset finance deals, debt or equity investments, in renewable energy generation in developing countries. The analysis is restricted to grid-scale projects with an installed capacity larger than 1.5 MW and excludes small-scale, distributed renewable projects. The sectoral scope is on seven technologies: biomass and waste, biofuels, geothermal, small hydro, marine, solar and wind energy. BNEF does not track large hydropower flows, which are therefore not considered in the analysis. However, as large hydropower can result in impactful negative externalities (such as land displacement), Brunnschweiler (2010) argues that it should be viewed as a non-viable source of renewable power.

As discussed in section 1, private finance is here defined as capital deployed by non-governmental entities (Haščič *et al*. 2015) and constitutes the main outcome of interest. Flows originating from governmental entities and public development banks are excluded from the analysis as they are classified as 100% public, which is consistent with the Development Assistance Committee (DAC) definition of official transactions (OECD 2018). In the theoretical literature, public and private finance are treated as two clearly separate entities, however, in practice this division is not as clear (Stadelmann *et al*. 2013). In fact, there remain cases where the inclusion of public flows cannot be ruled out, such as for energy utilities, which vary by country in terms of their share of public/private ownership. It is thus important to clarify that the inclusion of this type of investor into private financial flows is only indicative.

As this research tests the effects of chosen explanatory factors on both the likelihood of investment occurring and its size, there are two types of dependent variables: a set of continuous variables measuring investment flows (US$M) and a set of dummy variables that take the value of 0 when no investment has occurred at a given year and 1 if it has. Models are first run for cumulative financial flows, including commercial banks, corporate/large consumers, insurance, manufacturers, private equity, project developers, sovereign funds and utilities. Secondly, sub-samples of financial actors are analysed individually: 1) commercial banks, 2) corporate/large consumers, 3) private equity, 4) project developers and 5) utilities. These institutions were chosen as they are the top-five sources of finance in the sample.

3.2.2 Public interventions variables

The IEA/IRENA Joint Policies and Measures (2018b) and BNEF's Climatescope Policies (2018) databases are triangulated to construct a unique set of renewable policy indicators. According to IEA's categorisation, this paper considers the following five policy instruments: 1) grants and subsidies; 2) feed-in tariffs; 3) tax incentives (carbon taxes and tax reliefs); 4) market mechanisms (greenhouse gas emissions allowances, green certificates, public tenders and auctions); and 5) regulatory instruments (auditing and monitoring, codes and standards, obligation schemes and other mandatory requirements). Dummy variables are generated to track the implementation of specific instruments. For a given year and country, they take a value of 0 if they are in place and 1 if they are absent or not active. Further, a measure of aggregate renewable energy policies is constructed from the five dummy variables to illustrate the overall degree of renewable energy policy support shown by governments. This is an indicator of how many different policy instruments a country has implemented (0 none – 5 all of them).

It is important to note that, due to the scarcity of available data, policy measures only indicate whether a specific instrument is in place, but not its intensity (i.e. the size of subsidies or tax breaks is not accounted for). For the same reasons, similar indicators have been used in the literature (Carley 2009; Johnstone *et al*. 2010; Zhao *et al*. 2013). However, using fixed effects to control for unobserved time and country heterogeneity might contribute to mitigating the bias generated by policy intensity omission (Zhao *et al*. 2013). Finally, a measure of international public finance is constructed drawing from the Climatescope's database. This corresponds to the amount of public finance (US$M) provided by either national development banks or DFIs.

3.2.3 Investment environment and controls

The dataset used to measure the quality of the investment environment is assembled by gathering data from various sources: World Bank Development and Governance indicators, as well as data from the IEA's Energy Balances database. Firstly, a variable quantifying the political stability of hosting countries is used as a measure of the quality of public governance within hosting countries. Secondly, a variable measuring the days necessary to start a business is employed as a proxy for the overall quality investment policy and investment facilitation. Next, to illustrate the nature of trade policy within a given country, a measure of trade as a percentage of the gross domestic product (GDP) is included in the model, whilst a measure of natural resources rents as a percentage of GDP is used as a proxy indication of competitiveness within the energy market (Lin *et al*. 2017; Baldwin *et al*. 2017). Further, an indicator of domestic credit to private sector as a percentage of GDP is introduced as a proxy for financial market policy (Ang *et al*. 2017; Lin and Omoju 2017).

The effects of control variables on the outcome of interest are also estimated. In particular, GDP is a key economic indicator, as wealthier countries are in a better position to promote investment in renewable energy sources (Romano *et al*. 2017; Eyraud *et al*. 2013). GDP is also related to consumption in energy, which is often taken as a proxy for countries' economic development (Toklu *et al*. 2010). Furthermore, higher electricity demand might encourage the construction of new renewable power plants and it is thus included in the analysis (Romano *et al*. 2017).

3.3 Regression models

In this section the regression models are specified for testing the conceptual model, which is illustrated in Figure 3.

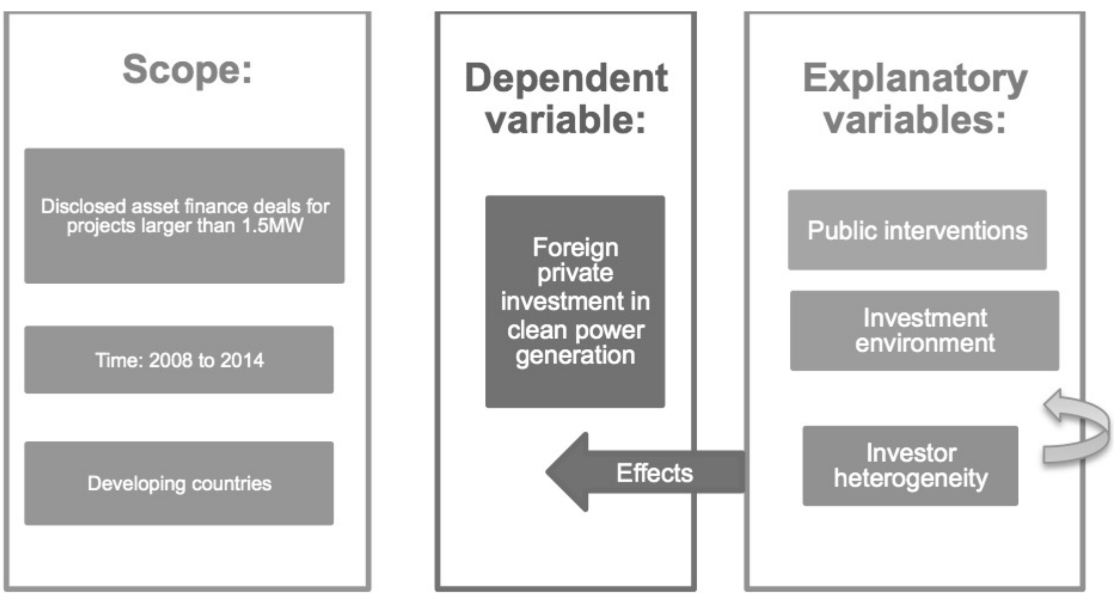

Figure 3 – *Conceptual model and scope of the analysis*

3.3.1 Logit model

To determine the effects of the chosen explanatory variables on the likelihood of the decision to invest, the first model is a conditional or fixed effects logistic model:

$$\Pr(Y_{i1} = 1, Y_{i2} = 2 \mid X_{i1}, a_i) = \frac{\exp\,(X_{i1}\beta + a_i)}{1 + \exp\,(X_{i1} + a_i)}$$

Where P_r is the probability of investment occurring, X_{i1} is the vector variable for explanatory factors, and α_i represents the individual fixed effect. Derived by Andersen (1970) and further developed by Chamberlain (1980), conditional logistic regression or fixed effects logit model is a specification for panel data analyses with binary outcomes, which "allows for unobserved time-invariant individual heterogeneity with an arbitrary distribution" (Stammann *et al*. 2016, p.2). It estimates the within-group relationship between the independent and the binary dependent variables, thus drawing parallels with fixed effects (Williams 2018). The problem of self-selection and omitted variable bias are hence drastically reduced (Pforr 2013).

3.3.2 Linear model

To assess the effects of the independent variables on the amount of investment, the following linear regression model is specified:

$$Y_{it} = a + \beta_1 Public_{it} + \beta_2 Environment_{it} + X_{it}\delta + u_i + v_t + \omega_{it}$$

Where Y_{it} is a measure of foreign private investment flowing into a country i at year t, $Public_{it}$ is a vector representing public interventions, $Environment_{it}$ the investment environment, X_{it} the control variables, and δ denotes the coefficients of control variables. α is the constant, u_i is country fixed effects, v_t is time fixed effects, and ω_{it} is the random error. To obtain robust results and control for as many factors as possible, this research employs two-way fixed effects. Such an approach allows factors to be controlled that affect investments that vary over time but are constant across units (e.g. global oil prices), as well as for time-invariant country determinants, such as renewable energy endowment and the region of the hosting country (Baldwin *et al*. 2017; Stock and Watson 2015). Furthermore, after running both the Breusch-Godfrey and Pesaran tests, which pointed to the existence of both serial correlation and cross-sectional dependence, standard errors are adjusted. In particular, this research adopts Driscoll and Kraay's (1998) SCC estimator, which employs clustered standard errors to correct for serial and cross-sectional dependence, as well as heteroskedasticity.

3.4 Overview of the data

Table 1 and Table 2 offer a summary of descriptive statistics, while Figure 4 shows the geographical distribution of total foreign private investment flows included in the sample. On average, each country received about 76 US$M of funding per year. Countries that received the highest average investment between 2008 and 2014 are: 1) Brazil (1200 US$M), 2) Mexico (906 US$M), 3) India (694US$M), Chile (671 US$M) and Indonesia (607 US$M). The top yearly-investors among the ones included in the sample are utility companies, which provided on average 118 US$M per year per country; followed by commercial banks and private equity investors, which scored 36 and 26 US$M, respectively.

Table 1 – *Summary of descriptive statistics of foreign private investment per country (US$M)*

Variable	Mean	Median	St. Dev.	Min	Max
Cumulative yearly investment	76.136	0	245.252	0	2890
Commercial banks yearly investment	11.856	0	47.883	0	496
Utilities yearly investment	21.521	0	132.256	0	2071
Corporate yearly investment	5.127	0	24.331	0	216
Project developers yearly investment	11.157	0	35.588	0	216
Private equity yearly investment	9.812	0	37.098	0	333

Table 2 – *Summary of descriptive statistics of public interventions*

Variable	Mean	St. Dev.	Min	Max
# of active renewable energy policies	1.598	1.426	0	5
Feed-in tariffs	0.245	0.431	0	1
Market-based mechanisms	0.180	0.385	0	1
Regulatory instruments	0.482	0.500	0	1
Grants and subsidies	0.209	0.407	0	1
Tax incentives	0.482	0.500	0	1
Yearly international public finance (US$M)	35.932	116.586	0	1419

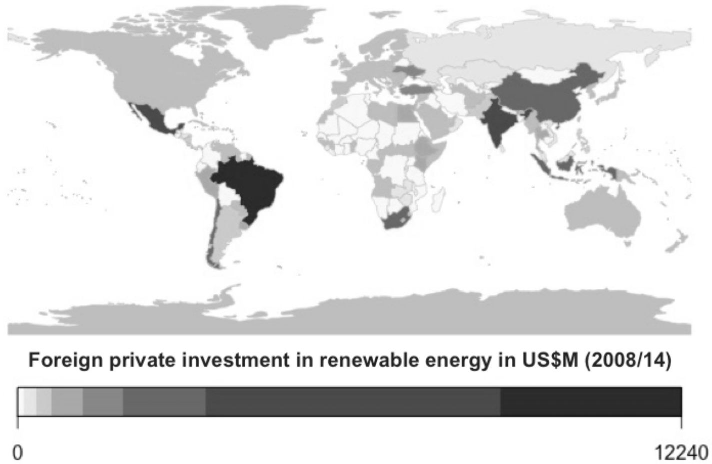

Figure 4 – *Foreign private investment in renewable energy generation projects >1MW 2008-2014 (US$M)*

On the five-scale renewable policies index elaborated in sub-section 3.2.2, countries scored 1.6 on average, meaning that they had less than two policy instruments in place each year. Only a few countries implemented all five instruments during any of the years considered in this study; amongst them are Brazil, China, Egypt, India, Indonesia, South Africa and Uruguay. The most frequently implemented policies are regulatory instruments and tax incentives, which are in place 48% of the years in countries included in the sample, while market-based mechanisms are the least implemented (18%). Figure 5 illustrates the sample's geographical distribution for international public financial flows. On average, countries received 36 US$M of international public finance per year. The countries that received the largest amount of international public finance on average over the 7 years included in the sample are India (285 US$M), South Africa (242 US$M) and Mexico (203 US$M).

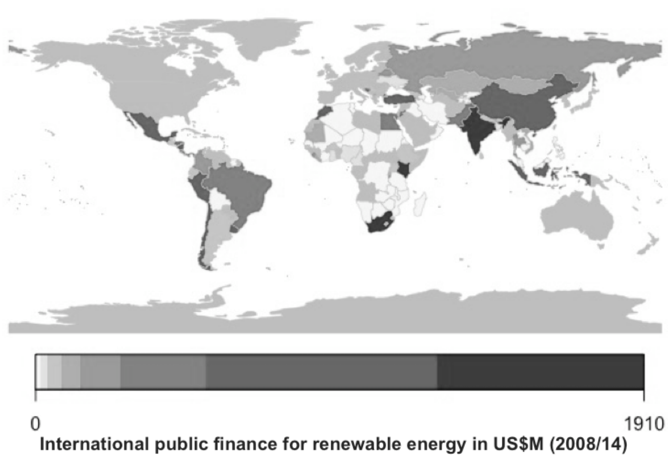

Figure 5: *International public finance into renewable energy generation projects >1MW 2008-2014 (US$M)*

4. Results and Discussion

Table 3 shows the models for two dependent variables: the cumulative amount of investment (US$M) and the binary variable measuring the decision to invest for all types of private finance. It should be noted that standard interpretation of fixed-effects logit is limited to odds-ratio effects and does not allow for easy substantive interpretation of probabilities of outcome (Pforr 2013). To understand the importance of these effects, the odds (exponentiated coefficients) are computed and analysed.

Table 3 – *Regression results for cumulative foreign investment*

	Foreign private investment			
	Logit	Linear	Logit	Linear
	(1)	(2)	(3)	(4)
# of renewable energy policies	0.416^{***}	23.964		
	(0.106)	(29.242)		
Feed-in tariffs			0.217	38.894^{*}
			(0.318)	(21.765)
Market-based mechanisms			0.143	68.611
			(0.361)	(66.907)
Regulatory instruments			0.791^{***}	89.166
			(0.282)	(84.790)
Grants and subsidies			0.321	-134.587
			(0.342)	(131.080)
Tax incentives			0.335	-22.693
			(0.298)	(30.965)
International public finance	0.016^{***}	0.500^{***}	0.016^{***}	0.461^{***}
	(0.004)	(0.094)	(0.004)	(0.106)
Days to start a business	-0.002	-0.094	-0.002	-0.127
	(0.003)	(0.116)	(0.003)	(0.147)
Political stability	-0.028	77.572^{*}	-0.028	78.256^{*}
	(0.180)	(45.829)	(0.185)	(47.112)
Trade openness	-0.0001	-0.980	0.00003	-1.210
	(0.005)	(0.950)	(0.005)	(0.995)
Domestic credit to the private sector	0.011^{*}	-3.627	0.011^{**}	-3.338
	(0.006)	(2.674)	(0.006)	(2.444)
Natural resources rents	-0.015	-4.258	-0.016	-3.405
	(0.015)	(3.262)	(0.015)	(2.935)
Gross domestic product (log)	-0.007	124.094	0.019	157.339^{*}
	(0.066)	(97.934)	(0.068)	(93.569)
Electricity consumption	0.003^{*}	-0.021	0.003^{*}	0.132
	(0.002)	(0.599)	(0.002)	(0.483)
R^2		0.143	0.293	
Wald Test	65.080^{***} (df = 9)		67.290^{***} (df = 13)	
LR Test	132.275^{***} (df = 9)		134.530^{***} (df = 13)	
Note:				$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

4.1 Public interventions

Model 1 (Table 3) shows that, if governments adopt one extra policy among the five types considered, the odds of receiving investment are multiplied by 1.51 (51%). Hence, results suggest that having a larger number of active renewable energy policies in place significantly raises the odds of attracting foreign private investment into renewable power generation. If we disentangle the effects of specific policies on the decision to invest (Model3), it appears that regulatory policies are the only significant policy predictor of the decision to invest – the odds of investment occurring are multiplied by 2.20 if such interventions are in place. This validates results by existing studies that point to regulatory support policies (such as easy access to grid infrastructure, smooth processes to obtain technological permits, clear technical standards and mandatory requirements), as particularly strong drivers of investment into renewable energy sources in developing countries (Keeley and Ikeda 2017; Friebe *et al*. 2014; Romano *et al*. 2017).

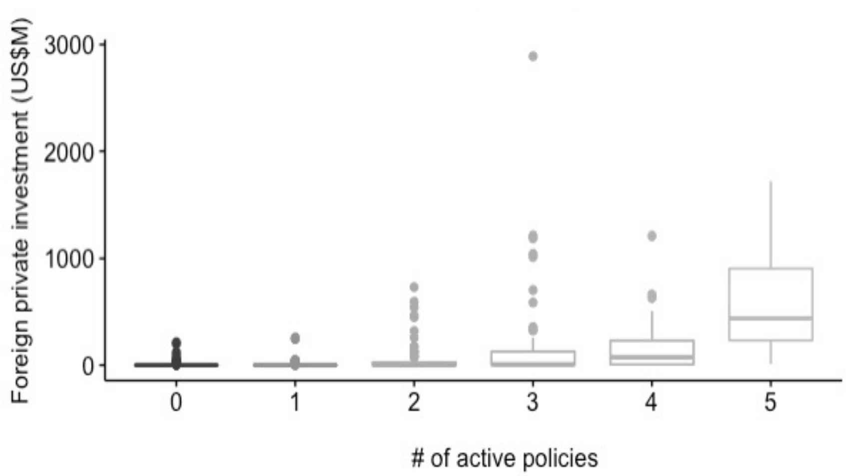

Figure 6 – *Foreign investment in renewable energy vs. the number of active renewable policies*

Model 2 shows that the number of active renewable energy policies similarly has a large and positive effect on the size of finance deployed by private investors (coefficient = 23.96); however, the effect is not significant at the 95% confidence level. As shown in Figure 6, the direction of this effect is consistent with findings by previous research that the number of policy measures is positively correlated with investment flows (Cárdenas-Rodríguez *et al*. 2014). However, its insignificance in this paper does not provide further evidence for this claim. If this explanatory variable is further disaggregated along different policy instruments (Model 4), the estimated effects of single types of policies are all insignificant with the exception of feed-in tariffs. In fact, regression results suggest that the adoption of this policy results into an increase in investment of about 39 US$M on average. This is in line with findings by previous research that feed-in tariffs are particularly effective in attracting investment (Eyraud *et al*. 2013; Cárdenas-Rodríguez *et al*. 2014).

Model 3 shows that receiving one extra US$M of international public finance multiplies the odds of investment occurring (by 1.016), holding everything else constant. The estimated effect of this variable on the amount of provided foreign private investment is also positive and significant, one extra US$M of international public finance leading to an increase in private investment of half-a-million US$ on average, holding other factors constant (Model 2).

These results provide evidence in support of the adopted theoretical framework, which posits that public interventions are a key driver of foreign investment in renewable energy in the context of developing countries. The null hypothesis $H0_1$ can thus be rejected. Whilst international climate finance slightly increases the likelihood of investment occurring and significantly boosts investments' size, the number of active renewable energy policies seems to have a significant effect only on the decision to invest. This is consistent with previous findings, which highlight that the mobilisation impact on investment flows of public finance is stronger of that of renewable energy policies in the context of developing countries (Haščič *et al*. 2015). This recurrent outcome is likely explained by the scarce policy support for renewable energy shown by most countries in this part of the world. It is important to note that the effect of *renewable energy policies* on the likelihood of investment is larger than that of *international public finance*. Thus, whilst policies drive the early decision to invest, international public finance is what might ultimately push investors to provide more capital for renewable energy projects. Finally, it appears that while regulatory instruments drive the early decision to invest, feed-in-tariffs seem to be associated with larger sums being deployed by investors.

4.2 Investment environment

Focusing on other key variables of interest, results seem to suggest that *time to start a business* is not a significant predictor nor of the decision to invest and nor of the amount deployed by investors (Models 1-4). This in contrast with findings by Ang *et al*. (2017), which suggest that the *time to start a business* is significantly and positively correlated to investment in renewables in emerging economies. Diverging results might be explained by the different characteristics of the samples considered. In fact, Ang *et al*. (2017) only consider 11 emerging economies, whereas this study has a sample of N=62 developing countries. Despite its insignificance, the negative direction of the effect is as expected and consistent with the argument that time-consuming procedures to start a business may deter investors from engaging in market activities. Further, *political stability* seems to be associated with larger investment size (Model 4). On average, if countries score one unit higher in the political stability index, the incoming investment increases by 78 US$M. This is consistent with a strand of existing research that has identified high chances of sudden political shifts as a major risk to the diffusion of renewables (Komendantova *et al*. 2014).

Model 1 shows that one percentage increase in the *domestic credit to the private sector* as a portion of GDP results in a slightly increase in the odds of investment occurring (multiplies by 1.011). This result seems to suggest that, in the process of deciding whether to invest or not, investors pay particular attention to the financial landscape of the hosting country. However, increased access to domestic credit does not significantly affect the amount of finance provided, signaling that this factor may be most influential in the early stage of financing decisions. In line with these results, Ang *et al*. (2017) also find that the effect of access to domestic credit on investment is not a statistically significant predictor of investment size in the context of emerging economies. Interestingly, the coefficients for *trade as a percentage of GDP* exhibit a negative and insignificant effect on both the outcomes of interest. This differs from previous research both in terms of the significance and direction of the relationship (Baldwin *et al*. 2017; Ang *et al*. 2017).

The coefficient for *natural resources rents*, though not significant, has a negative effect on both the decision to invest and the size of the investment (Models 1-4). This reflects the hypothesised direction of this effect, providing some weak evidence for the argument that failure by the developing country to promote competition may deter investors from engaging in a market dominated by incumbent actors. This also relates to findings of previous research that whilst *natural resources rents* is a significant determinant of renewable energy generation in the context of developed economies, the same is not true in the context of developing countries (Baldwin *et al*. 2017). This could be due to the fact that energy production facilities are state-owned in some developing countries. As expected, the size of the economy seems to have a positive impact on the amount of international private finance. In particular, a 1 US$bn rise in GDP leads to an increase in investment of around 157/100 points on average, which corresponds to 1.57 US$M, holding other factors constant.

Though research has shown that the investment environment is a crucial investment determinant in the context of OECD and G20 economies (Ang *et al*. 2017), no business environment factor has been found to be significant for the countries included in this analysis with the exception of *political stability* and *domestic credit to private sector*. It could be concluded that, in the context of developing countries, the null hypothesis $H0_2$ cannot be fully disproved.

4.3 Investor heterogeneity

Table 4 shows regression results for the binary outcome of the decision to invest, respectively, for five sub-samples of investors: utilities, commercial banks, project developers, private equity and corporate/large consumers.

Table 4 – *Logistic regression results for individual investors*

	Dependent variable:				
	Utility investors	Project developers	Private equity	Corporate investors	Commercial banks
	(1)	(2)	(3)	(4)	(5)
Feed-in tariffs	-2.251***	-0.294	0.226	0.029	0.385
	(0.790)	(0.369)	(0.340)	(0.427)	(0.369)
Market-based mechanisms	0.831	0.085	0.068	0.134	-0.501
	(0.643)	(0.393)	(0.388)	(0.484)	(0.450)
Regulatory instruments	0.940	0.872**	1.123***	1.298**	1.535***
	(0.668)	(0.374)	(0.368)	(0.562)	(0.459)
Grants and subsidies	0.161	0.619*	0.446	0.673	-0.264
	(0.635)	(0.375)	(0.371)	(0.470)	(0.427)
Tax incentives	0.627	0.650*	0.282	0.413	0.405
	(0.764)	(0.380)	(0.365)	(0.489)	(0.420)
International public finance	0.009***	0.006***	0.004***	0.005***	0.003**
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Days to start a business	-0.003	0.0002	-0.007	0.004	-0.003
	(0.014)	(0.004)	(0.008)	(0.003)	(0.009)
Political stability	0.648	0.017	0.260	-0.146	0.080
	(0.451)	(0.234)	(0.222)	(0.292)	(0.261)
Trade openess	-0.048***	-0.005	-0.0004	0.003	-0.007
	(0.014)	(0.006)	(0.006)	(0.007)	(0.006)
Domestic credit to the private sector	0.053***	0.025***	0.009	0.001	0.025***
	(0.013)	(0.006)	(0.005)	(0.007)	(0.006)
Natural resources rents	-0.216**	-0.018	0.005	-0.096**	-0.075*
	(0.097)	(0.026)	(0.020)	(0.047)	(0.040)
Gross domestic product (log)	0.504***	0.025	-0.008	-0.020	0.123
	(0.188)	(0.083)	(0.076)	(0.111)	(0.090)
Electricity consumption	-0.001	-0.0003	0.002*	0.003**	-0.001*

	(0.0004)	(0.0003)	(0.001)	(0.002)	(0.0003)
Observations	388	388	388	388	388
R^2	0.276	0.241	0.180	0.192	0.197
Wald Test (df = 13)	41.900***	65.570***	48.100***	41.680***	49.320***
LR Test (df = 13)	125.063***	106.785***	76.934***	82.547***	85.024***
Note:					*p<0.1; **p<0.05; ***p<0.01

Regulatory support policies seem to be particularly popular among project developers, private equity, corporate investors and commercial banks, whose odds of providing finance are multiplied by 2.39, 3.07, 3.66 and 1.53 respectively if such measures are in place, keeping all other factors constant. This seems to suggest that countries that create a strong regulatory support framework are more likely to attract capital from these types of financial sources. The provision of grants and subsidies by governments seems to encourage investment from project developers, whose odds of investing are multiplied by 1.85. Interestingly, a negative effect is observed for feed-in tariffs on the decision to invest of utility companies – odds are multiplied by 0.105. This is surprising given that this instrument is widely celebrated as effective in existing literature and might be due to the ownership characteristics of these companies.

Overall, the provision of international climate (public) finance has a consistently positive and significant effect on the decision to invest across all investor types. Though this seems to provide some additional support for the argument that this type of public intervention contributes to fostering foreign investment in renewable power generation, the magnitude of the effect is moderately small.

These findings shed light on the relative effectiveness of public interventions, which might vary according to the considered investor type. In particular, whilst some policy instruments encourage certain types of investor to deploy finance, their adoption might contribute to a decrease in investment from other sources, creating an adverse effect. Breaking down investment according by the type of financial thus actor contributes to explaining discordant signs found in research investigating the effects of public policies using cumulative measures of investment (Popp *et al*. 2011).

When looking at investment environment factors, it appears that one percentage increase in *access to domestic credit for private sector* as a part of GDP slightly multiplies the odds of investment occurring for utilities, project developers and private equity investors. It might be the case that the early financing decisions of these investors are particularly sensitive to the financial market policy of the hosting country. On the other hand, a one-percentage increase in *natural resources rents* as a portion of GDP results in a reduction odds of investment occurring for utilities (by 20%), private equity investors (10%) and commercial banks (8%). As a result, it could be argued that different types of investors perceive the "lobby effect" – lack of competitiveness in the energy market due to dependency on fossil fuels – as a more serious risk than others. Trade seems to be mostly unrelated to any outcome of interest, with the exception of utility investors, which see a slightly reduced likelihood of investment. This is a somewhat striking result and in contrast with previous findings from the literature (Ang *et al*. 2017; Baldwin *et al*. 2017). It is not clear why these types of investors should favour markets whose economies are less reliant on international trade and this requires further investigation.

Overall, there is some degree of variation among investors in terms of the effect of policy factors, thus disproving the null hypothesis $H0_3$. In particular, these results seem to indicate that, in conducting risk-return considerations, investors weigh the opportunities and risks found within specific countries differently, deploying finance accordingly.

5. Conclusion

This paper aimed to fill an important research gap in the academic literature by systematically unpacking the determinants of cross-border private investment in renewable energy in developing countries. In doing so, it contributed to an ongoing discussion on how to channel private finance towards renewable power generation in developing countries to meet the 'well-below' 2°C goal set out in the Paris Agreement. Linear and logistic fixed-effects models were employed to estimate the impact that public interventions (renewable energy policies and international climate public finance) and the wider investment environment have on both the decision to invest and the amount of private finance deployed in this sector. In the first step, the analysis was conducted for cumulative investment. In the second step, the effects on single investors were analysed individually.

Overall, when all sources of finance are considered, a larger number of active domestic renewable energy policies is associated with an increased likelihood of investment occurring. When the effect of individual policy instruments on the decision to invest is disentangled, the presence of regulatory support measures emerges as a particularly strong driver. However, the size of such investments do not seem to be significantly affected by the considered policy instruments, with the exception of feed-in-tariffs, whose adoption results into an increase in investment of about 39 US$M on average. When investors are considered individually, regulatory support measures remain a strong predictor of investment occurring for project developers, private equity, corporate investors and commercial banks. Project developers also seem more likely to invest when governments of developing countries offer grants or tax incentives. However, the analysis shows that certain policies might have some unintended consequences for some investors such as utilities, whose odds of investing decrease when feed-in tariffs are active. The provision of international public finance seems to be consistently associated with a slight increase in the likelihood of investment occurring for all investor types and significantly larger cumulative investment flows. More specifically, one extra US$M of international public finance leads to an average increase in private investment of half-a-million US$.

The results also highlight that, overall, the business environment is a less reliable determinant of financing decisions as opposed to public interventions. There are however some exceptions: political stability seems to positively affect the amount of finance provided by investors, whilst easier access to domestic credit slightly boosts the likelihood of investment. Finally, the analysis shows that the effect of investment environment determinants varies across financial providers. For example, commercial banks, utility and private equity investors are less likely to finance renewable generation in countries that are reliant on natural resources.

5.1 Implications for theory and practice on cleaner production

The factors and the effects identified in this study provide basis for further research on the determinants of foreign investment in clean energy technologies, whilst having direct implications for domestic policymakers and international development institutions wishing to increase investment in the renewable sector of developing countries. Foreign private investment can greatly contribute to advancing the transition to a cleaner energy system through the provision of capital and offering a channel for the diffusion of more efficient technologies and techniques in the context of many low-income economies (Keeley and Ikeda 2017). First, the analysis has highlighted the importance of political stability and the existence of a strong regulatory support framework to attracting foreign capital, a factor previously acknowledged in studies in studies of cleaner production (Keeley and Matsumoto 2018). By signaling long-term commitment, domestic governments can greatly reduce the risk faced by investors, who will be more likely to provide finance if they know they will be able to recoup investments in the absence of sudden policy shifts.

Further, this paper has demonstrated the importance of accounting for investor heterogeneity in models attempting to explain investment in clean technologies, shedding light on possible explanations for inconsistent results found in previous studies. For example, it was shown that feed-in tariffs tend to be generally conductive of increased investment, but can have unintended consequences for some investors. Many developing countries currently rely on a limited number of instruments types, which might have the effect of ruling out some sources of finance. Their success in a low-carbon future relies on their ability to increase the comprehensiveness of their policy packages, an area in which the international community can provide support through offering technical assistance such as trainings and capacity building. Further research should invest more resources in gaining a better understanding of the interactions between policies and how policy-mix characteristics affect investment in clean technologies, especially in the context of developing countries. This would contribute greatly to discussions around building a more holistic and systematic perspective on the study of technological innovation and sustainable growth (Cancino *et al*. 2018).

Thirdly, the analysis has shown the importance of accounting for both the decision to invest and investment size when investigating the determinants of foreign investment. In fact, while the number of adopted domestic renewable energy policies might be key in determining the decision to invest, findings highlight that the mobilisation impact of public finance on investment flows is steadier in the context of developing countries. This suggests that, besides the traditional focus on domestic renewable energy policy, more attention should be devoted to the role of national development banks and Development Finance Institutions (DFIs). It was in fact demonstrated that the international community could accelerate the clean energy transition through increasing the amount of international public finance flowing into developing countries.

5.2 Limitations and further research

Due to the use of BNEF data, which includes renewable energy projects >1MW capacity, small-scale renewable investments are not included in the analysis. As a result, a selection bias could arise if flows to developing countries (in particular the lowest-income countries) tend to disproportionately finance smaller projects (e.g. solar cookers) (Ang *et al*. 2017). Further, the dataset relies on non-verified publicly or bilaterally displayed data, which excludes confidential investments. Whilst it can be validated by cross-checking the data with other private databases on renewable energy investment projects (e.g. Financial Times market data), the main challenges of confidentiality, the non-verification of data, and an unclear definition of 'private finance' persist (Stadelmann *et al*. 2013). Furthermore, for reasons of data availability, the focus of the econometric analysis is on six renewable energy technologies (wind, solar, biomass, small hydro, marine and geothermal), which constitute only a subset of all clean energy technologies (which also includes technologies that do not fall into the 'renewable energy' category, such as CCUS, DSM, nuclear power and energy-from-waste.

More data becoming available, further research should aim to expand the generalisability of the findings by obtaining private finance data on other clean energy technologies and applying a similar methodological approach. Additionally, future studies could disentangle the effects of policy intensity on investment behaviour, as well as the individual effects of auctions and public tenders, which were included in the wider category of market-based mechanisms in the current study. This type of policies becoming increasingly popular in the developing world, it is important to assess whether they are delivering the needed investment (FS-UNEP 2017).

In spite of its limitations, this paper has contributed to filling an important knowledge gap in the academic literature by building a novel framework for studying foreign investment flows and highlighted the importance of both national and international public interventions in shaping a renewable future for developing countries.

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Appendix: List of variables included in the analysis

	Description and definition	Source
Dependent variables		
a. Foreign private investment flows	a. Asset finance deals for renewable energy projects larger than 1.5MW (US$M)	Bloomberg Climatescope (2018)
b. Foreign private investment (binary)	b. Whether investment has occurred (X=1) or not (X=0)	
Public interventions variables		
a. Grants and subsidies	a. A policy exists that offers grants or subsidies to renewable energy producers (binary)	IEA/IRENA Joint Policies and Measures database (2018)
b. Feed-in tariffs	b. A policy exists that guarantees an above-market price for renewably produced electricity for a long-term period (binary)	Bloomberg Climatescope (2018)
c. Tax incentives	c. A tax incentive exists that reduces the burden for renewable energy producers or a carbon tax is in place (binary)	
d. Market-based mechanisms (GHG allowances and green certificates + public tenders and auctions)	d. A market-based policy exists defining a market price for emissions, allows trading of green certificates; or offers a framework for auctions and tenders (binary)	
e. Regulatory instruments	e. Auditing, monitoring, codes and standards, obligation schemes or other mandatory requirements are in place (binary)	
f. International public finance	f. Financial flows from multilateral or national development banks (US$M)	
Investment environment		

variables		
Investment policy Investment promotion and facilitation Trade policy Competition policy Financial market policy Public governance	- Time required to start a business (days) - Political stability (-2.5 weak to + 2.5 strong) - Trade (% of GDP) - Natural resources rents (% of GDP) - Domestic credit to private sector (% of GDP)	World Bank Governance Indicators (2016) World Bank Development Indicators (2017)
Control variables		
a. GDP c. Electricity demand	a. Gross domestic product (US$bn) b. Electricity consumption (twh)	World Bank Development Indicators (2017) IEA World Energy Balances (2014)