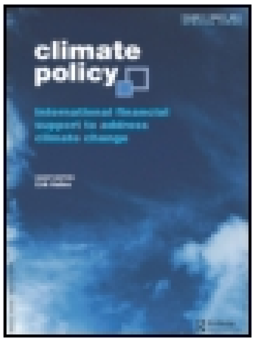

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RESEARCH ARTICLE

Which policy instruments attract foreign direct investments in renewable energy?

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ABSTRACT

Reducing GHG emissions and mitigating climate change would require significant investments in renewable energy technologies. Foreign direct investments (FDI) in renewable energy (RE) have increased over the last years, contributing to the diffusion of RE globally. In the field of climate policy, there are multiple policy instruments aimed at attracting investments in renewable energy. This article aims to map the FDI flows globally including source and destination countries. Furthermore, the article investigates which policy instruments attract more FDI in RE sectors such as solar, wind and biomass, based on an econometric analysis of 137 Organisation for Economic Co-operation and Development (OECD) and non-OECD countries. The results show that Feed in Tariffs (FIT) followed by Fiscal Measures (FM), such as tax incentives and Renewable Portfolio Standards (RPS), are the most significant policy instrument that attract FDI in the RE sector globally. Regarding carbon pricing instruments, based on our analysis, carbon tax proved to be correlated with high attraction of FDI in OECD countries, whereas Emissions Trading Schemes (ETS) proved to be correlated with high attraction of FDI mainly in non-OECD countries.

Key policy insights

- Feed in Tariffs is the most significant policy instrument that attracts FDI in the Renewable Energy sector globally.
- Fiscal Measures (FM), such as tax incentives, show a significant and positive impact on renewable energy projects by foreign investors, and particularly on solar energy.
- Carbon pricing instruments, such as carbon taxation and emissions trading, proved to attract FDI in OECD and non-OECD countries respectively.
- Public investments, such as government funds for renewable energy projects, proved not as attractive to foreign private investors, perhaps because public funds are not perceived as stable in the long run.

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Introduction

The impact of global warming on human and natural systems has drawn the attention of policy makers interested in improving environmental and economic sustainability. This is particularly important when concerning policy aimed at promoting energy investments that contribute to the mitigation of climate change. Under the United Nations Framework Convention on Climate Change (UNFCCC), industrialized countries are committed to providing financial support to developing countries. As part of this commitment, at the 2010 United Nations Climate Change Conference (COP16), they agreed to jointly mobilize US$100 billion per year, including through the newly established Green Climate Fund (GCF). However, the role that foreign investment can play in helping developing countries move onto a lower-carbon development path remains under explored,

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despite its strong potential to help mitigate the current global environmental threat (Matthews, Gillett, Stott, & Zickfeld, 2009; Peake & Ekins, 2016).

This study explores Green Foreign Direct Investment (GFDI), which concerns cross-border investments in the renewable energy sector. GFDI is of interest to both developed and developing economies, as GFDI already has a good track record of contributing to the growth of environmentally friendly industries, practices, technologies and skills that facilitate environmental sustainability and climate change mitigation. Furthermore, FDI in general benefits economic development by creating jobs and encouraging the transfer of capital, technology and knowledge to local communities, and by promoting regional competitiveness. It is therefore important that investment source and destination countries implement effective policies to encourage multinational corporations (*MNC*) to invest in green projects, especially in the renewable energy sector (Narula, 2012; UNCTAD, 2010).

United Nations Conference on Trade and Development (UNCTAD) (2010) defines GFDI as a transfer of technologies, practices or products by *MNCs* to destination countries through equity (FDI) and non-equity investments, such that the related activities generate significantly lower greenhouse gas emissions than would otherwise occur in the industry if established business practices were followed. In addition, there is increasing evidence that it would be more effective for donor agencies to promote private investment in developing countries, instead of themselves providing financing for individual clean energy projects (Buntaine & Pizer, 2015).

Given the above, which policies can best attract GFDI? In Europe, according to Bolkesjø, Eltvig, and Nygaard (2014), such fiscal instruments as Feed in Tariffs (FIT) have significantly affected deployment of renewable energy generation, although Carley (2009) showed that Renewable Portfolio Standards (RPS) do not significantly increase the use of renewable energy. However, only very few studies of non-OECD (Organisation for Economic Co-operation and Development) countries have been conducted (Aguirre & Ibikulne, 2014). Therefore, it can be argued that there is a lack of research covering a larger global sample of countries. This study aims to demonstrate the extent to which national sustainable energy policies are associated with attracting GFDI into both developed and developing countries by looking at a global sample of 137 countries. In addition, we investigate the geography of the global GFDI network, as well as policy instruments associated with it.

Green Growth

Green Growth is a concept that has gained visibility as an alternative economic development strategy (Sterner & Damon, 2011). It was first introduced by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) in 2006, to explore ways of encouraging a low-carbon sustainable development model for fast-growing Asian countries (UNESCAP, 2006). More recently, OECD (2010) has argued that Green Growth involves promoting a form of economic growth that ensures the capacity of existing natural assets is protected. The economic sectors that are closely related to the promotion of Green Growth include energy, mobility, natural resource management, green buildings, pollution prevention, treatment and abatement, and green services. Each of these sectors can contribute to the attainment of Green Growth through incentives for more efficient use of natural resources and should support innovation that allows new ways of addressing environmental problems and creation of new green technology markets (OECD, 2011). Furthermore, Green Growth stresses the need for policies that bridge economic and environmental challenges (Hammer, Kamai-Chaoui, Robert, & Plouin, 2011). However, it is most essential to integrate the natural resource base into dynamics that drive growth and to develop ways of creating economic payoffs that reflect the value of the natural resource base (OECD, 2011). Promoting and attracting GFDI is therefore instrumental to attainment of these objectives.

Green Foreign Direct Investment (GFDI)

GFDI in general

The precise definition of 'green investment' does not exist to date, as there is no theoretical consensus regarding this term (Inderst, Kaminker, & Stewart, 2012). However, studies often refer to GFDI in the context of representing clean, sustainable and pro-climate investments. Golub, Kauffmann, and Yeres

(2011) explore two hypotheses regarding FDI and the environment. The first concerns the pollution haven effect, whereby FDI seeks locations with weak environmental regulations, while the second is the pollution halo effect, whereby FDI spreads best environmental practices and technology. Our study focuses mainly on the second hypothesis, exploring the relationship between different policy instruments and deployment of renewable energy sources (RES).

The priorities of GFDI in destination countries and particularly of MNCs' decisions are considered to include: (1) general policy framework: environmental, energy, climate and industrial policies and regulations; (2) economic factors: the general determinants of FDI, such as market seeking, resource seeking, efficiency seeking, and strategic-asset seeking factors; (3) business facilitation: national and local policies that favour low-carbon investments and (4) costs of production: cost reductions resulting from material, resource and energy savings (Hanni, van Giffen, Kramer, Krüger, & Mirza, 2011; UNCTAD, 2010). Owing to such governmental priorities, MNCs are becoming more aware that the greening of their businesses and value chains can increase their competitiveness and create new markets for green products, services, technologies and innovation (Bisgaard, Henriksen, & Bjerre, 2012).

GFDI in renewable energy

GFDI in renewable energy, such as solar, wind, hydroelectric, geothermal and biomass, has risen since 2003 due partly to international efforts to reduce GHG emissions (REN21, 2017; UNCTAD, 2017). MNCs in developed economies, by means of FDI, are the dominant actors in renewable energy generation, e.g. European countries account for more than half of all GFDI projects, reflecting the commitment of the EU to strengthen the renewable energy sector. Between 2004 and 2010, Europe (Italy, Germany, Denmark and Spain), North America (the United States and Canada) and Asia (Japan and China) were the largest GFDI investors in renewable energy. Nonetheless, in recent years, developing economies have attracted more GFDI than developed economies. Between 2003 and 2010, China, India and Malaysia emerged as favourite destinations for GFDI in renewables. By 2010, China had invested more than Europe in renewable energy and become a world leader in production of photovoltaic modules and wind power equipment. Latin America and the Caribbean had become favoured destinations for renewable energy investments by 2009 and 2010 (Eyraud, Wane, Zhang, & Clements, 2011; Hanni et al., 2011; REN21, 2017; UNCTAD, 2017).

Policies for GFDI in renewable energy

According to the OECD (2014), 'technology and innovation, environmental services, environmentally related taxes and transfers and international financial flows' are among the aspects that contribute to the attainment of Green Growth objectives (OECD, 2014). Many international, national and local policies have been introduced in order to reduce GHG emissions and avoid climate change, improve energy security, encourage production and consumption of renewable energy, and foster Green Growth by promoting competitiveness, creating green jobs and innovation (Eyraud et al., 2011). Promotion and facilitation policies can determine locations of GFDI in renewable energy projects, especially when combined with market creation policies. These include capital subsidies, grants, sales taxes, energy taxes, VAT reduction, tax credits, public investments, feed-in-tariffs and loans (Hanni et al., 2011).

Another important consideration for green foreign investors are destination countries' FDI regulations and the state of their electricity market structure and infrastructure. To boost renewable energy deployments, many countries have adopted clear targets to attract investors in general and foreign investors in particular. Renewable energy generation targets also specify the percentage of total energy production expected to be provided by renewable energy sources (Hanni et al., 2011; Kitzing, Mitchell, & Morthorst, 2012). Policies and instruments employed to reach such targets can be regulatory or financial, and target either the price or the amount of energy. The choice of policies and policy combinations varies according to each country's resources, energy market maturity and political context (Kitzing et al., 2012). The most common renewable energy policy instruments are found in the Table A1 and discussed below (Michaelowa & Tuerk, 2014):

Regulatory policies:

- *Renewable Portfolio Standards* (*RPS*) place obligations on electricity generation companies to produce a certain percentage of electricity from renewable energy sources. RPS aim at the most cost-effective spread of renewable energy technologies.
- *Net Metering (NETMET)* allows a two-way flow of electricity between the electrical distribution grid and end users.

Market-based policies:

- *Renewable Energy Certificates* (REC) can be traded between companies and countries to satisfy their renewable energy quota obligations.
- *Emissions Trading Scheme (ETS)* caps the level of emissions for selected sectors and creates a market of tradable emission allowances.

Fiscal policies:

- *Feed-in-Tariffs (FIT)* are policies that regulate the selling price of renewable energy, ensuring its stability.
- *Fiscal Measures (FM)* include reduced taxation of renewable energy investments.
- *Carbon Tax (CT)* is a tax imposed on the carbon content of fossil fuels.
- *Financing Support (FS)* represents a one-time governmental payment, covering some or all of the capital cost of an investment.
- *Energy Production Payment (EPP)* is a direct payment by the government made per unit of renewable energy produced.

Public policies:

- *Tendering (TEND)* defines the required volume of renewable energy, with interested parties invited to submit proposals.
- *Public Investments (PUBLIC)* are governmental funds earmarked for renewable energy projects.

Among *Regulatory Policies*, RPS obligations tend to be effective instruments for promoting investments in renewable energy. This effectiveness has been confirmed empirically by a number of different studies, e.g. Bolkesjø et al. (2014) demonstrated that RPS obligations and tendering had a significantly positive effect on development of bioenergy for power generation in European countries. Similarly, Menz and Vachon (2006) revealed the effectiveness of RPS policies designed to promote wind power generation in the United States. However, Del Río and Bleda (2012) showed that RPS, despite having a positive effect on the spread of renewable electricity generation technologies, may not be the most efficient policy instrument.

Various scholars explain that *market policies*, such as emissions trading and tradable certificates, have the potential to foster investment in and deployment of renewable energy (Helm, 2002; Rogge & Hoffmann, 2010; Smith & Swierzbinski, 2007). However, a comprehensive study by Polzin, Migendt, Täube, and von Flotow (2015) obtained mixed support for market-based incentives, such as emission trading and green certificate schemes for renewable energy investments. The impact of trading systems seems to depend on the sector, as shown by Polzin et al. (2015), who observed a positive influence in wind and biomass sectors, contrasted with a negative influence on solar. The differences could be observed because solar energy technologies are less mature and more diverse than those of wind power generation, thus being more heavily dependent on regulatory instruments. The same applies to green certificates seemingly failing to strongly incentivise investments in solar owing to technological immaturity, resulting in a low quantity of certificates generated, given the capital invested, compared to sectors such as wind. According to Oikonomou, Flamos, and Grafakos (2010), although combining the maximum numbers of renewable energy policies is considered to provide more options and therefore have a wider effect, in practise the selection of combined policies needs to be made with care, and by considering the possible trade-offs and various targets instead of only economic criteria. Furthermore, regulatory policies are not sufficient to influence renewable energy investments without the additional support of financing schemes to support project development costs and to fill the market gap (Klessmann et al., 2013). Based on the above theoretical background, a further investigation of how different policies influence FDI in renewable energy for high-, middle- and low-income countries is clearly of interest.

Methodology

Methods and data

The data used in this research span a period from 2005 until 2014 and cover a variety of OECD and (mainly large middle-income) non-OECD countries worldwide (see Table 1). We collected data from three main sources. The Financial Times' database 'FDI Markets' provided the data on foreign investment in renewable energy, as well as such additional information as the source country, the destination country, the date the investments were made, and the sectors of renewable energy (i.e. solar, wind and biomass) being invested in. Based on the collected data, we constructed a panel dataset. Next, we obtained all policy indicators, except on ETS and carbon taxation, from the IEA\IRENA Policy database for the same time period. We represented the annual values of policy indicators by dummy variables, taking the value of one if the respective policy was effective during the respective year and zero otherwise. For ETS and carbon tax policy indicators, we used data from the International Carbon Action Partnership (ICAP) and the World Bank (2016). It is important to clarify that, for a few countries, e.g. the USA, Canada, China and Japan, ETS and carbon taxes were introduced at sub-national levels. Hence, our choice of data potentially underestimates FDI associated with these policies, and this should therefore be considered when interpreting results.

Finally, we added several macroeconomic variables into the panel dataset. These variables served as control variables and captured the effect of macroeconomic dynamics on FDI. Comparatively more directly related variables are *real interest rate*[1], *gross domestic product* (*GDP) purchasing power parity* (*PPP)*[2], *CO_2 emissions*[3] and *net energy imports*[4] of each country per year. To capture other likely determinants of GFDI we also included *business sophistication*, *government efficiency, control of corruption*, *outward GFDI*, *the Global Competitiveness index*, *market size*, *innovation*, and *quality of education*. These control variables are discussed in more detail later. The resulting research design requires longitudinal data analysis based on the panel data to enable us to capture possible dynamic relationships.

Statistical techniques

Fixed-effects model

We estimate the coefficients for the panel data by using the least squares method with two-way fixed-effects estimation, which includes both country and time effects. The choice of fixed-effects instead of random-effects is made to avoid bias in the estimation of coefficients that is common in the random-effects model. Additionally, applying the Hausman test suggests the absence of random-effects. The following equation presents the fixed-effects model.

$$y_{it} = a_i + D_t + \beta_1 X_{it,1} + \beta_2 X_{it,2} + \ldots + \beta_k X_{it,k} + \gamma_1 C_{it,1} + \ldots + \gamma_j C_{it,j} + \varepsilon_{it}.$$

Table 1. Number of selected countries.

Number of countries Included in the regression		
Total	OECD	23
	Large Middle-Income Non-OECD	114
Wind		137
Solar		137
Biomass		137

In the above, y_{it} denotes *FDI* (log-transformed), $X_{it,k}$ denotes the dummy variable with the value of 1if the respective policy is effective during year t and 0 otherwise, $C_{it,j}$ represents the *macroeconomic variables* and a_i and D_t are country-specific and year-dependent fixed effects.

Log-transformation

To better fulfil the assumptions of the least squares model, we log-transformed the dependent variable, adjusting for its skewness and bringing its distribution closer to being Gaussian. For the same reason, we applied a logarithmic transformation to the GDP variable, as well as to location-specific control variables, namely, business sophistication, corruption control and government efficiency.

Controls

Each country's attractiveness to FDI appears to depend on innumerable factors in addition to policy instruments. Concerning the omitted variables bias, we sought a complete, yet parsimonious model. Hence, we added the following variables: the *real interest rate*, *GDPPPP, net energy imports* and CO_2 emissions. In this study, we are not interested in these effects, yet we still include them to account for macroeconomic influences and thereby derive more accurate estimates. The reasoning behind choosing these variables stems from the idea that, e.g. the real interest rate variable is closely related to GFDI via the project finance aspect, while GDP represents the economic potential of a country to attract investments. In turn, net energy imports reflect the country's demand for energy, while CO_2 emissions indicate a country's level of clean energy development. As mentioned earlier, several other more general control variables have been included in the model, e.g. *business sophistication*, *government efficiency, corruption control*, *outward GFDI*, *the Global Competitiveness index*, *market size*, *innovation*, and *quality of education*. The summary of control variables can be found in the Appendix in Table A3.

Lag structure

We assume that an adopted policy affects the FDI with a certain delay, rather than immediately. On the one hand, investors are a priori informed and can be expected to prepare for an introduction of a new policy, on the other hand, certain investments, such as building a wind or solar park, have longer lead times. Consequently, for each policy variable, we added a lag of one to two years and applied variable selection procedures based on the Akaike Information Criterion in order to determine the necessary lag.

Further adjustments

As the final important note, having observed cross-sectional (as opposed to across time periods) heteroscedasticity, we computed White cross-sectional standard errors for a more robust estimation of regression's standard errors.

Results and discussion

The following results provide a general picture of GFDI over the years (Figure 1). First, we observe that GFDI grew steadily until the crisis of 2008 to 2009. After the crisis, the attractiveness of renewables declined sharply, arguably due to the global decline in financial activities, uncertainty about financial conditions in the future and reduced liquidity. However, between 2010 and 2014, the aggregate amount of foreign direct investment remained steady.

At a sector level, over 2005–2014, the wind sector GFDI changed considerably. In 2008 and 2009, wind GFDI accounted for more than the 50% of total GFDI, however, in subsequent years it experienced more than a fourfold decline by 2014. Conversely, solar GFDI rose significantly from \$1.6 billion in 2006 to \$25.1 billion in 2014 by then accounting for more than the 50% of the total Figure 2.

At a country level, countries listed in Table 2 were leaders in attracting renewable FDI, with the USA and the UK being the largest markets.

In Figure 3, the existence of a GFDI network is evident for the period from 2005 to 2014. Bilateral investments between countries are indicated with grey lines. Thicker lines correspond to more investments being made

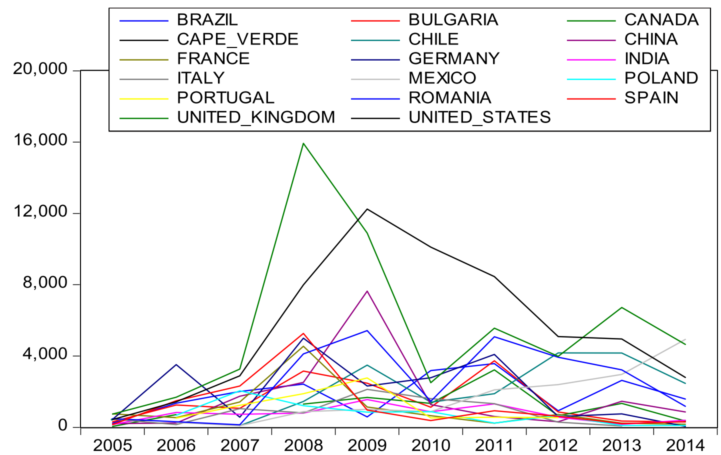

Figure 1. Total GFDI for selected countries across the years (in Billions USD).

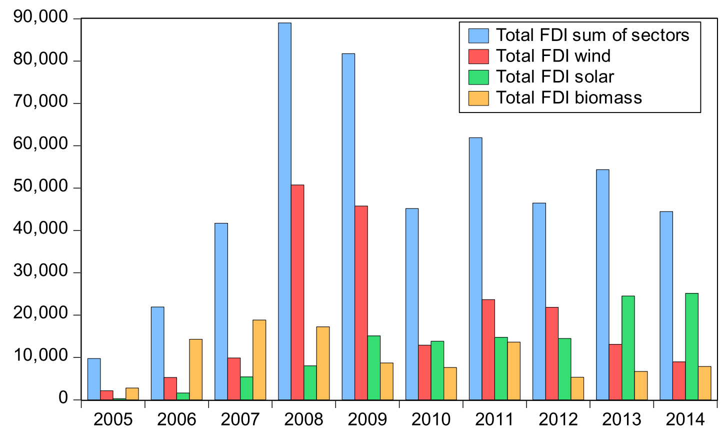

Figure 2. Total FDI per sector over the period 2005–2014 (in Billions USD).

between countries. The blue nodes represent per-country totals of all inward GFDI received by the respective country during that period. Larger nodes indicate greater investment amounts. Similarly, the green nodes represent the total outward GFDI, originating from the respective countries and made in other countries. The maps also show that the majority of renewable energy investment flows occurred between regions of the global North, i.e. Europe, North America and Asia-Pacific.

Furthermore, sizable investment flows also occur between northern regions and several countries in the global south, particularly Chile, Brazil, South Africa and Morocco, as well as Australia. The level of CO_2 emissions of individual countries is depicted by shades of yellow. Darker shades represent higher amounts of CO_2 emissions (tonnes of CO_2/per capita).

Examining the resulting correlation matrix in Table A2 of the Appendix, we observe, interestingly, that ETS is negatively correlated with EPP and TEND. ETS aims at reducing carbon emissions by creating a market for tradable emissions permits through setting a cap on the level of carbon emissions. Research in Europe and the US on the interaction of ETS with other policy instruments has shown that, depending on the cap level and the abatement costs of different technologies (e.g. wind and solar), ETS could lead to the widespread expansion of renewable energy sources, making renewable energy policy instruments such as EPP and TEND sometimes less efficient or even redundant. Furthermore, regardless of whether the RES support mechanism is implemented by targeting price (i.e. EPP) or quantity (i.e. TEND), the increased share of RES has a direct impact on the level

Table 2. Top 15 countries ranked by GFDI attractiveness.

Country	No. of Investments	Aggregated amount of FDI (Billions USD)
Canada	54	106,510
United states	483	56,408
UK	161	55,951
Romania	86	25,356
Germany	46	20,122
Chile	60	19,535
Brazil	60	18,526
China	54	16,879
Mexico	49	15,535
Bulgaria	78	14,623
Spain	98	12,656
France	80	10,424
Italy	71	7902
India	59	7401
Poland	44	6787

Figure 3. Global GFDI in renewable energy in relation to CO_2 emissions (tones of CO_2/capita) at the country level (2005–2014). GFDI destinations = blue nodes, GFDI sources = green nodes. Grey lines = GFDI flows. Yellow areas = CO_2 emissions. Source: authors, 2017, based on FDI Markets World Bank data. Colour online.

of emissions. A larger share of RES reduces demand for emission permits and thus lowers permit prices (Abrell & Weigt, 2008; Oikonomou et al., 2010). Research on the interaction of policy instruments in different geographical areas can shed more light on this issue, particularly by examining policies that seek to enhance the spread of RES and to reduce carbon emissions (e.g. Lin, Gu, Wang, & Liu, 2016).

Table 3 below presents a typical example of our regression results.

Based on results presented in Table 3, we first conclude that *FIT* are significantly and positively associated with attracting total GFDI, as well as GFDI in wind, solar and biomass subsectors. This result concurs with previous research (Polzin et al., 2015; Eyraud et al., 2011) that also observed a significant effect of *FIT* on increasing renewable energy capacity in all sectors (solar, wind and biomass) in OECD countries. Additionally, the study by Bolkesjø et al. (2014) that examined European countries presented clear evidence for *FIT* affecting significantly

Table 3. Policies' effects on attracting renewable energy GFDI in various sectors (2005–2014).

	Total		Wind		Solar		Biomass	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Const.	5.12	11.05	5.25	10.44	2.13	9.49	6.99	11
FIT	1.21*	0.63	0.50*	0.30	0.72**	0.27	0.43*	0.27
REC							−0.83*	0.48
RPS			0.94**	0.48	0.75*	0.44		
NEMET							−0.83**	0.39
FS								
FM	1.58***	0.55					0.47*	0.27
EPP	−2.05**	0.92	−0.85**	0.42				
TEND	1.31**	0.63			0.76**	0.30		
PUBLIC	−2.06***	0.56	−0.81**	0.27	0.59**	0.25	−0.75*	0.29
ETS					2.82**	0.91		
CT	3.98***	1.07	1.79**	0.69	4.62**	0.63	0.12*	0.14
Control Variables								
GDP			3.94**	2.07	2.63*	1.87		
Real interest rate	0.06*	0.04						
CO_2 emissions	−0.53*	0.28						
Energy import	0.01*	0.01					4.08*	1.36
Business sophistication			−5.16**	2.39	−3.95**	2.13		
Government efficiency			4.64*	2.53	3.05*	2.24	1.59*	0.99
Control of corruption							−0.05*	0.04
Outward FDI							i	1.65
Global competitiveness index	5.18**	3.00			2.56**	1.76		
Market Size			1.86*	0.59	1.28*	0.52		
Innovation			−1.87*	1.00	−1.54*	0.90		
Quality of education								
Year Fixed Effects	YES		YES		YES		YES	
R^2	0.65		0.61		0.56		0.49	
AIC	3.26		3.08		3.17		3.21	
No of Countries	137		137		137		137	

Notes: Significance levels: ***$a < 0.001$, **$a < 0.05$, *$a < 0.1$; n.s.: not significant, without lagged variables.

the development of solar and wind energy. Our research also corroborates studies by Polzin et al. (2015) and Verbruggen and Lauber (2012), who underscore the superiority of *FIT* in providing incentives to foreign investments in green growth. According to Verbruggen and Lauber (2012), the main reason behind *FIT's* success is robust inclusion of generated electricity in the existing power grid, through purchasing obligations and the guarantee of a fixed return on investment. In addition, Del Río and Bleda (2012) concluded that *FITs* had a positive impact on different functions of innovation systems (e.g. knowledge development and dissemination, market formation and resource mobilisation), supporting the spread of renewable energy technologies. Johnstone, Haščič, & Popp, 2010 also found that *FITs* had a significantly positive influence on the number of renewable energy patents granted, particularly in solar energy.

Next, as seen in Table 3, *FM* such as tax incentives show a significant and positive association with the 'total' renewable energy, as well as with biomass energy. This result is in line with the study by Polzin et al. (2015) of the positive impact of tax-related incentives on the energy sector as a whole and, specifically, on the renewable energy sector. Furthermore, our results confirm those of Marques and Fuinhas (2012), who showed that in general, fiscal instruments have a positive impact on the spread of renewable energy. Our study goes beyond this conclusion by illustrating the impact of each fiscal instrument on increasing GFDI, as well as within its subsectors. On the other hand, our results contradict the conclusions of Aguirre and Ibikulne (2014) that showed a negative impact of fiscal instruments.

Additionally, our results show that *CT* policies have a strongly positive association with GFDI, as they increase the unit costs of electricity production for fossil fuel-based energy generation. This statement holds particularly true for the total GFDI, as well as for solar and biogas sectors but is insignificant for the wind sector. This result is in line with previous studies (Eyraud et al., 2011) showing that carbon pricing has a statistically significant and positive effect on investment. *EPP* is also observed in our study to have a strongly negative association with the total GFDI and within the wind sector. According to our results, *EPP* is not associated with attracting FDI to the wind sector and with the total FDI and, on the contrary, reveals negative effects. This appears counterintuitive. Johnstone, Haščič, & Popp (2010) attribute this phenomenon to investors having little confidence in public budgeting policies being maintained, as newly elected governments tend to withdraw them immediately. In line with the existing empirical evidence, *RPS* have a positive association with total GFDI attractiveness but not at the sectoral level. In contrast, neither *NETMET* nor *FS* show relevance at the aggregate and sectoral levels, with the exception of *NEMET* showing a negative effect in the biomass sector. Lastly, *REC* and *ETS* show no statistical significance to FDI attractiveness at the aggregate level. At the sectoral level, *REC* has no association with wind and solar but shows a negative effect on biomass, whereas *ETS* shows no association with wind and biomass and a positive association with solar. These findings contradict existing empirical evidence that shows a positive impact of REC and ETS on renewable energy investment, particularly in the wind sector. One reason for no statistical significance of ETS to wind energy and total renewable energy FDI could be the fact that, for the selected countries (i.e. the USA, Canada, China and Japan), we used policy data at the subnational level, whereas FDI was aggregated at the national level. This could have resulted in underestimating the FDI association with introduction of ETS specifically in these countries. On the other hand, the negative and statistically significant coefficients contradict the common sense. The complication of coefficients having this unexpected sign could arise due to the following reasons. First, the policy dummy variables are correlated and act as substitutes for each other within the model. Second, the model may have omitted significant variables; however, we are not able to include many control variables. Next, the model exhibits the so-called mean reversion; hence, the model may also try to pick up negative signals.

In the next part, shown in Table 4, we repeated the previous analysis but aggregated the data to OECD and large middle-income (LMI) non-OECD countries. As expected, *FIT* are significantly present in both groups, although with a greater effect on OECD countries. In OECD countries, TEND, *FM* and *CT* policies have a strong positive association with attraction of renewable GFDI, while *PUBLIC* reveals a negative association with investment in renewables. In the case of large middle-income non-OECD countries, *CT* has no impact on attracting GFDI, while *ETS* is demonstrated to be an important policy instrument, indicating a statistically significant and positive association with investment in renewables. Conversely, results in Table 4, as well as those for OECD countries (Table 4), might be of interest to countries in Latin America, Africa and Asia wishing to embark on developing renewable energy practices and the policies required to attract future investors in GFDI.

The results of the robustness tests regarding the time lag of the implementation of policies are shown in Tables A4 and A5 of the Appendix. The estimations suggest that our main model is robust. In particular, regarding overall renewable energy investments, we observe that most of the independent variables remain significant in all models with 0, 1 and 2 years lag. Only FM proved not to be significant when we run our model

Table 4. Policies' effects on attracting renewable energy GFDI in OECD/LMI non-OECD countries (2005–2014).

	Total FDI – OECD		Total FDI – LMI Non-OECD	
	Coeff.	S.E.	Coeff.	S.E.
Const.	6.5	7.26	5.3	3.31
FIT	3.41**	1.37	0.68*	0.39
REC				
RPS				
NEMET				
FS			−1.02**	0.41
FM	2.30**	1.12	0.87**	0.34
EPP				
TEND	1.86*	1.08		
PUBLIC	−3.12***	1.03		
ETS			3.66*	2.06
CT	3.94***	1.14		
Control Variables	YES		YES	
Year Fixed Effects	YES		YES	
R^2	0.65		0.59	
AIC	3.24		3.02	
No of countries	23		114	

Notes: Significance levels: ****a* < 0.001, ***a* < 0.05, **a* < 0.1; n.s.: not significant, without lagged variables.

with 1 and 2 years lag, whereas TEND proved to be insignificant with the two years lagged values model. When looking at the individual sectors, results are slightly more unstable as can be seen in Tables A4 and A5 of the Appendix. This is logical as the large number of control variables, the year fixed effects, and the lag structure create a smaller estimation sample and more coefficients to be estimated. More specifically, in the wind energy sector, FIT, PUBLIC and CT proved to be significant in all models with different time lag structures. However, results for RPS and EPP show that these variables were significant with 0 and 2 years lagged values, but insignificant with 1 year lagged values. Similarly, in the solar energy sector, results for FIT, RPS, ETS, CT proved to be robust irrespective of the time lag, whereas results for RPS and EPP proved to be unstable under the model with 1 year lagged values. Moreover, the models are robust with the inclusion or exclusion of the predictor variables.

Conclusions

In this article, we investigated the global GFDI network and found that the majority of investment flows were between developed countries, e.g. Europe, North America and Asia-Pacific. Furthermore, the study revealed the policy instruments most associated with attracting GFDI. Based on a panel analysis of data during 2005 to 2014 covering 137 countries, CT and FM were demonstrated to be the instruments having the greatest association with GFDI globally. Conversely, public investments were demonstrated to have a negative relationship with GFDI, showing that investors do not rely significantly on government funds. Effects of various other policies have been discussed in the results section. We also ascertained whether other factors besides policy instruments play a role in attracting GFDI. FIT proved to be the policy instrument associated with attraction of GFDI in all categories, including all renewable energy sectors such as wind, solar and biomass, and both in OECD and large middle-income non-OECD countries.

It is important to note that this study remains quantitative and does not allow detailed conclusions to be drawn regarding the comparative effectiveness of certain policy instruments in certain countries but not others. To meaningfully draw such conclusions, we would need to conduct more qualitative studies, which is beyond the scope of this article. However, we recommend this potentially very interesting area for future research. Furthermore, data limitations, such as the necessity in this analysis to introduce policy instruments (i.e. ETS and CT) at the sub-national level, which may have led to underestimation of the association of ETS with GFDI, will need to be overcome in the future. Further research is also needed to include a larger sample of countries and FDI data at the country level. Similar research could also be conducted at the regional or city level, to identify policy instruments available to local governments that are associated with attracting investments in low carbon energy technologies.

Notes

1. *Real interest rate* is the lending interest rate, adjusted for inflation as measured by the GDP deflator. The terms and conditions attached to lending rates differ by country, limiting their comparability. Source: International Monetary Fund, International Financial Statistics and data files using World Bank data on the GDP deflator.
2. *GDP PPP* is GDP per capita based on purchasing power parity (PPP). PPP GDP is gross domestic product, converted to international dollars using purchasing power parity exchange rates. An international dollar has the same purchasing power relative to GDP as the U.S. dollar has in the United States. GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy, plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2011 international dollars. Source: World Bank, International Comparison Program database.
3. *CO_2 emissions*: Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gaseous fuels and gas flaring. Source organization: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
4. *Net energy imports* are estimated as energy use less production, with both measured in oil equivalents. A negative value indicates that the country is a net exporter. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. Source: IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/.

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References

Abrell, J., & Weigt, H. (2008). *The interaction of emissions trading and renewable energy promotion* (MPRA working paper). Munich.

Aguirre, M., & Ibikulne, G. (2014). Determinants of renewable energy growth: A global sample analysis. *Energy Policy*, *69*, 374–384.

Bisgaard, T., Henriksen, K., & Bjerre, M. (2012). *Green business model innovation: Conceptualisation, next practice and policy*. (Nordic Innovation Publication No. 2012: 12). Oslo: Nordic Innovation.

Bolkesjø, T. F., Eltvig, P. T., & Nygaard, E. (2014). An econometric analysis of support scheme effects on renewable energy investments in Europe. *Energy Procedia*, *58*, 2–8.

Buntaine, M. T., & Pizer, W. A. (2015). Encouraging clean energy investment in developing countries: What role for aid? *Climate Policy*, *15*(5), 543–564. doi:10.1080/14693062.2014.953903

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071–3081. doi:10.1016/j.enpol.2009.03.062

Del Río, P., & Bleda, M. (2012). Comparing the innovation effects of support schemes for renewable energy technologies: A function of innovation approach. *Energy Policy*, 50, 272–282.

Eyraud, L., Wane, A., Zhang, C., & Clements, B. (2011). *Who's going green and why? Trends and determinants for green investment (IMF working paper; WP/11/296*. Washington: International Monetary Fund (IMF).

Golub, S. S., Kauffmann, C., & Yeres, P. (2011). *Defining and measuring green FDI: An exploratory review of existing work and evidence (OEDC working papers on international investment; 2011/02)*. Paris: OECD Publishing. doi:10.1787/5kg58j1cvcvk-en

Hammer, S., Kamai-Chaoui, L., Robert, A., & Plouin, M. (2011). *Cities and green growth: A conceptual framework (OECD regional development working papers; 2011/08)*. Paris: OECD Publishing. doi:10.1787/5kg0tflmzx34-en

Hanni, M. S., van Giffen, T., Kramer, R. M., Krüger, R., & Mirza, H. (2011). Foreign direct investment in renewable energy: Trends drivers and determinants. *Transnational Corporations*, *20*(2), 29–65. doi:10.18356/673b9e6f-en

Helm, D. (2002). Energy policy: Security of supply, sustainability and competition. *Energy Policy*, *30*, 173–184.

Inderst, G., Kaminker, Ch., & Stewart, F. (2012). *Defining and Measuring Green Investments: Implications for Institutional Investors Asset Allocations* (OECD Working Papers on Finance, Insurance and Private Pensions, No.24). OECD Publishing.

Johnstone, N., Haščič, I., & Popp, D. (2010). Renewable energy policies and technological innovation: Evidence based on patent counts. *Environmental and Resource Economics*, *45*, 133–155.

Kitzing, L., Mitchell, C., & Morthorst, P. E. (2012). Renewable energy policies in Europe: Converging or diverging? *Energy Policy*, *51*, 192–201. doi:10.1016/j.enpol.2012.08.064

Klessmann, C., Rathmann, M., de Jager, D., Gazzo, A., Resch, G., Busch, S., & Ragwitz, M. (2013). Policy options for reducing the costs of reaching the European renewables target. *Renewable Energy*, *57*, 390–403. doi:10.1016/j.renene.2013.01.041

Lin, W., Gu, A., Wang, X., & Liu, B. (2016). Aligning emissions trading and feed-in tariffs in China. *Climate Policy*, *16*(4), 434–455. doi:10.1080/14693062.2015.1011599

Marques, A., & Fuinhas, J. A. (2012). Is renewable energy effective in promoting growth? *Energy Policy*, *46*, 434–442. doi:10.1016/j.enpol.2012.04.006

Matthews, H. D., Gillett, N. P., Stott, P. A., & Zickfeld K. (2009). The proportionality of global warming to cumulative carbon emissions. *Nature*, *459*, 829–832.

Menz, F. C., & Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy*, *34*(14), 1786–1796.

Michaelowa, A., & Tuerk, A. (2014). *Financing renewable energy for Europe: The way forward (POLIMP policy brief series; 2)*. Groningen: POLIMP [Joint Implementation Network (JIN)]. Retrieved from http://www.polimp.eu/images/2nd_Policy_Brief_on_Financing_Renewable_Energy_for_Europe.pdf

Narula, K. (2012). 'Sustainable investing' via the FDI route for sustainable development. *Procedia - Social and Behavioural Sciences*, *37*, 15–30.

OECD. (2010). *Meeting of the OECD council at ministerial level: Green growth strategy interim report: Implementing our commitment for a sustainable future: C/MIN(2010)5, Paris 27-28 may 2010*. Paris: Author.

OECD. (2011). *Towards green growth*. Paris: Author. doi:10.1787/9789264111318-en

OECD. (2014). *Green growth indicators 2014*. Paris: Author. doi:10.1787/9789264202030-en

Oikonomou, V., Flamos, A., & Grafakos, S. (2010). Is blending of energy and climate policy instruments always desirable? *Energy Policy*, *38*(8), 4186–4195.
Peake, S., & Ekins, P. (2016). Exploring the financial and investment implications of the Paris Agreement. *Climate Policy*, *17*(7), 832–852.
Polzin, F., Migendt, M., Täube, F. A., & von Flotow, P. (2015). Public policy influence on renewable energy investments—A panel data study across OECD countries. *Energy Policy*, *80*, 98–111. doi:10.1016/j.enpol.2015.01.026
REN21. (2017). *Renewables 2017 global status report*. Paris: Author.
Rogge, K. S., & Hoffmann, V. H. (2010). The impact of the EU ETS on the sectoral innovation system for power generation technologies – Findings for Germany. *Energy Policy*, *38*, 7639–7652.
Smith, S., & Swierzbinski, J. (2007). Assessing the performance of the UK Emissions Trading Scheme. *Journal of Environment Resource Econonics*, *37*, 131–158.
Sterner, T., & Damon, M. (2011). Green growth in the post-Copenhagen climate. *Energy Policy*, *39*(11), 7165–7173. doi:10.1016/j.enpol.2011.08.036
UNCTAD. (2010). *World investment report 2010: Investing in a low-carbon economy*. Geneva: United Nations.
UNCTAD. (2017). *The least developed countries report 2017: Transformational energy access*. Geneva: United Nations.
UNESCAP. (2006). *State of the environment in Asia and the Pacific 2005: Economic growth and sustainability*. Bangkok: Author.
Verbruggen, A., & Lauber, V. (2012). Assessing the performance of renewable electricity support instruments. *Energy Policy*, *45*, 635–644.
World Bank, Ecofys, & Vivid Economics. (2016). *State and trends of carbon pricing 2016*. Washington, DC: World Bank. doi:10.1596/978-1-4648-1001-5

Appendix

Table A1. Policy instruments included in the study.

Policy instruments	Abbreviation	Policy Category
Renewable Portfolio Standard	*RPS*	Regulatory Policies
Net Metering	*NEMET*	Regulatory Policies
Feed-In tariffs	*FIT*	Fiscal Measures
Financial Support	*FS*	Fiscal Measures
Fiscal Measures	*FM*	Fiscal Measures
Energy production payment	*EPP*	Fiscal Measures
Carbon Tax	*Carbon Tax*	Fiscal Measures
Renewable Energy (Tradable) Certificates	*REC*	Market based
Emissions Trading Schemes	*ETS*	Market based
Tendering	*TEND*	Public Financing
Public Investment, Loans, and Grands	*PUBLIC*	Public Financing

Table A2. Correlation matrix of policy indicators.

	FIT	REC	RPS	NEMET	FS	FM	EPP	TEN	PUBLIC	ETS	CarbTax
FIT	1.00	0.24	0.25	0.24	0.29	0.32	0.33	0.31	0.34	0.23	0.19
REC	0.24	1.00	0.38	0.25	0.42	0.17	0.18	0.07	0.22	0.51	0.21
RPS	0.25	0.38	1.00	0.47	0.50	0.28	0.22	0.32	0.38	0.02	0.32
NEMET	0.24	0.25	0.47	1.00	0.33	0.27	0.17	0.31	0.31	0.13	0.19
FS	0.29	0.42	0.50	0.33	1.00	0.37	0.18	0.16	0.37	0.36	0.19
FM	0.32	0.17	0.28	0.27	0.37	1.00	0.23	0.34	0.36	0.25	0.12
EPP	0.33	0.18	0.22	0.17	0.18	0.23	1.00	0.34	0.14	−0.04	0.34
TEN	0.31	0.07	0.32	0.31	0.16	0.34	0.34	1.00	0.34	−0.13	0.23
PUBLIC	0.34	0.22	0.38	0.31	0.37	0.36	0.14	0.34	1.00	0.14	0.15
ETS	0.23	0.51	0.02	0.13	0.36	0.25	−0.04	−0.13	0.14	1	0.003
CT	0.19	0.21	0.32	0.19	0.19	0.12	0.34	0.23	0.15	0.003	1

Table A3. Summary of control variables.

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
CTRL CO_2	−5.62	0.22	0.28	0.38	0.39	5.64
CTRL energy import	−693	−51	23	−19	64	100
CTRL real int. rate	−42.31	0.95	3.09	3.59	5.3	43.5
CTRL GDP	0.0035	0.0128	0.0226	0.0271	0.038	0.0958
OUTWARD FDI	0	0	0	3.3	3	54
Loc. global comp. index	3.4	4.2	4.5	4.6	5.1	5.8
Loc. market size	2.2	3.9	4.5	4.6	5.4	6.9
Loc. business sophistication	2.9	4.1	4.4	4.5	4.9	5.9
Loc. Innovation	2.4	3.2	3.5	3.8	4.5	5.8
Loc. government efficiency	2.5	3.3	3.9	3.9	4.4	6.1
Loc. quality of education	2.8	3.9	4.4	4.5	5.1	6.2
Loc. control of corruption	−1.79	−0.3	0.27	0.43	1.26	2.46

Table A4. Policies' effects on attraction renewable energy GFDI in various sectors (2005–2014).

	Total		Wind		Solar		Biomass	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Const.	5.12	11.05	5.25	10.44	2.13	9.49		
FIT	1.25*	0.65	1.15***	0.35	1.05***	0.33		
REC								
RPS					1.46**	0.53		
NEMET								
FS								
FM			0.65**	0.31				
EPP	−1.95**	0.96						
TEND	1.65**	0.78			0.90**	0.37		
PUBLIC	−2.28***	0.67	−0.82**	0.33	0.74**	0.31		
ETS					2.21*	1.11		
CT	3.60***	1.27	2.32**	0.83	4.38***	0.78		
Control Variables	YES		YES		YES			
Year Fixed Effects	YES		YES		YES			
R^2	0.65		0.61		0.56			
AIC	3.26		3.08		3.17			
No of Countries	137		137		137			

Notes: Significance levels: ***$a < 0.001$, **$a < 0.05$, *$a < 0.1$; n.s.: not significant, with one year lagged values.

Table A5. Policies' effects on attracting renewable energy GFDI in various sectors (2005–2014).

	Total		Wind		Solar		Biomass	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Const.	5.12	11.05	5.25	10.44	2.13	9.49		
FIT	0.33*	0.59	0.65`	0.57	1.37***	0.38		
REC								
RPS			2.24*	1.20	2.94***	0.64		
NEMET					−1.79**	0.55		
FS			1.36*	0.77				
FM								
EPP	−2.13*	1.13	−3.51**	1.20				
TEND			0.91*	0.41				
PUBLIC	−1.64**	0.79	−1.98*	0.69				
ETS					2.76*	1.49		
CT	2.44*	1.53	2.96*	1.51	2.30**	0.93		
Control Variables	YES		YES		YES			
Year Fixed Effects	YES		YES		YES			
R^2	0.65		0.61		0.56			
AIC	3.26		3.08		3.17			
No of Countries	137		137		137			

Notes: Significance levels: ***$a < 0.001$, **$a < 0.05$, *$a < 0.1$; n.s.: not significant, with two year lagged values.