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Empirical determinants of renewable energy deployment: A systematic literature review

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ABSTRACT

A large share of greenhouse gas emissions can be attributed to the energy sector. Renewable energy (RE) appears to be a mean to decarbonize economies. To fight global warming, which might have substantial impacts on ecosystems and economies, it is essential to understand the empirical determinants of RE deployment for public policy guidance and to foster future research. This paper aims to review the growing, though limited, body of literature that has emerged in the late 2000s to study the quantitative determinants of RE development at a country level. Results show that there is little consensus on the influence of the economic, environmental, and energy-related determinants predominantly studied. The other main determinants considered are regulatory, political, and demographic. Results are often tempered by the fact that authors use diverse measures of RE deployment and have a variety of frameworks. This paper ends with several recommendations to improve the comparability of future papers to enhance their potential to make credible public policy recommendations. More specifically, the recommendations concern the choice of a RE deployment indicator, the determinants considered for further exploration, and the methodologies adopted.

1. Introduction

The international recognition of the impact of human activity on climate change (IPCC, 2014) has led to calls for concrete political actions, as highlighted by the recent "Global Warming of 1.5 °C" report of the Intergovernmental Panel on Climate Change (IPCC, 2018). As more than two-thirds of anthropogenic greenhouse gases (GHG) emissions are related to the energy sector (IEA, 2018, p. 3), low-carbon renewable energy (RE) sources (IPCC, 2012, p. 124)[1] are likely to help curb emissions. However, as shown by Fig. 1, fossil fuel sources have continued to dominate total energy consumption over the past few decades, while RE consumption increases slowly. Indeed, even though RE technologies, in particular wind and solar, have been known for decades, their large scale deployment[2] takes time (Fouquet, 2016). This reveals the existence of barriers to, and factors facilitating, RE technologies' deployment (see for instance Painuly, 2001). Furthermore, significant differences exist between countries regarding RE development levels (Reboredo, 2015).[3]

Building on this context, this paper aims to better understand the empirical determinants of RE deployment at the country level. It thus contributes to the energy economics literature by exploring the relationship between renewable energy aggregates and, among others, macroeconomic, environmental, and other energy variables at a country level. In the recent years, and following the seminal papers of Sadorsky (2009a,b) and Chang et al. (2009), a flourishing literature has indeed emerged to identify the quantitative factors that prompt RE deployment at a country level. However, the very understanding of the determinants of RE development remains limited, in part due to the use of different methodologies and frameworks (Šener et al., 2018). The literature on the factors that impact RE deployment has been surveyed in two major contributions.

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[1] The RE sources considered by the IPCC (2012) are used for electricity, mechanical, and thermal energy supply, and fuels generation. The list given is: direct solar, geothermal, ocean, and wind energies, bioenergy, and hydropower.

[2] In this paper, the terms deployment and development are used as synonyms.

[3] For example, computed based on data from BP (2019) (excluding hydropower) the share of RE sources in primary consumption (resp. in electricity generation) in 2018 reached 15% in Germany (32%), 9% in the European Union (21%), 5% in the United States (10%), 4% in China (9%), and is still close to zero in many countries.

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0140-9883/

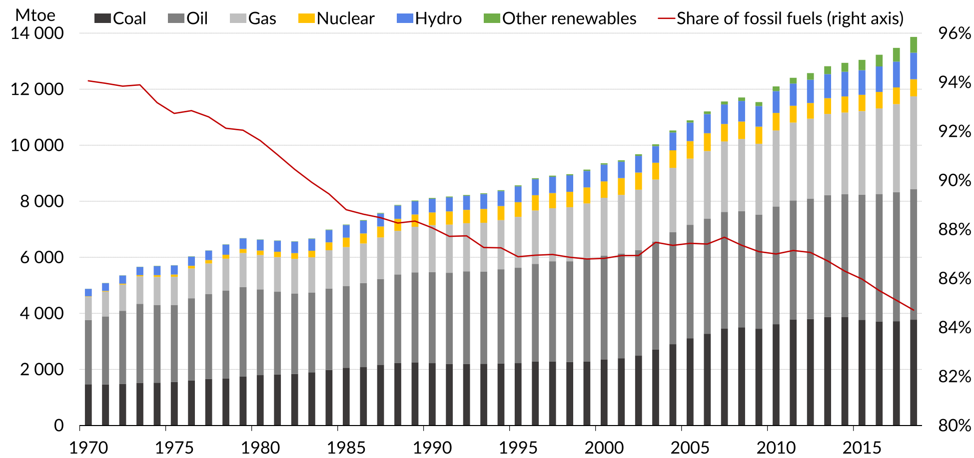

Fig. 1. World primary energy consumption in million tonnes oil equivalent and fossil fuel share.

Data source: BP (2019).

Šener et al. (2018) review both qualitative and quantitative papers to identify categories of determinants but the detailed methodologies, indicators, and economic mechanisms identified are not precisely discussed. In a slightly older paper, Darmani et al. (2014) review papers focusing only on a limited sample composed of eight European countries, and restrict the analysis to four RE sources (solar, wind, and wave energies, and biomass), for which they propose a typology of drivers.

In this paper, I extend these contributions by carrying out a comprehensive literature review of the empirical determinants of RE deployment at a country level. This allows me to identify and classify the main quantitative determinants investigated by econometric papers with samples of at least five countries. In addition to identifying the main directions for future research, investigating empirical determinants of RE deployment helps to shed some light on relevant policy recommendations. To do so, this paper follows the guidelines prescribed by the Collaboration for Environmental Evidence (2018) and Pickering and Byrne (2014); Pickering et al. (2015) to conduct a systematic literature review. The methodology relies on a precise search strategy coupled with explicit paper selection criteria and specific research questions to systematically review the existing literature and provide objective results.

Regarding the design of econometric analyses, this paper shows that RE development is assessed with different scopes and specifications (i.e., RE supply, consumption, or installed capacity taken as absolute level, per capita level, or share in total energy or electricity). Furthermore, varying RE sources are considered. Authors generally investigate a specific set of determinants among all possible and the main control variables taken are: income, fossil fuel prices, electricity or energy consumption, CO_2 emissions, and regulatory variables (in particular RE support policies). Regarding the results, the review shows that (at first sight) there is little consensus regarding the influence of the determinants considered on RE deployment partly due to the differences in frameworks. However, a consensus emerges on a few mechanisms: (i) RE support policies and Kyoto protocol (overall positive effect), (ii) lobby effect from traditional (or preexisting) energy sources (overall negative effect), (iii) population size (overall positive effect), (iv) ambiguous income effect (positive effect for developing countries, negative effect for European countries), (v) unclear effect of CO_2 emissions (negative effect for European countries, and dependent variable specified as a share in total energy supply, but positive when specified as a per capita level of consumption), (vi) counter-intuitive effect of energy security for European countries (negative effect), and (vii) local financial sector development and institutional quality levels (overall no consensus based on papers count but positive effect when considering estimation results). In addition, some recommendations can be formulated for comparability between the papers, and to reduce misspecifications and production of misleading results in the perspective of policy guidance. In particular, they address the specification of dependent and independent variables, and methodologies.

This paper is organized as follows. Section 2 presents the literature review methodology used. Section 3 gives an overview of the frameworks of reviewed papers. Section 4 describes the determinants investigated by authors and their econometric results. Section 5 discusses the frameworks and formulates recommendations for future research. Finally, Section 6 concludes this review.

2. Survey methodology and search strategy

This section briefly presents the methodology used to carry out this literature review and details the data collection process and results.

2.1. Systematic review methodology

This paper aims to systematically review the quantitative literature investigating the determinants of RE deployment. Contrary to conventional narrative literature reviews, this review relies on an explicit and detailed protocol to identify papers and produce an analysis and discussion of the existing literature. More precisely, the protocol is centred around the choice of a combination of keywords that form a search string used to identify papers. By relying on precise criteria and formulating specific research questions to select relevant contributions and review them, this methodology limits selection and analysis bias and strives to offer a comprehensive and objective view of the surveyed literature (Pickering et al., 2015).

In this paper, I follow the methodology proposed by Pickering and Byrne (2014) and the Collaboration for Environmental Evidence (2018). First, the precise topic is defined and relevant research questions are formulated. Second, relevant keywords are selected for use in a chosen database. Third, precise selection criteria are formulated to select papers relevant to the topic investigated. Finally, the analysis is conducted by creating a database with explicit indicators selected to synthesize the information needed to answer the research questions. The systematic literature review methodology was first presented by health science researchers. It was used over the past few years for instance to review the literature in education

Table 1
Methodology for identification and selection of relevant papers following Pickering and Byrne (2014), Pickering et al. (2015), and the Collaboration for Environmental Evidence (2018).

1. – Topic
Country level empirical determinants of RE deployment

2. – Research questions
Primary research question: What is the significance of the different determinants of RE deployment at a country level?
Sub-research questions:
- What are the different measures of RE deployment?
- What kind of econometric models and estimation techniques are used to assess the influence of potential determinants on RE deployment?
- What are the different determinants that were investigated and what is the influence found on RE deployment?
- What recommendations can be formulated for future research?

3. – Keywords of the search string
(renewable* OR "renewable energ*" OR "renewable electric*") AND (invest* OR source* OR generat* OR technolog* OR consum* OR deploy* OR diffus* OR develop*) AND (motiv* OR factor* OR driv* OR promot* OR determin* OR influence* OR relation* OR impact* OR potential* OR affect*) AND (panel OR estimat* OR regression OR data*) AND (countries* OR states*)

4. – Papers' database
Scopus

5. – Selection criteria
- The econometric paper was published in English in a peer-reviewed journal
- A measure of RE deployment is the main dependent variable to investigate RE development determinants
- Three or more RE sources are considered
- The analysis is conducted at a country level and the sample population is composed of at least five countries

(Riebe et al., 2016), urbanism (Boulton et al., 2018), sustainable and resilient urban food systems (Vieira et al., 2018), or place attachment in relation to climate change engagement (Nicolosi and Corbett, 2018). However, to the best of my knowledge, it has not been used for RE related subjects.

2.2. Data collection and analysis

The methodology described previously was applied to the topic of empirical determinants of RE deployment, as detailed in Table 1. More precisely, this paper seeks to address a primary research question related to the significance of the different determinants of RE deployment at a country level. To do so, several sub-research questions are formulated linked to: (i) the RE deployment measurements, (ii) the econometric framework of the reviewed papers, (iii) the determinants and the influence found (to map the existing literature and identify potential gaps), and (iv) possible recommendations for future research.

In relation to the research questions, a search string was designed with different categories of keywords to identify papers specifically looking at: (i) renewable energy sources, (ii) their use, (iii) potential related determinants, and with: (iv) an econometric approach, (v) conducted at a country level. Different synonyms are integrated to each categories linked with a Boolean "OR", and categories are linked using a Boolean "AND".[4] In addition to the combination of keywords, two specifications were also added to the search string: articles from disciplines not related to the research questions are excluded, and only articles and reviews in English are included to identify papers that can be found and understood by any reader. Besides this, as the review process started in early 2018, the articles published after December of 2017 are not considered. The search string was used in the Scopus database. The choice of Scopus is motivated by its interdisciplinary coverage (approximately 21,000 journals) and because it has been recently used to conduct literature reviews and bibliometric analyses in relation to renewable energy (Alcayde et al., 2018; Perea-Moreno et al., 2018).[5]

The database keywords search strategy enabled to identify 1,725 results (see Table 7 in Appendix A for the number of document results obtained at each step and a more precise description of the search string). First, the title and abstract of the 1,725 results were read in order to evaluate their accordance with the topic investigated. Then, if an article was considered eligible or if there was any doubt, the full article was read. To be included in the list of reviewed papers, several criteria were defined in relation to the research questions. More precisely, only papers using a measure of RE deployment as the main dependent variable, with the aim to investigate its determinants, are considered. The focus of this paper is on RE sources in general. Thus, the papers reviewed look at three or more RE sources. In addition, for public policy recommendations and to reduce country-specific results, papers considering fewer than five countries are excluded from this review.

To conduct the analysis, a database[6] was created with quantitative information extracted from the papers. Adapting the typology of Šener et al. (2018), this paper reviews the literature based on the following categories of determinants: (i) economic (income, prices, international flows, and local financial sector development), (ii) energy (security, consumption, mix, and local fossil fuels), (iii) environmental, (iv) population, (v) regulatory and political, and (vi) RE potential. Table 8 in Appendix B, presents the different categories of independent variables considered in each of the papers reviewed. To report the influence of an independent variable on RE deployment, a results count (positive, negative, or not significant) for each inclusion in an econometric model estimated was done. To aggregate all the results for one variable, it is considered to be a consensus on the positive (respectively negative) influence only if there is a majority of positive (respectively negative) results. The so-called no consensus result derives from a majority of not significant results or from an absence of majority of positive or negative results.

2.3. Result of the search strategy: overview of the relevant papers identified

The 48 papers included in this review were published between 2009 and 2017. Fig. 2, in Appendix C, presents the breakdown of papers per publication year. 2011 and 2014 were particularly prolific years and a growing number of papers were published in recent years. In addition, as it can be seen in Table 9 in Appendix C, the papers reviewed were mostly published in energy specialized journals with Energy Economics, Energy Policy, and Renewable and Sustainable Energy Reviews composing the top three. It is also to be noted that certain authors have contributed several times to this strand of literature, e.g., Marques and Fuinhas, Apergis and Payne, and Romano and Scandurra.

Besides this, the reviewed papers do not systematically make reference to previous papers that investigate the empirical determinants of RE deployment. Table 3 in Appendix C, presents a citation network of the different papers reviewed. The central posi-

[4] It should be noted that authors investigating the determinants of RE deployment use very different phrases that is why a large number of synonyms are considered to prevent any article from being missed.

[5] For these reasons and due to the similarities of coverage between Scopus and Web of Science, I decided to rely on Scopus. I expect that the number of relevant papers that could have been identified using the Web of Science database would be similar.

[6] The database constructed is available upon request. In addition to descriptive information about the papers reported in lines, diverse columns are used to describe the dependent and independent variables and the framework of the authors (methodology, period of time, and sample of countries considered).

Table 2
Dependent variables and RE sources considered by reviewed papers (percentages in total, small differences due to rounding). "elec." = "electricity". As an illustration, the number in the first row, first column reads: 2.1% of reviewed papers consider a dependent variable specified as an absolute level of all RE sources supplied.

	Absolute level	Per capita level	Share	Absolute level and share	*Total*
Supply	- All RE (2.1%) - All RE elec. (2.1%) - All RE elec. and non-hydro RE elec. (2.1%)	- All RE (2.1%) - All RE elec., hydro and non-hydro RE elec. (2.1%) - Non-hydro RE elec. (2.1%)	- All RE (18.8%) - All RE elec. (8.3%) - Non-hydro RE elec. (10.4%) - All RE elec., hydro and non-hydro RE elec. (2.1%) - Hydro and non-hydro RE elec. (2.1%)	- All RE elec., non-hydro RE elec. (2.1%) - Non-hydro RE elec. (2.1%)	58.5%
Consumption	- All RE (8.3%) - Non-hydro RE (2.1%)	- All RE elec. (8.3%) - All RE (6.3%) - Non-hydro RE (2.1%)	- All RE (4.2%)		31.3%
Installed capacity	- Non-hydro RE elec. (2.1%)	- Non-hydro RE elec. (6.3%)			8.4%
Supply and capacity	- All RE and incentivized RE elec. (2.1%)				2.1%
Total	20.9%	29.3%	45.9%	4.2%	100%

tion of the following articles is noticeable: Sadorsky (2009a,b) (only cited) and Marques et al. (2010) (that cites previous articles and is cited many times). Interestingly enough, despite the fact that the article of Chang et al. (2009) was published early, it was relatively rarely cited. The clustering operated by the software (VOSviewer) also reveals that some researchers are mainly referring to a limited group of articles which makes this branch of literature quite fragmented. Finally, four articles that were identified do not either cite any previous papers nor are being cited by any reviewed papers.[7]

3. Current frameworks to investigate RE deployment determinants

This paper aims to better understand RE deployment dynamics at a country level. As suggested by Kalimeris et al. (2014), this section reviews the methodologies considered in the literature to analyse the comparability of the results that will be discussed in Section 5.

3.1. RE deployment measurement

Interestingly enough, relatively few authors precisely define RE sources. Furthermore, authors consider different indicators of RE deployment with diverse specifications and types of energy sources included, as presented in Table 2. Indeed, in the reviewed papers RE sources are used in: absolute levels (21% of the papers), per capita levels (29%), or levels as a share of total energy or electricity (46%). A small number of papers take two different types of indicators (Carley et al., 2017; Lin and Omoju, 2017). Moreover, the scope of the indicator selected can be energy supply (59% of the papers), energy consumption (31%), or installed capacity (8%). A small number of papers includes two different scopes (Nicolini and Tavoni, 2017).

Unlike Šener et al. (2018), it is difficult here to distinguish which RE sources are integrated given that this level of detail is rarely provided in the papers. Generally speaking, nearly half of the papers look at RE sources for energy in general whereas the other half investigates electricity generated from RE sources. Furthermore, certain authors exclude or account for differences in the development of hydroelectricity compared to other RE sources (40% of the papers). Besides this, several authors (e.g., Zhao et al., 2013; Best, 2017; Popp et al., 2011), show separate results for each RE source to investigate the influence of determinants at a disaggregated level.

3.2. Samples and methodologies

As can be seen in Table 3, the countries sampled vary among papers. Overall, authors either carry out a global analysis with developed and developing countries together (35% of the papers), or focus on developed (42%) or developing countries (23%).[8] The overall average number of countries is 41. The average reaches 72 countries for samples at a global scale (developed and developing countries taken together). The number of countries selected ranges from 5 (Nicolini and Tavoni, 2017; Zeb et al., 2014) to 164 (Carley et al., 2017). Additionally, 21% of the papers focus on European countries in a broad or a narrow sense (all or some members of the European Union (EU)). These papers mostly consider a dependent variable reflecting the development of all RE sources as a share of total energy produced. Furthermore, the majority of papers considering samples of countries at a global scale were published in 2016 and 2017 with a particular focus on dependent variables specified as a share of RE sources in electricity generation. It is worth mentioning that, with the exception of Romano and Scandurra (2014), papers focusing on developing countries do not measure RE deployment as a share of the energy mix.

In addition to the economic development and geographic criteria,[9] some authors also select countries based on: (i) the human development index (Carley et al., 2017), (ii) the carbon intensity of gross domestic product (GDP) (Romano and Scandurra, 2011), (iii) membership to the Organization of the Petroleum Exporting Countries (OPEC) (Romano and Scandurra, 2014) and more broadly the production of oil (Ackah and Kizys, 2015), or (iv) the presence of nuclear power plants (Romano and Scandurra, 2016c). Certain authors use these typologies to compare their results.

As shown in Table 3 the analysis time frame ranges from 3 (Narbel, 2013) to 42 years (Ackah and Kizys, 2015), with an average of 22. For more than one third of the papers, the analysed period

[7] Despite this and due to the limited number of papers identified, these papers (Apergis and Eleftheriou, 2015; Bayulgen and Ladewig, 2017; Bengochea and Faet, 2012; Cheon and Urpelainen, 2013) were included in the list of reviewed papers.

[8] Whenever authors refer to emerging or transitioning countries, they are here considered as developing countries.

[9] A few authors also specifically look at countries in Central or South America, Africa, and Asia. Furthermore, in accordance with the selection criteria, all papers focusing solely on the United States with state level data were not reviewed in this paper.

Table 3
Settings of the reviewed papers. "%" = "percentage", "min" = "minimum number", "max" = "maximum number", "av" = "average number", "sd" = "standard deviation".

Economic development level	Papers (%)	Countries				Period			
		(min)	(max)	(av)	(sd)	(min)	(max)	(av)	(sd)
Global (developed and developing)	35	16	164	72	50	3	39	21	9
Developing	23	5	119	31	42	10	42	29	8
Developed (European)	21	5	30	21	7	8	24	16	5
Developed (global)	21	6	30	20	8	10	32	20	8
Total	100	5	164	41	42	3	42	22	9

Table 4
Methodologies of the reviewed papers. "%" = "percentage".

Methodologies	Papers (%)
Static panel model estimation techniques	44
Panel cointegration and Granger causality tests	21
Dynamic panel model estimation techniques	19
Static and dynamic panel model estimation techniques	6
Others	10

Table 5
Determinants' categories of interest of the reviewed papers and maximum number of independent variables considered simultaneously. "%" = "percentage", "av" = "average number", "sd" = "standard deviation".

Authors' categories of interest	Papers (%)	Maximum number of independent variables	
		(av)	(sd)
Regulatory and political	27	14	4
Diverse	23	13	8
Economic and environmental	23	4	2
Economic	19	6	3
Energy security	4	10	5
Technological innovation	4	9	6
Total	100	10	6

starts in 1980 or earlier, for about another third it begins in 1990, and for the last third it commences in the 1990s or later. Due to a lack of data availability, the dataset generally ends several years before the analysis.

Table 4 shows the econometric methodologies used by the various papers. Almost all papers conduct panel data analyses to take advantage of time-varying differences between countries. More precisely, 21% of the papers conduct cointegration analysis and Granger causality tests, 44% of them adopt static panel model with a diversity of estimation techniques (see Table 8 in Appendix B for more details), and 19% of the authors use dynamic panel model (mostly with Generalized Method of Moments (GMM) estimators). In addition, three papers compare both static and dynamic model results (Brunnschweiler, 2010; Marques and Fuinhas, 2011b; Ackah and Kizys, 2015). There is no specific pattern of methodologies used based on papers publication year. However, with the exception of Marques and Fuinhas (2011b) that also use dynamic model, papers focusing on European countries only consider static panel model estimation techniques. In relation to the types of dependent variables, as can be seen in Table 10, in Appendix D, no dynamic panel model estimation technique was tested for installed capacity, either in absolute terms or normalized per capita. For papers with dependent variables specified as a share in total energy or electricity, more than half of the papers opt for static panel model estimation techniques and more than one fourth for dynamic models. Dynamic panel model estimation techniques have been used mostly with samples of countries at a global scale and particularly for dependent variables specified as a share of RE sources in electricity generated. Additionally, cointegration techniques, are mainly applied for dependent variables specified as per capita level of consumption of RE sources.

4. Determinants investigated

To complete the overview of the empirical frameworks used in the relevant literature, this section focuses on the different categories of factors addressed, the mechanisms investigated, and the results for each determinant of RE deployment. The data sources for the different variables are presented in Table 11 in Appendix D.

4.1. Overview

As illustrated by Šener et al. (2018), various categories of potential RE deployment determinants can be distinguished. The empirical literature is split accordingly. The authors either, simultaneously investigate several categories of determinants to identify the main ones (usually relying on a sample of international countries), or focus on a specific category of factors (controlling for one or several others). Table 5 presents the main topic of interest to authors as stated in the papers. If in early years the literature concentrated on economic and environmental factors, it expanded and diversified over the past few years to various categories of determinants. More recently, a growing number of papers has investigated the impact of regulatory and political changes (together or separately), especially with dependent variables expressed as a share and for global samples of countries or samples of European countries. Economic factors are also a major and regular interest of this literature, especially with regards to financial aspects. Other subject matters include energy security with a dependent variable representing a share of RE, and technological innovation for samples of developed countries at a global scale.

As shown in Table 5, the maximum number of variables considered simultaneously varies depending on the author's categories of interest. More specifically, when authors investigate primarily economic, and economic and environmental determinants, the maximum number of independent variables is the lowest with an average respectively of 6 and 4. This average reaches 14 for the authors investigating specifically regulatory and/or political aspects. Overall, the average maximum number of variables considered simultaneously is 10.

4.2. Main determinants considered

I will now review in further detail the categories of determinants. Table 6 presents the main independent variables considered

Table 6
Main independent variables considered by at least five authors. "%" = "percentage", "NC" = "no consensus".

Independent variables	Papers (%)	Countries	Scopes and types of dependent variable	Types of RE sources	Expected sign	Results
Economic variables	98					
Income	96	All	All	All	+	+, − or NC
Fossil fuel prices	48	All	All except absolute level of capacity, and share of consumption	All	+	+ or NC
Local financial sector	21	Developing, global	All except per capita level and share of consumption, and per capita level of capacity	All except non-hydro RE sources for energy	+	+ or NC
Energy/electricity price	19	All	All except per capita level of capacity	All except non-hydro RE sources for energy	+/−	+, − or NC
International flows	19	Developing, global	Absolute and per capita level and share of supply, and absolute level of consumption	All	+	NC
Environmental variable	67					
CO_2 emissions	67	All	All except per capita level of capacity	All	+/−	+, − or NC
Energy variables	60					
Energy/electricity consumption	48	All	All except absolute and per capita level of consumption, and absolute level of capacity	All except non-hydro RE sources for energy	+/−	+, − or NC
Other sources weight in the mix	44	All	All except absolute and per capita level of consumption	All except non-hydro RE sources for energy	−	− or NC
Energy security	42	All except developing	All except per capita level of supply, absolute and per capita level of consumption	All except non-hydro RE sources for energy	+	− or NC
Fossil fuel production	10	All except developed (European)	Per capita level and share of supply, and per capita level of capacity	All except non-hydro RE sources for energy	+/−	NC
Regulatory variables	48					
RE support policies	40	All	All except absolute and per capita level of consumption	All except non-hydro RE sources for energy	+	+ or NC
Kyoto protocol	15	All	Absolute and per capita level and share of supply, and per capita level of capacity	All except non-hydro RE sources for energy	+	+ or NC
Political variables	23					
Institutional quality	17	All except developed (global)	All except per capita level of consumption, and absolute and per capita level of capacity	All except non-hydro RE sources for energy	+	+ or NC
Government ideology (left)	13	All except developing	Absolute level and share of supply, share of consumption, and absolute level of capacity	All except non-hydro RE sources for energy	+	+ or NC
Demographic variable	17					
Population size	17	All except developed (global)	All except per capita level of supply, and absolute and per capita level of capacity	All except non-hydro RE sources for energy	+/−	+, − or NC

in the papers,[10] and their expected and estimated impact on RE deployment.

4.2.1. Economic variables

Generally speaking, except for Marques and Fuinhas (2012), every author considered at least one economic variable as a control variable. In their papers, Sadorsky (2009a,b) and Chang et al. (2009) were the first authors to investigate some economic determinants of RE deployment. Following these papers, income (generally taken as GDP per capita) is the most frequently used variable. Indeed, authors often assert that an increase in income might lead to a higher energy consumption, including from RE sources (see for instance Salim and Rafiq, 2012; Omri and Nguyen, 2014). Moreover, some authors claim that higher income could foster RE deployment by raising the (financial) resources that can be dedicated to investment in capital intensive RE projects, or to fund regulatory RE supportive incentives (see for instance Pfeiffer and Mulder, 2013; Aguirre and Ibikunle, 2014). Income appears to have a positive influence on RE development in the papers focusing on developing countries. The positive influence is documented with dependent variables representing per capita consumption of RE sources and also when considering RE sources for electricity. However, a negative influence is found for European countries, and there is no consensus for samples of developing and developed countries taken together and for samples of developed countries at a global scale. An explanation given by Cadoret and Padovano (2016) is that a high energy demand, resulting from high economic activity, may offset the income effect meaning that after a certain threshold, income has a negative influence on RE deployment because RE sources might not be able to immediately meet this increase in demand.

The (international) price of fossil energy was introduced by Sadorsky (2009b), provided RE and fossil energy sources (particularly oil) are possible substitutes. A little less than half of the papers follow this insight (i.e., introducing the price of oil and occasionally of gas and coal) expecting that an increase in the price of fossil fuel should *ceteris paribus* lead to a decrease (resp. increase) in fossil fuel (resp. RE sources) consumption (substitution effect). However, overall no clear consensus is observed. Nonetheless, a positive influence is found when authors are taking per capita level of RE sources consumption as the dependent variable. On the other hand, if no price of fossil fuel is introduced, 19% of the papers consider another price variable for energy or electricity.[11] The expected influence is not clear for authors. In an early study, Chang et al. (2009) observe a threshold effect regarding the pace of economic growth, measuring a positive influence of energy price on the share of RE in energy supply for countries with high economic growth in the previous period. However, in the majority of papers, there is no clear consensus regarding the existence of an influence of energy or electricity price on RE development.

Moreover, for Brunnschweiler (2010), RE deployment is expected to be supported by developed local financial sectors, particularly the banking sector. 21% of the papers reviewed investigate the influence of the development of the local financial sector on RE deployment with diverse variables for developing countries and samples of international countries, or consider a few ones as control variables (see the full list in Table 12 in Appendix D). When more than two indicators are taken together, there is evidence of a positive influence on RE deployment. However, when only one or two indicators related to financial development are taken, the authors generally have no significant findings. Besides this, if overall there is no consensus based on papers count, when considering estimation results, a positive influence is documented.

Finally, 19% of the reviewed papers also control for the size of international flows (i.e., trade openness, and/or foreign direct investment) only for samples of developing countries and at the global scale. A positive influence on RE sources is expected mainly in relation to technology and knowledge transfers, even though it may depend on the country specifics, e.g., physical and human capital, environmental regulations (Pfeiffer and Mulder, 2013). Indeed, globally authors find no clear proof of the existence of a significant relationship.

4.2.2. Environmental variable

Following the early contribution of Sadorsky (2009b), 67% of the reviewed papers introduce an environmental indicator (related to CO_2 emissions) as a proxy for environmental concerns and degradation in relation to global warming. Overall, authors expect an increase in CO_2 emissions to lead to a higher use of low-carbon RE sources. Nevertheless, for Marques and Fuinhas (2011b, p. 353), a negative influence could also reflect the apathy of societies towards environmental issues because it "creates political conditions to maintain the commitment with fossil fuels". Moreover, for Valdés Lucas et al. (2016), the dependency on fossil fuels and the power of lobbies might balance out environmentally friendly (and thus pro RE) policies. These conflicting mechanisms might explain why, different conclusions are documented. Indeed, a positive influence is found when considering the per capita level of RE consumption. However, a negative influence is observed when taking the overall estimation results (but not based on papers count), for samples of European countries, and when authors consider a share of RE in total supply as dependent variable.

4.2.3. Energy variables

The impact of energy indicators has been extensively addressed in the literature (60% of the reviewed papers), partly to control for countries characteristics. In particular, about half of the papers, state that an increase in energy (or electricity) consumption (or intensity) could be satisfied with both RE and conventional energy sources thus having an unclear expected influence on RE deployment. Indeed, there is no clear consensus on the existence and direction of a relationship between energy (electricity) demand and RE deployment. It should be noted that a positive influence is found if one considers all RE sources for energy.

In addition, most of the authors, particularly those investigating European countries, control for the weight of other sources in the electricity or energy mix. This is done because of the potential lobby effect of existing energy technologies (fossil fuels, nuclear, and hydro energies), due to their past and present relative prevalence on investments, employment and economies in general (Marques et al., 2010). Moreover, due to their low carbon intensity, a large

[10] Other determinants considered by few authors include: population characteristics (human capital, poverty, female or working-age population ratios) (Pfeiffer and Mulder, 2013; Romano et al., 2017; Zhao et al., 2013; Apergis and Eleftheriou, 2015; Ackah and Kizys, 2015; Zeb et al., 2014), official development assistance and clean development mechanism (Brunnschweiler, 2010; Pfeiffer and Mulder, 2013; Baldwin et al., 2017; Carley, 2009), physical potential of RE sources in general (Marques et al., 2010, 2011; Best, 2017; Bayulgen and Ladewig, 2017) or specific to some RE technologies (Aguirre and Ibikunle, 2014), political system related variables (Cadoret and Padovano, 2016; Cheon and Urpelainen, 2013; Apergis and Eleftheriou, 2015), EU membership (Marques et al., 2010, 2011; Biresselioglu and Karaibrahimoglu, 2012; Cheon and Urpelainen, 2013), knowledge accumulation related to RE patents (Popp et al., 2011; Geng and Ji, 2016; Cheon and Urpelainen, 2013), capital accumulation or flow (Lin and Omoju, 2017; Ackah and Kizys, 2015), fossil fuel rents (Baldwin et al., 2017; Carley et al., 2017; Lin and Omoju, 2017; Bayulgen and Ladewig, 2017), resources depletion (Ackah and Kizys, 2015; Zeb et al., 2014), energy or electricity mix concentration (Valdés Lucas et al., 2016; Pfeiffer and Mulder, 2013), power sector reforms (Brunnschweiler, 2010; Aguirre and Ibikunle, 2014), industrial or energy-intensive sector size (Cadoret and Padovano, 2016; Nyiwul, 2017; Cheon and Urpelainen, 2013), previous commitment to RE (Marques et al., 2010; Marques and Fuinhas, 2012; Aguirre and Ibikunle, 2014; Cheon and Urpelainen, 2013).

[11] Only Aguirre and Ibikunle (2014) have both fossil fuel prices and electricity price in their model.

development of nuclear and/or hydro power is expected to have a negative influence on RE deployment (Pfeiffer and Mulder, 2013). Whatever the level of economic development, a higher level of energy produced from fossil fuels and nuclear power plants (and also of hydro power, which is included in a small number of papers) is indeed likely to have a negative impact on RE deployment. It is well documented for global samples of countries and European countries. The impact is particularly clear when the dependent variable taken by authors is specified as a share in total energy generated.

The energy security issue is specifically addressed in two papers (Narbel, 2013; Valdés Lucas et al., 2016). 42% of the reviewed papers include one or more related variables such as energy import dependency or electricity imports. Indeed, the attempt to reach energy self-sufficiency, i.e., reducing imports, is expected to have a positive influence on the development of RE sources (Marques et al., 2010). However, there is no consensus for samples at a global scale. Restricting to European countries, a counter-intuitive negative influence of energy security emerges, supporting the lobby effect of traditional sources mentioned earlier (Marques and Fuinhas, 2012). In addition, surprisingly this variable was never considered for a sample of developing countries only.

Finally, 10% of the authors control for the level of fossil fuel production. They also note that a lobby effect of traditional energy sources, i.e., a local production of fossil fuels, could reduce the price of fossil fuels and diminish energy security and global warming concerns (Pfeiffer and Mulder, 2013), thus negatively impacting RE development. However, in their study of oil producing countries, Romano and Scandurra (2014), argue that increasing oil extraction could encourage RE investments to cope with a more rapid depletion of this resource. Nevertheless, there is no consensus in the authors' results.

4.2.4. Regulatory variables

About half of the papers include a variable related to countries' regulatory context. Following the early papers of Menz and Vachon (2006) and Carley (2009), RE support policies were considered by 40% of the reviewed papers. For Marques and Fuinhas (2012, p. 110) "[there] is broad consensus in the literature concerning the need for public intervention to promote RE use". As a result, the existence of support policies is expected to have a global positive influence on RE development. Authors use either diverse categories of support policies, or support measures at a disaggregated level (e.g., feed-in tariffs). A few authors combine national and supranational policies (e.g., RE development targets assigned by the EU). Despite the fact that there is no clear consensus for samples of global developed countries and of developing and developed countries taken together, overall support policies are found to have a positive influence on RE deployment (particularly when measured as a share in energy supply). Some authors insist on the fact that there are different impacts associated to diverse policies. For instance, voluntary instruments are found to have a rather negative influence (Zhao et al., 2013; Aguirre and Ibikunle, 2014).

To control for the influence of other energy or green policies, some papers include one or several related variables. The most commonly used (in 15% of the papers) addresses the implementation or the ratification of the Kyoto Protocol. Indeed, the Kyoto Protocol is viewed as a change in the commitment of countries towards global warming, and more specifically towards RE sources (Brunnschweiler, 2010). Overall, authors find a positive influence of the Kyoto Protocol on RE deployment with less clear results when looking at the diverse types of country samples.

4.2.5. Political variables

The political environment complements the regulatory environment, and is a dimension investigated by a few papers (23%). The main indicators selected encompass institutional quality (e.g., democracy, governance; see the full list in Table 13 in Appendix D) and government ideology (e.g., left or right wing ruling party). For Brunnschweiler (2010, p. 251), "[it] is in fact likely that RE projects, like other types of investment projects, benefit from general political stability, sound regulatory frameworks, effective governance and secure property rights.". Indeed, institutional quality is expected to have a positive influence on RE development (Wu and Broadstock, 2015). No clear consensus about the impact of this factor emerges from the literature based on the number of papers. However, overall the result associated to the inclusion of such independent variables in estimations suggests a positive relationship. In addition, regarding government orientation, leftist parties are generally viewed as more environmentally conscious and thus more likely to favour RE deployment (Nicolini and Tavoni, 2017). However, there is no clear consensus in the reviewed papers. It is to be noted that this type of independent variable was never investigated with a sample of developing countries only.

4.2.6. Demographic variable

Few of the reviewed papers (17%), control for population size or growth dynamic. Indeed, for Aguirre and Ibikunle (2014) the sign of a potential influence is not clear. An increase in population is expected to increase energy demand. If the latter increase is too high, it may discourage RE deployment in favour of conventional sources. Overall, it seems that population size is found to have a positive influence on RE deployment, even if this is less clear when looking at the different types of samples of countries.

5. Discussion of the results

This section builds on the overview of the frameworks and determinants described in Sections 3 and 4 to provide a synthesis of the main results of the empirical literature on RE deployment and discuss them to formulate some recommendations for future research.

5.1. Synthesis of the main results

Economic, environmental, energy, regulatory, and to a lesser extent political, and demographic determinants have been discussed by the reviewed literature. A consensus emerges on a few mechanisms: (i) RE support policies and Kyoto protocol (positive effect), (ii) a lobby effect from traditional (or preexisting) energy sources (negative effect), and (iii) population size (positive effect). In addition, several results are counter-intuitive or worth discussing. Contrary to what is found by Šener et al. (2018), the reviewed papers do not find that income has a systematic positive influence. Indeed, overall, there is no consensus but an ambiguous impact of income when considering the different types of samples of countries based on economic development level (positive effect for developing countries, negative effect for European countries). Additionally, when counted as the number of papers, there is no consensus regarding the influence of CO_2 emissions on RE deployment. However, when taking the number of estimation results, it appears that there is a rather negative influence of CO_2 emissions and this is also found by authors looking at samples of European countries and considering the deployment of RE sources with a dependent variable representing a share in the mix. A positive influence of CO_2 emissions is documented for a dependent variable representing per capita level of energy or electricity consumption. While a positive influence of energy security is expected, there is no global consensus and even a negative influence for European countries. Moreover, when taking the number of papers, there is no consensus regarding the influence of the local financial sector development and institutional quality levels. Nevertheless, these two types of independent variables appear to have a positive influence when considering all estimation results.

Hence, the seemingly fragile consensus regarding the influence of the determinants of RE deployment investigated by the literature (presented in Table 14 in Appendix E) should be tempered by the variety of frameworks, samples, and specifications used by authors. The differences can lead to misinterpretations, especially whenever a unique mechanism is assessed through different (and non-comparable) specifications of the dependent variables. Table 15 in Appendix E details this decomposition and suggests that this contradiction partly disappears with each choice of specification. Furthermore, the databases considered by the authors vary, as can be seen in Table 11 in Appendix D.[12] Lastly, as illustrated by Table 16 in Appendix E, commonalities are also documented within similar samples of countries.

5.2. Discussion and recommendations

The relative lack of consensus that appears at first glance regarding the influence of the determinants considered on RE deployment can be partly explained by the different methodologies and frameworks of the papers. Therefore, this final section provides some elements to guide future research and to structure the policy recommendations that can be derived from this literature.

5.2.1. RE deployment measurement

The literature reviewed lacks a clear and motivated definition of the indicator chosen to measure RE deployment, despite the critical impact the indicator can have on the results.[13] Moreover, coherent policy recommendations can only be formulated based on a common approach. As a result, misspecification issues and particularities related to RE sources need to be addressed by the literature.

Indeed, the indicators used to measure RE deployment fall into three categories: absolute, or per capita levels, and share (of the mix). To investigate the determinants of RE deployment, a simple absolute level measure is not completely applicable due to the differences in population, economic development, and energy market conditions across countries. It is thus crucial to standardize the dependent variable used to account for the deployment dynamic of RE sources. Moreover, one should distinguish an *absolute* and a *relative* definition of the RE deployment. The first one refers to an absolute increase, while the second one captures the substitution potential of RE sources. The second definition seems more appropriate because: (i) governments generally set share targets for RE development, and (ii) to mitigate climate change, a substitution of fossil by RE sources is a mean to reduce GHG emissions (Aguirre and Ibikunle, 2014; Marques and Fuinhas, 2012). From this perspective, normalizing by population size still corresponds to an absolute definition of deployment (an increase in per capita level of RE sources does not necessarily imply that its relative share in total energy is increasing). Besides this, no author has considered measuring RE deployment as a share in total installed capacity.

Moreover, the scope of the dependent variable matters. RE production and installed capacity correspond to the energy and industrial policy choices of a given country, whereas RE consumption represents the actual use of RE sources of a country, provided RE consumption encompasses net imports. For instance, a high national deployment of intermittent RE sources, might increase electricity imports resulting in a (relatively) lower rise in RE consumption. As a result, the commitment of a country (materialized by its energy policy orientations) is better evaluated by the supply or installed capacity of RE sources.

Last but not least, only considering RE sources for electricity is too restricting in the sense that RE sources can also be used for heat and for the transport sector.[14] Furthermore, hydro power has specific technical characteristics (Omri and Nguyen, 2014) and can thus potentially have different determinants compared to other RE sources. Moreover, hydroelectricity has potential negative social and environmental consequences (Pfeiffer and Mulder, 2013) and is already highly exploited in many countries (Lin and Omoju, 2017). That is why separating hydro from non-hydro RE sources might be relevant.

The choice of another dependent variable can be coherent if, and only if, it is motivated. For instance, Brunnschweiler (2010) justifies the choice of per capita values given that total energy supply might be highly correlated with some independent variables integrated in the model (financial sector development variables). In addition, as Kim and Park (2016) want to reflect investment decisions, they decide to select a measure of RE development with installed capacity because electricity generated with RE sources is influenced by factors difficult to control for investors, e.g., meteorology. Moreover, considering diverse dependent variables to account for the particularities of different RE sources (e.g., distinguishing between hydro and non-hydro sources) could be of significant interest to identify the existence of specific dynamics and preclude bias in the assessment.

5.2.2. Determinants considered and to be investigated

Several categories of determinants have been considered. Economic and energy variables have received particular attention with the main control variables being: income, fossil fuel prices (mainly oil), and energy or electricity consumption. CO_2 emissions, the only environmental variable used, and regulatory variables (in particular RE support policies) are also control variables taken by more or about half of the papers. Among other possible control variables, few authors have tried to diversify the possible variables that could reflect the existence of a lobby effect from traditional energy sources. Examples of possible control variables (subject to data availability) are: the size of the (conventional) energy sector in the economy, the size of brown public subsidies, or else local fossil fuel reserves. This analysis could be particularly interesting in the case of European countries. Furthermore, very few papers control for the potential of RE sources associated to natural resources, while "[the] feasibility of renewable energy options depends to a large extent on geophysical characteristics of the area where the option is implemented" (IPCC, 2018, Chap. 4, p. 18).

Regarding the independent variables of interest, it could be interesting to consider other environmental performance measures, especially because it is not certain that CO_2 emissions capture the entire relationship between environmental consideration and the choice of RE sources. Indeed, "[in] addition to reducing GHG emissions, RE technologies can also offer benefits with respect to air pollution and health compared to fossil fuels" (IPCC, 2012, p. 43). Moreover, more research is necessary to assess the impact of diverse national energy or green policies that are not directly

[12] Overall, data from the United States Energy Information Administration are mainly used for the dependent variables but other sources are also found (e.g., the International Energy Agency). There is the same diversity of data sources for independent variables (income is an interesting example with eight different data sources).

[13] For instance, as shown in Table 15 in Appendix E, the results for CO_2 emissions depends on the scope considered (i.e., RE supplied, consumed or installed capacity) and the type of indicator (absolute or per capita levels, or share).

[14] As per the REN21 (2018) report, the power sector represents about 20% of the total final energy consumption in the world with about 25% from RE sources. RE sources are also used for heat (close to 50% of the world consumption with about 30% from RE sources) and transportation (around 30% of the world consumption with roughly 3% from RE sources).

related to RE sources, such as local energy market regulation or the existence of a carbon tax. Additionally, the socio-demographic dynamics have been rarely explored by the authors. The characteristics of the population and the attitudes towards RE technologies could influence the deployment of RE sources including at the country level (Sovacool et al., 2015; IPCC, 2018). Finally, authors looking only at samples of developed countries have not considered financial variables. As suggested by Mignon and Bergek (2016), some financial challenges can exist in developed countries for instance because RE technologies require a high upfront investment.

More generally, several specifications of a determinant are found in the reviewed papers.[15] The data sources might also be different. That is why, for comprehension, repeatability, and public policy orientation, it is essential that authors describe the mechanism being investigated, the data sources, and the precise specification of independent variables chosen, notably by referring to previous papers.

5.2.3. Methodological framework

In addition to the two aspects previously discussed, it is key to mention that the specification of the econometric model (and the related estimation techniques) are likely to influence the results obtained by the reviewed papers. For instance, focusing on the set of papers that define their indicator of RE deployment as a share in the total energy production (9 papers), which is advocated in this paper to be a more accurate definition, most of the authors use static panel estimation techniques including: quantile regressions, fixed effects vector decomposition models, and/or panel corrected standard errors estimation methods (see Table 8 in Appendix B for more details).

Country-specific characteristics and the temporal dimension are two aspects that seem to be relevant in the inference and shall be considered by authors. For one thing, it is very likely that country-specific characteristics (meteorological conditions, natural resources endowment, existing policies, citizens' views on the RE sector, preexisting level of RE development, etc.) do influence RE development patterns. For another, country might be hit by weather, climate, and economic shocks that could interact with RE deployment. Both of these aspects shall thus be controlled for in estimations. Moreover, RE development, especially when measured as a share in production, is very likely to exhibit a path dependency, previous levels of installed capacities influencing new ones. Dynamic panel methods could capture the latter aspect. Besides this, as suggested by Marques and Fuinhas (2012, p. 111), "heteroskedasticity, panel autocorrelation, and contemporaneous correlation phenomena must be adequately addressed" by authors. A complete set of specification and robustness checks is required to ensure the validity of the methodology used (this is not systematically done as of today).

If a more precise discussion of econometric specifications falls beyond the scope of this paper, an additional methodological recommendation is to systematically justify the choice of econometric models and estimations techniques with regard to the research question addressed. Such a justification is central for the comprehension and the repeatability of the papers.

6. Conclusion

Understanding the determinants of RE deployment is essential because developing these low-carbon sources could be a way to reduce GHG emissions and thus mitigate global warming. To gain insight on the dynamics behind the development of RE sources, both for public policy recommendations and for structuring future research, this paper aims at surveying the existing literature on related empirical determinants. It follows a systematic review methodology to describe and discuss the variety of measures of RE deployment considered and to detail the framework of the reviewed papers.

Indeed, different types of RE deployment metrics have been used in terms of: (i) scope (supply, consumption, or installed capacity), (ii) types of indicator (absolute, or per capita levels, or share), and (iii) energy sources (energy, electricity, or excluding hydroelectricity). Among the diverse specifications, a specification with a share of supply (or capacity) seems to better represent the commitment of countries towards RE deployment. Moreover, the authors have considered a variety of determinants, in particular economic and energy-related. The other main categories of determinants investigated are environmental, regulatory, political, and demographic. The main control variables are: income, fossil fuel prices, electricity or energy consumption, CO_2 emissions, and regulatory variables (in particular RE support policies). Even though, there is little consensus overall, in classifying the papers based on the types of dependent variables and samples of countries some significant results emerge. Indeed, a consensus exists on a few mechanisms: (i) RE support policies and Kyoto protocol (overall positive effect), (ii) lobby effect from traditional (or preexisting) energy sources (overall negative effect), (iii) population size (overall positive effect), (iv) ambiguous income effect (positive effect for developing countries, negative effect for European countries), (v) unclear effect of CO_2 emissions (negative effect for European countries and dependent variable specified as a share in total energy or electricity supply, but positive when specified as a per capita level of consumption), (vi) counter-intuitive effect of energy security for European countries (negative effect), and (vii) local financial sector development and institutional quality levels (overall no consensus based on papers count but positive effect when considering estimation results). In addition, some dimensions have been only rarely or partly explored, yet could shed new light on the RE deployment process after 1980. They include socio-demographic, environmental, or public policy aspects.

To conclude, the strand of literature to which the reviewed papers contribute is relatively new and fragmented. That is why, after mapping the existing literature, this paper also formulates some recommendations to structure future research. It aims at favouring comparability between the papers and repeatability that are keys for relevant public policy guidance. More specifically, they target the choice of RE deployment measurements, the determinants investigated, and the methodologies considered. Finally, a meta-analysis could be the next step in order to go further in the analysis of the reviewed papers' results and methodologies.

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[15] For instance, energy consumption is taken in absolute terms, or in relative ones divided by population or GDP.

Appendix A. Search strategy

Table 7
Description of the search strategy in relation to the search string. As the articles search started in early 2018, the articles published after December of 2017 are not considered here.

Keywords and refinements	Description and rationale	Scopus results
Search string (search in Article title, Abstract, Keywords)		
(renewable* OR "renewable energ*" OR "renewable electric*")	This enables to precisely identify the type of energy sources considered.	144,577 results
AND (invest* OR source* OR generat* OR technolog* OR consum* OR deploy* OR diffus* OR develop*)	These terms refer to the use of this type of energy sources.	122,139 results
AND (motiv* OR factor* OR driv* OR promot* OR determin* OR influence* OR relation* OR impact* OR potential* OR affect*)	These terms are related to the study of potential determinants.	69,922 results
AND (panel OR estimat* OR regression OR data*)	This enables to capture only econometric analyses.	17,004 results
AND (countries* OR states*)	This terms are used to identify papers conducting an analysis with a panel of countries.	3,023 results
Specification of the fields of research		
AND ((EXCLUDE (SUBJAREA, "EART") OR EXCLUDE (SUBJAREA, "MATE") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "PHAR") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "NURS") OR EXCLUDE (SUBJAREA, "HEAL") OR EXCLUDE (SUBJAREA, "NEUR") OR EXCLUDE (SUBJAREA, "VETE") OR EXCLUDE (SUBJAREA, "COMP"))	Due to the focus of this review, the following subject areas are excluded: Materials Science, Earth and Planetary Sciences, Chemistry, Medicine, Biochemistry, Genetics and Molecular Biology, Physics and Astronomy, Pharmacology, Toxicology and Pharmaceutics, Immunology and Microbiology, Health Professions, Nursing, Neuroscience, Veterinary, and Computer Science.	2,399 results
Document type and language specification		
AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO(LANGUAGE, "English"))	This article aims at reviewing papers published in English in peer-reviewed journals to ensure that the papers that are reviewed can be found and understood by any reader.	1,725 results

Appendix B. Presentation of the reviewed papers

Table 8
Description of the reviewed papers.

References	Period	Countries	Methodology	Dependent variable	Independent variables
Chang et al. (2009)	1997–2006	30 developed	Static panel model estimation techniques (panel threshold regression model)	Share of all RE in energy supply	Economic (income, prices)
Sadorsky (2009a)	1994–2003	18 developing	Panel cointegration techniques, Granger causality	Level of all RE consumption per capita	Economic (income, prices)
Sadorsky (2009b)	1980–2005	7 developed	Panel cointegration techniques, Granger causality	Level of all RE consumption per capita	Economic (income, prices), Environmental
Brunnschweiler (2010)	1980–2006	119 developing	Static panel model estimation techniques (GLS), dynamic panel model estimation techniques (GMM)	Level of all RE electricity, hydro and non-hydro RE electricity generated per capita	Economic (income, prices, international flows, financial), Energy (fossil fuels), Regulatory and Political
Marques et al. (2010)	1990–2006	24 developed (European)	Static panel model estimation techniques (OLS, RE, FE, FEVD)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Political, RE potential
Gan and Smith (2011)	1994–2003	26 developed	Static panel model estimation techniques (GLS)	Level of all RE and bioenergy supply per capita	Economic (income, prices), Environmental, Regulatory
Marques and Fuinhas (2011b)	1990–2006	24 developed (European)	Static panel model estimation techniques (FE), dynamic panel model estimation techniques (difference and system GMM, LSDVC)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix)

Table 8 (*Continued*)

References	Period	Countries	Methodology	Dependent variable	Independent variables
Marques and Fuinhas (2011a)	1990–2006	21 developed (European)	Static panel model estimation techniques (OLS, quantile regression model)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory
Marques et al. (2011)	1990–2006	24 developed (European)	Static panel model estimation techniques (OLS, quantile regression model)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory, RE potential
Popp et al. (2011)	1991–2004	26 developed	Static panel model estimation techniques (FGLS)	Installed capacity per capita of non-hydro RE electricity	Economic (income), Energy (security, consumption, mix, fossil fuels), Regulatory, RE potential
Romano and Scandurra (2011)	1980–2008	29 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (consumption, mix)
Bengochea and Faet (2012)	1990–2004	15 developed (European)	Static panel model estimation techniques (OLS, FE, RE, PCSE, FGLS)	Level of all RE supply	Economic (prices), Environmental
Biresselioglu and Karaibrahimoglu (2012)	1999–2009	30 developed (European)	Static panel model estimation techniques (?)	Share of all RE in energy consumption	Economic (income), Energy (security, consumption, mix), Population, Regulatory and Political, RE potential
Marques and Fuinhas (2012)	1990–2007	23 developed (European)	Static panel model estimation techniques (RE, FE, PCSE)	Share of all RE in energy supply	Environmental, Energy (security, consumption, mix), Regulatory, RE potential
Salim and Rafiq (2012)	1980–2006	6 developing	Panel cointegration techniques, Time series analysis (cointegration and Granger causality)	Level of all RE consumption	Economic (income, prices), Environmental
Cheon and Urpelainen (2013)	1989–2007	19 developed	Dynamic panel model estimation techniques (?)	Share of non-hydro RE in electricity generated	Economic (income, prices), Energy (consumption, mix), Regulatory, Political, RE potential
Narbel (2013)	2007–2009	107 developing and developed	Cross-section analysis (OLS)	Share of non-hydro RE in electricity generated	Economic (income), Energy (security, mix)
Pfeiffer and Mulder (2013)	1980–2010	108 developing	Static panel model estimation techniques (Two-part model (probit, OLS) and two-step selection model (probit))	Level of non-hydro RE electricity generated per capita	Economic (income, international flows, financial), Energy (consumption, mix, fossil fuels), Population, Regulatory and Political
Sick et al. (2013)	1991–2009	18 developed	Static panel model estimation techniques (?)	Installed capacity per capita of non-hydro RE electricity	Economic (income, prices), Energy (consumption, mix), Regulatory
Zhao et al. (2013)	1980–2010	122 developing and developed	Static panel model estimation techniques (OLS, Poisson pseudo-maximum likelihood estimation)	Share of non-hydro RE in electricity generated	Economic (income, international flows, financial), Environmental, Energy (security), Population, Regulatory
Aguirre and Ibikunle (2014)	1990–2010	38 developing and developed	Static panel model estimation techniques (GLS, FEVD, PCSE)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix) Population, Regulatory, RE potential
Apergis and Payne (2014a)	1980–2011	25 developed	Panel cointegration techniques, Granger causality	Level of all RE electricity generated per capita	Economic (income, prices), Environmental
Apergis and Payne (2014b)	1980–2010	7 developing	Panel cointegration techniques with possible structural breaks, Granger causality	Level of all RE electricity generated per capita	Economic (income, prices), Environmental
Omri and Nguyen (2014)	1990–2011	64 developing and developed	Dynamic panel model estimation techniques (GMM)	Level of non-hydro RE consumption	Economic (income, prices, international flows), Environmental
Romano and Scandurra (2014)	1980–2009	6 developing	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, fossil fuels)

Table 8 (*Continued*)

References	Period	Countries	Methodology	Dependent variable	Independent variables
Zeb et al. (2014)	1975–2010	5 developing	Panel cointegration techniques, Granger causality	Level of all RE electricity generated	Economic (income), Environmental, Population
Ackah and Kizys (2015)	1971–2012	11 developing	Static panel model estimation techniques (two-stage EGLS and least squares), dynamic panel model estimation techniques (GMM)	Level of all RE consumption per capita	Economic (income, prices), Environmental, Energy (other), Population, RE potential
Apergis and Eleftheriou (2015)	1995–2011	16 developing and developed	Panel cointegration techniques, Granger causality	Level of all RE consumption	Economic (income), Population, Political
Apergis and Payne (2015)	1980–2010	11 developing	Panel cointegration techniques, Granger causality	Level of all RE electricity generated per capita	Economic (income, prices), Environmental
Kehrel and Sick (2015)	1991–2010	18 developed	Time-series cross-section analysis (multivariate linear regression)	Installed capacity of non-hydro RE electricity and production volume of biofuels per capita	Economic (income, prices), Energy (consumption, mix), Regulatory
Wu and Broadstock (2015)	1990–2010	22 developing	Dynamic panel model estimation techniques (GMM)	Level of all RE consumption	Economic (incomre, prices, international flows, financial), Environmental, Population, Political
Cadoret and Padovano (2016)	2004–2011	26 developed (European)	Static panel model estimation techniques (Two-step estimation technique (LSDV, OLS))	Share of all RE in energy consumption	Economic (income, prices), Environmental, Energy (security), Regulatory and Political
Geng and Ji (2016)	1980–2010	6 developed countries	Panel cointegration techniques, Granger causality	Level of non-hydro RE in energy consumption per capita	Economic (income, prices) Environmental, RE potential
Kilinc-Ata (2016)	1990–2008	27 developed	Static panel model estimation techniques (FE)	Share of non-hydro RE in electricity generated	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory
Kim and Park (2016)	2000–2013	30 developing and developed	Static panel model estimation techniques (OLS, Tobit)	Installed capacity of non-hydro-electricity	Economic (income, financial), Regulatory, RE potential
Romano and Scandurra (2016a)	2000–2008	32 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of hydro and non-hydro RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, mix), Regulatory
Romano and Scandurra (2016b)	1980–2008	60 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, mix), Regulatory
Romano and Scandurra (2016c)	1980–2008	32 developing and developed	Dynamic panel model estimation techniques (GMM)	Share of all RE in electricity generated	Economic (income), Environmental, Energy (security, consumption, mix), Regulatory
Valdés Lucas et al. (2016)	1990–2013	21 developed (European)	Static panel model estimation techniques (RE, FGLS, PCSE)	Share of all RE in energy supply	Economic (income, prices), Environmental, Energy (security, consumption, mix), Regulatory
Baldwin et al. (2017)	1990–2010	149 developing and developed	Static panel model estimation techniques (FE)	Level of all and non-hydro RE electricity generated	Economic (income, international flows, financial), Energy (security, consumption, fossil fuels), Population, Regulatory and Political
Bayulgen and Ladewig (2017)	1974–2012	125 developing and developed	Static panel model estimation techniques (mixed-effect)	Share of all, hydro and non-hydro RE in electricity generated	Economic (income, prices, financial), Environmental, Energy (security, fossil fuels), Population, Political, RE potential
Best (2017)	1998–2012	Up to 137 developing and developed	Cross-section analysis (OLS), static panel model estimation techniques (FE)	Share of all RE in energy supply and electricity generated	Economic (income, financial), Energy (consumption, fossil fuels), RE potential
Carley et al. (2017)	1990–2010	164 developing and developed	Dynamic panel model estimation techniques (differences-in-differences estimator)	Level and share of all and non-hydro RE in electricity generated	Economic (income, international flows, financial), Energy (security, consumption, fossil fuels), Population, Regulatory and Political

Table 8 (*Continued*)

References	Period	Countries	Methodology	Dependent variable	Independent variables
Lin and Omoju (2017)	1980–2011	46 developing and developed	Panel cointegration techniques, Granger causality	Level and share of non-hydro RE in electricity generated	Economic (income, prices, international flows, financial), Energy (fossil fuels), Regulatory, RE potential
Lu (2017)	1990–2012	24 developing and developed	Panel cointegration techniques, Granger causality	Level of all RE consumption per capita	Economic (income), Environmental
Nicolini and Tavoni (2017)	2000–2010	5 developed (European)	Static panel model estimation techniques (pooled OLS, FE, RE, Hausman Taylor estimator)	Level and installed capacity of all and incentivized RE	Economic (income, prices), Environmental, Energy (security, mix), Regulatory and Political
Nyiwul (2017)	1980–2011	27 developing	Panel cointegration techniques (DOLS, FMOLS, FE)	Level of all RE consumption	Economic (income, prices, other), Environmental, Population
Romano et al. (2017)	2004–2013	56 developing and developed	Static panel model estimation techniques (PCSE)	Share of non-hydro RE in electricity generated	Economic (income, prices, international flows), Environmental, Energy (security, consumption, mix, fossil fuels), Population, Regulatory

Appendix C. Statistics around the reviewed papers

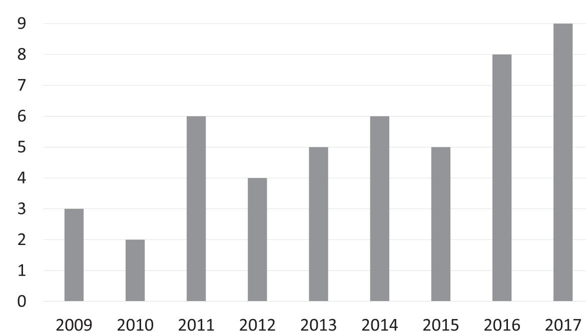

Fig. 2. Number of papers published per year.

Table 9
Journals of the reviewed papers.

Journal	Number of papers
Energy Economics	8
Energy Policy	5
Renewable and Sustainable Energy Reviews	5
Energy Sources, Part B: Economics, Planning and Policy	4
Renewable Energy	4
Energy for Sustainable Development	2
Environmental and Resource Economics	2
Applied Economics	1
Biomass and Bioenergy	1
Clean Technologies and Environmental Policy	1
Energy	1
Environment and Development Economics	1
Environmental Politics	1
Environmental Science and Policy	1
Environmental Science and Pollution Research	1
Foresight	1
International Journal of Economic Policy in Emerging Economies	1
International Journal of Energy Economics and Policy	1
International Journal of Energy Sector Management	1
International Journal of Global Environmental Issues	1
Journal of Applied Statistics	1
Journal of Comparative Policy Analysis: Research and Practice	1
Metodoloski Zvezki	1
Political Studies	1
Singapore Economic Review	1

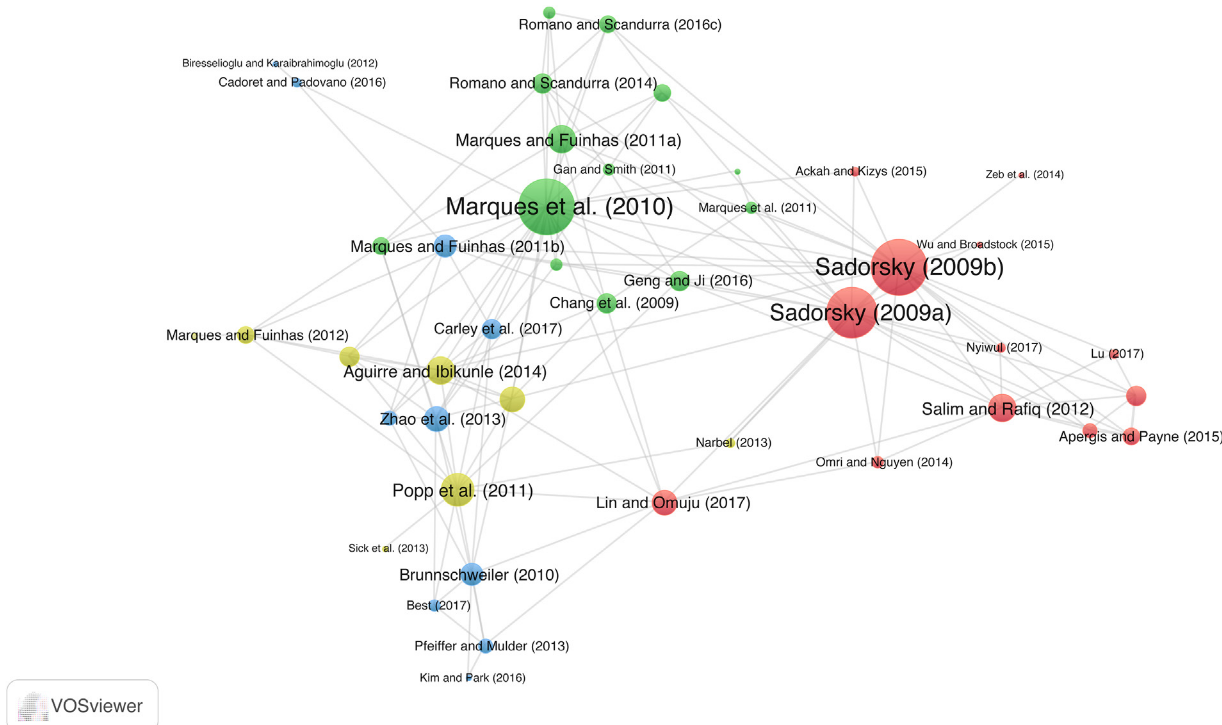

Fig. 3. Network of citations of and by the reviewed papers.

Appendix D. Details regarding the framework of the reviewed papers

Table 10
Dependent variables types, sample of countries, and methodologies considered by reviewed papers (percentages in total, small differences due to rounding).

	Absolute level	Per capita level	Share	Absolute level and share	*Total*
Supply	*Developed (European):* - Static panel model estimation techniques (2.1%) *Developing:* - Panel cointegration techniques and Granger causality tests (2.1%) *Developing and developed:* - Static panel model estimation techniques (2.1%)	*Developed (global):* - Static panel model estimation techniques (2.1%) *Developing:* - Static panel model estimation techniques (2.1%), - Static and dynamic panel model estimation techniques (2.1%)	*Developed (global):* - Dynamic panel model estimation techniques (2.1%) - Static panel model estimation techniques (4.2%) *Developed (European):* - Static panel model estimation techniques (10.4%), - Static and dynamic panel model estimation techniques (2.1%) *Developing:* - Dynamic panel model estimation techniques (2.1%) *Developing and developed:* - Dynamic panel model estimation techniques (8.3%), - Static panel model estimation techniques (8.3%), - Others (4.2%)	*Developing and developed:* - Dynamic panel model estimation techniques (2.1%), - Panel cointegration techniques and Granger causality tests (2.1%)	58.5%
Consumption	*Developing:* - Dynamic panel model estimation techniques (2.1%), - Others (4.2%) *Developing and developed:* - Dynamic panel model estimation techniques (2.1%), - Panel cointegration techniques and Granger causality tests (2.1%)	*Developed (global):* - Panel cointegration techniques and Granger causality tests (6.3%) *Developing:* - Panel cointegration techniques and Granger causality tests (6.3%), - Static and dynamic panel model estimation techniques (2.1%) *Developing and developed:* - Panel cointegration techniques and Granger causality tests (2.1%)	*Developed (European)* - Static panel model estimation techniques (4.2%)		31.5%

Table 10 (*Continued*)

	Absolute level	Per capita level	Share	Absolute level and share	*Total*
Installed capacity	*Developing and developed:* - Static panel model estimation techniques (2.1%)	*Developed (global):* - Static panel model estimation techniques (4.2%), - Others (2.1%)			8.4%
Supply and capacity	*Developed (European):* - Static panel model estimation techniques (2.1%)				2.1%
Total	21.0%	29.4%	45.9%	4.2%	100%

Table 11
Main data sources considered by the authors in order of importance. "OECD" = "Organisation for Economic Co-operation and Development", "IEA" = "International Energy Agency", "IMF" = "International Monetary Fund".

Variables	Main data sources
Dependent variables	
Supply	U.S. Energy Information Administration, OECD, IEA, Eurostat, national authorities.
Consumption	U.S. Energy Information Administration, OECD, IEA, Eurostat, national authorities.
Capacity	IEA, Bloomberg New Energy Finance, U.S. Energy Information Administration, national authorities.
Independent variables	
Economic variables	
Income	World Bank, U.S. Energy Information, IMF, OECD, Penn World Table, United Nations, Eurostat, IEA, national authorities.
Fossil fuel prices	BP, Thomson Reuters.
Local financial sector	World Bank, Bloomberg New Energy Finance.
International flows	World Bank.
Energy/electricity price	IEA, OECD, IMF, Eurostat.
Environmental variable	
CO_2 emissions	U.S. Energy Information, Eurostat, World Bank, BP, European Commission, OECD, national authorities.
Energy variables	
Energy/electricity consumption	Eurostat, U.S. Energy Information Administration, IEA, European Commission, World Bank.
Other sources weight in the mix	U.S. Energy Information Administration, Eurostat, World Bank, European Commission, IEA.
Energy security	Eurostat, US U.S. Energy Information, World Bank, European Commission, IEA, BP.
Fossil fuel production	U.S. Energy Information Administration, BP.
Regulatory variables	
RE support policies	IEA, Eurostat, REN21, OECD, national authorities.
Kyoto Protocol	IEA, United Nations.
Political variables	
Institutional quality	World Bank, Transparency international, Freedom house, TransResearch Consortium Center for Systemic Peace, Heritage Foundation, Fraser Institute, Center on Democratic Performance, University of Pennsylvania.
Government ideology (left)	World Bank.
Demographic variable	
Population size	World Bank, Eurostat, Penn World Table.

Table 12
Local financial development independent variables considered by the authors. "LCOE" = "levelized cost of energy".

References	Indicators
Brunnschweiler (2010)	Deposit money bank assets/(deposit money + central) bank assets, Private credit by deposit money banks/GDP, Financial depth (liquid liabilities/GDP).
Pfeiffer and Mulder (2013)	Deposit money bank assets/total bank assets.
Zhao et al. (2013)	Domestic credit to the private sector/GDP.
Wu and Broadstock (2015)	Stock market total value traded/GDP, Bank return on assets, Bank overhead costs/total assets, Bank cost-income ratio, Public bond market capitalization/GDP, Bank credit/bank deposits, Loans from non-resident banks/GDP, Offshore bank deposits/domestic bank deposits, Bank return on equity.
Kim and Park (2016)	Annual equity market development*Dependence, Annual credit market development * Dependence, Variable composed of the 2 previous variables * Dependence. Dependence measures the dependence on external financing (based on U.S. RE firms, also tested with U.K. RE firms and U.S. LCOE).
Best (2017)	For 10-year change: Private credit from deposit money banks/GDP. For panel data: Private credit from deposit money banks/GDP, Domestic private debt securities, International private debt securities, Public debt securities, Stock market capitalization.
Bayulgen and Ladewig (2017)	Domestic credit to the private sector/GDP.
Lin and Omoju (2017)	Domestic credit to the private sector/GDP.
Baldwin et al. (2017)	Private credit by deposit money banks/GDP, Bank credit/bank deposits.
Carley et al. (2017)	Private credit by deposit money banks/GDP.

Table 13
Institutional quality independent variables considered by the authors.

References	Indicators
Brunnschweiler (2010)	Economic freedom index.
Pfeiffer and Mulder (2013)	Polity score.
Wu and Broadstock (2015)	Political stability and absence of violence, Voice and accountability, Regulatory quality.
Apergis and Eleftheriou (2015)	Political (Number of political parties), Institutional (Size of government, Legal system and property rights, Freedom to trade internationally, Regulation level).
Cadoret and Padovano (2016)	Quality of governance (Corruption Perception Idex; Control of Corruption Index).
Baldwin et al. (2017)	Freedom House rating, Government ability to appropriate and collect portions of GDP (proxy for state administrative capability).
Bayulgen and Ladewig (2017)	Political constraint, Polity score.
Carley et al. (2017)	Freedom House rating.

Appendix E. Detailed results

Table 14
Overall results for the main independent variables (considered by at least five authors).

Independent variables	Global results (papers)	Global results (estimations)
Economic variables		
Income	NC	NC
Fossil fuel prices	NC	NC
Local financial sector	NC	+
Energy/electricity price	–	NC
International flows	NC	NC
Environmental variable		
CO_2 emissions	NC	–
Energy variables		
Energy/electricity consumption	NC	NC
Other sources weight in the mix	–	–
Energy security	NC	NC
Fossil fuel production	NC	NC
Regulatory variables		
RE support policies	+	+
Kyoto Protocol	+	+
Political variables		
Institutional quality	NC	+
Government ideology (left)	NC	NC
Demographic variable		
Population size	+	+

Table 15
Detailed results by types of dependent variable for the main independent variables (results in parentheses correspond to less than 5 papers).

Independent variables	Supply			Consumption			Capacity	
	Absolute	Per capita	Share	Absolute	Per capita	Share	Absolute	Per capita
Economic variables								
Income	NC	(+)	NC	NC	+	(−)	(NC)	(NC)
Fossil fuel prices	(NC)	(NC)	NC	(NC)	+			(+)
Local financial sector	(NC)	(NC)	NC	(NC)			(+)	
Energy/electricity price	(−)	(NC)	(NC)	(NC)	(−)	(+)	(−)	
International flows	(NC)	(NC)	(NC)	(NC)				
Environmental variable								
CO_2 emissions	(NC)	(NC)	−	(+)	+	(+)	(NC)	
Energy variables								
Energy/electricity consumption	(NC)	(NC)	NC			(−)		(NC)
Other sources weight in the mix	(NC)	(NC)	−			(−)	(NC)	(NC)
Energy security	(NC)		NC			(NC)	(NC)	(NC)
Fossil fuel production		(NC)	(NC)					(NC)
Regulatory variables								
RE support policies	(NC)	(NC)	+			(+)	(+)	(NC)
Kyoto Protocol	(NC)	(+)	(NC)					(+)
Political variables								
Institutional quality	(NC)	(NC)	(+)	(NC)		(+)		
Government ideology (left)	(NC)		(NC)			(+)	(NC)	
Demographic variable								
Population size	(NC)		(NC)	(NC)	(+)	(−)		

Table 16
Detailed results by types of sample of countries for the main independent variables (results in parentheses correspond to less than 5 papers).

Independent variables	Global	Developing	Developed (European)	Developed (global)
Economic variables				
Income	NC	+	−	NC
Fossil fuel prices	NC	NC	NC	NC
Local financial sector	NC	(NC)		
Energy/electricity price	(NC)	(−)	(NC)	(NC)
International flows	NC	(NC)		
Environmental variable				
CO_2 emissions	NC	NC	−	NC
Energy variables				
Energy/electricity consumption	NC	(NC)	(+)	NC
Other sources weight in the mix	−	(NC)	−	(NC)
Energy security	NC		−	(NC)
Fossil fuel production	(NC)	(NC)		(NC)
Regulatory variables				
RE support policies	NC	(+)	(+)	NC
Kyoto Protocol	(NC)	(+)	(NC)	(NC)
Political variables				
Institutional quality	(NC)	(NC)	(+)	
Government ideology (left)	(NC)		(+)	(NC)
Demographic variable				
Population size	(+)	(+)	(−)	

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