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Opening Pandora's box of twenty years of research on energy policies: On the rise of a 'technology-driven' debate

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ABSTRACT

Since the Kyoto Protocol, there has been increasing attention by scholars on energy issues, with this trend having strong implications for policy. The design and implementation of energy policies depend on the underlying scientific literature and adapt to new stimuli and research findings. Energy challenges today and in the coming years will require the adoption of policy efforts across a range of different fields and technologies. The purpose of this paper is to provide an investigation of energy policy studies based on more than 22 thousand research products published between 1997 and 2017. This synthesis aims to improve the mutual understanding of the policy debate on diverse and multifaceted energy issues to allow more efficient, concerted and rapid action. Results highlight how the debate on energy policies is becoming increasingly 'technology-driven', that is more sophisticated and technical in its approach and terminology.

1. Introduction

In the last twenty years, researchers' level of attention towards energy issues has been high and has grown, with this trend having strong implications for policy (Ryan et al., 2014). The design and implementation of energy policies increasingly depend on the underlying scientific literature and continuously adapt to new stimuli and research findings (Evans et al., 1979; Spreng, 2014). For example, the Swiss government to attain the goal of the promotion of rational use of energy has supported research on power electronics, more specifically the research on the effects on energy consumption of introducing LESIT technologies (Hilty and Aebischer, 2015). This literature is propaedeutic to public debates, is useful for discussing technical and operational aspects of single policy actions, and has turned to assessing their effects.

At the same time policy-makers addressing energy challenges have reached an unprecedented consensus on several crucial concerns and issued many bold regulations (to mention a few, the Kyoto Protocol on greenhouse gas emissions in 1997; the Chinese Renewable Energy Law in 2005 setting national targets for energy production; the United States' Energy Independence and Security Act in 2007 to increase national independence; the European Union's regulatory packages in 2008 and 2009 to reduce emissions, increase energy efficiency and open the gas and electricity markets; Australia's Clean Energy Act in 2011 defining emission trading schemes; and, lastly, the worldwide Climate agreement signed in Paris in 2016).

Looking at energy policies designed and implemented throughout the world, it is clear that energy challenges today and in the coming years will require the adoption of efforts across a range of different fields, approaches and technologies. Like the proverbial blind men describing the elephant, the broad vision needed to understand the energy policy debate will develop only when narrowly focused perspectives endeavour to see through the eyes of others (Long, 2008).

The paper aims to improve the mutual understanding of the policy debate on diverse and multifaceted energy issues to allow more efficient, concerted and rapid action, by identifying the basic structure and crystallizing the multiple and changing foci and approaches of research in energy policy. This helps to answer some relevant questions: What is the stage of the energy policy research life cycle? Which issues push the energy debate? Which institutions and scholars drive research in the field?

The literature on energy policy is vast and complex, and it is difficult to find the direction of research because of its interdisciplinary nature, the variety of approaches across the world, and the extraordinarily high number of different topics (which have diversified characterizations depending on the geographical area under consideration) falling under the umbrella of energy policy.

The wide spectrum of topics, approaches and issues has made any attempt to select criteria by which to systematize the existing literature discretionary. It is not a coincidence that the efforts of all researchers

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aimed at reviewing the literature on energy policy have de facto been geared towards single sectors and/or specific topics (Saidur et al., 2010; Solangi et al., 2011; Meyar-Naimi and Vaez-Zadeh, 2012; Tanaka, 2011) and to defined geographical areas (Byrne et al., 2007; Carley, 2011). No application can be found with the purpose of providing a large-scale overview of research in energy policies.

The proposed analysis is based on more than 22 thousand products published between 1997 and 2017. The field is undergoing an unprecedented stage of growth, with more than one thousand publications per year since 2006 and the involvement of more than 58 thousand researchers from 148 countries. The paper shows that the interest in energy policy is large and diversified. Despite the large number of keywords, a few topics emerge as central in the debate: renewable energy, in particular solar and bioenergy; energy efficiency; energy sustainability; and energy security. It is to notice how the debate on energy policies is becoming increasingly 'technology-driven', that is more sophisticated and technical in its approach and terminology. This is a point that asks for attention, since energy issues are increasingly affected by technological developments and the latter seem to run at a very high speed of improvement.

2. Method

Bibliometrics is the statistical analysis of publications. Whereas conventional quantitative analyses focus on the number and citations of articles, new methods display connections underlying evolving scientific knowledge (Ho, 2007). We use an index calculated starting from articles' citation counts: the h-index (Hirsch, 2005). The h-index is a criterion for evaluating the scientific output of a researcher based on both quantity (the number of published articles by a researcher) and quality (that is, their impact, in terms of number of citations of a researcher's product). Moreover, geo-localization tools help to reveal the geographic areas in which a large amount of research activities take place.

Network analysis is a widely used approach in social sciences that is useful for describing, exploring, and understanding structural and relational characteristics of different phenomena by means of graph theory. In this paper, network analysis helps from two different perspectives. Firstly, it allows us to identify connections between researchers' countries and visualize them. Secondly, network analysis emphasizes the evolving debate on energy policy linking research keywords on adopted approaches, investigated issues, and technologies.

3. Data

Scopus is the source for data collection. Scopus, with over 21,500 titles from more than 5000 international publishers, is the largest abstract and citation database of peer-reviewed literature. The keyword energy policy, together with all possible declinations and synonyms, served to filter and collect research products (articles, book reviews, editorial materials, letters, conference papers, notes, and reviews). The time interval starts with the year of the Kyoto Protocol. Even though today some neglect the importance of such agreement, it represents a fundamental step in energy policy, especially with respect to the control and reduction of greenhouse gas emissions. Over the period of January 1997 - January 2017, the observed dataset includes a total number of 22,487 products. Once retracted articles and duplications are removed, the total number of products equals 22,443.

4. Results and discussion

4.1. An overview

The total number of research products in energy policy grew substantially in the period of 1997–2017, with the highest level of publications (1999 outputs) in 2008 (Fig. 1). 'Article' is the document type with the highest number of products (13,822), accounting for 61.6% of the total number of publications, followed by 'conference paper' (6074 products, 27%) and 'review' (1640, 7.3%).

Out of the 22,443 scientific publications about energy policy, 377 publications (1.7% of the total number of publications, TP) are cited more than one hundred times, 883 outputs (3.9%) are cited between 50 and 99 times, and 1764 publications (7.9%) are cited between 25 and 49 times.

The total number of citations (TC) per year increased slowly in the first nine years and grew substantially during the period of 2007– 2010. A visible decline can be observed from 2011 to 2017. The average number of citations per publication (ACPP) was high between 1997 and 2009, with a peak in 2000 (23.9%), and has decreased since 2010. Publications had the highest value of total citations in 2008 (11.3%) but had the greatest number of total citations per year in 2011 (3921). From a temporal point of view it is interesting to note that such high levels in the number of citations, as well as the high number of contributions to the scientific debate on energy issues, can be associated with significant (energy-related) political facts at global level, such as the escalation of the Russia–Belarus energy dispute in 2007, the financial crisis and the release of the UNFCCC Bali Road Map in the same year, the largest natural gas supply crisis in the European Union, and the release of the Copenhagen Protocol in 2009 (Table 1).

The publications belong to twenty-five subject areas (scientific disciplines) according to the ASJC (All Science Journal Classification) codes provided by Scopus. As expected, the 'Energy' subject area is the discipline that contributes most to the development of energy policy research, with a total of 13,036 products (34.6%). 'Environmental Science' and 'Engineering' are also relevant, with 7587 (20.2%) and 6119 (16.3%) records, respectively. Although less relevant, other disciplines include, among others, 'Social science' (5.8%), 'Computer Science' (5.5%), 'Economy Econometrics and Finance' (2.9%), 'Business Management & Accounting' (2.5%), 'Chemical Engineering' (2.4%) and 'Earth & Planetary Sciences' (2.1%). It is not a surprise that 'Social science' plays only a marginal role, with a relatively small number of researchers engaged in the policy debate. This occurs despite the intimate interrelation of energy issues to the central sectors of socio-economic life. Social scientists should be encouraged to devote more efforts to the study of energy policy issues and to develop the basis for a mutual understanding with other scholars more involved in technical research areas (Lowe et al., 2013; Sovacool et al., 2015).

The total number of authors (TA) involved in energy policy studies is 58,777. As shown in Table 1, the average number of authors per product increased from 1.5 to 3.3 during the period of observation. To address current and prospective energy challenges, researchers have to mix information from different sources and backgrounds and implicitly recognize the need for more inter-disciplinary and skilled intellectual capital. Energy challenges, including changing mixes of energy, development of alternative energy sources, creation of smart grid technology, minimizing environmental impacts, using fossil fuel resources more efficiently, and so on, require engineers, social scientists, statisticians, and lawyers to address discipline-specific technical, environmental, social, business, and policy problems.

Since 2010, collaborations between researchers from different institutions have become a relevant phenomenon, particularly compared to collaborations between researchers from different countries, which have not emerged as expected. With regards to this latter aspect, the primacy over time of the number of products published by scientists affiliated with institutions from the same country is not disputable (Fig. 1).

The geographical distribution shows that there are 148 countries with research institutions involved in energy policy, a rather high number that represents more than three quarters of countries worldwide (Fig. 2). However, the top 10 countries are responsible for 64.1% of the total number of publications.

Six groups of countries emerge by clustering by the number of