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Expanding and shifting trends in carbon market research: a quantitative bibliometric study

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ABSTRACT

This paper examined the carbon market literature from 1992 to 2011 using bibliometric techniques based on the database of Science Citation Index (SCI) and Social Science Citation Index (SSCI). Of 5809 publications, 82% were journal articles. Our analysis documents that carbon market publications are expanding rapidly. Based on the contribution of countries and their h-index, the US has published most and been most influential in this area, followed by the UK, Canada, Germany and China. The Chinese Academy of Sciences (120), US Forestry Service (70) and University of Maryland (68) were the most productive research institutes. The most common subject category, Environment Sciences (1551), experienced an exponential increase with an average growth rate of about 50%, and the most productive journal was Energy Policy (469). According to the analysis of keywords, the hotspots related to carbon markets were "global warming" and "carbon tax" in the 1990's, but "climate change" and the "clean development mechanism" superceded them in the most recent decade. The most cited article published in Science in carbon market research is presented. This analysis is not only helpful for policymakers and others to understand trends in the field, but may also influence researchers' selection of future studies.
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1. Introduction

Climate change triggered by the enhanced greenhouse effect is causing global warming, more severe tropical storms, ocean acidification, melting of glaciers, snow pack, sea ice and sea level rise (IPCC, 2013), and it is one of the greatest threats to human survival and political stability. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) produced an international treaty focused on stabilizing GHG concentrations in the atmosphere at a level that would "prevent dangerous anthropogenic interference with the climate system". Since then, the 1997 Kyoto Protocol of the UNFCCC was signed by 192 parties with the goal of limiting GHG concentrations in the atmosphere. Since its implementation in 2005, governments have taken measures to mitigate global warming by reducing GHG emissions, thereby reducing damages from climate change (Zhang and Wei, 2010). Three flexibility mechanisms were established with the intention of diminishing the overall cost to achieve emission targets such as the Joint Implementation mechanism (JI), Clean Development mechanism (CDM) and Emissions Trading (ET). The JI aims at carbon emission reduction through the project-based cooperation between developed countries while the CDM enables industrialized countries to reach their individual goals through projects implemented in developing countries. It was designed to allow developed countries with emission caps to offset their carbon emissions by granting carbon removal projects in developing countries (Huisingh et al., 2014). Since 2000, the CDM has allowed crediting of project-based emission reductions in developing countries with over 4000 CDM projects submitted for validation by the end of 2008 and 4626 projects registered by 14 September 2012. There has been rapid growth on the development of CDM in terms of countries involved and scale of emission reductions (Costa-Júnior et al., 2013; Purohit, 2009; Wang and Chen, 2010; Zhao et al., 2013). Given the rising expectations for carbon emission reduction technology as one of the solutions to cope with climate change, an increasingly number of researchers are focusing on different aspects of reaching

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the carbon emission goal. For example, carbon capture and storage (CCS) (Chaudhry et al., 2013; Diamante et al., 2014) helps to prevent the release of large quantities of CO_2 into the atmosphere. In addition, the improvement of energy efficiency (Morrow III et al., 2014) can be achieved by adopting a more efficient technology or production processes; or by applying commonly accepted methods to reduce energy losses; or the substitution of fossil energy with renewable energy resources (Zhao et al., 2011; Zuo and Zhao, 2014; Purohit, 2009). Concern for energy security has also been a motivator for investing in climate change mitigation (Brown and Sovacool, 2011).

Meanwhile, carbon emission trading markets have rapidly developed around the world. For example, the European Commission created the European Union Emission Trading System (EU-ETS) in 2005. EU-ETS has become the largest mechanism for trading carbon emissions in the world (Mizrach, 2012). Although the US and has not ratified the Kyoto Protocol and Australia only became a signatory in 2007, regions and individual states in both countries are participating in emissions trading schemes. In the US, the Regional Greenhouse Gas Initiative (RGGI) was formed in 2003. Participating RGGI states have agreed to establish a cap on emissions of carbon dioxide from power plants, beginning with baseline levels in 2009, and then reduce emissions 10 percent by 2019. According to the National Academy of Sciences (2010), over 50 percent of Americans live in jurisdictions that have enacted a GHG emissions cap or target. In Australia, the New South Wales Greenhouse Gas Abatement Scheme is conducting at the state level and more recently, Australian state premiers have released early proposals for a national cap and trade system starting in 2010 (Anger, 2008). Corresponding to the rapid increasing recognition of carbon market, the associated literatures also spring up substantially (Duic et al., 2003; Lin and Sun, 2010; Zhang and Wei, 2010). Studies of the EU ETS are also increasing progressively (Alberola et al., 2009; Asselt and Biermann, 2007; Reilly and Paltsev, 2005; Skjærseth and Wettestad, 2010).

So far, the operating design mechanism has been regarded as a key feature of carbon markets and has attracted much attention, including the design of allowance allocation and pricing mechanisms (Cramton and Kerr, 2002; Springer, 2003; Zhao et al., 2010). Since the Kyoto Protocol entered into force, the carbon emission allowance has been turned into an international commodity accompanied by an increasing number of investment banks, hedge funds, private equity funds, securities companies, and other financial institutions (Oberndorfer, 2009; Simshauser et al., 2012).

The establishment of carbon emission trading markets is a low-cost marketization measure for reducing GHG emissions in developed countries. Another measure of emission reduction, the carbon tax is also a market-based instrument that depends fundamentally on the efficient working of the market system for its success. In the early 1990's, five European countries (Finland, the Netherlands, Norway, Sweden and Denmark) established carbon taxes, followed by UK which set up the Climate Change Levy in 2001. The Levy raised approximately $1.17 billion in revenues from 2007 to 2009, which were used to offset cuts in National Insurance Contributions. The choice of policy instruments concentrate on uncertainty over prices and quantities. Greater certainty of the economically efficient quantity of pollutant emissions required to internalize social damages favors a cap-and-trade program (Keohane, 2009). Alternatively, pollution taxes may be more desirable if the economically efficient level of the tax is known, or regulators are willing to experiment to explore the efficiency level, (Tietenberg, 2006). An extensive academic literature suggests that macroeconomic efficiency favors a carbon tax with socially productive revenue recycling (Brown et al., 2012; Dinan, 2008). Others have argued that policy choice is less important than the effective policy design (Aldy and Stavins, 2012). Therefore, the discussion and debate between alternative carbon policies is growing (Ekins and Barker, 2001; Ermolieva et al., 2010; He et al., 2012).

With the mitigation of GHGs, the carbon market is gradually maturing in terms of the expanding geographic scope of participating countries, the multi level market structure, and the increasing complexity of financing. This has undoubtedly contributed to the increasing literature on carbon markets, including the review articles (Mansanet-Bataller and Pardo, 2008; Newell et al., 2012; Zhang and Wei, 2010) but rarely quantitative research. Thus, it is time for us to evaluate the growing body of literature on carbon markets by utilizing bibliometric analytical techniques.

The purpose of this study is to quantitatively and qualitatively evaluate the global research literature related to carbon markets from 1992 to 2011. Using bibliometric methods, we can characterize the literature by publication type, subject categories, journals, institutions, countries, citation and content analysis using keywords. In addition, we are able to conduct a detailed analysis of author institution and cited frequency. This study is not only helpful for policymakers and others with interest in carbon market research to assess trends quickly, but may also influence researchers' future studies and publications.

2. Methods

To analyze the trends and characteristics of carbon market research, bibliometric, social network analysis and h-index are valuable. These are introduced below.

2.1. Bibliometric analysis

Bibliometrics, which is a multifaceted endeavor encompassing subareas such as structural, dynamic, evaluative and predictive scientometrics, is one of the rare and interdisciplinary research approaches to extend to almost all scientific fields (Glanzel, 2003). It adopts statistical and mathematical methods to research the distributed architecture, mathematical regularities, varying pattern and quantitative management of the information, and subsequently investigates the structure, characteristics and patterns of the underlying science and technology. As one of the most important methods in the researching of library and information science and a newly developing discipline, the bibliometric technique has become an indispensable instrument for measuring scientific progress (Van Raan, 2005). It is worth noting that bibliometrics is quantitative by nature, but is used to make pronouncements about qualitative features. In fact, this is the major feature of all sorts of bibliometric techniques to transform something intangible (scientific quality) into a manageable entity (Du et al., 2013). The research objects can be all kinds of literatures themselves and the characteristics they reveal include topics, authors, publication dates, reference literatures, content and so on.

2.2. Social network analysis

Social network, which stems from graph theory, is a regulation or a method of analyzing social relations, focusing on the structure of relationships, ranging from casual acquaintance to close bonds (Serrat, 2010). In other words, social network refers to the assemblage of social actors and the relationships between them. It can not only reflect the overall characteristics of the network structure, but also can indicate the correlations among individuals by using quantitative indices to describe interaction relationships among established objects. In this paper, social network analysis was utilized to research the cooperative relationships among 20 productive countries and institutions.

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