Energy Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Short Communication

Potential cooperation in renewable energy between China and the United States of America

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HIGHLIGHTS

- An indicator called “renewable energy cooperation index” is introduced.
- A model correlates GDP, CO_2 emission, energy price and the cooperation index.
- The cooperation can stimulate economy and reduce CO_2 emission.
- Combining US and Chinese resources will be mutually beneficial.

ARTICLE INFO

Article history:
Received 20 June 2014
Received in revised form
17 September 2014
Accepted 18 September 2014

Keywords:
Renewable Energy Cooperation
China
United States of America

ABSTRACT

China and the United States of America (US) are developing renewable energy concurrently. In this paper, we seek the opportunities for potential cooperation between these two countries based on the analysis of annual economic data. A mathematical model has been established to characterize correlations among GDP, carbon dioxide emissions, energy prices and the renewable energy cooperation index. Based on statistical analyses, such cooperation can promote economic development, reduce carbon dioxide emissions, improve the environment and realize green growth. If US monetary and technology resources and Chinese markets are combined, benefits can be mutually gained.

1. Introduction

In terms of annual energy consumption, coal utilization and carbon dioxide (CO_2) emissions, China and the United States of America (US) are currently in first and second places globally, respectively. To meet domestic energy needs, both countries heavily depend on imported oil, but with two different trajectories. For China, the amount of imported oil amounted to approximately 7% of all oil consumption in 1993, jumping to 40% in 2004 and to 60% in 2013. If this trend continues, the imported oil share may reach 66% in 2020. Recently, the Chinese government placed a cap of 61% by 2015. For the US, imported oil accounted for 49% in 1993, increasing to 65% in 2004 and decreasing to 40% in 2013 (BP, 2013; EIA). If both countries develop large-scale renewable energy profiles, reliance on imported oil can be reduced (Yao and Chang, 2014; Aslani and Wong, 2014). Furthermore, additional renewable energy production may slow the depletion of traditional energy reserves, reduce carbon dioxide (CO_2) emissions, and provide benefits to the environment. The countries should jointly develop strategic plans to enhance economic growth via renewable energy while achieving sustainability (Mezher et al., 2012). For China, the majority of its population is made of farmers who are familiar with the concept of renewable energies and are willing to consider efficient harvesting technologies (Ding et al., 2014). For the US, some of its renewable energy technologies may be readily exportable to Chinese markets (Zhu et al., 2011). With potential cooperation, China may solve some energy and environmental issues, and the US may recover its early R&D (research and development) investments in technologies (Wan and Craig, 2013; Christoffersen, 2010). In the past 10 years or so, different cooperation possibilities were explored, and a few consortia were formed (Wendt, 2008; Lieberthal and Sandalow, 2009; Lewis, 2014). Simultaneously, limited renewable energy policies were proposed, and their effectiveness was discussed (Buckman, 2011; Yin and Powers, 2010; Menz and Vachon, 2006). At present, both solar and wind technologies are currently being utilized for electrical power generation, and fuel

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http://dx.doi.org/10.1016/j.enpol.2014.09.016

cell technologies are being considered for automotive applications (Bosetti et al., 2012; Friebe et al., 2014; Barbir, 2005; Tuo, 2013a,b; Hwang, 2013).

Historically, economic growth is affected by the availability of traditional energies. In early studies, energy elements were introduced in the Cobb–Douglas production function. In addition to capital and labor factors, energy can be considered as a third factor of production. In production, the cost of energy is usually small, whereas its effect is large (Gastaldo and Ragot, 1996; Rasche and Tatom, 1997). If energy utilization becomes more efficient, economic growth may be extended to a longer time period (Norman, 1996). If energy consumption is reduced, an economy may not grow at its original pace. If traditional energies are exhausted, economic growth may not be sustained (Ayres et al., 2013). After four decades of research, technologies to efficiently harvest renewable energies, which are naturally replenished energy sources that can be regenerated, are available. In addition to solar and wind energy, biomass, hydroelectricity, geothermal and tidal energy are also considered renewable energy. Today, some renewable energy can replace traditional energy in electricity generation, hot water/space heating and motor fuel applications (Grimaud and Rouge, 2003). Depending on the locations of such energy resources, one type of technology may be more suitable for economic growth than others (Tuo, 2013a,b; Karlstrøm and Ryghaug, 2014). For economic development, one prefers a large renewable energy proportion in the overall energy profile because it should lead to more sustainable development and more benefits to the economy (Valente, 2005; Apergis and Payne, 2010).

Thus, in the context of cooperation between China and US, it is desirable to systematically study the relationship between renewable energy and economic growth. In 2012, the Chinese annual renewable energy consumption was 226.69 million tons of oil equivalent (MTOE), including 194.79 MTOE of hydroelectricity and 31.90 MTOE of other renewable energy. Currently, renewable energies contribute approximately 8.5% of overall energy consumption, and the goal is to reach 15% by 2020. To meet this goal, China is aggressively increasing the power generation capacities for different types of renewable energies (Liu and Goldstein, 2013). In the US, the annual renewable energy consumption was 113.92 MTOE, including 63.20 MTOE of hydroelectricity and 50.72 MTOE of other renewable energy in 2012. Currently, renewable energies contribute 9% of overall energy consumption, and the goal is to reach 12% in 2020. For the electrical power generation sector, renewable energy will exceed 10% of overall energy consumption in 2015 and 20% in 2020 (Lean and Smyth, 2013).

In this paper, a mathematical model is established to correlate GDP, CO_2 emissions, energy prices and the renewable energy cooperation index. In Section 2, the research methods are described, in which a measure for cooperation is proposed. In Section 3, the results are provided based on a vector auto-regression model and its analysis. In Section 4, discussions are provided. In Section 5, conclusions and policy implications are given.

2. Methods

Cooperation between China and US on renewable energies started around 2000 and expanded around 2014.[1] Currently, such cooperation is at governmental, non-governmental and/or academic levels and may lead to green growth in the world economy. To reduce CO_2 and other greenhouse gas emissions, both China and the US need to find solutions in the power generation, transportation, manufacturing and construction sectors (Guo et al., 2010). In addition, coal and other traditional energy supplies are limited and will be exhausted in the future, which further motivates both countries to seek solutions collaboratively (Gullberg et al., 2014). The costs of R&D are relatively high, and the Chinese renewable energy industry is still in its early stages, without an effective mechanism for the deployment of renewable energy (Yuan et al., 2014; Schuman and Lin, 2012). If the R&D results in the US can be transferred to China, where the manufacturing base is being built, it may be a win-win situation for both countries (Wan and Craig, 2013).

[1] The milestones are as follows: "The cooperation agreement of energy efficiency and renewable energy science and technology for China and the US" in 2000, the "Sino-US clean energy technology forum" in 2001, "The cooperation protocol of energy efficiency and renewable energy" in 2006, "The green partnership project framework under the ten-year cooperation of energy for China and the US and the large-scale consulting cooperation of renewable energy generation for China and the US" in 2008, "The understanding memorandum of strengthening

Table 1
Stationarity test results.

	ADF		PP		KPSS	
	Level	First difference	Level	First difference	Level	First difference
CO_2	1.968	−4.328***	0.560	−3.212**	0.6695**	0.131
GDP_c	0.636	−2.633*	0.253	−2.599*	0.673**	0.069
GDP_u	−2.126	−3.030**	−1.800	−3.030**	0.660**	0.322
$RNCI_c$	−0.821	−5.110***	−0.821	−5.140***	0.341*	0.293
$RNCI_u$	−2.483	−4.488***	−2.415	−4.482***	0.245	0.188
EPRICE	−0.651	−7.173***	−0.454	−7.202***	0.480**	0.281

RNCIU analyzed by KPSS being always stable.
*** Denotes statistical significance at the 1% levels.
** Denotes statistical significance at the 5% levels.
* Denotes statistical significance at the 10% levels.

Table 2
Lag orders of the VAR model.

Lag	Log *L*	AIC	SC
0	231.5572	−18.12457	−17.88080
1	291.5794	−21.95478[a]	−19.46370[a]
2	325.3011	−21.02036	−18.94256

[a] Lag order selected by the criterion.

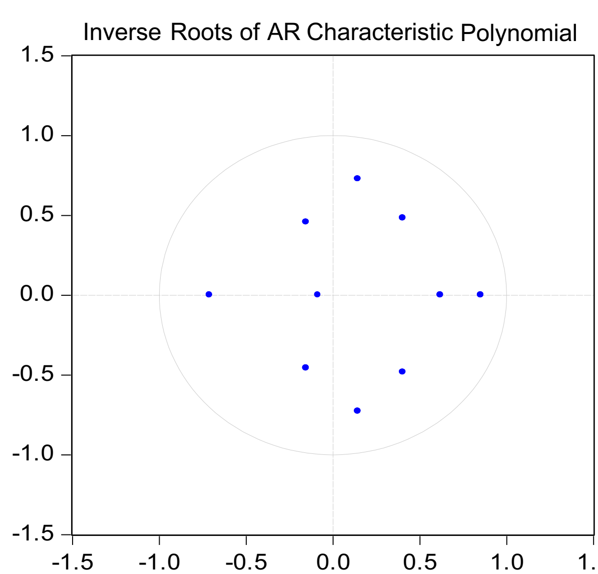

Fig. 1. Inverse roots of AR characteristic polynomial.