POSSIBLE ENTANGLEMENT BETWEEN WIND AND PHOTOVOLTAIC WITHIN UNCERTAIN TECHNOLOGY ECOLOGICAL SYSTEM

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Overview

Global energy consumption has skyrocketed with the rapid development of the world economy over the last several decades. The International Energy Agency (IEA) has forecasted that global energy demand will surge from 12 billion tonnes of oil equivalent in 2010 to 17.7 billion tonnes in 2030, with an average growth rate of 2.4% per year for the next 20 years. Under the increasing pressure of an energy shortage and the threat of climate change, the search for low-carbon alternatives is a common goal among countries worldwide, which will undoubtedly provide a wonderful opportunity for the development of new technologies.

Wind power and solar power, the dominant alternatives to fossil fuels, are plentiful, renewable and widely distributed, and their unit cost has largely decreased with their cumulative installed capacity growing to a substantial level. Our first intention in this paper is to describe the competitive dynamics in a niche market dominated by two competitors and to explore the potential relationship between wind and PV solar technologies within uncertain technology ecological system. Just as the battle for food and space never ends for different biological species sharing the same ecosystem, the "crowd out" effect also exists for wind and PV solar technologies regarding the allocation of funds, land utilisation, etc. Since the end product of both wind and solar technology is electricity, product homogeneity may be another issue that creates competition between these two technologies in the niche market. Predator–prey, mutualism, and competi- tion are three of the most common relationships between biological species; it will be interesting to explore whether these types of relationship can also be explored in the renewable energy market. Our second task is to determine the impact of different energy technology development modes on the diffusion of renewable technologies. Centralised mode and distributed mode are the most popular ways of developing wind and solar energy. In fact, wind is widely used in a centralised way, such as large-scale wind power plants, while PV solar may be mainly exploited in distributed mode, especially in remote areas. Hence, we seek to explore how the different development patterns may affect the penetration of wind and PV solar technologies.

Methods

In this paper, we attempt to examine the relationships between the two most promising renewable alternatives, wind and PV solar technology, by employing the revised Lotka–Volterra model (1). Here, x_1 and x_2 represent the cumulative installed capacity of wind power and PV solar energy, respectively, at time t. dx_i/dt denote the growth rate of technology i, i.e. newly added installed capacities. Therefore, the degree of energy technology diffusion is represented by the size of the cumulative installed capacity. The self-interaction parameter a_{ij} captures the inhibitive growth level of some specific technology (i.e., wind or PV solar) as well as the effect of scale-dependence on their technical penetration; $B_i(t)$ are standard Brownian motion processes.

$$\begin{cases} dx_1(t) = x_1(t)[(r_1 - a_{11}x_1(t) + a_{12}x_2(t))dt + \sigma_1 dB_1(t)], \\ dx_2(t) = x_2(t)[(r_2 + a_{21}x_1(t) - a_{22}x_2(t))dt + \sigma_2 dB_2(t)], \end{cases} \tag{1}$$

Results

Through empirical analysis, we found significant entanglement relationships across various countries, the represnetaive results for China and the US are summarized in the following figure (Fig. 1).

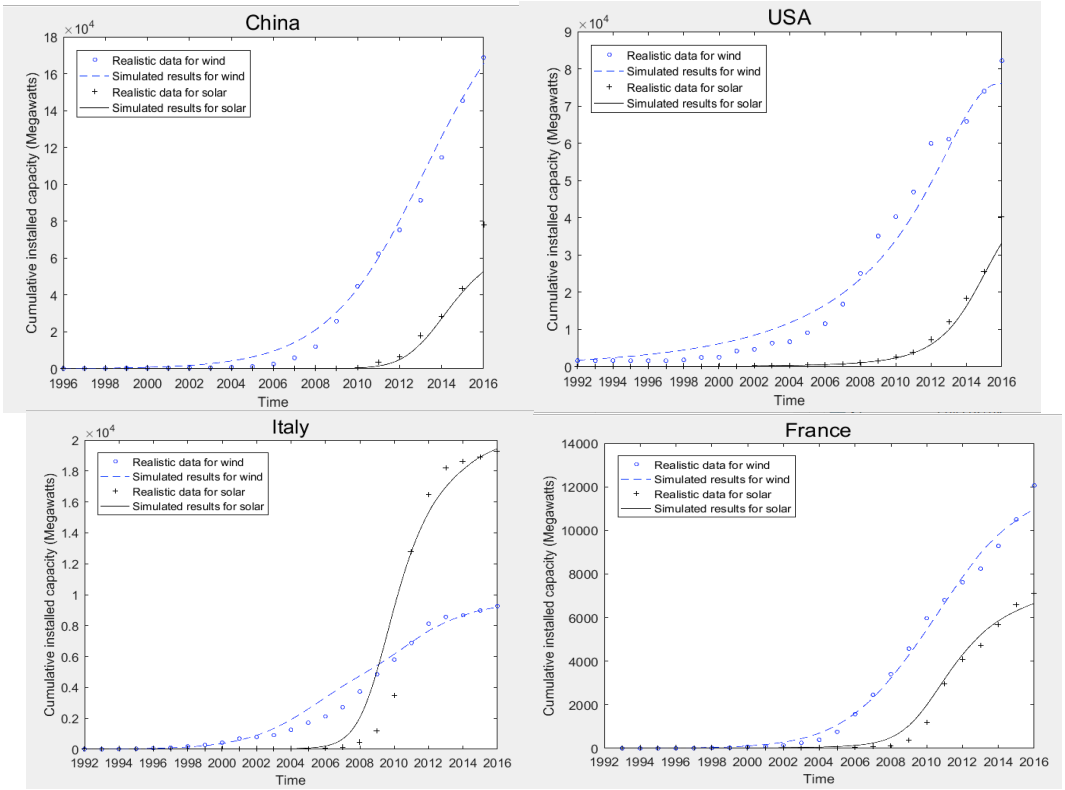

Fig.1 Potential relationships between wind and PV solar across countries

Conclusions

Through simulations, we observed that our model fits the historical data well, and the uncertainty in prediction for nearly all of the targeted countries is acceptable, which in turn enhances the reliability of our results. Moreover, the diffusion of both wind and PV solar energy moves along an S-shaped curve, which conforms to the general rule for innovation diffusion. The other main findings are drawn in the following:

(1) Diffusion of wind technology has experienced a rapid growth phase on a global scale, and a scale-dependent effect exists widely in the wind market across countries. Exploiting the renewable energy demand market will be an effective way to overcome the scale-dependent effect.

(2) Tthe scale-dependent phenomenon is not prevalent in the PV solar market across countries.

(3) Competitive relationships between wind and PV solar diffusion are dominated by types of mutualism and predator–prey.

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