Available online at www.sciencedirect.com
ScienceDirect
International Journal of Forecasting 27 (2011) 592–601
international journal of forecasting
www.elsevier.com/locate/ijforecast

Forecasting accuracy of wind power technology diffusion models across countries

Alessandra Dalla Valle, Claudia Furlan*

Department of Statistical Sciences, University of Padua, Padua, Italy

Abstract

Wind power technology is analyzed in terms of diffusion, with incentive effects introduced as exogenous dynamics in the Generalized Bass Model (GBM) framework. Estimates and short-term forecasts of the life-cycles of wind power are provided for the US and Europe, as they have similar geographic areas, as well as for some leading European countries. GBMs have the best performance in model selection, and are ranked first in terms of forecast accuracy over a set of different accuracy measures and forecasting horizons, relative to the Standard Bass, Logistic, and Gompertz models.

Keywords: Diffusion models; Bass; Logistic; Gompertz; Wind power; Forecasting accuracy; Incentives

1. Introduction

An enhanced sensitivity to both environmental problems, such as global warming and air pollution, and energy problems, such as oil depletion, has spread worldwide. The era of fossil fuels is closing and the new prospects are not encouraging. The major oil-exporting countries are near their peak oil production (see Guseo & Dalla Valle, 2005, and Guseo, Dalla Valle, & Guidolin, 2007), and it is well-known that, in spite of the increasingly sophisticated technological approaches to oil mining, the quantity of oil being extracted is lower than either expectations or demand. In light of this, new sources of energy that are both clean and cost-effective are required in the interests of preserving the environment.

In this paper we study the technological diffusion of wind power, which is considered to be an innovation, since it possesses the five attributes that Rogers (1962) uses to define an innovation: relative advantage, compatibility, complexity, trialability and observability. The decision process involved with investing in a wind power system is quite complex. Its adoption implies large markups and a long-term profit horizon, and it takes time to become familiar with the complicated administrative procedure, legislative constraints, architectural and environmental barriers, and technical opinions. Nevertheless, wind power

* Corresponding author. Tel.: +39 049 827 4129; fax: +39 049 827 4170.
E-mail address: furlan@stat.unipd.it (C. Furlan).

0169-2070/$ - see front matter
doi:10.1016/j.ijforecast.2010.05.018

technology provides a distinct advantage in generating clean energy and is completely compatible with the existing electricity grid. Although the technological adaptation required for this form of power system does not allow limited time period or smaller-scale trials, observation of the development of new plants is useful in the decision-making process. For further details on the attributes of innovation for cleaner technology, in particular for a photovoltaic system, see Jager (2005).

Despite a growing level of public interest in environmental protection, very little research has been done on clean technology, as a subcategory of technology, and only minor attention has been paid to quantitative analyses and forecasts. Through their review, Kemp and Volpi (2008) hope to stimulate, in general, wider research in the area of clean technologies. Until now, to the best of our knowledge, only a few attempts have been made to model the process of adopting wind power: Diaz-Rainey (2005), with a diffusion pattern based on logistic and log-logistic models; Söderholm and Klaassen (2007), with a simultaneous innovation-diffusion econometric model, based on a learning curve, applied to some European countries; and Usha Rao and Kishore (2009), with a Bass model for selected states in India. Incentive schemes have been explicitly included in the model by Söderholm and Klaassen (2007), while Usha Rao and Kishore (2009) evaluate the correlation between the diffusion growth and a composite policy index ex post.

In technological diffusion, it is well known that the timing of adoption is affected not only by endogenous mechanisms, but also by exogenous dynamics. However, to date, only a few efforts have been made to unify endogenous and exogenous mechanisms, especially for clean technology (Montalvo & Kemp, 2008), for which the main factor that exogenously affects the rate of adoption is represented by incentive schemes. The Generalized Bass Model (GBM) seems to be particularly suitable for evaluating both endogenous and exogenous mechanisms, as it allows for the inclusion of the innovative and imitative behavior of the adopters of a particular technology, as well as the assessment of the strength of the incentive policies passed by the local governments of a given country.

In this work, we attempt to fill in the gaps with regard to wind power technology by (a) modelling the endogenous dynamics in the framework of the GBM to overtake the models proposed by Diaz-Rainey (2005) and Söderholm and Klaassen (2007); while simultaneously (b) measuring the exogenous mechanisms by including local incentive schemes in the model, extending the model of Usha Rao and Kishore (2009), (c) in a cross-country analysis. Moreover, (d) the proposed GBMs are compared with the common models used in diffusion studies (Bass, Logistic, and Gompertz) through both the BIC and $\bar{R}^2$ adjusted, and in terms of the forecasting accuracy (1 and 3 years ahead) using a set of accuracy measures. Finally, (e) short-term forecasts based on the most reliable models are provided.

The remainder of the paper is structured as follows. Section 2 discusses the GBM in relation to wind power systems, while Section 3 exhibits the data and modeling results of the leading countries with regard to geographic extension. Section 4 provides the forecasting accuracy results of the GBM, relative to the Bass, Logistic, and Gompertz models. Short-term forecasts of GBMs for each region/country follow in Section 5, and our conclusions are given in Section 6.

2. The model

In the field of innovation studies, technological diffusion has a long history, starting in the 1960s with the works of Fourt and Woodlock (1960) and Rogers (1962). In their review, Meade and Islam (2006) highlight the wealth of research on modelling and forecasting the diffusion of innovations and propose several alternative models, including the Bass Model (BM), which was first presented by Bass (1969). The BM (and its generalization) is the only model among the S-shaped curves (e.g., the Logistic and Gompertz models) that includes the innovative and imitative behaviour of adopters introduced by Rogers (1962). Typically, the diffusion of a technology is very slow initially, since adopting it means taking a risk in a situation of uncertainty. Only a few brave adopters are disposed to take these risks, while "*the great majority adopts a wait-and-see approach*" (Kemp & Volpi, 2008). Here, wind power satisfies the assumptions required for the BM to be applied. In particular, the members of the social system adopting this innovation are the individuals who decide to support the companies involved in wind