Forecasting number of ISO 14001 certifications of selected countries: Application of Even GM (1, 1), DGM and NDGM models

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ABSTRACT

The adaptability of ISO 14001 is considered as one of the most useful tools for environmental sustainability and worldwide competitive advantage, however, the future of ISO 14001 certification faces some uncertainties because of its uneven acceptance in various countries. These uncertainties, if not properly managed, can hinder the implementation of business management systems in these countries. In order to guide policymakers in better management of ISO 14001 in future with certainty, this study aims to forecast the ISO 14001 certifications for ten years for China, India, USA, Italy, Japan and Germany, the top six certified countries, through advanced mathematical modeling, namely grey models, Even GM (1, 1), Discrete GM (1,1), and non-homogenous discrete grey model (NDGM). The benefits of mentioned models are ensured accuracy in assessment using small samples and poor information. Moreover, current research is a pioneer in the certifications growth analysis using the Synthetic Relative Growth Rate and Synthetic Doubling Time models. Finally, the empirical analysis indicated that China is constantly leading in terms of its ISO 14001 certifications till 2026 and the performance of developing

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countries was spectacular. Furthermore, the article has proposed some suggestions for the policymakers to make the environment more sustainable.

Keywords: ISO 14001; forecasting; Environmental Sustainability; Competitive advantage; doubling time; relative growth rate

1. Introduction

Since 1996 the ISO 14000 series certified organizations have continuously demonstrated the great reorganization and wide popularity of the certification due to the growing concerns about climate change. In 2015 the Conference of Parties (COP) of the United Nations Framework Convention for Climate Change (UNFCCC) agreed to limit the increase in the global temperature to 2 °C above pre-industrial levels by 2020 (United Nations Framework Convention on Climate Change 2016). After that, Intergovernmental Panel on Climate Change (IPCC) emphasized that limiting global warming to 1.5 °C will be a challenging task in the years ahead (Science Insight 2019). Hence, the future forecasting by using the most accurate and well-accepted methodologies can guide the specific measurement criteria at the micro and macro level. As we know, since the pre-industrial era, a gradual increase in emission of greenhouse gases (GHG) has exceedingly affected the human and natural system due to economic and population growth, and it is now higher than ever (IPCC 2014). Continued increase of industrial pollution in the environment causes further global warming and long-lasting effects on all components of the ecosystem. Many models and techniques have been developed to mitigate the emissions and pollutants yet. Environmental Management System (EMS) ISO 14001 is one of them and was published in the mid-1900s by International Organization for Standardization (ISO). Environmental sustainability is a big challenge for companies nowadays because International Energy Outlook (IEA 2015) reports that

CO_2 emissions due to combustion of fossil fuels are worsening, and this is directly associated with the climate change context. The report predicts that worldwide energy-induced CO_2 emissions will increase by 35.6 billion metric tons in 2020, increasing further by 7.6% in 2040 to reach a value of 43.2 billion metric tons.

Several studies have been conducted to understand the importance of ISO 14001 and its contribution towards environmental performance (Campos et al. 2015; Neves et al. 2017). ISO 14001 introduces companies to their environmental stewardship to draw broad interest toward their customers worldwide (Darnall and Carmin 2005). From improved efficiencies, it offers cost-effective benefits to companies, and from a social perspective, ISO 14001 is a roadmap to increase the quality of life by reducing the environmental and regional risks such as health problems, food insecurity, heat waves, and floods. The implementation of ISO 14001 provides some external and internal benefits to organizations, as it externally increases customer confidence, improves public image and community relationship, provides internal improvement in business processes, reduces liability and incidents, cost saving and enhances efficiency (Strachan et al. 2003). Numerous studies have been widely conducted on ISO 14001 in different sectors in the last decades (Vastag et al. 2004; Zeng et al. 2005; Prakash and Potoski 2006; Uchida and Ferraro 2007; Gavronski et al. 2008; Cañón-de-Francia and Garcés-Ayerbe 2009; Wahba 2010; Qi et al. 2011; Mohee et al. 2012; Khan 2013; Singh et al. 2014; Ismail et al. 2014; Daddi et al. 2015; Jabbour 2015; Ferrón-Vílchez 2016; Hojnik and Ruzzier 2017; Salim et al. 2018; Graafland 2018). Also, in the literature (Llach et al. 2011, 2015; Sampaio et al. 2011; To and Lee 2014) one finds ISO 9001 forecasting model in association with a statistical technique such as regression analysis for the prediction of the future of Quality Management System between the period 2007 to 2010.

The implementation of EMS mitigates the weaknesses of traditional regulations and provides a suitable alternative for companies to gain sustainability, reduction in high cost and improvement in the corporate image (McGuire 2014). Similarly, Arimura, Darnall, Ganguli, and Katayama (2016) also illustrated that the adaptability of EMS leads to minimization of companies' CO_2 emission level and causes a reduction in the overall pollution. There is a direct relationship between a company's competitive position and ISO 14001 implementation, as noted by Giménez Leal et al. 2003. For more clarification, the relationship and differences between ISO 14000 and 14001 standards ought to be addressed. In fact, ISO 14000 is a global standard that supplies a framework for all firms that want to enhance their environmental management efforts. The ISO 14000 standard consists of several standards while ISO 14001 is one of the most important among them. It should be noted that ISO 14001 determines the necessities of an EMS for all size of organizations. Also, the ISO 14001 standard encourages the Plan-Check-Do-Review-Improve cycle. The objective of the current study is the empirical prediction of ISO 14001 certifications for the year 2017-2026 for the six selected countries China, Japan, India, Germany, Italy, and the USA, based on the data available at ISO (2018) from 2005-2016 while executing advanced mathematical modeling, namely grey forecasting models i.e., Even Grey Model GM (1,1), Discrete GM (1,1) and non-homogenous discrete grey model (NDGM). Synthetic Relative Growth Rate (RGR) and Synthetic Doubling Time (D_t), as proposed by Javed and Liu (2018), were used to analyze the certification growth and comparison among these countries. The grey forecasting models, especially the GM (1, 1) models, can be superior to other forecasting models in the context of small samples and poor information (Zhou and He 2013). Hence, current research has utilized grey models for forecasting. The study would increase the understanding of possible expected ISO 14001 performance in China, Japan, India, the USA, Italy, and Germany in the upcoming years.

Finally, the study investigated the future trends in the ISO 14001 performance so that policy makers can make decisions using the future expected outcomes. The study provides valuable information for decision makers in a holistic way.

This paper is organized as follows: Section 1 is the introduction; Section 2 presents the background/literature review of Environmental Management System (EMS) ISO 14001 and the current scenario in developed and developing countries; Section 3 describes the method we used to forecast ISO 14001 in the given scenario; Section 4 presents the results. Finally, section 5 concludes the study, with limitations and future research direction.

2. Literature Review

In 1987, a report was published by Commission on the Environment and Development of the United Nations with future agenda, in which the definition of sustainable development is to meet the present and future generations' needs without compromising their abilities (WCED 1987). This report inaugurated new routes for a decision support system by effective environmental management. ISO and International Electrotechnical Commission (IEC) became partners in development and environmental standard (ISO 2012a) in Rio de Janeiro when the United Nations hosted the earth summit in 1992. A technical committee was formed by ISO and IEC to inspect the development of environmental management system a few months after their partnership. In 1996 Environment Management System was launched by ISO and has been updated twice, in 2004 and 2015. According to (ISO 2012b) the ISO 14001:2015 has the following properties: (a) setting and systematically achieving environmental goals and objectives and illustrating the goals and objectives achieved; (b) internal and external scanning for identification of relevant environmental aspects to control the companies activities, products, and services influenced by environmental impact; (c). ISO 14001 is a tool used by companies to continuously observe environmental performance. ISO 14001 is a general environmental standard for all types of organizations, the main objective of the standard is to construct a framework for organizations to set up their goals, policies, and actions. The adoption ratio of EMS certification varies from country to country. Prakash and Potoski (2006) analyzed the actual data of 108 countries and investigated whether adoption rate was higher in those countries where trading partners adopted this innovative and friendly environmental mechanism for consumer attraction. The lack of EMS diffusion studies and a logistic curve were used to analyze the diffusion of ISO 14001 certification with a dataset of 13 countries from 1995 to 2005. Casadesús et al. (2008) reported in their study that in 2005 ISO 14001 certification saturation level was 64.6%, with a maximum number of certification it would be 160000. Casadesús et al. (2008) also argued that the saturation would move to 95% in 2008 in most of the 13 selected countries, but later, unfortunately, the situation was different at the global and country level. Qi et al. (2011) reported in their study diffusion of ISO 14001 effected positively in China because of community stakeholder and foreign customer demand. Likewise, Marimon et al. (2011) investigated the diffusion of ISO 14001 and argued that diffusion among sectors on global and specific country level tend to be undiversified. Furthermore, the diffusion of EMS was analyzed by using logistic curve function technique and by the end of 2010 a 51% increase in certification and tendency toward saturation at 379900 worldwide were illustrated. They also argued that there would be a 50000 increase in ISO 14001 certification in 2011 and 2012, and 45800 from the start of 2013 to the end of 2015. The Far East followed by Europe, and Africa/West Asia will be the most prominent in some new ISO 14001 certifications. Castka and Prajogo (2013) have studied the relationship between the pressure of secondary stakeholders and ISO 14001. In order to investigate the issue, they have chosen 328 companies from Australia and New Zealand. Based on the results, ISO 14001 is an acceptable certificate from secondary stakeholders, yet pressure from secondary stakeholders has not affected internalization of ISO 14001 significantly. Testa et al. (2014) believed that the impact of ISO 14001 and the EMAS should be addressed to enhance environmental performance. Hence, they have investigated the effect of two mentioned standards on 229 energy plants in Italy. They found that ISO 14001 and EMAS have a significant effect on environmental performance. Nguyen and Hens (2015) have investigated the influence of ISO 14001 in Vietnam's cement plants. In their research, they have tried to use a questionnaire for comparing certified and non-certified cement companies. Their results illustrated that ISO 14001 is a potential tool in order to promote environmental performance in developing nations with increasing growth ratio. Boiral et al. (2018) have reviewed the papers that have been published between 1996 and 2015. They illustrated that most researches have presented optimistic results and the influence of ISO 14001 on environmental performance is shown. Their results have provided a suitable framework for managers in order to make a desirable decision. Ozusaglam et al. (2018) believed that EMS is the most important tool for management to reduce the impact of a firm's activities on the environment. Based on the results, implementation of EMS can lead to win-win opportunities for companies and early adopters can achieve European market. Iatridis and Kesidou (2018) have investigated the role of internal motivation and external pressure on the implementation of ISO 14001. They believe that internal motivation plays a vital role in the implementation of ISO 14001 and external pressures have an effect on internalization of ISO 14001, but their relationship may not be the linear type.

2.1 Current Scenario of ISO 14001

In the recent decade the popularity of ISO 14001 standard has been increased worldwide (Prajogo et al. 2014), but still with a comparison of developing and developed countries we can see the uneven adoption of ISO 14001 (Neumayer and Perkins 2004). According to ISO (2018), in Asia, the number of certifications increased from 5234 to 173324 during 2000-2015, meanwhile European countries have moved from 7235 certifications in 2000 to 119754 in 2015. Although in the USA the growth of ISO 14001 certifications is not like other developed countries, every year many American organizations apply for ISO 14001 certification to adopt green processes (Lee et al. 2017). In the current scenario, the significance of EMS has increased to justify the fact that the environmental performance of organizations has improved by controlling their production processes and services on the environment (Rino and Salvador 2017). Despite that, the growth of ISO 14001 certification in Asia is increasing such as China, India, Japan, and South Korea. Neumayer and Perkins (2004) suggested that the low adoption of ISO 14001standard in developed and developing countries will result in the exclusion of uncertified companies, which in return could serve those countries where companies are not ISO 14001 certified. Morrow and Rondinelli (2002) reported that EMS and other international standard registration is gradually increasing by organizations around the world. This scenario may impose pressure on companies to adopt ISO 14001 certification for environmental sustainable development (Prajogo et al. 2012). Likewise the rising trend of ISO 14001 adoption gives a competitive advantage to the organizations in the international market (Yu and Choi 2016). In developed regions like the USA and Europe adoption of ISO 14001 (Morrow and Rondinelli 2002) is an indicator of environmental sustainability and a tool for competitive advantage.

3. Methodology

In this section, the models used have been discussed, along with the data collection methods.

3.1. Data collection and analyses

In the current study, environmental sustainability indicates ISO 14001 certification. First of all, top ISO 14001 accreditated countries globally were selected. They were China, Japan, Italy, Germany, India, and the USA. The data used in this paper is from 2005 to 2016, collected from the International Organization for Standardization (ISO)'s official website (ISO, 2018). Nanjing University of Aeronautics and Astronautics (NUAA)'s Grey System software (v8.0) was used to forecast ISO 14001 certifications output, from the period 2017-2026 by Even Grey model GM(1, 1), Discrete Grey Model GM (1, 1) and Nonhomogeneous Discrete Grey Model (NDGM). However, NDGM (1, 1) was solved with the help of MATLAB and MS Excel. This data analysis and modeling methodology have been previously successfully executed by Javed and Liu (2018).

3.2. Grey Forecasting Models

3.2.1. Even Grey Model GM (1, 1)

The concept of a grey system for the first time was proposed by Deng Julong in 1982 as a scientific theory for forecasting uncertain system involving small and poor data (Zhao and Guo 2016; Javed and Liu 2018; Javed et al. 2018). In many cases, grey system theory based predictions have outperformed the predictions made through statistics (Javed and Liu 2018; Javed et al. 2018). There are different types of grey models in order to forecast data, some of which current research will examine. Fractional order accumulation is a new model of the grey system that can emphasize recent data instead of considering old and new data with the same weight (Wu et al. 2013). GM (1, 1) is a basic and key component of grey system theory that is used for a prediction using limited data, or small sample size. The applications of grey system forecasting model GM (1,1) have been used in numerous studies such as rural household net income (Zhao et al. 2012), wind speed (El-Fouly et al. 2006), industrial output (Wang and Hsu 2008), electricity demand in China (Zhou et al. 2006) and research publications' analysis (Javed and Liu 2018). GM (1, 1) presents one variable with first order grey model to obtain forecasting information with the original sequence of data. There are four basic kinds of GM(1, 1), Even Grey model is one of the most reliable models with non-exponential increasing sequence proved by (Liu et al. 2017), as follows in equation 1:

$$\hat{x}^{(0)}(k) = \left(1-\mathrm{e}^{a}\right)\left(k^{(0)}(1)-\frac{b}{a}\right)\mathrm{e}^{-a(N-1)}, \quad K=1,2,\ldots n \tag{1}$$

$x^{(0)}$ represents the original sequence of actual data in the above equation, further parameters *–a* represent *development index* and reflect the trend of $\hat{x}^{(0)}$ and $\hat{x}^{(1)}$ while *b* is called *grey actuating quantity*. These are the contacts of an Even GM (1,1) model. As literature reveals, the predictions are most suitable in data sequence for the first two data values after the last origin value.

$$\hat{x}^{(1)}(k) = \left(x^{(0)}(1)-\frac{b}{a}\right)\mathrm{e}^{-a(k-1)}+\frac{b}{a}, \quad k=1,2,\ldots n \tag{2}$$

3.2.2. Discrete Grey Model GM (1, 1)

Even though results obtained from EGM are reliable and satisfactory, more improved outcomes are needed, thus we used DGM. The accuracy of GM (1,1) is an important issue; many scholars pay attention to solving this issue to obtain more accurate results and remove errors. Xie and Liu (2009) proposed a study in which they investigated the relationship between Even GM and DGM with the help of McLaurin formula. They proved that the accuracy level of DGM and its optimization model is better than GM (1, 1). In our case, the MAPE (%) of DGM turned out to be significantly better than Even GM (1, 1), as indicated in table 7 of the current paper. If $\mathrm{x}^{(0)}$ represents the actual data sequence and $\mathrm{x}^{(1)}$ indicates the general accumulated sequences then the discrete grey model is followed by (Liu et al. 2017):

$$\hat{x}^{(1)}(N) = [x^{(0)}(1) - \frac{\beta 2}{1-\beta 1}]\beta 1^{N} + \frac{\beta 2}{1-\beta 1} \tag{3}$$

3.2.3. Nonhomogeneous Discrete Grey Model (NDGM)

The mechanism of NDGM is followed by the law of approximation non-homogenous exponential growth (Wu et al. 2014) based on the assumption of a sequence of actual/original data. Xie, Liu, Yang, and Yuan (2013) suggested that the original data sequence is an agreement with a homogenous trend like GM (1, 1). They also indicated that NDGM model accuracy level is much better than DGM (1, 1) and GM (1, 1) in terms of mean sequence value and value set of the interval (Xie and Liu 2015). In our case, table 7 indicated the overall accuracy level of NDGM is 95.47% among the six countries that was higher than DGM and EGM. NDGM model has been applied in different fields such as Pirthee (2017) that predicted tourism in Mauritius and investigated whether NDGM forecasting accuracy level is better than another grey model. Meanwhile, Duan, Xiao and Pei (2017) forecasted the traffic flow in China and illustrated NDGM showed better performance than other grey forecasting models.

If the same sequence follows the non-homogenous discrete grey model $x^{(0)}$ and $x^{(1)}$ as above in GM (1, 1), DGM (1, 1) in equations 1, 2 and 3, then:

$$\hat{x}^{(1)}(N+1) = \beta_1 \hat{x}^{(1)}(N) + \beta_2 . N + \beta_3 \tag{4}$$

$$\hat{x}^{(1)}(1) = x^{(1)}(1) + \beta_4 \tag{5}$$

$\hat{x}^{(1)}$(N) is the simulated value of $x^{(1)}$ with four parameters $\beta 1, \beta 2, \beta 3$ and $\beta 4$. We can rewrite the equation in matrix form if N=1, 2, 3….n-1

$$\begin{bmatrix} x^{(1)}(2) \\ x^{(1)}(3) \\ \vdots \\ x^{(1)}(n) \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} \begin{bmatrix} x^{(1)}(1) & 1 & 1 \\ x^{(1)}(2) & 2 & 1 \\ \vdots & \vdots & \vdots \\ x^{(1)}(n-1) & N-1 & 1 \end{bmatrix}$$

For input data, the following matrix equation satisfies parameters β1, β2, β3, and β4, which are the constants with a fixed value in each case, by applying the following relation in equation 6:

$$\hat{\beta} = (B^{\mathrm{T}}B)^{-1}B^{\mathrm{T}}Y = [\beta_1, \beta_2, \beta_3]^{\mathrm{T}} \tag{6}$$

Where

$$B = \begin{bmatrix} x^{(1)}(1) & 1 & 1 \\ x^{(1)}(2) & 2 & 1 \\ \vdots & \vdots & \vdots \\ x^{(1)}(n-1) & N-1 & 1 \end{bmatrix},\ Y = \begin{bmatrix} x^{(1)}(2) \\ x^{(1)}(3) \\ \vdots \\ x^{(1)}(n) \end{bmatrix},$$

By using the following formula to calculate β4 for minimizing the sum of square error:

$$\beta_4 = \frac{\sum_{N=1}^{n-1}\left[x^{(1)}(N+1) - \beta_1^N x^{(1)}(1) - \beta_2 \sum_{j=1}^{N} j\beta_1^{N-j} - \frac{1-\beta_1^N}{1-\beta_1}.\beta_3 \right].\beta_1^N}{1 - \sum_{N=1}^{n-1}\left(\beta_1^N\right)^2} \tag{7}$$

$$\hat{x}^{(1)}(N+1) = \beta_1^N \hat{x}^{(1)}(1) + \beta_2 \sum_{j=1}^{N} j\beta_1^{N-j} + \frac{1-\beta_1^N}{1-\beta_1} \cdot \beta_3; \quad N = 1, 2, \ldots, n-1 \tag{8}$$

Liu and Forrest (2010) can be referred for further information about NDGM, its properties, and its parameters. This model can easily be executed on *Matlab* software.

3.2.4. Approach for comparative analysis of the performance of the models

Mean Absolute Percentage Error (MAPE) highlights the performance criteria for comparative analysis between the three grey models.

$$\text{MAPE}(\%) = \frac{1}{n}\sum_{N=1}^{n}\left|\frac{x^{(0)}(N) - \hat{x}^{(0)}(N)}{x^{(0)}(N)}\right| \times 100\% \tag{9}$$

Here $x^{(0)}(k), \hat{x}^{(0)}(k)$ represent forecasting data values (Javed and Liu 2018).

3.3. Certification Growth and Doubling time Analysis

To the best of our knowledge, there is no certificate growth analysis model available. Therefore, publication growth analysis model was used as an alternative considering the similarities between the number of certifications and number of publications. For this purpose, literature suggests using relative growth rate, which is taken as ISO 14001 certificates' relative growth rate, and doubling time models. The Doubling Time (D_t) and Relative Growth rate (RGR) were calculated by following (Javed and Liu 2018). They applied two parameters (D_t and RGR) to predict certification growth of four countries by using EGM and NDGM models. The formula of RGR is given by,

$$\text{RGR} = (\ln K_2 - \ln K_1)/(t_2 - t_1) \tag{10}$$

Where K_2 and K_1 represent the cumulative number of certifications in a respective year t_2 *and* t_1. In our case, the above equation can be rewritten because $t_2 - t_1$ is one year.

$$\text{RGR} = \ln(K_2/K_1) \tag{11}$$

Whereas doubling time (D_t) indicates time needed to become ISO 14001 double certification in terms of numbers in specified RGR. The (D_t) is given by:

$$D_{\mathrm{t}} = (t_2 - t_1)\ln[2/(\ln K_2 - \ln K_1)] \tag{12}$$

Meanwhile, we can reduce this equation to this state:

$$D_{\mathrm{t}} = \ln[2/(\ln K_2 - \ln K_1)] \tag{13}$$

However, if the *RGR* and D_t produce a different trend in the future as compared to that of a past trend then Javed and Liu (2018) solved this issue by proposing *Synthetic Relative Growth Rate* ($\mathrm{RGR_{synthetic}}$) and *Synthetic Doubling Time* ($\mathrm{D_{synthetic}}$) models. They defined the Synthetic Relative Growth Rate ($\mathrm{RGR_{synthetic}}$) model in equation (14):

$$\mathrm{RGR_{synthetic}} = \theta(\mathrm{RGR_{past}}) + (1-\theta)(\mathrm{RGR_{future}}) \tag{14}$$

Where $\mathrm{RGR_{past}}$ indicates the Relative Growth Rate obtained from original data and $\mathrm{RGR_{future}}$ indicates the Relative Growth Rate obtained for forecasted data. Here, θ indicates the coefficient of relative weights and value of θ can be taken as 0.5, generally.

The Synthetic Doubling Time ($\mathrm{D_{synthetic}}$) model is given in equation (15):

$$\mathrm{D_{synthetic}} = \theta(\mathrm{D_{past}}) + (1-\theta)(D_{\mathrm{future}}) \tag{15}$$

Where, $\mathrm{D_{past}}$ indicates the Doubling Time got from actual data and $\mathrm{RGR_{future}}$Reports the Relative Growth Rate got from simulated/forecasted data, and θ indicates the relative weight.

4. Results and Discussion

In this study, we used three Grey Models – EGM, DGM, and NDGM – to forecast the ISO 14001 certification output among six countries. By using given data set from 2005-2016 by applying Even Grey model GM(1, 1), Discrete Grey model GM(1, 1) and Non-homogeneous discrete Grey Model NDGM (1, 1) the calculated simulated values are presented in table 1,2,3,4,5 and 6. Interesting results are obtained, table 1 represents the results for China. The values calculated by MAPE % indicate the accuracy level of EGM, DGM and NDGM acquired 90.43%, 91.71%, and 92.1% respectively which implies that NDGM is best fit Grey model and showed a slightly more effective method to predict ISO 14001 certification output for six countries as compared to EGM and DGM. According to EGM model parameters *a*= -0.15648621 and *b*= 24284.5233, equation (16) will be obtained:

$$x^{0}(N) = 407928.4799(1 - \mathrm{e}^{-0.15648621})\mathrm{e}^{0.15648621(N-1)} \tag{16}$$

These *a* and *b* parameters can be calculated by the software mentioned in the Methodology section.

Similarly for China, by using the DGM time response formula based on forecasting equation parameters β1=1.169 and β2=26433.357, equation (17) can be written:

$$\hat{x}^{(1)}(N) = [x^{(0)}(1) - \frac{26433.357}{1-1.169}]1.169^{N} + \frac{26433.357}{1-1.169} \tag{17}$$

These β1 and β2 parameters can be calculated by the software mentioned in the Methodology section.

Moreover, for China, by NDGM forecasting equation parameters β1= 1.128, β2= 2664.166, β3= 20927.409 and β4= -247.952 respectively in the time series formula of NDGM can be obtained. These parameters can be calculated by the *Matlab* software. For a clear and easy comparison among actual data and NDGM simulated data from the period 2005-2026 against the total number of EMS, certifications have been shown in figure 1.

Table 1 ISO 140001 certification growth for China

Years	Actual Data	EGM	DGM	NDGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	12683	12683	12683	12683	12683	-			
2006	18842	28436	28582	25185	31525	0.911	0.374	0.787	1.825
2007	30489	33253	33425	31077	62014	0.677		1.084	

2008	39195	38886	39088	37725	101209	0.490		1.407
2009	55316	45473	45710	45224	156525	0.436		1.523
2010	58116	53176	53455	53684	214641	0.316		1.846
2011	63460	62184	62511	63229	278101	0.259		2.044
2012	67874	72717	73102	73996	345975	0.218		2.215
2013	80292	85035	85487	86144	426267	0.209		2.260
2014	98979	99440	99971	99849	525246	0.209		2.260
2015	114303	116284	116909	115311	639549	0.197		2.318
2016	137230	135982	136716	132753	776779	0.194		2.331
2017		159017	159879	152432	152432			
2018		185953	186967	174633	327065	0.763	0.329	0.963	1.916
2019		217453	218644	199679	526744	0.477		1.434
2020		254288	255688	227935	754679	0.360		1.716
2021		297363	299007	259812	1014491	0.296		1.911
2022		347735	349667	295775	1310266	0.256		2.056
2023		406640	408909	336348	1646614	0.228		2.169
2024		475522	478189	382120	2028734	0.209		2.260
2025		556073	559206	433758	2462492	0.194		2.334
2026		650269	653949	492015	2954507	0.182		2.396
MAPE (%)		9.57	8.29	7.9				

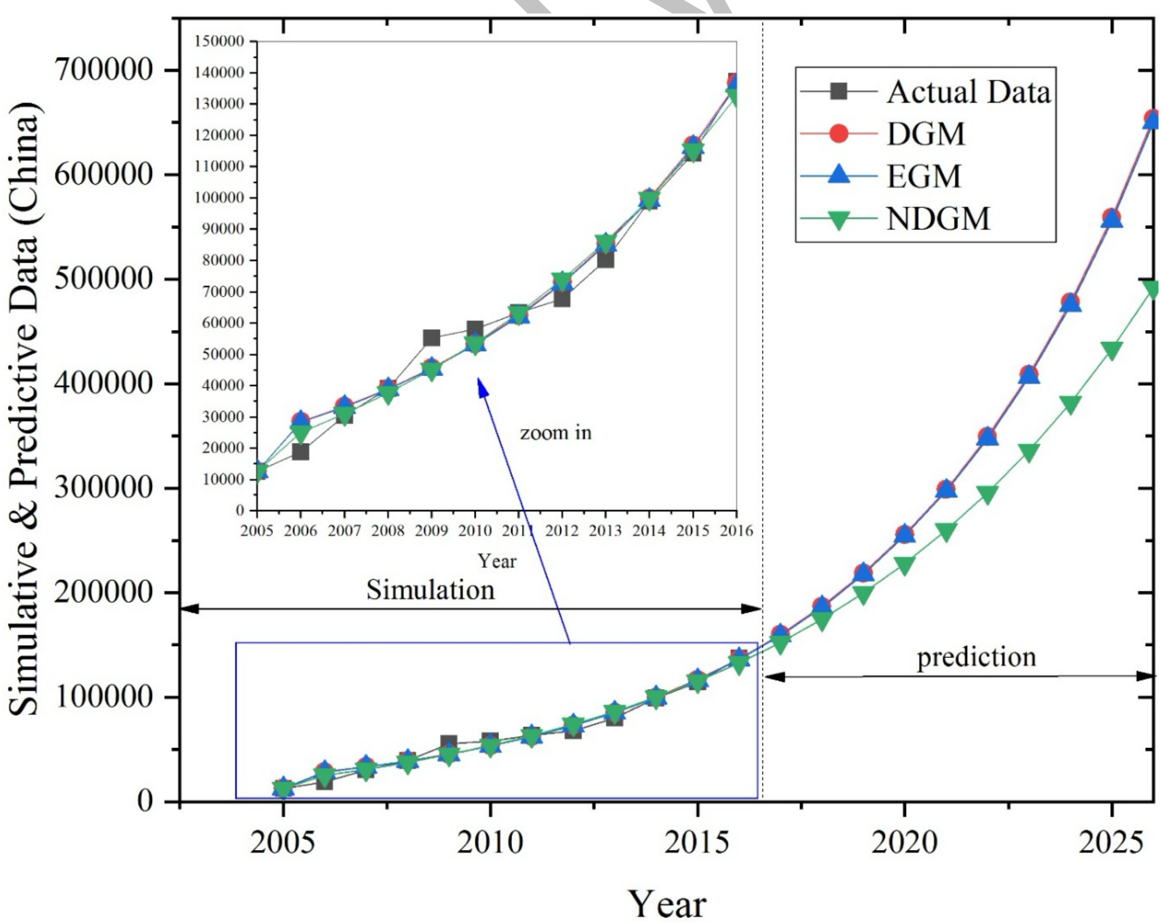

Figure 1. Prediction of China's ISO 14001 certifications

Table 2 represents Japan's results, 86.8%, 86% and 88.10% MAPE accuracy for EGM, DGM and NDGM respectively. Hence, NDGM shows slightly more forecasting effectiveness comparatively than EGM and DGM, as shown in figure 2. According to EGM model parameters *a*= -0.01691495 and *b*= 32228.834 equation (18) will be resulted:

$$x^{(0)}(N) = 1928812.087(1 - \mathrm{e}^{-0.01691495})\mathrm{e}^{0.01691495(N-1)} \tag{18}$$

Similarly for Japan, by using the DGM based forecasting equation parameters β1=0.982 and β2=32190.501, equation (19) can be presented.

$$\hat{x}^{(1)}(N) = [x^{(0)}(1) - \frac{32190.501}{1-0.982}]1.088^{N} + \frac{32190.501}{1-0.982} \tag{19}$$

Additionally, for Japan, on the basis of NDGM forecasting equation parameters β1= 0.869, β2= 3459.439, β3= 31145.425 and β4= -1332.496.

Table 2 ISO 140001 certification growth for Japan

Years	Actual Data	EGM	DGM	NDGM	Cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	23466	23466	23466	23466	23466	-			
2006	22593	23466	31766	31696	46059	0.674	0.244	1.087	2.381
2007	27955	31564	31190	30991	74014	0.474		1.439	
2008	35573	31035	30626	30378	109587	0.392		1.628	
2009	39556	30514	30071	29845	149143	0.308		1.870	
2010	34852	30002	29527	29383	183995	0.210		2.254	
2011	30397	29499	28992	28981	214392	0.153		2.571	
2012	27774	29004	28467	28632	242166	0.122		2.798	
2013	23723	28518	27952	28329	265889	0.093		3.063	
2014	23581	28040	27446	28066	289470	0.085		3.159	
2015	26069	27569	26949	27837	315539	0.086		3.144	
2016	27372	27107	26461	27639	342911	0.083		3.180	
2017		26652	25982	27466	27466				
2018		26205	25511	27316	54782	0.690	0.257	1.064	2.257
2019		25766	25049	27186	81969	0.403		1.602	
2020		25334	24596	27073	109042	0.285		1.947	
2021		24909	24150	26975	136017	0.221		2.203	
2022		24491	23713	26890	162906	0.180		2.406	
2023		24080	23284	26816	189722	0.152		2.574	
2024		23676	22862	26751	216473	0.132		2.719	
2025		23279	22448	26695	243169	0.116		2.845	

2026	22889	22042	26647	269816	0.104	2.957
MAPE (%)	9.57	8.29	7.9			

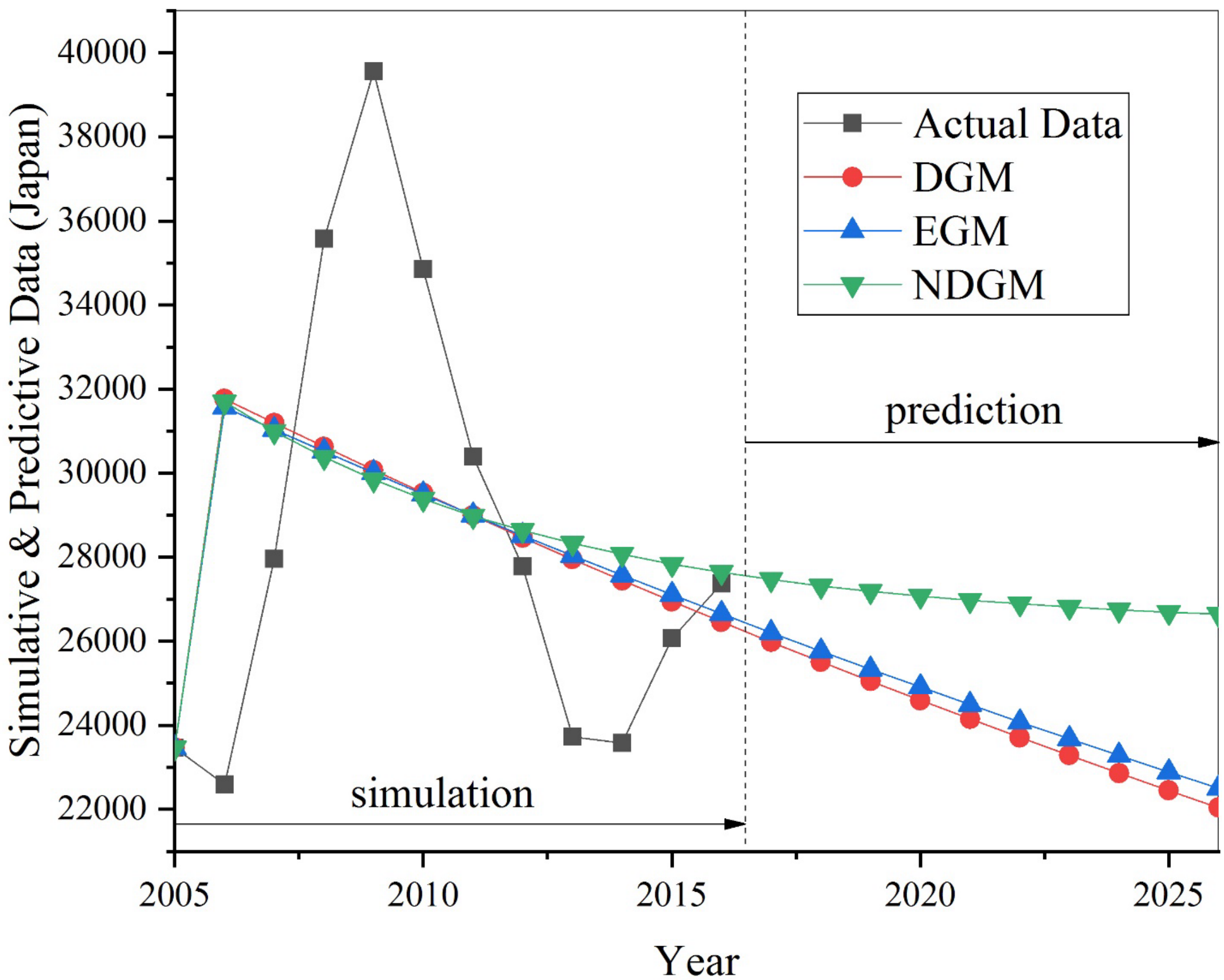

Figure 2. Prediction of Japan's ISO 14001 certifications

Table 3 represents the results of Italy, 95.47%, 95.6% and 96.86% MAPE accuracy for EGM, DGM and NDGM respectively. As a result, NDGM shows slightly more forecasting effectiveness comparatively than EGM and DGM, as shown in figure 3. According to EGM model parameters a= -0.08488172 and b= 10247.228, equation (20) is presented:

$$x^{(0)}(N) = 127803.614(1 - \mathrm{e}^{-0.15648621})\mathrm{e}^{0.15648621(N-1)} \tag{20}$$

Similarly for Italy, by using the DGM based forecasting equation parameters β1=1.088 and β2=10715.384, equation (21) can be resulted:

$$\hat{x}^{(1)}(N) = [x^{(0)}(1) - \frac{10715.384}{1-1.088}]1.088^{N} + \frac{10715.384}{1-1.088} \tag{21}$$

Furthermore, for China, on the basis of NDGM forecasting equation parameters β1= 0.985, β2= 1796.408, β3= 8309.663 and β4= 0.073.

Table 3 ISO 14001 certification growth for Italy

Years	Actual Data	EGM	DGM	NDGM	cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	7080	7080	7080	7080	7080	-			
2006	9825	11322	11342	10002	16905	0.870	0.305	0.832	2.059
2007	12057	12325	12345	11650	28962	0.538		1.312	
2008	12922	13417	13437	13275	41884	0.369		1.690	
2009	14542	14605	14626	14875	56426	0.298		1.904	
2010	17675	15899	15920	16452	74101	0.272		1.993	
2011	17340	17308	17329	18005	91441	0.210		2.253	
2012	19512	18841	18862	19536	110953	0.193		2.336	
2013	21300	20510	20531	21043	132253	0.176		2.433	
2014	22616	22327	22347	22529	154869	0.158		2.539	
2015	22350	24305	24324	23993	177219	0.135		2.697	
2016	26655	26458	26476	25435	203874	0.140		2.658	
2017		28802	28818	26856	26856				
2018		31353	31368	28255	55111	0.719	0.278	1.023	2.136
2019		34131	34143	29634	84746	0.430		1.536	
2020		37154	37164	30993	115739	0.312		1.859	
2021		40446	40452	32332	148071	0.246		2.094	
2022		44029	44030	33651	181722	0.205		2.279	
2023		47929	47926	34950	216672	0.176		2.431	
2024		52175	52166	36230	252902	0.155		2.560	
2025		56797	56781	37492	290394	0.138		2.672	
2026		61829	61805	38734	329129	0.125		2.771	
MAPE (%)		4.53	4.40	3.14					

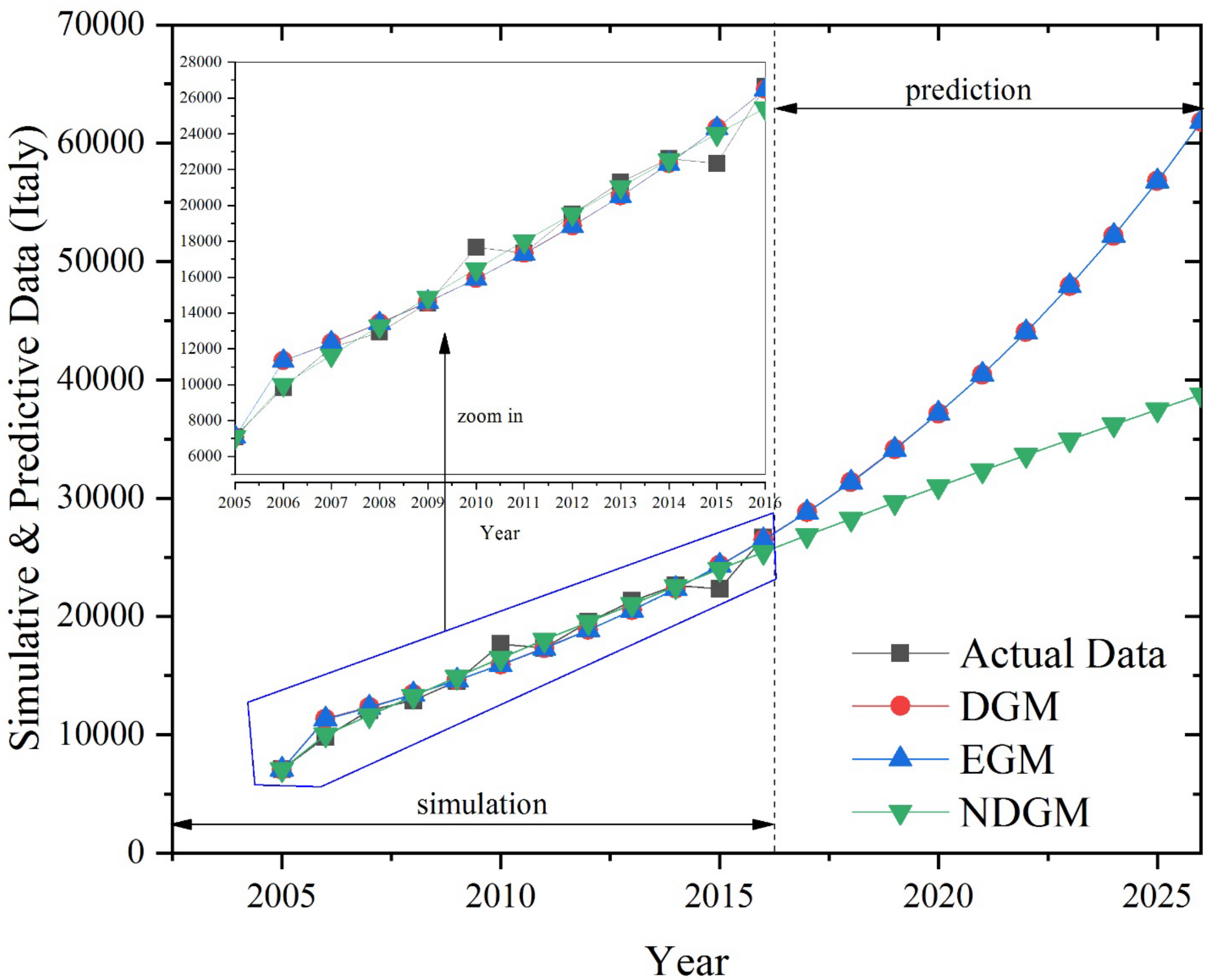

Figure 3. Prediction of Italy's ISO 14001 certifications

Table 4 represents MAPE accuracy level for Germany, 95.67%, 95.6% and 96.11% by EGM, DGM and NDGM respectively. Consequently, NDGM shows slightly more effectiveness comparatively than EGM and DGM, as shown in figure 4. According to EGM model parameters *a*= -0.06171916 and *b*= 4450.1471, equation (22) has been resulted:

$$\hat{x}^{(0)}(N) = 7654317023(1 - \mathrm{e}^{-0.15648621})\mathrm{e}^{0.15648621(N-1)} \qquad (22)$$

Similarly for Germany, by using the DGM based forecasting equation parameters β1=1.064 and β2=4596.36, equation (23) has been obtained:

$$\hat{x}^{(1)}(N) = [x^{(0)}(1) - \frac{4596.36}{1-1.064}]1.064^{N} + \frac{4596.36}{1-1.064} \tag{23}$$

Table 4 ISO 14001 certification growth for Germany

Years	Actual Data	EGM	DGM	NDGM	cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	4440	4440	4440	4440	4440	-			
2006	5415	4873	4879	5071	9855	0.797	0.306	0.920	2.211
2007	4877	5183	5189	5292	14732	0.402		1.604	
2008	5709	5513	5518	5544	20441	0.328		1.809	
2009	5865	5864	5869	5829	26306	0.252		2.070	
2010	6001	6238	6242	6152	32307	0.205		2.276	
2011	6254	6635	6639	6519	38561	0.177		2.425	
2012	7015	7057	7061	6935	45576	0.167		2.482	
2013	7983	7506	7509	7406	53559	0.161		2.517	
2014	7702	7984	7987	7941	61261	0.134		2.700	
2015	8224	8493	8494	8547	69485	0.126		2.765	
2016	9444	9033	9034	9234	78929	0.127		2.753	
2017		9608	9608	10013	10013				
2018		10220	10219	10897	20910	0.736	0.307	0.999	2.000
2019		10871	10868	11899	32808	0.450		1.491	
2020		11563	11559	13035	45843	0.335		1.788	
2021		12299	12293	14323	60166	0.272		1.996	
2022		13082	13075	15784	75949	0.233		2.150	
2023		13915	13906	17440	93389	0.207		2.270	
2024		14800	14789	19318	112707	0.188		2.364	
2025		15743	15729	21447	134155	0.174		2.441	
2026		15743	16729	23862	158017	0.164		2.503	
MAPE (%)		4.33	4.40	3.89					

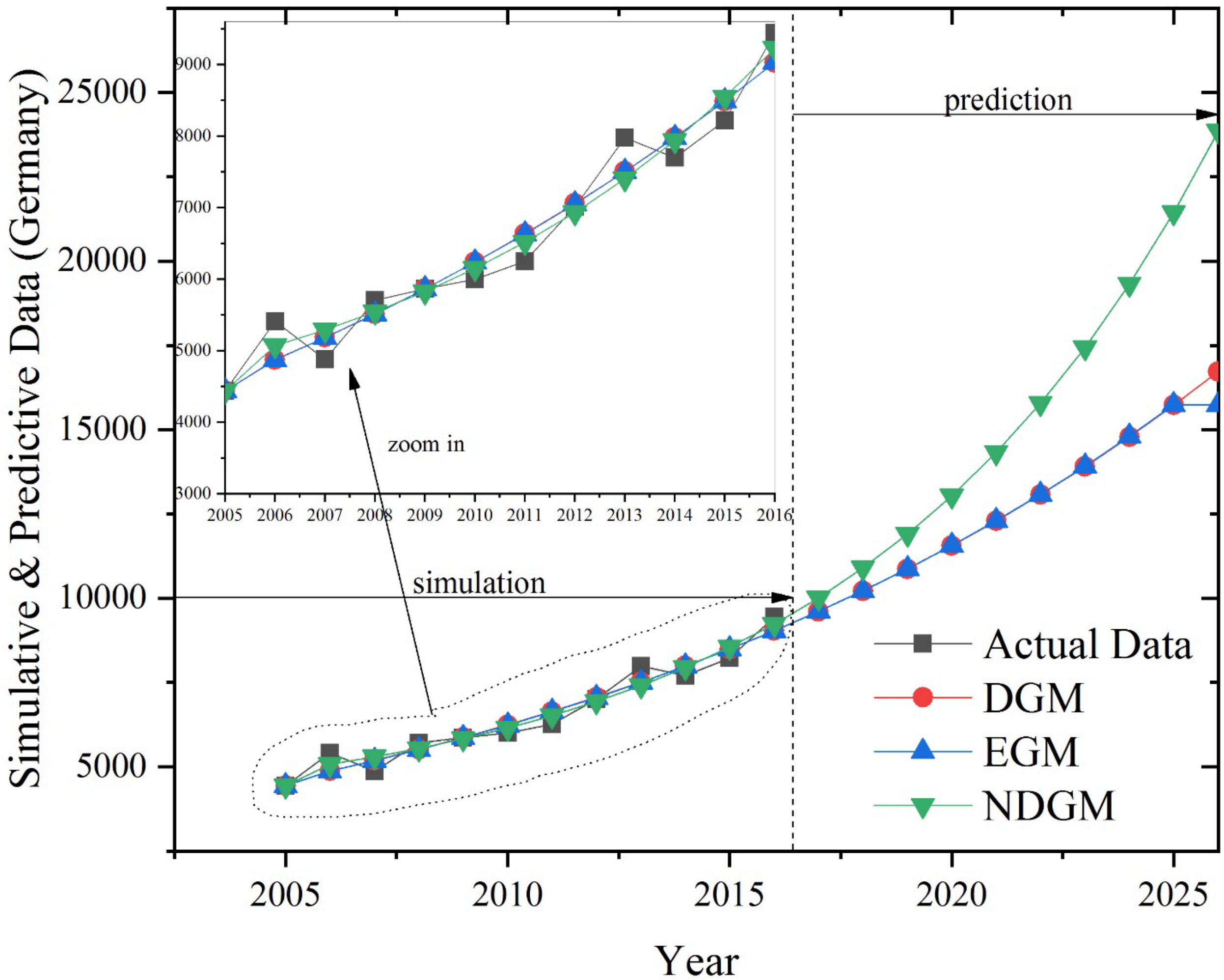

Figure 4. Prediction of Germany's ISO 14001 certifications

Additionally, for Germany, by NDGM forecasting equation parameters β1= 1.133901, β2= -457.165268, β3= 4931.3784 and β4= 13.4530144 respectively in the time series formula of NDGM.

Table 5 represents the results of India, 93.48%, 93.70% and 94.12% MAPE accuracy for EGM, DGM and NDGM respectively. Hence, NDGM shows slightly more effectiveness comparatively than EGM and DGM, as shown in figure 5. According to EGM model parameters *a*= -0.11794128 and *b*= 2058.6473, equation (24) has been resulted:

$$x^0(N) = 19152.84957(1 - \mathrm{e}^{-0.15648621})\mathrm{e}^{0.15648621(N-1)} \quad (24)$$

Similarly for India, by using the DGM based forecasting equation parameters β1= 1.125 and β2= 2192.669, equation (25) can be obtained:

$$\hat{x}^{(1)}(N) = [x^{(0)}(1) - \frac{2192.669}{1-1.125}]1.1.25^{N} + \frac{2192.669}{1-1.125} \quad (25)$$

Moreover, for India, by NDGM forecasting equation parameters β1= 1.087009, β2= 166.669348, β3= 1932.740253 and β4= 0.1909553 respectively in the time series formula of NDGM.

Table 5 ISO 14001 growth for India

Years	Actual Data	EGM	DGM	NDGM	cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	1698	1698	1698	1698	1698	-			
2006	2016	2398	2405	2247	3714	0.783	0.312	0.938	2.000
2007	2640	2698	2706	2609	6354	0.537		1.315	
2008	3281	3035	3044	3003	9635	0.416		1.569	
2009	3799	3415	3425	3431	13434	0.332		1.795	
2010	3878	3843	3853	3896	17312	0.254		2.065	
2011	4147	4324	4335	4402	21459	0.215		2.231	
2012	4286	4865	4878	4952	25745	0.182		2.396	
2013	5872	5474	5488	5549	31617	0.205		2.276	
2014	6443	6159	6174	6199	38060	0.185		2.378	
2015	6782	6930	6946	6905	44842	0.164		2.501	
2016	7725	7798	7815	7672	52567	0.159		2.532	
2017		8774	8793	8506	8506				
2018		9872	9892	9413	17919	0.745	0.309	0.987	1.998
2019		11108	11130	10399	28318	0.458		1.475	
2020		12499	12522	11470	39788	0.340		1.772	
2021		14063	14088	12635	52423	0.276		1.981	
2022		15823	15850	13901	66324	0.235		2.140	
2023		17804	17832	15277	81601	0.207		2.267	
2024		20033	20062	16773	98374	0.187		2.370	
2025		22541	22572	18399	116773	0.171		2.457	
2026		25362	25395	20167	136939	0.159		2.530	
MAPE (%)		6.52	6.30	5.88					

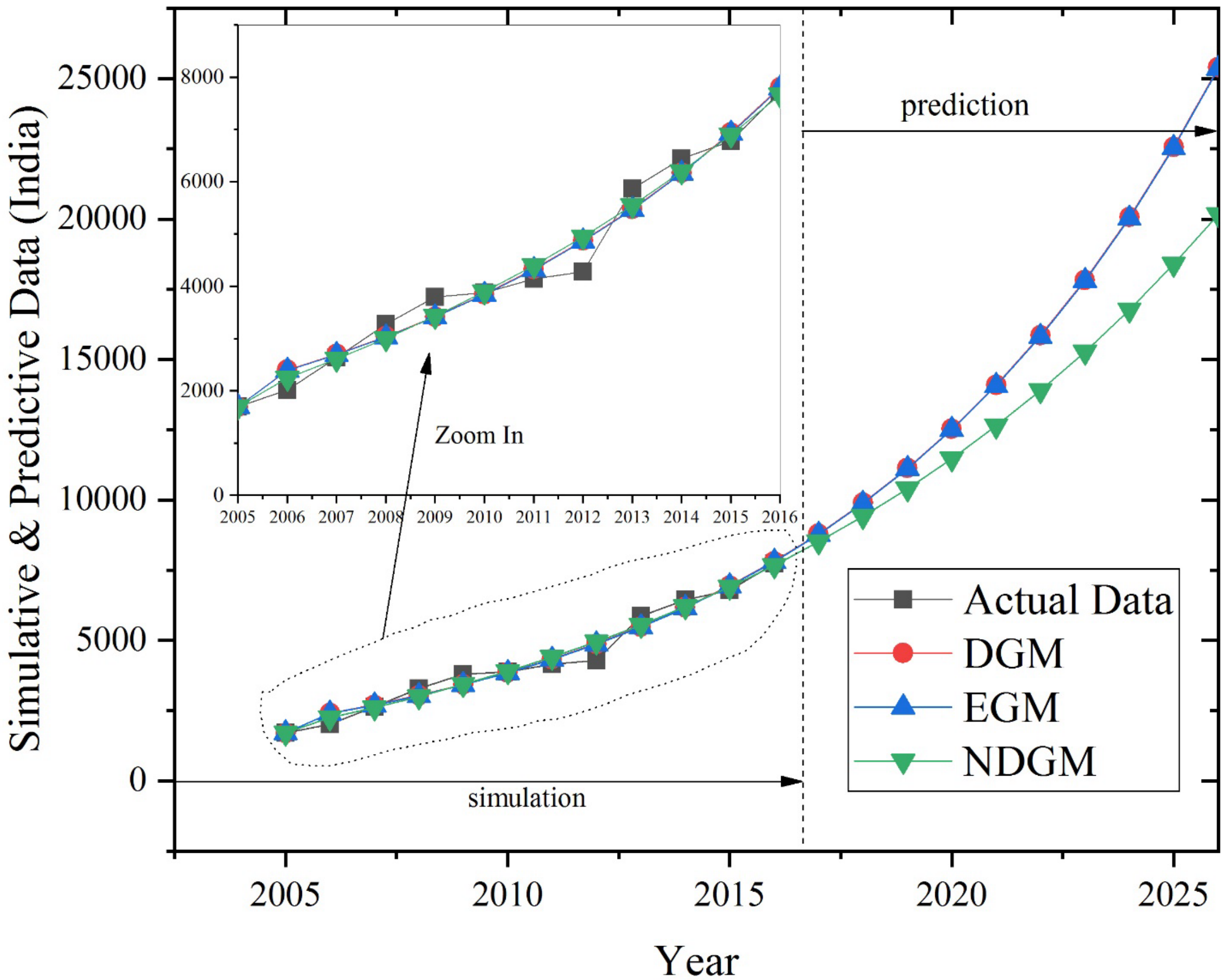

Figure 5. Prediction of India's ISO 14001 certifications

Table 6 represents the results of the USA, 93.35%, 93.58% and 93.17% MAPE accuracy for EGM, DGM and NDGM respectively. Accordingly, DGM shows slightly more effectiveness comparatively than EGM and NDGM, as shown in figure 6. According to EGM model parameters *a*= -0.01262588 and *b*= 4990.322, equation (26) has been resulted:

$$x^0(N) = 400306.4799(1 - \mathrm{e}^{-0.15648621})\mathrm{e}^{0.15648621(N-1)} \tag{26}$$

Similarly for the USA, by using the DGM based forecasting equation parameters β1= 1.012 and β2= 5032.194, equation (27) can be obtained:

$$\hat{x}^{(1)}(N) = [x^{(0)}(1) - \frac{5032.194}{1-1.012}]1.012^{N} + \frac{5032.194}{1-1.012} \tag{27}$$

Moreover, for the USA, by NDGM forecasting equation parameters β1= 0.9030998, β2=580.897527, β3= 4990.067165 and β4= 56.278536 respectively in the time series formula of NDGM.

Table 6 ISO 14001 certification growth for the USA

Year	Actual Data	EGM	NDGM	DGM	cumulative	RGR	Mean RGR	Dt	Mean Dt
2005	5061	5061	5061	5061	5061	-			
2006	5585	5086	5075	5095	10646	0.744	0.246	0.989	2.373
2007	5462	5151	5164	5158	16108	0.414		1.575	
2008	4974	5216	5245	5222	21082	0.269		2.006	
2009	5225	5283	5317	5286	26307	0.221		2.201	
2010	4407	5350	5383	5352	30714	0.155		2.558	
2011	4957	5418	5442	5418	35671	0.150		2.593	
2012	5699	5487	5496	5485	41370	0.148		2.602	
2013	6071	5556	5544	5553	47441	0.137		2.681	
2014	5617	5627	5588	5622	53058	0.112		2.883	
2015	6067	5698	5627	5692	59125	0.108		2.916	
2016	5582	5771	5663	5762	64707	0.090		3.099	
2017		5844	5695	5833	5833				
2018		5918	5724	5906	11739	0.699	0.262	1.051	2.214
2019		5994	5750	5979	17718	0.412		1.581	
2020		6070	5774	6053	23771	0.294		1.918	
2021		6147	5795	6128	29899	0.229		2.166	
2022		6225	5815	6204	36103	0.189		2.362	
2023		6304	5832	6281	42383	0.160		2.523	
2024		6384	5848	6358	48741	0.140		2.661	
2025		6465	5862	6437	55178	0.124		2.780	
2026		6547	5875	6517	61695	0.112		2.886	
MAPE (%)		6.65	6.83	6.42					

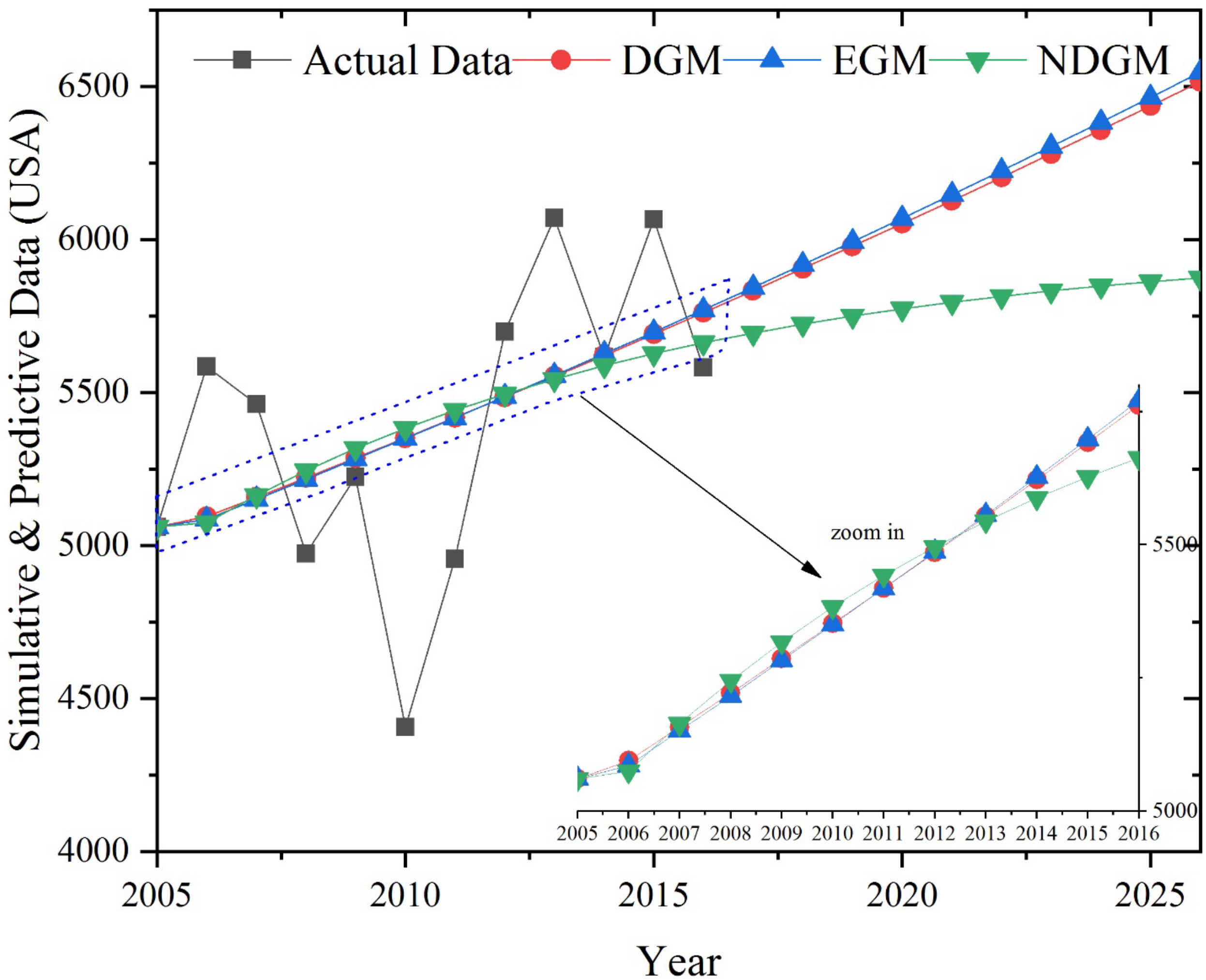

Figure 6. Prediction of USA's ISO 14001 certifications

We used three grey models to forecast ISO 14001 certification output in six countries. The results reveal that the NDGM showed more accuracy than DGM and EGM in case of China, Italy, Germany, and India, meanwhile DGM showed slightly effectiveness than EGM and NDGM in the USA case given in table 7. According to average MAPE %, overall comparison scenario accuracy level of NDGM was 94.47 %, which is slightly better than EGM 93.68% and DGM 94.04 % respectively.

Table 7. MAPE (%) Comparison

	MAPE %		
	EGM	**NDGM**	**DGM**
Countries			
China	9.57	7.9	8.29
Japan	13	11.90	13.20
Italy	4.53	3.14	4.4
Germany	4.33	3.89	4.4
India	6.52	5.88	6.3
USA	6.65	6.83	6.42
Average MAPE %	6.32	5.53	5.96
Overall accuracy Level %	93.68	94.47	94.04

In contrast, wise country comparison among six countries based on Relative Growth rate (RGR) and doubling time (D_t) achieves interesting results, as per actual data 2005-2016 provided by ISO the RGR equation (28) was obtained:

$$China_{(0.374)} > India_{(0.312)} > Germany_{(0.306)} > Italy_{(0.305)} > USA_{(0.246)} > Japan_{(0.244)} \quad (28)$$

According to doubling time (D_t) comparison based on actual data between six countries the following sequence of results was obtained:

$$Japan_{(2.381)} > USA_{(2.373)} > Germany_{(2.211)} > Italy_{(2.059)} > India_{(2.00)} > China_{(1.825)} \quad (29)$$

These two exciting findings show that the relative growth rate of developing countries (China & India) is relatively greater and for the developed countries (Germany, Italy, USA, and Japan) is relatively less great. Meanwhile, these findings also reveal that developing countries need less time to double ISO 14001 certifications numbers for a given RGR than developed countries. Therefore relative growth of EMS in developing countries is a source of competitive benefits, more employee satisfaction, cost saving, environmental sustainability, improved relationship with communities, better image and more business opportunities in the international market over strong competitors in developed countries (Hojnik and Ruzzier 2017).

However, we used NDMG based simulated data to ascertain the situation of ISO 14001 certification in future from 2017-2026. According to RGR sequence, the result was obtained in equation (30):

$$China_{(0.329)} > India_{(0.309)} > Germany_{(0.307)} > Italy_{(0.278)} > USA_{(0.258)} > Japan_{(0.254)} \tag{30}$$

The same sequence was obtained on the simulated base data, in the next ten years developing countries (China and India) will retain their position in terms of relative growth (3.29%) and (3.09%) respectively followed by Germany, Italy, the USA, and Japan.

According to doubling time (D_t) comparison based on simulated data between six countries the following sequence of the result was obtained:

$$China_{(1.916)} < India_{(1.998)} < Italy_{(2.136)} < Germany_{(2.000)} < USA_{(2.238)} < Japan_{(2.257)} \tag{31}$$

Our finding also reveals that China needs (1.916) years to double its number of certifications because of the higher relative growth rate followed by India, Italy, Germany, the USA, and Japan. Three different Grey model results presented above by actual data and simulated base data, forecast EMS certification for the next ten years. Now here a question arises in the long run as to who will get a maximum number of ISO 14001 accreditations. Therefore, to answer this question (Javed and Liu 2018) generated two grey synthetic indices by actual (past) and forecasted (future) data, which implies that $RGR_{synthetic}$ indicates Synthetic Relative Growth Rate has been obtained in equation (32):

$$\mathrm{RGR}_{\mathrm{synthetic}} = \theta(\mathrm{RGR}_{\mathrm{past}}) + (1-\theta)(\mathrm{RGR}_{\mathrm{future}}) \tag{32}$$

Where $\mathrm{RGR}_{\mathrm{past}}$ indicates the Relative Growth Rate got from original data and $\mathrm{RGR}_{\mathrm{future}}$States the Relative Growth Rate got from forecasted data. Here, θ indicates the *coefficient of relative weights* and value of θ can be taken as 0.5. If the decision makers in decision making consider the relative growth rate of original data more important, then $\theta > 1-\theta$.

Furthermore, if $D_{synthetic}$ indicates Synthetic Doubling time (STD) it resulted in equation (33):

$$\mathrm{D}_{\mathrm{synthetic}} = \theta(\mathrm{D}_{\mathrm{past}}) + (1-\theta)(D_{\mathrm{future}}) \tag{33}$$

Where, $\mathrm{D}_{\mathrm{past}}$ indicates the Doubling Time obtained from actual data and $\mathrm{RGR}_{\mathrm{future}}$Reports the Relative Growth Rate got from simulated/forecasted data, and θ indicates the relative weight. Whereas, on the basis of Relative Growth Rate by using these two Grey Synthetic indices the following sequence was obtained.

$$China_{(0.338)} > India_{(0.311)} > Germany_{(0.307)} > Italy_{(0.292)} > USA_{(0.252)} > Japan_{(0.249)} \tag{34}$$

According to doubling time (D_t) comparison based on STD between six countries, the following sequence of the result was obtained.

$$Japan_{(2.319)} > USA_{(2.306)} > Germany_{(2.106)} > Italy_{(2.089)} > India_{(1.999)} > China_{(1.871)} \tag{35}$$

Hence, based on synthetic model feasibility we get the sequence by applying SRGR and STD, which is similar to the sequence obtained against the actual data RGR and doubling time (D_t). Whereas the results are aligned and confirm that ISO 14001 certification growth in developing countries is more than that of a developed country and they need less time to double in number. Our finding also reveals that in the long run China and India would have a competitive edge over other more developed countries.

5. Conclusion

We developed a forecasting framework to predict the ISO 14001 trends in China, Japan India, the USA, Germany, and Italy by using the most popular and accurate methodology of the grey foresting system. Results presented that methodology of three grey prediction models were satisfactory and were successfully applied based on actual data to forecast the ISO 14001 trends from the period 2017 to 2026 in the USA, Japan, Germany, Italy, China, and India. All six countries show the inclined trend in ISO 14001 certification from 2015 to 2016 in figure 1 to 6. However the results indicate in the long run China and India are more likely to maintain their positions as leaders in adopting the higher standard in some ISO 14001 certifications followed by Germany, Italy, the USA, and Japan. A linear trend in growth of accreditation is found in this study. The study confirms the accuracy level of NDGM model is better than the other two forecasting Even GM(1,1) and Discrete GM (1,1) grey models. It indicates that the EMS certification growth rate in developing countries is higher whereas developed countries tend to possess less growth rate in certification and require more time to take their double certification in numbers. Furthermore, two synthetic grey models were tested successfully to analyze the relative growth rate and time expected to double the quantity of certification.

Also, the study has some policy implications for academicians and practitioners. In an academic perspective, this article provides an essential contribution to studying ISO 14001 future trends by grey forecasting models. For the practitioner community, this study can help out the International Organization for Standardization to analyze 14001 market trend till 2026. Similarly, this research can also increase the interest of certification bodies to strengthen those countries where companies' environmental sustainability requires more efforts through registration of ISO 14001. The government should take some serious steps to provide subsidies and provide training on ISO 14001 standard to make organizations more environmentally sustainable. The study can be used as a valuable awareness tool for the customers who can demand environment-friendly and sustainable products and services as a value addition in the existing product line.

Lastly, considering the challenging task of limiting global warming to 1.5 ^{o}C, the need for sustainability-oriented companies and industries is very important for the countries. The study encourages the ISO 14001 certifications for the companies who want to remain profitable as well as sustainable.

References

Arimura TH, Darnall N, Ganguli R, Katayama H (2016) The effect of ISO 14001 on environmental performance: Resolving equivocal findings. J Environ Manage 166:556–566. doi: 10.1016/j.jenvman.2015.10.032

Boiral O, Guillaumie L, Heras-Saizarbitoria I, Tayo Tene CV (2018) Adoption and Outcomes of ISO 14001: A Systematic Review. Int J Manag Rev 20:411–432. doi: 10.1111/ijmr.12139

Campos LMS, De Melo Heizen DA, Verdinelli MA, Cauchick Miguel PA (2015) Environmental performance indicators: A study on ISO 14001 certified companies. J Clean Prod. doi: 10.1016/j.jclepro.2015.03.019

Cañón-de-Francia J, Garcés-Ayerbe C (2009) ISO 14001 environmental certification: A sign valued by the market? Environ Resour Econ 44:245–262. doi: 10.1007/s10640-009-9282-8

Casadesús M, Marimon F, Heras I (2008) ISO 14001 diffusion after the success of the ISO 9001 model. J Clean Prod 16:1741–1754. doi: 10.1016/j.jclepro.2007.11.002

Castka P, Prajogo D (2013) The effect of pressure from secondary stakeholders on the internalization of ISO 14001. J Clean Prod 47:245–252. doi: 10.1016/J.JCLEPRO.2012.12.034

Daddi T, Frey M, De Giacomo MR, et al (2015) Macro-economic and development indexes and ISO14001 certificates: A cross national analysis. J Clean Prod 108:1239–1248. doi: 10.1016/j.jclepro.2015.06.091

Darnall N, Carmin J (2005) Greener and cleaner? The signaling accuracy of U.S. voluntary environmental programs. Policy Sci 38:71–90. doi: 10.1007/s11077-005-6591-9

Duan H, Xiao X, Pei L (2017) Forecasting the Short-Term Traffic Flow in the Intelligent Transportation System Based on an Inertia Nonhomogenous Discrete Gray Model. Complexity 2017:1–16. doi: 10.1155/2017/3515272

El-Fouly THM, El-Saadany EF, Salama MMA (2006) Grey Predictor for Wind Energy Conversion Systems Output Power Prediction. IEEE Trans Power Syst 21:1450–1452. doi: 10.1109/TPWRS.2006.879246

Ferrón-Vílchez V (2016) Does symbolism benefit environmental and business performance in the adoption of ISO 14001? J Environ Manage 183:882–894. doi: 10.1016/j.jenvman.2016.09.047

Gavronski I, Ferrer G, Paiva EL (2008) ISO 14001 certification in Brazil: motivations and benefits. J Clean Prod 16:87–94. doi: 10.1016/j.jclepro.2006.11.002

Giménez Leal G, Fa MC, Pasola JV (2003) Using environmental management systems to increase firms' competitiveness. Corp Soc Responsib Environ Manag 10:101–110. doi: 10.1002/csr.32

Graafland JJ (2018) Ecological impacts of the ISO14001 certification of small and medium sized enterprises in Europe and the mediating role of networks. J Clean Prod 174:273–282. doi: 10.1016/j.jclepro.2017.10.322

Hojnik J, Ruzzier M (2017) Does it pay to be eco? The mediating role of competitive benefits and the effect of ISO14001. Eur Manag J 35:581–594. doi: 10.1016/j.emj.2017.07.008

Iatridis K, Kesidou E (2018) What Drives Substantive Versus Symbolic Implementation of ISO 14001 in a Time of Economic Crisis? Insights from Greek Manufacturing Companies. J Bus Ethics 148:859–877. doi: 10.1007/s10551-016-3019-8

International Energy Agency (IEA) (2015) Energy and climate change. World energy outlook special report. World Energy Outlook Spec Rep. doi: 10.1038/479267b

IPCC (2014) Climate Change 2014 Synthesis Report - Approved Summary for Policy Makers

Ismail MS, Ramli A, Darus F (2014) Environmental Management Accounting Practices and Islamic Corporate Social Responsibility Compliance: Evidence from ISO14001 Companies. Procedia - Soc Behav Sci 145:343–351. doi: 10.1016/j.sbspro.2014.06.043

ISO. (2012). Environmental Management - the ISO 14000 Family of International Standards. Retrieved January 14, 2019, from http://www.iso.org/iso/theiso14000family_2009.pdf

ISO. (2012b). ISO 14000-Environmental Management. Retrieved January 14, 2019, from http://www.iso.org/

ISO. (2018). ISO Survey Report. Retrieved January 14, 2019, from https://isotc.iso.org/

Jabbour CJC (2015) Environmental training and environmental management maturity of Brazilian companies with ISO14001: Empirical evidence. J Clean Prod 96:331–338. doi: 10.1016/j.jclepro.2013.10.039

Javed SA, Liu S (2018) Predicting the research output/growth of selected countries: application of Even GM (1, 1) and NDGM models. Scientometrics 115:395–413. doi: 10.1007/s11192-017-2586-5

Javed SA, Syed AM, Javed S (2018) Perceived organizational performance and trust in project manager and top management in project-based organizations. Grey Syst Theory Appl 8:230–245. doi: 10.1108/GS-01-2018-0009

Khan Z (2013) A Strategy for Incorporation of ISO 14001 in Accreditation Process of Engineering Degree Programs. Procedia - Soc Behav Sci 102:543–547. doi: 10.1016/j.sbspro.2013.10.770

Lee SM, Noh Y, Choi D, Rha JS (2017) Environmental Policy Performances for Sustainable Development: From the Perspective of ISO 14001 Certification. Corp Soc Responsib Environ Manag 24:108–120. doi: 10.1002/csr.1395

Liu S, Forrest JYL (2010) Grey systems: theory and applications. Springer

Liu S, Yang Y, Forrest J (2017) Grey Data Analysis. Springer Singapore, Singapore

Llach J, Marimon F, Alonso-Almeida MDM (2015) Social Accountability 8000 standard certification: Analysis of worldwide diffusion. J Clean Prod 93:288–298. doi: 10.1016/j.jclepro.2015.01.044

Llach J, Marimon F, Bernardo M (2011) ISO 9001 diffusion analysis according to activity sectors. Ind Manag Data Syst 111:298–316. doi: 10.1108/02635571111115191

Marimon F, Llach J, Bernardo M (2011) Comparative analysis of diffusion of the ISO 14001 standard by sector of activity. J Clean Prod 19:1734–1744. doi: 10.1016/j.jclepro.2011.06.003

McGuire W (2014) The effect of ISO 14001 on environmental regulatory compliance in China. Ecol Econ 105:254–264. doi: 10.1016/j.ecolecon.2014.06.007

Mohee R, Surroop D, Mudhoo A, Rughooputh BK (2012) Inventory of waste streams in an industrial port and planning for a port waste management system as per ISO14001. Ocean Coast Manag 61:10–19. doi: 10.1016/j.ocecoaman.2012.02.003

Morrow D, Rondinelli D (2002) Adopting corporate environmental management systems: Motivations and results of ISO 14001 and EMAS certification. Eur Manag J 20:159–171. doi: 10.1016/S0263-2373(02)00026-9

Neumayer E, Perkins R (2004) What explains the uneven take-up of ISO 14001 at the global level? A panel-data analysis. Environ Plan A 36:823–839. doi: 10.1068/a36144

Neves F de O, Salgado EG, Beijo LA (2017) Analysis of the Environmental Management System based on ISO 14001 on the American continent. J Environ Manage 199:251–262. doi: 10.1016/j.jenvman.2017.05.049

Nguyen QA, Hens L (2015) Environmental performance of the cement industry in Vietnam: the influence of ISO 14001 certification. J Clean Prod 96:362–378. doi: 10.1016/J.JCLEPRO.2013.09.032

Ozusaglam S, Robin S, Wong CY (2018) Early and late adopters of ISO 14001-type standards: revisiting the role of firm characteristics and capabilities. J Technol Transf 43:1318–1345. doi: 10.1007/s10961-017-9560-5

Pirthee M (2017) Grey-based model for forecasting Mauritius international tourism from different regions. Grey Syst Theory Appl 7:259–271. doi: 10.1108/GS-04-2017-0008

Prajogo D, K.Y. Tang A, Lai K-H (2014) The diffusion of environmental management system and its effect on environmental management practices. Int J Oper Prod Manag 34:565–585. doi: 10.1108/IJOPM-10-2012-0448

Prajogo D, Tang AKY, Lai K (2012) Do firms get what they want from ISO 14001 adoption?: an Australian perspective. J Clean Prod 33:117–126. doi: 10.1016/j.jclepro.2012.04.019

Prakash A, Potoski M (2006) Racing to the bottom? trade, environmental governance, and ISO 14001. Am J Pol Sci 50:350–364. doi: 10.1111/j.1540-5907.2006.00188.x

Qi GY, Zeng SX, Tam CM, et al (2011) Diffusion of ISO 14001 environmental management systems in China: Rethinking on stakeholders' roles. J Clean Prod 19:1250–1256. doi:

10.1016/j.jclepro.2011.03.006

Rino CAF, Salvador NNB (2017) ISO 14001 certification process and reduction of environmental penalties in organizations in Sao Paulo State, Brazil. J Clean Prod 142:3627–3633. doi: 10.1016/j.jclepro.2016.10.105

Salim HK, Padfield R, Hansen SB, et al (2018) Global trends in environmental management system and ISO14001 research. J Clean Prod 170:645–653. doi: 10.1016/j.jclepro.2017.09.017

Sampaio P, Saraiva P, Guimarães Rodrigues A (2011) ISO 9001 certification forecasting models. Int J Qual Reliab Manag 28:5–26. doi: 10.1108/02656711111097526

Science Insight (2019) Limiting global warming to 1.5 °C will require drastic action, says IPCC – The Science Insight. http://thescienceinsight.com/ipcc-says-limiting-global-warming-to-1-5-c-will-require-drastic-action/. Accessed 28 Jan 2019

Singh M, Brueckner M, Padhy PK (2014) Insights into the state of ISO14001 certification in both small and medium enterprises and industry best companies in India: The case of Delhi and Noida. J Clean Prod 69:225–236. doi: 10.1016/j.jclepro.2014.01.040

Strachan PA, Sinclair IMK, Lal D (2003) Managing ISO 14001 implementation in the United Kingdom continental shelf (UKCS). Corp Soc Responsib Environ Manag 10:50–63. doi: 10.1002/csr.29

Testa F, Rizzi F, Daddi T, et al (2014) EMAS and ISO 14001: the differences in effectively improving environmental performance. J Clean Prod 68:165–173. doi: 10.1016/J.JCLEPRO.2013.12.061

To WM, Lee PKC (2014) Diffusion of ISO 14001 environmental management system: Global, regional and country-level analyses. J Clean Prod 66:489–498. doi: 10.1016/j.jclepro.2013.11.076

Uchida T, Ferraro PJ (2007) Voluntary development of environmental management systems: Motivations and regulatory implications. J Regul Econ 32:37–65. doi: 10.1007/s11149-006-9016-6

United Nations Framework Convention on Climate Change (2016) Summary of the Paris Agreement. United Nations Framew Conv Clim Chang 1:7–8

Vastag G, Corbett CJ, Kirsch D a (2004) Revisiting ISO 14000 Diffusion: A New "Look" at the Drivers of Certification/Response. Prod Oper Manag 13:260–267. doi: 10.1111/j.1937-5956.2004.tb00511.x

Wahba H (2010) How do institutional shareholders manipulate corporate environmental strategy to protect their equity value? A study of the adoption of ISO 14001 by Egyptian firms. Bus Strateg Environ 19:495–511. doi: 10.1002/bse.654

Wang C-H, Hsu L-C (2008) Using genetic algorithms grey theory to forecast high technology industrial output. Appl Math Comput 195:256–263. doi: 10.1016/j.amc.2007.04.080

WCED (1987) Our Common Future. The United Nations World Commission on the Environment and Development.

Wu L, Liu S, Yao L, et al (2013) Grey system model with the fractional order accumulation. Commun Nonlinear Sci Numer Simul 18:1775–1785. doi: 10.1016/J.CNSNS.2012.11.017

Wu LF, Liu SF, Cui W, et al (2014) Non-homogenous discrete grey model with fractional-order accumulation. Neural Comput Appl 25:1215–1221. doi: 10.1007/s00521-014-1605-1

Xie N, Liu S (2015) Interval grey number sequence prediction by using non-homogenous exponential discrete grey forecasting model. J Syst Eng Electron 26:96–102. doi: 10.1109/JSEE.2015.00013

Xie N ming, Liu S feng (2009) Discrete grey forecasting model and its optimization. Appl Math Model 33:1173–1186. doi: 10.1016/j.apm.2008.01.011

Xie NM, Liu SF, Yang YJ, Yuan CQ (2013) On novel grey forecasting model based on non-homogeneous index sequence. Appl Math Model 37:5059–5068. doi: 10.1016/j.apm.2012.10.037

Yu Y, Choi Y (2016) Stakeholder pressure and CSR adoption: The mediating role of organizational culture for Chinese companies. Soc Sci J 53:226–235. doi: 10.1016/j.soscij.2014.07.006

Zeng SX, Tam CM, Tam VWY, Deng ZM (2005) Towards implementation of ISO 14001 environmental management systems in selected industries in China. J Clean Prod 13:645–656. doi: 10.1016/j.jclepro.2003.12.009

Zhao H, Guo S (2016) An optimized grey model for annual power load forecasting. Energy 107:272–286. doi: 10.1016/j.energy.2016.04.009

Zhao Z, Wang J, Zhao J, Su Z (2012) Using a Grey model optimized by Differential Evolution algorithm to forecast the per capita annual net income of rural households in China. Omega 40:525–532. doi: 10.1016/j.omega.2011.10.003

Zhou P, Ang BW, Poh KL (2006) A trigonometric grey prediction approach to forecasting electricity demand. Energy 31:2503–2511. doi: 10.1016/j.energy.2005.12.002

Zhou W, He J-M (2013) Generalized GM (1, 1) model and its application in forecasting of fuel production. Appl Math Model 37:6234–6243. doi: 10.1016/J.APM.2013.01.002