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Cross-country diffusion of the ISO Energy Management Standard: How important is the neighbourhood effect?

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This study examines the uneven spread of ISO-50001 standards at the country level with sample size of ninety-six (96) countries from 2011-2019. For the empirical estimation, we applied probit regression to analyse the reach of the certification across countries, and the negative binomial regression to analyse the intensity of diffusion. The findings show that infrastructural and institutional quality facilitate the ISO standard's diffusion. Countries with more developed energy sectors are more than expected to have a greater level of energy management certification. Furthermore, the diffusion of the certification is strongly affected by the geographic location of a country. The number of ISO-50001 certificates in a country is linked to the intensity of the certification in the neighbouring countries. We also found the neighbourhood effect measured in terms of distance-weighted corticates in other countries as a strong predictor of the diffusion process .

Keywords: Energy management; ISO-50001; Certification; Diffusion;
JEL Code: P18, P28. Q43, Q47, Q48

The diffusion of global standards on energy management techniques has increased substantially across the globe in the last two decades (Heras-Saizarbitoria & Boiral, 2013; Marimon et al., 2011). The geography of a country can also affects the diffusion of organizational innovation such as ISO certification. The ISO-50001, an energy management system in centred on the Continual improvement model that can use for other well-recognized standards i.e., ISO-9001 or ISO-14001 as well. It becomes easy for the organizations to incorporate energy management into their overall attempts to enhance quality and eco-friendly management (ISO, 2018). In 2015, all United Nations member counties adopted the 2030 agenda for Sustainable Development, which gives a collective plan for peace, harmony and affluence for the people and the planet. This plan draws 17 Sustainable Development Goals (SDGs) which are an imperative call for action by all developing and developed countries (UNDP, 2022). This standard contributes to the following Sustainable Development Goals: affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), and climate action (SDG 13) (ISO, 2018). Given the importance of energy management, 71 percent of municipalities in the European Union have obtained ISO 50001 certification (Kaselofsky et al., 2021). Similarly, ISO-50001

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certification has been proliferating in China as it has accrued more than half of the ISO 50001 certificates in Asia by 2018 (Jin et al., 2021).

The ISO-50001 certification was initiated in 2011. In the first year, there were 459 certificates in a total of 31 countries. Over the past years, the certification spread rapidly to 99 countries with a total of 18,209 certificates of the standard worldwide in 2019 - see Figure 1. With the modifications done by a few of the contributors of data about the number of sites, certificates and sectors, the aggregate number of legitimate certificates was lower than in 2017 (ISO, 2019). The ISO describes this in their 2018 Survey Report as "The overall total number of valid certificates was lower than in 2017 […]. Some large certification bodies reported in past surveys the number of certificates that included the number of sites. In this survey, they have split the number of certificates and the number of sites which led to important reduction in the number of certificates reported."

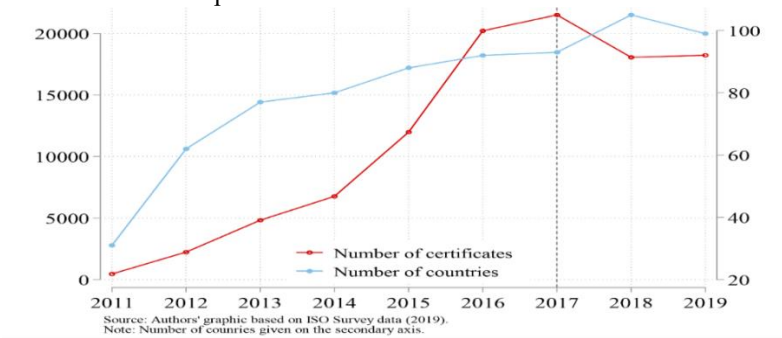

Figure 1- ISO-50001 diffusion over time

However, the spread of ISO-50001 certification across the world is rather uneven. In some countries, the incidence of certification is high. The top countries with a high incidence of the certification include Germany (5,786), China (2,934), the United Kingdom (1,184), Italy (1,150), and France (812). Alternatively, in some countries, the number of ISO-50001 certificates is as low as only 1 certificate in each Guatemala, Kenya, Lebanon, Monaco, Senegal, and Zimbabwe, as of 2019. Figure 2 shows the uneven spread of ISO-50001 certification across the world.

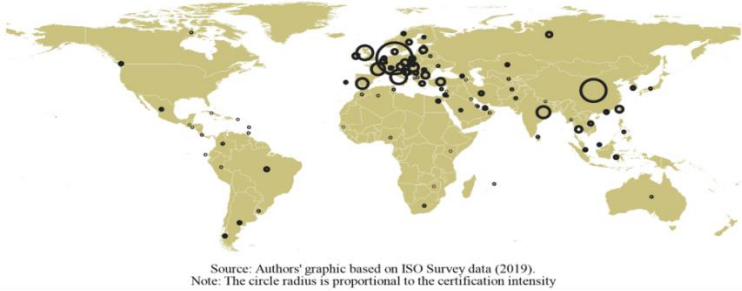

Figure 2- Uneven spread of ISO-50001 certification across the world[1]

[1] The location of each circle is based on the latitude and longitude values whereas the circle radius is proportionate to the number of ISO-50001 certificates in the country in 2019.

The current study aims to examine the uneven spread of the Energy Management Standard certification across countries. As the ISO-500001standard is launched recently, the existing literature on the standard is rather scant. To the best of our understanding, there is only one research by Sousa Lira et al., (2019) that looked into cross-country diffusion of the energy management certification. However, the study covers a sample of 12 countries over the period 2011-2016. We analyzed the number of ISO-50001 certificates in 96 countries over the period 2011-2019. We particularly focused on the neighbourhood effect. The outcomes of the present study show that the incidence of the certification in neighbouring countries is a strong predictor of the diffusion. While the diffusion process depends upon the characteristics of the energy sector, better institutional quality and strength of available infrastructure.

The remainder of the article is designed as; Section 2 describes literature review on the diffusion process. The theoretical framework, estimation approach, and data are discussed in Section 3. Next, Section 4 offers the results of the t-test, probit regression, and the negative binomial regression. Finally, the study concludes in Section 5.

Diffusion of organizational innovation

A big set of literature is available on the diffusion of standards. Certification schemes like ISO certification is considered as organizational innovations (Ryan & Gross, 1943). Standards improve competency (Bansal & Bogner, 2002) and help in improving operational performance and greater customer satisfaction. Several studies analyse the global diffusion of ISO standards (Albuquerque et al., 2007; Nishitani, 2010) which find that diffusion of certification is deterministic to various country-level factors including bilateral trade, cultural and historical relationships such as colonial ties, economic and governance level of a country. The contagion effect of the past adoption of certification in a country is measured through certified firms existing in the country. Similarly, the gross domestic product of a country reflects the potential for the magnitude of certification (Albuquerque et al., 2007). In the following, first we review some important studies pertaining to the diffusion of ISO-9000 and ISO-14000 standards. Later, we discuss the literature particularly associated to the diffusion of ISO-50001 certification.

Several studies investigate the diffusion of ISO-9000 and ISO-14000 certifications. For instance, Albuquerque et al., (2007) compared the diffusion of ISO-9000 and ISO-14000 certifications. The study discovers the diffusion of ISO 9000 is mainly determined by geography and joint trade relationships, but ISO 14000 is mainly determined by the geography and cultural similarities. Likewise, the diffusion rate of ISO standards is greater for later — implementing nations and the later ISO 14000 standard. One of the acknowledged objectives in the wake of the creation of the International Organization for Standardization was to build standards to accelerate global businesses in goods and services. Franceschini et al., (2010) used the single linkage clustering algorithm to examine the diffusion of ISO certificates in Europe. European nations were found to differ in forms of ISO-9000 certification diffusion in terms of saturation, growth, rate of decline in the certification. In this regard, a recent study by Hikichi et al., (2017) examines the development of ISO 14001 in the American nations and as well as its economic zones. The study revealed that the number of ISO 14001 certifications has steadily expanded on the continent, but unequally amongst its countries. The number of ISO 9001 certifications stays greater than the ISO 14001, but the difference among them is declining at the country level.

While earlier researchers briefly described the diffusion procedure of these standards among sectors of activity, some studies investigate the process of diffusion at the sectoral level. For example, Corbett, (2008) find the impact ISO 9000 on diffusion and find that exporting firms may concurrently be importing the management practices of importing countries. Llach et al., (2011) examine the development of the global diffusion of ISO 9000 standard specific to activities of industrial sectors. Based on the ISO survey data from 1998 to 2008, they analysed diffusion in relations of specific manufacturing sectors to measure the discrepancy of diffusion among different sectors of activity. Their results shows that the diffusion of ISO 9001 exhibit a logistic curve in all sectors, though the existing phase of diffusion (in terms of the preliminary, growth, and saturation phases respectively) varies among distinct areas of action. These sectors have been categorized into three units based on their potential future progress. Similarly, Marimon et al., (2011) examine that there are models of diffusion of the ISO-14001 standard that are unusual in particular areas of economic activity. The study was conducted by employing a logistic curve that comprehensively clarify the nature of this development, and uncertainty and concentration indices were computed to evaluate the development of the positions of the sectors joining the number of certifications ISO 14001. It accomplishes that the diffusion between areas is consistent: all areas have undergone related behaviour.

Among recent studies on the subject, Castka & Corbett, (2016) postulate that social and environmental standards could be more broadly implemented if they are well administered, less strict, and more positively cover up in the media. The writers gather data on 41 eco-labels from various data resources. The study finds that the better-governed brands are broadly accepted, however, strict labels within the sample have less wide acceptability. More promising media exposure is not linked with broader adoption. Although the diffusion of ISO certification had been studied extensively, a more recent work by Rodriguez-Arnaldo and Martínez-Lorente, (2021) looks into the matter in a newer way. This study analysed the impact of six factors on ISO-9001 execution: exporting to Europe, economic growth, innovation, repute, business sophistication and competitiveness. Based on the data for the period 2009-2018, their findings reveal a robust positive association for the nation's economic growth only when nations with lower incomes are judged. In case of developed countries, a negative but significant relationship is realized for reputation, competitiveness, business sophistication and innovation, while the results are reversed when considering the less developed countries.

There are comparatively fewer studies on the diffusion of the ISO-50001, the energy management standard of the ISO. The primary reason is that the standard commenced in 2011, which is much more recent as compared to ISO-9000, ISO-14000, and several other standards. Non-renewable energies are the planet's primary resource of energy. Nevertheless, the decline in supply, enhanced demand, greater merchandise manufacturing expenditures, and harmful impacts on the ecosystem headed to the necessity to develop the ISO 50001 standard to employ the energy management system for enhancing energy productivity and decrease the greenhouse gases emission. As an early study, Rodriguez et al., (2015) aims at examining the early implementation of the ISO 50001 standard. The results enable the classification of ISO 50001 accredited companies and expect the advantages of the implementation of the standard. The conclusions established on the study have showed the benefits and motivations of the initial acceptance of ISO 50001. The three extremely important reasons to accept ISO 50001 were the internal factors for instance “increasing energy efficiency”, “developing energy awareness between employees” and “leader’s initiative”. It was determined that internal factors rather than external factors stimulate the application of ISO 50001.

Pertaining to ISO-50001 adoption at the company level, Fuchs et al., (2020) explored several motivations for the adoption of the energy management standard. According to this study, environmental sustainability, government incentives or rules and prevailing principles and objectives are the most repeatedly identified determinants. Though, the improvement in productivity, cost reduction, and operating developments are the leading advantages; the primary obstacle is lacking a culture of energy management. Similarly, Marimon & Casadesús (2017) examined the adoption of ISO-50001 certification at the firm level. They studied 87 Spanish firms to investigate the relations between the corporate motivations that lead organizations to develop the ISO 50001 certification. For the analysis, they applied exploratory factor analyses and structural equation modelling. The study shows that social obligations describe operational obstacles, which in turn impact operating advantages. Ecological factors are directly linked to ecological advantages. Organizational obstacles have a negative association with ecological and operational benefits. Operational complexities are associated to ecological and operational benefits.

Looking into the diffusion process at the cross-country level, Sousa et al. (2019) examine the diffusion of ISO-50001 certification covering 12 countries over the period 2011-2015. The study aims to explain the diffusion process against various country-level factors such as the existing level of ISO certification as well as characteristics of the energy sector e.g., energy creation from gas, coal, and oil resources; share of renewable energy production; and per capita energy use, among others. The study characterizes the diffusion procedure of the ISO 50001 standard across the globe and explored that what are the key aspects that define the adoption of energy management in the various regions of the world. Multiple regression model was employed for the certification numbers and environmental, societal, and economic parameters, energy mining and climate change. Thus, it was noted that Europe has the maximum number of ISO-50001 certifications and Asia is the quickest-developing region. Amongst the countries, the United Kingdom and Germany are those with the highest diffusion of ISO-50001, but China has been enhancing its diffusion with each year.

While there are benefits associated with the certification, compliance with ISO certification, nevertheless, requires additional cost which may act as a hindrance in the adoption process, particularly in the case of smaller firms. Incentive programs by governments can play a vital role in this regard. Reis et al., (2020) investigate the diffusion of the ISO-500001 standard by employing the system dynamics modelling method. It suggests an expansion of the diffusion model associated to market participant pressure, built on institutional theory. The findings demonstrated that monetary and economic incentives offered the most substantial influence on the overall number of certified industries. Large companies are the most pertinent sector for certification without supplementary policies, while smaller ones benefit substantially from incentive programs. This study reiterates the significance that participants have in fostering environmentally friendly standards and programs and extends valuable learnings on the procedures of embracing energy management systems.

Method

Conceptual framework

The cross-country diffusion of ISO-50001 certification can be demonstrated theoretically as any other organizational innovation, in such a way that the stated incidence of certification signifies the accumulated behaviour of logically acting manufacturers in the country. Let's assume a representative manufacturer, who intends at certification if discounted benefits exceed discounted costs of conformity. The cost associated with the adoption of a

standard includes various factors such as the creation of grading and cleanliness facilities or training of personnel, along with the modifications in the production procedure, e.g., documentation and water testing, and the cost of auditing, etc.

The adoption of a certification scheme can be studied at the firm level. In this regard, firm size, location, industrial sector, and several other factors can affect the adoption. However, there are country-level factors that are beyond the reach of individual managers. The current study investigates various country-level factors which affect the global spread of the ISO-50001 certificates. Accumulating all the manufacturers in single country and assessing acceptance among countries, produces between-country difference in factors outside the reach of individual companies. We identify five categories of prospective factors affecting the number of released certificates per country, as shown in Figure 3.

Literature shows that the overall inclination of certification affects the diffusion of new standards. The intensity of diffusion is related to the economic scale. That is, larger economies have a greater number of firms which is linked to the higher number of certificates in the country (Herzfeld et al., 2011; Rodriguez-Arnaldo & Martínez-Lorente, 2021). The diffusion process is also affected by a sectoral-specific condition (Llach et al., 2011). There is a body of literature related to the role of infrastructural and institutional quality and their role in the diffusion of diffusion (Berliner & Prakash, 2013; Orcos et al., 2018) Based on the literature, we develop a conceptual framework to explain the diffusion of ISO-50001 certification at the country level.

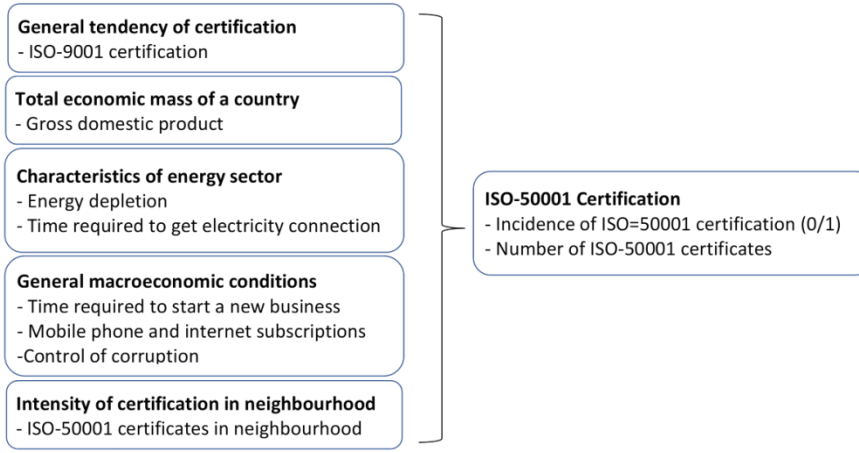

Figure 3- Conceptual framework for the country level diffusion process

The global spread of the ISO-50001 can be analysed in two forms. First, taking the incidence of certification in a country as a binary variable takes a value equal to 1 in case there is at least one producer with the ISO-50001 certification. In other words, the standard has diffused to that country. Second, taking the number of certified firms in that country measures the intensity of the diffusion process. In case the outcome takes the form of a binary variable, i.e., take value 1 when there is at least one certificate of ISO50001 and 0 otherwise, the probit model takes the form given in Equation (1).

$$Pr(Y = 1|X) = \Phi(\beta_0 + \beta_1 X) \quad (1)$$

In the equation, a vector of regressors X affects the probability of outcome Y, whereas Φ denotes the cumulative distribution function of the standard normal distribution. In this

way, we can estimate the impact of country-level variables on the probability of the incidence of ISO-50001 certification in a country.

Next, we analyse the impact of country-level factors on the intensity of certification in a country. Instead of the binary variable, the dependent variable, in this case, is the number of ISO-50001 certificates in a country. As the dependent variables are count data, and non-negative integers, hence we opt for a count data estimator. In the case of count data, Poisson and negative binomial estimators are generally superior to OLS estimators (Winkelmann, 2008). Poisson distribution assumes that mean and variance are equal. However, the variance surpasses the mean in case of over dispersion, while in comparison with the Poisson model, a negative binomial model is more suitable. Moreover, the negative binomial estimator is capable of dealing with undetected heterogeneity in the deviation of the determined variable. The number of certificates can be explained by following negative binomial model.

$$\Pr(Y_i = y_i|x, \alpha) = \frac{\Gamma(y_i + \alpha)}{\Gamma(\alpha)y_i!}\frac{\exp(y_i x_i'\beta)\alpha^{\alpha}}{(\exp(x_i'\beta) + \alpha)^{y_i+\alpha}} \quad , y_i = 1, 2, 3, \ldots \tag{2}$$

Where y_i is the number of ISO-50001 certificates in country *i*, while *x* is a vector of predictors including a constant. β is a vector of parameters to be estimated. The observations are assumed to be independently distributed across countries.
All variables included in the analysis are tabulated along with their description and data sources in Table 1 below.

Table 1
Variable description and data sources

Variable	Description	Source
ISO-50001	Number of ISO-50001 certificates in a country	ISO Survey
ISO50Contiguity	As explained below	Constructed
ISO50Proximity	As explained below	Constructed
ISO-9001	Number of ISO-9001 certificates in a country	ISO Survey
GDP	Annual gross domestic product in US$	WDI
EDepletion	Adjusted savings: energy depletion (% of GNI)	WDI
EDays	Time required to get electricity (days)	WDI
BDays	Time required to start a business (days)	WDI
Mobile	Mobile cellular subscription per 100 people	WDI
Internet	Fixed broadband subscriptions per 100 people	WDI
CCRank	Control of corruption rank (1=lowest to 10=highest)	WGI
D1819	Takes value 1 for years 2018 and 2019, zero otherwise	Constructed

To estimate the impact of the geographic neighbourhood, we formulated two variables as given below.

$$\text{ISO50Contiguity}_{it} = \sum_j \text{ISO50}_j \text{ where } j \text{ shares border with } i \tag{3}$$

$$\text{ISO50Proximity}_{it} = \sum_j \frac{\text{ISO50}_{jt}}{\text{Distance}_{ij}} \text{ where } j \neq i \tag{4}$$

We formulate the variable *ISO50Contiguity* to capture the neighbourhood effect in terms of the number of certificates in the neighbouring countries, whereas *ISO50Proximity* is

the distance weighted certificates in all other countries. The information on countries with shared borders and bilateral distance between them is taken from the French Institute Centre d'Etudes Prospectives et d'Informations (CEPII). Note that we estimated the equation for the full sample over the period 2011-2019 (96 countries × 9 years = 864 observations). To capture any effect specific to the procedural change in the ISO survey from 2018 onwards, we have included the dummy variable *D1819*. Nevertheless, we additionally estimate the specified models for the period 2011-2017 as a robustness check.

For the empirical estimation, we specify our probit model as follows.

$$\begin{aligned} \mathrm{dISO50001}_{it} = {} & \beta_0 + \beta_1 \ln(\mathrm{ISO50Contiguity})_{it-1} + \beta_2 \ln(\mathrm{ISO9001})_{it-1} \\ & + \beta_3 \ln(\mathrm{GDP})_{it-1} + \beta_4 \ln(\mathrm{EDepletion})_{it-1} \\ & + \beta_5 \ln(\mathrm{EDays})_{it-1} + \beta_6 \ln(\mathrm{BDays})_{it-1} + \beta_7 \ln(\mathrm{Mobile})_{it-1} \\ & + \beta_8 \ln(\mathrm{Internet})_{it-1} + \beta_9 \mathrm{CCRank}_{it-1} + \beta_{10} \mathrm{D1819}_t + \varepsilon_{ijt} \end{aligned} \quad (5)$$

$$\begin{aligned} \mathrm{dISO50001}_{it} = {} & \beta_0 + \beta_1 \ln(\mathrm{ISO50Proximity})_{it-1} + \beta_2 \ln(\mathrm{ISO9001})_{it-1} \\ & + \beta_3 \ln(\mathrm{GDP})_{it-1} + \beta_4 \ln(\mathrm{EDepletion})_{it-1} \\ & + \beta_5 \ln(\mathrm{EDays})_{it-1} + \beta_6 \ln(\mathrm{BDays})_{it-1} + \beta_7 \ln(\mathrm{Mobile})_{it-1} \\ & + \beta_8 \ln(\mathrm{Internet})_{it-1} + \beta_9 \mathrm{CCRank}_{it-1} + \beta_{10} \mathrm{D1819}_t + \varepsilon_{ijt} \end{aligned} \quad (6)$$

Note that the dependant variable *dISO50001* is a binary variable taking a value equal to 1 in case of at least one certified firm exists in a country, and 0 otherwise. In equation (5), we measure the neighbourhood effect through the variable $ISO50Contiguity$, which is the intensity of certification in the neighboring countries. Alternatively, the effect is measured as the distance-weighted certification in other countries, the variable $ISO50Proximity$.

For the negative binomial estimation, the specified region model is given in equations (7) and (8) below. In these models, the dependent variable ISO50001 is the count of certificates per country. In other words, it is a continuous variable consisting of non-negative integers.

$$\begin{aligned} \mathrm{ISO50001}_{it} = {} & \beta_0 + \beta_1 \ln(\mathrm{ISO50Contiguity})_{it-1} + \beta_2 \ln(\mathrm{ISO9001})_{it-1} \\ & + \beta_3 \ln(\mathrm{GDP})_{it-1} + \beta_4 \ln(\mathrm{EDepletion})_{it-1} \\ & + \beta_5 \ln(\mathrm{EDays})_{it-1} + \beta_6 \ln(\mathrm{BDays})_{it-1} + \beta_7 \ln(\mathrm{Mobile})_{it-1} \\ & + \beta_8 \ln(\mathrm{Internet})_{it-1} + \beta_9 \mathrm{CCRank}_{it-1} + \beta_{10} \mathrm{D1819}_t + \varepsilon_{ijt} \end{aligned} \quad (7)$$

$$\begin{aligned} \mathrm{ISO50001}_{it} = {} & \beta_0 + \beta_1 \ln(\mathrm{ISO50Proximity})_{it-1} + \beta_2 \ln(\mathrm{ISO9001})_{it-1} \\ & + \beta_3 \ln(\mathrm{GDP})_{it-1} + \beta_4 \ln(\mathrm{EDepletion})_{it-1} \\ & + \beta_5 \ln(\mathrm{EDays})_{it-1} + \beta_6 \ln(\mathrm{BDays})_{it-1} + \beta_7 \ln(\mathrm{Mobile})_{it-1} \\ & + \beta_8 \ln(\mathrm{Internet})_{it-1} + \beta_9 \mathrm{CCRank}_{it-1} + \beta_{10} \mathrm{D1819}_t + \varepsilon_{ijt} \end{aligned} \quad (8)$$

Table 2 shows the summary statistics of the variables involved in the analysis. It shows that the ISO-50001 certification ranges from 0 to 9024 certificates across countries with average of 113 certificates.

Table 2
Summary statistics

	(2)	(3)	(4)	(5)
Variables	**Mean**	**SD**	**Min**	**Max**
ISO-50001	113.1	611.5	0	9,024
ISO50Contiguity	3.805	6.266	0	66.26
ISO50Proximity	462.0	1,463	0	11,525
ISO-9001	9,420	33,771	0	393,008

GDP	6.866e+11	2.154e+12	1.377e+09	2.061e+13
EDepletion	3.803	7.025	2.77e-05	54.37
EDays	99.71	56.70	10	411.6
BDays	28.23	46.77	1.500	690
Mobile	1.074e+06	346,964	11,739	2.126e+06
Internet	119,168	124,591	21.58	437,705
CCRank	5.532	2.789	1	10

Results

Comparison of group means

To begin with, we present the comparison of mean values for the explanatory variables across the two groups using a t-test – see Table 3. The estimates show that the countries with ISO-50001 certification have a higher incidence of the certification in their neighbourhood. Similarly, the higher certification of quality standards (ISO-9001) is associated with a higher incidence of the energy management standard. Furthermore, the non-certified group of countries performs worse, on average, in terms of energy depletion conditions. In the noncertified countries, it takes roughly 15 days more to get the electricity connection compared to the mean number of days for the same task in the countries with certification. Similarly, in the countries with certification, it takes around 21 days, on average, to start a business. The time for the same take is around 38 days in the non-certified group. Looking at the variables related to the quality of infrastructure and institutions, it is clear that the countries with better infrastructure and intuitional quality have the incidence of ISO-50001 certification.

Table 3

Comparison of group means using t-test

	(1)	(2)	(3)
Variables	**Certified**	**Non-certified**	**Differences**
ISO50Contiguity	725.1	100.7	624.4***
ISO50Proximity	5.5	1.5	4.0***
ISO-9001	14932.2	1849.3	13082.9***
GDP	1.1e+12	1.5e+11	9.2e+11***
EDepletion	2.1	6.1	–4.0***
EDays	93.4	108.4	–15.1***
BDays	20.5	38.8	–18.3***
Mobile	1201777.7	899651.5	302126.2***
Internet	178496.9	37671.2	140825.7***
CCRank	6.7	3.9	2.9***

Diffusion probability analysis

Table 4 presents the estimates of Probit regression where the certification is treated as a binary variable. That is, the variable *dISO50001* takes a value of 1 when the certification exits in a country, and 0 otherwise. Estimations for the period 2011 to 2019 are reported under Colum (1) and (2) whereas Columns (3) and (4) present estimates of the sub-sample for the first eight years 2011-2017. Note that the dependant variables are taken in lags. That means the country level conditions are assumed to affect the diffusion in the next time interval.

Table 4
Diffusion of ISO50001 certification: Diffusion probability

	Dependent variable: ISO-50001 certification (0/1)			
	Period: 2011-2019		Time Period: 2011-2017	
VARIABLES	(1)	(2)	(3)	(4)
$\ln(ISO50Contiguity)_{it-1}$	0.480***		0.494***	
	(0.108)		(0.111)	
$\ln(ISO50Proximity)_{it-1}$		1.391***		1.338***
		(0.230)		(0.204)
$\ln(ISO\text{-}9001)_{it-1}$	0.316**	0.307**	0.221	0.242**
	(0.158)	(0.136)	(0.158)	(0.112)
$\ln(GDP)_{it-1}$	0.502**	0.470***	0.549**	0.482***
	(0.195)	(0.161)	(0.226)	(0.157)
$\ln(EDepletion)_{it-1}$	-0.175**	-0.114**	-0.165**	-0.105*
	(0.071)	(0.055)	(0.080)	(0.054)
$\ln(EDays)_{it-1}$	-0.353	-0.261	-0.421	-0.291
	(0.340)	(0.278)	(0.369)	(0.247)
$\ln(BDays)_{it-1}$	0.257	0.206	0.258	0.210
	(0.269)	(0.202)	(0.238)	(0.151)
$\ln(Mobile)_{it-1}$	0.479	0.205	0.648	0.196
	(0.631)	(0.412)	(0.758)	(0.337)
$\ln(Internet)_{it-1}$	-0.138	-0.071	-0.047	-0.002
	(0.106)	(0.085)	(0.111)	(0.089)
$CCRank_{it-1}$	0.294***	0.234***	0.263***	0.221***
	(0.102)	(0.084)	(0.094)	(0.067)
$D1819_t$	0.454**	-0.097		
	(0.231)	(0.200)		
Constant	-21.761*	-17.615**	-25.144*	-17.867***
	(11.224)	(8.363)	(14.115)	(6.737)
N	864	864	672	672
Countries	96	96	96	96

Note: Robust standard errors presented in parentheses. ***, **, shows Statistical significance at $p<0.01$, $p<0.05$ and $p<0.1$ respectively.

Diffusion intensity analysis

Next, we analyse the intensity of the certification of energy management standards at the country level using the negative binomial regression. The results are displayed in Table 5. The first two columns report the estimates of the full sample where we have estimated the impact of contiguity and proximity parameters. However, the last time two columns report the estimations of the subsample for the period 2011-2017. The dependent variable is the number of ISO-50001 certificates in a country. These estimates corroborate with the earlier estimation using the probit model.

Table 5

Diffusion of ISO50001 certification: Diffusion intensity

	Dependent variable: ISO50001 Certification (Counts)			
	Time period: 2011-2019		Time period: 2011-2017	
Variables	(1)	(2)	(3)	(4)
$\ln(\text{ISO50Contiguity})_{it-1}$	0.319***		0.335***	
	(0.019)		(0.021)	
$\ln(\text{ISO50Proximity})_{it-1}$		0.901***		0.910***
		(0.044)		(0.046)
$\ln(\text{ISO-9001})_{it-1}$	-0.037	-0.021	-0.050	0.036
	(0.066)	(0.069)	(0.083)	(0.085)
$\ln(\text{GDP})_{it-1}$	0.273***	0.334***	0.320***	0.337***
	(0.069)	(0.071)	(0.085)	(0.084)
$\ln(\text{EDepletion})_{it-1}$	-0.127***	-0.029	-0.138***	-0.041
	(0.026)	(0.027)	(0.032)	(0.032)
$\ln(\text{EDays})_{it-1}$	-0.424***	-0.239**	-0.607***	-0.300**
	(0.093)	(0.095)	(0.129)	(0.129)
$\ln(\text{BDays})_{it-1}$	-0.082	0.023	-0.237**	0.048
	(0.077)	(0.078)	(0.100)	(0.098)
$\ln(\text{Mobile})_{it-1}$	0.879***	1.002***	1.584***	1.308***
	(0.237)	(0.239)	(0.287)	(0.287)
$\ln(\text{Internet})_{it-1}$	0.125*	0.194***	0.060	0.173**
	(0.071)	(0.074)	(0.086)	(0.082)
CCRank_{it-1}	0.016	0.008	0.000	0.048
	(0.036)	(0.035)	(0.044)	(0.039)
$D1819_t$	0.067	-0.185***		
	(0.061)	(0.061)		
Constant	-19.580***	-24.566***	-28.456***	-29.265***
	(3.924)	(3.972)	(4.838)	(4.819)
N	864	864	672	672
Countries	96	96	96	96

Note: Robust standard errors presented in parentheses. ***, **, shows Statistical significance at $p<0.01$, $p<0.05$ and $p<0.1$ respectively.

Discussion

Our study explores the neighbourhood effect on diffusion of ISO 50001 — energy management standards across 96 countries of the world. It explores that Contiguity — neighbourhood effect in terms of the number of certificates in the neighbouring countries and Proximity — distance weighted certificates in all other countries have positive and statistically significant effect on the adoption and intensity of certification of ISO 50001 in the neighbouring countries.

It is noticeable that the ISO-9001 certification does not have any impact on the intensity of the ISO-50001 certification. In connection to the probit regression, the ISO-9001 certification only affects the probability of ISO-50001 certification, not the intensity of the latter. Looking at the other variables, the coefficient for the variable GDP shows a higher incidence of certification in larger economies – the scale effect (Castka & Corbett, 2016; Herzfeld et al., 2011; Rodriguez-Arnaldo & Martínez-Lorente, 2021).

The diffusion process is also evident to be affected by the characteristics of the energy sector. energy depletion conditions prevailing in a country are negatively related. Sousa Lira et al., (2019) found a similar negative effect for this variable. Countries with a more developed energy sector (as captured by the number of days required to get electricity) are more like to have intensive diffusion of the ISO-50001 certification. Similarly, the longer time needed to begin a business is negatively related to the diffusion process. Pertaining to infrastructure, we see that development in terms of communication facilitates the diffusion process. Similarly, intuitional quality is evident to foster the diffusion of ISO-50001 certification. The dummy for the years 2018 and 2019, *D1819*, has a negative coefficient in the negative binomial regression which implies the intensity of certification decreased in the years 2018 and 2019. The coefficient for the same variable is negative in the case of probit regression above showing the diffusion of ISO-50001 standard to newer countries. Collectively, this means the number of certificates decreased (due to the procedural change in the ISO survey) while the diffusion to more countries continued. These findings corroborate with the ISO-50001 certification visualized in Figure 1.

Conclusions

Governments and firms pursue to develop technologies for energy management as the energy sources around the world are becoming scarcer with increasing prices. Therefore, optimization of electricity use and improvement in energy efficiency has become crucial for firms. Given this, organizations be likely to implement ISO 50001 in all operational and organizational form. ISO 50001 aids small and large organizations to get the maximum efficiency of the energy generated and enhance the permanence of organizations in public or private sectors. However, the incidence of ISO-50001 certification is rather uneven across the globe. This study examines the uneven spread of ISO-50001 standards at the country level with sample size of ninety-six (96) countries from 2011-2019. For the empirical estimation, we applied probit regression to analyse the reach of the certification across countries, and the negative binomial regression to analyse the intensity of diffusion.

The cross-country level spread can be explained by two types of factors. The first group includes factors that a country cannot change. For instance, a country cannot change its history and geography. We find that the diffusion of the certification is strongly affected by the geographic location of a country. The number of ISO-50001 certificates in a country is connected to the intensity of the certification in the neighbouring countries. We also found the neighbourhood effect measured in terms of distance-weighted corticates in other countries as a strong predictor of the diffusion process. Furthermore, the contagion effect of the past adoption of certification is an important factor. Similarly, the gross domestic product of a country reflects the potential for the magnitude of certification – the scale effect.

Apart from these factors, the diffusion process is affected by the macroeconomic situations prevalent in the country. The findings show that infrastructural and institutional quality facilitate the diffusion of the ISO standard. Control of corruption help to preserve the incentive for certification. Mobile and internet communication facilitate the diffusion of knowledge and thus foster the diffusion process. Countries with a more developed energy sector are more likely to have a higher level of energy management certification. Therefore, governments should improve the sectoral condition as well as develop infrastructure to encourage the diffusion of ISO-50001 certification. Consequently, this would contribute to improvement in energy management across the globe.

Appendix A

List of countries included in the analysis:

Afghanistan	Czech Republic	Kuwait	Russian Federation
Albania	Denmark	Kyrgyzstan	Saudi Arabia
Algeria	Ecuador	Libya	Senegal
Angola	Egypt	Lithuania	Slovakia
Argentina	Equatorial Guinea	Malawi	Slovenia
Austria	Estonia	Malaysia	South Africa
Azerbaijan	France	Mexico	South Korea
Bangladesh	Gabon	Moldova	Spain
Belarus	Georgia	Mongolia	Sudan
Belize	Germany	Morocco	Suriname
Bolivia	Ghana	Mozambique	Swaziland
Bosnia and Herzegovina	Greece	Myanmar	Tajikistan
Botswana	Guatemala	Nepal	Tanzania
Brazil	Hungary	Netherlands	Thailand
Brunei Darussalam	India	Niger	Tunisia
Bulgaria	Indonesia	Nigeria	Turkey
Cameroon	Iran	Norway	Ukraine
Canada	Iraq	Oman	United Arab Emirates
Chad	Ireland	Pakistan	United Kingdom
Chile	Israel	Papua New Guinea	United States of America
China	Italy	Peru	Uzbekistan
Colombia	Ivory Coast	Poland	Viet Nam
Congo	Jordan	Qatar	Zambia
Croatia	Kazakhstan	Romania	Zimbabwe

References

Albuquerque, P., B.J.J.A.M., B., & Ch.J., C. (2007). A spatiotemporal analysis of the global diffusion of ISO 9000 and ISO 14000 certification. *Management Science*, *53*(3), 451–468. https://doi.org/10.1287/mnsc.1060.0633

Bansal, P., & Bogner, W. C. (2002). Deciding on ISO 14001: Economics, Institutions, and Context. *Long Range Planning*, *35*(3), 269–290. https://doi.org/10.1016/S0024-6301(02)00046-8

Berliner, D., & Prakash, A. (2013). Signaling Environmental Stewardship in the Shadow of Weak Governance: The Global Diffusion of ISO 14001. *Law and Society Review*, *47*(2), 345–373. https://doi.org/10.1111/LASR.12015

Castka, P., & Corbett, C. (2016). Adoption and diffusion of environmental and social standards: The effect of stringency, governance, and media coverage. *International Journal of Operations and Production Management*, *36*(11), 1504–1529. https://doi.org/10.1108/IJOPM-01-2015-0037/FULL/HTML

Corbett, C. J. (2008). Global diffusion of ISO 9000 certification through supply chains. *International Series in Operations Research and Management Science*, *119*, 169–199. https://doi.org/10.1007/978-0-387-75240-2_7/COVER

Franceschini, F., Galetto, M., Maisano, D., & Mastrogiacomo, L. (2010). Clustering of European countries based on ISO 9000 certification diffusion. *International Journal of Quality and Reliability Management*, *27*(5). https://doi.org/10.1108/02656711011043535

Fuchs, H., Aghajanzadeh, A., & Therkelsen, P. (2020). Identification of drivers, benefits, and challenges of ISO 50001 through case study content analysis. *Energy Policy*, *142*, 111443. https://doi.org/10.1016/J.ENPOL.2020.111443

Heras-Saizarbitoria, I., & Boiral, O. (2013). ISO 9001 and ISO 14001: Towards a Research Agenda on Management System Standards*. *International Journal of Management Reviews*, *15*(1), 47–65. https://doi.org/https://doi.org/10.1111/j.1468-2370.2012.00334.x

Herzfeld, T., Drescher, L. S., & Grebitus, C. (2011). Cross-national adoption of private food quality standards. *Food Policy*, *36*(3), 401–411. https://doi.org/10.1016/J.FOODPOL.2011.03.006

Hikichi, S. E., Salgado, E. G., & Beijo, L. A. (2017). Characterization of dissemination of ISO 14001 in countries and economic sectors in the Americas. *Journal of Environmental Planning and Management*, *60*(9), 1554–1574. https://doi.org/10.1080/09640568.2016.1240070

ISO. (2018). *ISO - ISO 50001:2018 - Energy management systems — Requirements with guidance for use*.

ISO. (2019). *The ISO Survey of Management System Standard Certifications – 2018 – Explanatory Note*. .

Jin, Y., Long, Y., Jin, S., Yang, Q., Chen, B., Li, Y., & Xu, L. (2021). An energy management maturity model for China: Linking ISO 50001:2018 and domestic practices. *Journal of Cleaner Production*, *290*. https://doi.org/10.1016/j.jclepro.2020.125168

Kaselofsky, J., Roš¯, M., Jekabsone, A., Favre, S., Loustalot, G., Toma, M., Pablo, J., Marín, D., Nicolás, M. M., & Cosenza, E. (2021). Getting Municipal Energy Management Systems ISO 50001 Certified: A Study with 28 European Municipalities. *Sustainability*, *13*(3638). https://doi.org/10.3390/su13073638

Llach, J., Marimon, F., & Bernardo, M. (2011). ISO 9001 diffusion analysis according to activity sectors. *Industrial Management and Data Systems*, *111*(2). https://doi.org/10.1108/02635571111115191

Marimon, F, & Casadesús, M. (2017). Reasons to adopt ISO 50001 energy management system. *Sustainability*, *9*(10), 1740. https://doi.org/10.3390/su9101740

Marimon, Frederic, Llach, J., & Bernardo, M. (2011). Comparative analysis of diffusion of the ISO 14001 standard by sector of activity. *Journal of Cleaner Production*, *19*, 1734–1744.

Nishitani, K. (2010). Demand for ISO 14001 adoption in the global supply chain: An empirical analysis focusing on environmentally conscious markets. *Resource and Energy Economics*, *32*(3). https://doi.org/10.1016/j.reseneeco.2009.11.002

Orcos, R., Pérez-Aradros, B., & Blind, K. (2018). Why does the diffusion of environmental management standards differ across countries? The role of formal and informal institutions in the adoption of ISO 14001. *Journal of World Business*, *53*(6), 850–861. https://doi.org/10.1016/J.JWB.2018.07.002

Reis, C., Benvenutti, L., … L. C.-B. B. B., & 2020, undefined. (n.d.). The Influence of Company Size on Energy Management Systems Adoption: A System Dynamics Model. *SciELO Brasil*.

Rodriguez-Arnaldo, O., & Martínez-Lorente, A. R. (2021). What determinants influence the diffusion of ISO 9001 by countries? *TQM Journal*, *33*(1), 223–246. https://doi.org/10.1108/TQM-03-2020-0055/FULL/HTML

Ryan, B., & Gross, N. (1943). The diffusion of hybrid seed corn in two Iowa communities. *Rural Sociology*, *8*(1), 15–24.

Sousa Lira, J. M., Salgado, E. G., & Beijo, L. A. (2019). Which factors does the diffusion of ISO 50001 in different regions of the world is influenced? *Journal of Cleaner Production*, *226*, 759–767. https://doi.org/10.1016/J.JCLEPRO.2019.04.127

UNDP. (2022). *Sustainable Development Goals | United Nations Development Programme*.

Winkelmann, R. (2008). *Econometric analysis of count data*.

Wulandari, M., Laskurain, I., Fa, M. C., & Heras-Saizarbitoria, I. (2015). *Early Adoption of ISO 50001 Standard: An Empirical Study*. 183–202. https://doi.org/10.1007/978-3-319-14002-5_9