Received on: 12 November 2024 **Revised on: 15 January 2025** **Published: 30 March 2025**

RESEARCH ARTICLE
DOI: 10.47703/ejebs.v69i1.477

The Influence of Economic and Environmental Factors on the Adoption of Responsible Production Standards

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How to cite this article:
Zhidebekkyzy, A. & Amangeldiyeva, B. (2025). The Influence of Economic and Environmental Factors on the Adoption of Responsible Production Standards. Eurasian Journal of Economic and Business Studies, 69(1), 97-110.

Conflict of interest:
author(s) declare that there is no conflict of interest

ABSTRACT

In the context of global sustainability challenges, understanding the determinants of environmental management standard adoption has become increasingly relevant. This study aims to investigate the impact of economic and ecological factors on the adoption of ISO 14001 certifications in five selected countries: China, Germany, Japan, Sweden, and the United States. Utilizing a fixed-effects panel regression model, the research analyzes longitudinal data from five countries over the period 2012–2022. Data were sourced from the World Bank, International Energy Agency, Global Carbon Atlas, and ISO survey reports. The results indicate that GDP per capita positively impacts the number of certifications ($p < 0.01$), suggesting that higher economic resources are associated with an increase in the adoption of environmental standards. Additionally, CO2 emissions show a strong positive correlation ($p < 0.01$), indicating that more significant environmental pressure encourages the adoption of certification. The proportion of renewable energy demonstrates a conditionally significant effect ($p < 0.05$), highlighting the need for further research. These findings confirm that environmental concerns and economic capacity contribute to adopting sustainable production practices. The study emphasizes the crucial role of economic affluence and environmental priorities in promoting responsible production standards. Future research should extend the analysis by incorporating institutional variables, policy incentives, and sector-specific dynamics to deepen understanding of ISO 14001 diffusion in heterogeneous economic environments.

KEYWORDS: Responsible Production, Environmental Sustainability, Sustainable Development, Renewable Energy, Green Economy, Economic Growth

SCSTI: 06.51.02

JEL Code: C33, Q56, L15

FINANCIAL SUPPORT: This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (grant No. AP19576593).

1. INTRODUCTION

Responsible production, considering minimal negative environmental impacts, is an increasingly important component in the sustainable development of the global economy. During an era of growing environmental concern and increased environmental awareness, international standards like ISO 14001 are instrumental to businesses seeking to improve their environmental performance. ISO 14001 is an internationally recognized standard developed by the International Organization for Standardization (ISO) that aims to establish effective environmental management systems and improve the environmental performance of companies (ISO, 2024).

Various factors are influential in implementing standards, such as ISO 14001. Economic factors, such as GDP per capita, become important since a country with a higher income can invest more in environment-friendly technologies and standards. More developed economies can establish conditions to effectively enforce environmental standards and promote sustainable production (Delmas & Montes-Sancho, 2011). Apart from economic factors, environmental performance significantly influences the adoption of responsible production standards. Countries with high greenhouse gas emissions are under pressure from international organizations and domestic legislation to implement standards to reduce environmental impacts. Additionally, using renewable energy is a crucial indicator of environmental sustainability, affecting the implementation of ISO 14001. However, while many studies have focused on adopting ISO 14001 in specific countries or industries, limited attention has been given to comparative, cross-country analysis of the factors that drive ISO 14001 certification on a global scale. The existing literature does not comprehensively understand how economic and environmental factors interact across countries with different economic structures and environmental policies. This study aims to fill this gap by conducting a cross-country analysis, examining developed and developing economies to understand the global drivers of responsible manufacturing standards (Daddi et al., 2015; Casadesús et al., 2008).

The selected countries - China, Germany, Japan, Sweden, and the United States - are world leaders in industrial and environmental initiatives, making them ideal for exploring the adoption of responsible production standards such as ISO 14001. Each country demonstrates a different approach to balancing economic growth with environmental responsibility. Developed economies such as Germany, Sweden, and Japan have a long history of implementing strict environmental regulations and promoting corporate sustainability. China faces growing environmental challenges as a rapidly industrializing country but has made significant strides in adopting responsible production practices in recent years. The United States, although home to many forward-thinking companies, has varying levels of commitment to environmental standards influenced by regional policies and industrial sectors. This diverse context allows for a broad study of how economic and environmental factors contribute to adopting ISO 14001 in different regions.

This study aims to investigate the influence of economic and environmental factors on the number of ISO 14001 certifications in different countries. Implementing the ISO 14001 standard in various countries allows for examining the connection between economic growth, environmental accountability, and sustainable production. Thus, this study seeks to improve comprehension of how economic and environmental factors affect the progression of responsible production worldwide.

Thus, the research questions (RQ) are as follows:

RQ1: How do country-specific economic and environmental factors impact the adoption of ISO 14001 standards?

RQ2: To what extent do GDP per capita, renewable energy use, and greenhouse gas emissions drive the number of ISO 14001 certifications globally?

2. LITERATURE REVIEW

Recent literature highlights the growing importance of responsible production (RP) in manufacturing, emphasizing its role in minimizing negative environmental impacts while maintaining economic viability (Liu et al., 2021). Key factors influencing the successful implementation of RP practices include social responsiveness, legislation compliance, and economic performance (Yusup et al., 2014). Research on RP has seen significant growth, particularly in developing countries like China, with an increasing focus on its financial implications (Ziegler & Rennings, 2004). Studies generally indicate a positive correlation between environmental and economic performance. Environmental regulations have been found to improve environmental outcomes without necessarily compromising economic performance, though more research is needed to generalize these findings across different sectors and policy types (Dechezleprêtre et al., 2019). The literature emphasizes the importance of sustainable supply chains, consumer behavior, and Industry 4.0 in realizing RP principles (Liu et al., 2021).The implementation of responsible manufacturing standards, such as ISO 14001, has been widely studied in the context of sustainable development. ISO 14001, part of the ISO 14000 family, is the most prominent international standard for environmental management systems (EMS). It provides a framework for companies to manage their environmental responsibilities systematically (ISO, 2024).

2.1 Economic factors and ISO 14001 certification

Economic development is a key determinant in the adoption of responsible manufacturing standards. Higher-income levels generally allow countries to invest in new technologies, research and development (R&D), and more sustainable production practices. Casadesús et al. (2008) found that countries with higher GDP per capita tend to have more ISO 14001 certifications, suggesting a direct relationship between economic affluence and environmental responsibility. Daddi et al. (2015) found that firms in countries with higher GDP were more likely to pursue ISO 14001 certification.

The review indicates that ISO 14001 certification positively correlates with national economic factors and corporate performance. Studies have found that GDP per capita, foreign direct investment, and exports to Europe and Japan are positively associated with ISO 14001 adoption rates across countries (Neves et al., 2017). At the organizational level, ISO 14001 implementation has been linked to improved financial performance, with certified companies showing higher sales returns than non-certified counterparts. The standard appears to significantly impact globally oriented firms significantly, enhancing their innovation capabilities and environmental commitment (Grandic, 2017). Additionally, research suggests that national macroeconomic indicators, particularly GDP, influence the number of ISO 14001 certifications within EU member states (Črv, 2021). These findings highlight the interconnected relationship between economic factors, environmental management systems, and corporate performance in the context of ISO 14001 implementation.

However, economic growth has not been found to be a driver of adopting ISO 14001. A study by Sarkis et al. (2010) discovered that in as much as economic resources play an important role, governments' policies and institutional frameworks can also play equally important roles. In those countries where the governments offer incentives, tax breaks, or subsidies for adopting sustainable practices, the rating of ISO 14001 certifications turns out higher, regardless of the nation's GDP per capita.

2.2 Environmental factors and ISO 14001 certification

Research shows that environmental factors are most influential in ISO 14001 certification.

Environmental pressures such as CO2 emissions and fossil fuel consumption have been considered the driving factors for introducing ISO 14001 in the American continent (Hikichi et al., 2017). Internalization of ISO 14001 acts as a mediating agent between certification and environmental performance, and internal motivation is the crucial driving force for this process (Qi et al., 2012). Companies' decision to pursue ISO 14001 certification is frequently driven by ethical and competitive motivations (Benito & González-Benito, 2005). In developing countries, environmental pressures and trade openness positively impact the adoption of ISO 14001, although the relationship varies across regions (Liu et al., 2019). These findings highlight the complex interactions between environmental factors, economic considerations, and ISO 14001 certification, underscoring the standard's importance in addressing environmental issues and encouraging sustainable practices across various contexts.

Various studies exist on the relationship between renewable energy and ISO 14001 certification. ISO 14001 certification reduces CO2 emissions in SAARC nations and renewable energy consumption (Ikram et al., 2020). In addition, in the BRICS, MINT, and G7 economies, ISO 14001 has the potential for greener growth, while renewable energy cleans carbon emissions in most blocs (Ofori et al., 2024). The integration of ISO 50001 (energy management) with ISO 14001 (environmental management) can be beneficial for companies, as there are strong compatibilities between the two standards (Uriarte-Romero et al., 2017). This integration can lead to energy savings and improved environmental performance. Furthermore, ISO 14001 has been found to support sustainable development, particularly in contexts where legal enforcement mechanisms are weak (Fortuński, 2008).

Environmental factors, especially the proportion of renewable energy in a country's total energy consumption, significantly influence the adoption of ISO 14001 standards (Daddi et al., 2015). Countries investing heavily in renewable energy tend to show a stronger commitment to sustainability, which is evident in their industrial practices. Renewable energy reflects a nation's overall environmental priorities and can promote the adoption of responsible manufacturing standards as part of a comprehensive sustainability agenda.

Besides the positive impact on reducing greenhouse gas emissions, renewable energy favours an environment where industries can align with international environmental standards. Delmas and Montes-Sancho (2011) also said that "environmental regulation, along with a high level of production of renewable energies, is positively correlated to the adoption of ISO 14001, as this acts as a market inducement for industries to align themselves according to environmental standards".

The literature review confirmed that economic and environmental factors are crucial in implementing environmentally sound manufacturing standards, such as ISO 14001. It has been confirmed in prior research that GDP per capita positively correlates with the number of certifications since more developed economies have a greater capacity to invest in environmental standards. The impact of renewable energy on the implementation of standards is conditionally significant and requires further analysis. Additionally, high levels of greenhouse gas emissions compel companies and governments to implement green standards.

Despite recent scientific advances, knowledge gaps regarding cross-country differences and the long-term effects of such factors exist. This study aims to bridge this gap by providing a comprehensive quantitative analysis of how economic and environmental factors influence the adoption of ISO 14001 and, in doing so, to gain further insights into the mechanisms of responsible production in various economic and institutional contexts.

3. RESEARCH METHODS

A panel regression analysis was conducted to examine the factors influencing the number of ISO 14001 certifications across five

countries such as China, Germany, Japan, Sweden, and the United State, during the period 2012–2022. The data were obtained from the World Bank (GDP per capita), the International Energy Agency (IEA) (share of renewable energy in total energy consumption), the Global Carbon Atlas (CO2 emissions), and the International Organization for Standardization (ISO) (number of ISO 14001 certifications). These countries were chosen due to their significance in the global economy and diverse environmental responsibility approaches. They represent varying levels of economic development and energy consumption patterns, encompassing developed economies with high GDP per capita (e.g., Germany, Japan, USA) and emerging economies like China.

Additionally, the sample includes countries with different shares of renewable energy sources, allowing for an investigation into the impact of environmental policies and greenhouse gas emission levels on ISO 14001 certification. This approach ensures the study's representativeness and contributes to more generalized conclusions about the relationship between economic and environmental factors and the level of implementation of environmental standards.

Based on the research objective and analysis, three hypotheses have been formulated:

H1: GDP per capita positively affects the number of ISO 14001 certifications.

Previous studies confirm a positive relationship between GDP per capita and the number of ISO 14001 certifications. More developed countries are more likely to adopt environmental management standards because of their ability to invest in environmental technologies and growing environmental awareness (Neumayer & Perkins, 2004; Sam & Song, 2022). Economic development is also increasing pressure from civil society and environmentally oriented export markets to increase the adoption of standards (McGuire, 2014).

H2: The increasing share of renewable energy in total energy consumption contributes to the growing number of ISO 14001 certifications.

Studies show that an increasing share of renewable energy positively impacts adopting ISO 14001 certification (Ikram et al., 2020; Ofori et al., 2024). The shift to renewable energy contributes to the broader adoption of environmental management standards, especially in developed countries where support for sustainable practices is more pronounced (Garrido et al., 2020). These results emphasize the role of renewable energy in promoting responsible production and sustainable development.

H3: Higher greenhouse gas (CO2) emissions lead to more ISO 14001 certifications.

It has been revealed that high levels of CO2 emissions encourage the adoption of ISO 14001 as a measure to reduce environmental impacts. Sam and Song (2022) found that ISO 14001 certification significantly reduced carbon dioxide emissions among certified manufacturing companies in South Korea. McGuire (2014) also observed a methane and CO2 emissions reduction due to certification. However, Garrido et al. (2020) emphasize that the effect of ISO 14001 implementation varies according to national conditions, with a stronger impact in countries with high levels of ethical behavior of companies.

The analysis used data from reliable sources to cover economic and environmental indicators for China, Germany, Japan, Sweden, and the United States from 2012 to 2022.

The selection of variables was based on their significance in evaluating economic and environmental factors' influence on adopting ISO 14001 standards. GDP per capita is a critical economic indicator, as nations with higher GDP have more resources to invest in sustainable technologies and enforce environmental standards (Casadesús et al., 2008). The proportion of renewable energy

showcases a nation's dedication to environmental sustainability, and its growth contributes to an uptick in environmental certifications (Daddi et al., 2015). Greenhouse gas emissions are a crucial indicator of environmental pressures, and elevated emission levels prompt the implementation of standards to alleviate their impact (Testa et al., 2014).

The GDP per capita information was obtained from the World Bank and consists of countries' current and historical data. The share of renewable energies in total energy consumption emanates from the International Energy Agency data on energy sources, as well as the share that is renewable in electricity generation. GHG emissions include CO2 obtained from the Global Carbon Atlas database. Data on ISO 14001 certifications were obtained from ISO annual reports. These provide information on the number of ISO 14001 certifications issued in every country during each reporting period.

The main variables used in the study and their descriptive statistics are given in Table 1.

TABLE 1. Descriptive statistics

Variable	Obs. number	Mean	Std.dev.	Min	Max
Y, ISO 14001 certification number	55	36723.7	60960.1	2783.0	295501.0
X1, GDP per capita	55	42478.4	18944.1	6300.5	77246.6
X2, Share of renewable energy in total energy consumption	55	30.0	17.3	9.4	68.4
X3, GHG (CO_2) emissions	55	4014321.7	4622359.5	37850.0	12942868.0

Note: compiled by authors

Table 1 is the core of the study, as it indicates the main variables used in the regression analysis. It illustrates how various economic and environmental variables (independent variables) influence the adoption of responsible production standards, which is captured through the number of ISO 14001 certifications (dependent variable). The presented data also shows the descriptive statistics of the main variables included in the study: mean, standard deviation, and minimum and maximum values. This provides an overview of the general characteristics and distribution of data.

To ensure the robustness of the cross-country analysis, a comparative approach was employed in this study, analyzing the relationships between selected variables across five countries. The analysis was conducted to understand how economic and environmental factors, such as GDP per capita, the share of renewable energy, and CO2 emissions, affect the adoption of ISO 14001 certifications in China, Germany, Japan, Sweden, and the United States. The relevant data were collected for each country from 2012-2022, ensuring continuity and comparability of variables.

Background factors, including each country's level of industrialization, regulatory frameworks, and key environmental policies, were included to provide context for the quantitative findings. The study examined the differences and similarities in the economic and environmental contexts by employing panel regression analysis, providing insights into the dynamics specific to each country.

4. FINDINGS AND DISCUSSIONS

This section presents the key findings of a study examining economic and environmental factors impact on adopting responsible manufacturing standards (ISO 14001) across various countries. The first part presents a cross-country comparative analysis that examines the differences in regulatory frameworks, the level of ISO 14001 implementation, and the specifics of responsible manufacturing in the United States, Japan, China, Germany, and Sweden. The second part presents the results of a quantitative

analysis based on a panel regression model that assesses the impact of GDP per capita, the share of renewable energy, and CO_2 emissions on the number of ISO 14001 certifications. This approach helps identify patterns and determine the key factors contributing to responsible manufacturing standards' global adoption.

Table 2 illustrates the influence of national regulatory environments and innovative policies on adopting ISO 14001 in different countries.

TABLE 2. Results of the cross-country analysis

Country	Environmental regulations	ISO 14001 adoption	Key responsible production practices
USA	National Environmental Policy Act (1969), Energy Policy Act (2005)	Varies by state, with more substantial adoption in regions with stricter laws	GE focuses on energy efficiency, and Tesla integrates ISO 14001 in EV production
Japan	Act on the Promotion of Efficient Use of Resources (2000), Green Purchasing Act (2001)	High adoption in technology and sustainability sectors	Toyota and Sony use ISO 14001 to improve resource efficiency and reduce emissions
China	Environmental Protection Law (2020), Circular Economy Promotion Law (2018)	Rapid increase due to government policies	Huawei and Sinopec implement ISO 14001 for supply chain sustainability
Germany	Circular Economy Act (KrWG, 2021), Renewable Energy Sources Act (EEG)	One of the global leaders, broad adoption in energy-intensive sectors	BASF and Siemens integrate ISO 14001 to reduce environmental impact
Sweden	Environmental Code (1999), Circular Economy Strategy (2016)	High adoption, supported by strong government commitment	IKEA and Volvo focus on sustainable materials and energy-efficient production

Note: compiled by authors

The most significant level of ISO 14001 adoption is seen in Germany and Sweden, for which sustainable development is a national policy priority. China has shown rapid certification development, which is driven by government policy and prompted by international pressure. Countries with strong regulatory support and sustainability-focused industries demonstrate higher ISO 14001 adoption rates, indicating a global shift toward environmentally responsible manufacturing.

Figure 1 shows a comparison of the number of ISO environmental standard certifications and per capita GDP for selected countries.

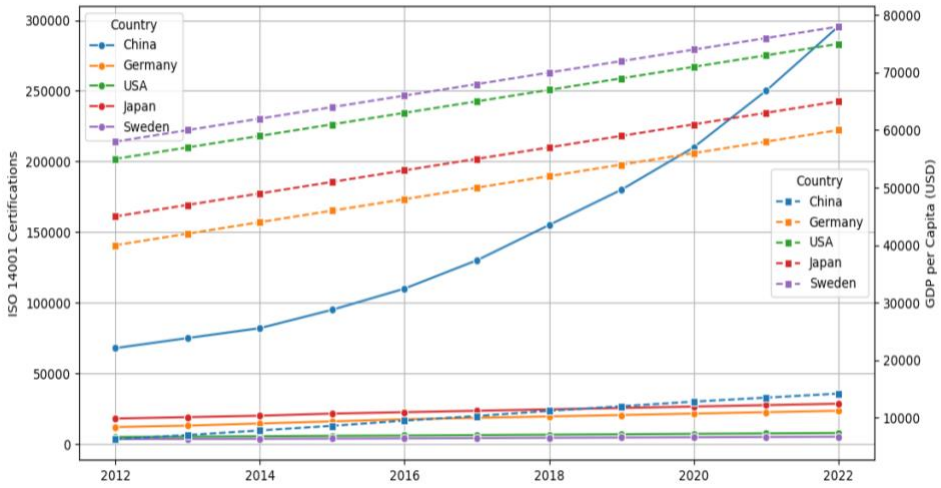

FIGURE 1. ISO 14001 certifications and GDP per capita

Note: compiled by authors based on calculations

According to the data presented, the dynamics of the number of ISO 14001 certifications varies significantly between countries, especially in the context of their level of economic development. The most noticeable growth is observed in China, which may indicate an increasing attention to environmental management issues in the context of industrial growth. For developed countries such as Germany, the USA, Japan and Sweden, the growth rate of certifications remains more moderate. This may be due to the high level of environmental standards already achieved and fewer new enterprises requiring certification. In addition, a high GDP can facilitate stricter regulation and compliance with standards without the need for formal certifications.

Furthermore, Figure 2 shows a comparison of the renewable energy share and CO2 emissions for selected countrie

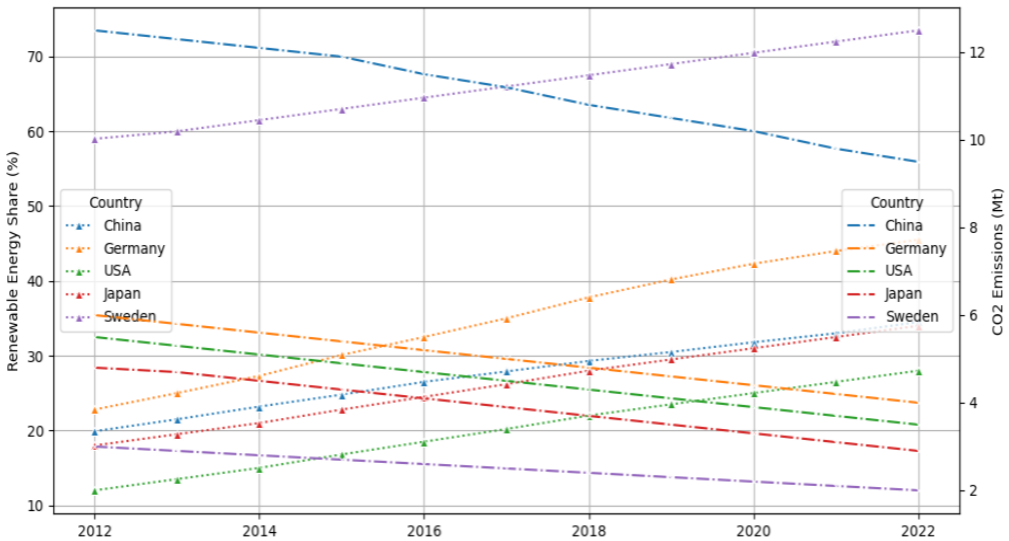

FIGURE 2. Renewable energy share and CO2 emissions

Note: compiled by authors based on calculations

As can be seen from Figure 1 and Figure 2, China has seen a dramatic increase in ISO 14001 certifications over 11 years, rising from 67 874 certifications in 2012 to 295 501 in 2022. This dramatic growth suggests that China's policy measures and economic shift towards sustainability have had a significant impact. Other countries, including Germany, Japan, Sweden, and the US, show a more stable trend in the number of certifications, indicating either a maturing market or more moderate growth in adopting environmental management standards. Germany consistently has about 7000 to 13000 certifications, Japan has between 18000 and 27000, and Sweden and the US have less than 5000 certifications yearly.

GDP per capita data provides context for each country's economic development. China shows significant GDP growth, from $6300 per capita in 2012 to over $12600 in 2022, reflecting its rapid economic development. Meanwhile, developed economies such as Germany, Japan, Sweden, and the US show higher and more stable levels of GDP per capita. The US shows the highest levels, peaking at $77246 in 2022. Sweden also shows strong growth in GDP per capita, from $58037 in 2012 to $56299 in 2022, despite slight fluctuations over the period.

Renewable energy share data reflects countries' commitment to transition to cleaner energy sources. Sweden leads the way, with its

share of renewable energy increasing from 59% in 2012 to around 68.3% in 2022, remaining consistently high throughout the period. Germany's renewable energy share has increased significantly from 22.8% in 2012 to 43.3% in 2022, demonstrating the success of its initiatives to transition to renewable energy. China and the US, although starting from lower levels, have shown steady growth, with China increasing from 19.9% to 29.7% and the US increasing from 12% to 21.3% over the period.

China's CO2 emissions remain significantly higher than in other countries, reflecting its position as a global manufacturing center despite the growth of renewable energy. China's emissions peaked in 2020 at more than 12.9 million metric tons but declined slightly by 2022. In contrast, Germany, Japan, Sweden, and the US show much lower emissions, with Sweden maintaining the lowest levels (around 37850 in 2022) due to its reliance on renewables. The US shows a significant decline in emissions, from over 6 million metric tons in 2012 to 4.85 million in 2022, reflecting a shift to cleaner energy.

Based on the data presented, it is clear that countries with a higher share of renewable energy, such as Sweden and Germany, have made consistent progress in their sustainability efforts, as evidenced by the growing number of ISO 14001 certifications. Despite its higher emissions, China's rapid growth in certifications indicates its increasing focus on environmental management, driven by economic growth and policy changes. Meanwhile, countries such as the US and Japan are showing more moderate progress with stable levels of renewable energy adoption and certification numbers. These trends highlight the approaches and outcomes of adopting responsible production standards in different economic and environmental contexts.

Before building the regression model, a test for multicollinearity between the explanatory variables was conducted. The results of the correlation analysis are presented in Table 3.

TABLE 3. Correlation matrix of independent variables

Variable	x1	x2	x3
x1	1	0.243	-0.692
x2	0.243	1	-0.402
x3	-0.692	-0.402	1

Note: compiled by authors based on calculations

As shown in Table 3, variables x1 (GDP per capita) and x3 (GHG (CO2)) have a notable negative correlation (-0.692). This indicates that countries with higher GDP per capita tend to have lower GHG emissions. Meanwhile, there is a negative correlation (-0.402) between variable x2 (share of renewable energy in total energy consumption) and emissions x3 (GHG (CO2)), which also confirms the relationship between increasing the share of renewable energy and reducing emissions.

A panel regression analysis employing fixed effects was utilized to examine the influence of economic and environmental factors on the quantity of ISO 14001 certifications. The Hausman test demonstrated that the fixed effects model is more suitable than the random effects model due to a correlation between individual country effects and explanatory variables.

GDP per capita, the share of renewable energy, and the level of greenhouse gas emissions were independent variables. Results of fixed effects regression analysis are presented in Table 4.

Almost all variables have significant coefficients at the 1% level, except GDP per capita in the random effects model, which lacked statistical significance. The Hausman test confirmed the fixed effects model is preferred due to correlation between country effects and explanatory variables. A positive coefficient for the share of renewable energy indicates that an increase in the share of renewable energy leads to an increase in the number of ISO 14001 certifications.

TABLE 4. Results of the panel data analysis

Variable	Fixed-effect	Random-effect
x1	2,128*** (0,781)	-1,51*** (0,298)
x2	1348,139** (679,786)	588,755** (256,125)
x3	0,054*** (0,010)	0,007*** (0,001)
Constant	-312445,6*** (61111,77)	54865,89*** (19677,45)
Number of observations	55	55
Number of groups	5	5
R^2	0,567	0,773
Test for significance	F (3, 47) = 11,58 [0,0000]	Wald chi2 (3) = 173,33 [0,0000]
, * - significance of coefficients at 5% and 1% levels, respectively		

Note: compiled by authors based on calculations

The positive and significant coefficient for CO_2 emissions in the fixed effects model confirms the importance of environmental pressure in adopting ISO 14001 standards.

In the fixed effects model, the coefficient for GDP per capita is 2.13. It is significant at the 1% level, indicating a positive effect of economic growth on the number of ISO 14001 certifications. The coefficient for the share of renewable energy in the fixed effects model is 1348.14 and is conditionally significant at the 5% level, which confirms its positive impact. CO_2 emissions also have positive and statistically significant coefficients at the 1% level, indicating that high emissions contribute to an increase in ISO 14001 certifications. The constant is significant at the 1% level in the fixed effects model.

The high R^2 value and Fisher's test results confirm the model's overall statistical significance, indicating its good explanatory power. The results confirm the important role of economic and environmental factors in promoting responsible production standards. The main conclusions from the regression analysis are as follows in Table 5.

TABLE 5. Hypotheses and results

Hypothesis	Result
H1: GDP per capita positively affects the number of ISO 14001 certifications.	Justified
H2: The increasing share of renewable energy in total energy consumption contributes to the growing number of ISO 14001 certifications.	Conditionally justified
H3: Higher greenhouse gas (CO_2) emissions lead to more ISO 14001 certifications.	Justified

Note: compiled by authors

H1: GDP per capita positively affects the number of ISO 14001 certifications.

The coefficient for the GDP per capita variable was 2.13 and is statistically significant at the 1% level (p = 0.009). This supports hypothesis H1, showing that economic growth contributes to an increase in the number of ISO 14001 certifications. The GDP per capita growth stimulates enterprises and governments to pay more attention to implementing environmental responsibility standards.

H2: The increasing share of renewable energy in total energy consumption contributes to the growing number of ISO 14001 certifications.

The coefficient for the share of renewable energy was 1348.14 with a p-value of 0.05 making it significant at the 5% level. Although a positive effect of renewable energy share on the number of ISO 14001 certifications is observed, the significance level requires further confirmation. Hypothesis H2 can be tentatively supported, although further research is needed for its final validation.

H3: Higher greenhouse gas emissions lead to more ISO 14001 certifications.

The coefficient for GHG CO2 emissions is positive and statistically significant ($\beta = 0.054$, $p < 0.001$). This supports hypothesis H3, showing that countries with higher GHG emissions are more likely to implement ISO 14001 standards, which may be related to the need to mitigate environmental impacts and comply with environmental standards.

The analysis confirms all three hypotheses. GDP per capita and greenhouse gas emissions significantly increase the number of ISO 14001 certifications, while the impact of the share of renewable energy requires further study for more precise confirmation.

Regarding the quality of the model, the results of Fisher's test indicate its high statistical significance ($p < 0.001$), which confirms the reliability of the model as a whole.

Based on the above analysis, the panel regression results indicated that both economic factors and environmental performance are statistically significant determinants of the number of ISO 14001 certifications. A rise in GDP per capita and the consumption of renewable energy positively affect the adoption of the standards of environmental responsibility, while high levels of CO2 emissions encourage companies and governments to pursue certification measures.

Results from the panel regression analysis provide really valuable information on the factors affecting the adoption of ISO 14001 certification in various countries. Both economic and environmental factors seem important in encouraging responsible manufacturing practices. The positive and statistically significant coefficient of the GDP per capita in the fixed effects model reinforces the hypothesis (H1) that economic growth exerts a significant effect on the number of ISO 14001 certifications. This result also points to the same direction as earlier findings indicating that countries with higher economic means are in a better position to invest in sustainable technologies and put into practice environmental standards (Casadesús et al., 2008). The results suggest that at higher GDP per capita, governments are more like to be concerned with environmental responsibility and seek the certification of such as proof of an enabling environment of sustainable best practices.

The analysis also emphasizes the contribution of renewable energy to the determination of ISO 14001 certification, while the share of renewable energy enters positively and significantly at 5% in the fixed effects model (H2). Although the significance of this relationship requires further testing, the results show that countries with a higher share of renewable energy are more likely to adopt environmental standards, strengthening the link between renewable energy use and sustainable production practices (Daddi et al., 2015). This is also in line with the findings of Darnall and Edwards, who argue that the use of renewable energy is associated with a higher likelihood of adopting environmental management systems such as ISO 14001, especially in the context of improving resource efficiency and sustainability (Darnall N. & Edwards D., 2006).

The impact of the greenhouse gas emission factor (CO2) was positive and highly significant in the fixed and random effects models, too (H3). This result confirms that the higher the emission level, the more pressure on companies and governments to adopt standards like ISO 14001 to mitigate environmental damage and contribute to sustainable development (Testa et al., 2014). Neumayer & Perkins and Ziegler & Rennings also report a similar observation and highlight that environmental pressure-high pollution levels exercise the pulling effect for adopting environmental management standards. This variable's importance indicates that regulatory and environmental pressure is decisive in stimulating the adoption of responsible production standards, particularly for countries with high pollution levels (Neumayer & Perkins, 2004; Ziegler & Rennings, 2004).

The above results prove the hypothesis that economic development, renewable energy use, and environmental stress significantly affect ISO 14001 certification. In more detail, although the effects of GDP per capita and greenhouse gas emissions have been proven to

be strong and persistent, the economically positive impact of renewable energy needs further confirmation regarding its statistically significant effect in various contexts.

5. CONCLUSIONS

The primary purpose of this study was to analyze the influence of economic and environmental factors on the diffusion of ISO 14001 certifications in the period 2012-2022 for the five countries of China, Germany, Japan, Sweden, and the United States. The analysis provided key insights into the dynamics of responsible production standards in these diverse economies.

First, the findings confirm that GDP per capita is a significant driver of ISO 14001 adoptions. Economically resourced countries like Germany and the USA are better positioned to invest in green technologies and international environmental standards. This result supports previous studies that have indeed found a strong correlation between economic affluence and environmental responsibility since richer countries can afford to implement comprehensive environmental management systems.

Second, the share of renewable energy also becomes important, especially in countries like Sweden and Germany, where renewable energy sources are well integrated. While the relationship between renewable energy and ISO 14001 certifications was conditionally significant, this suggests that moving toward cleaner energy sources supports adopting sustainable production practices. This confirms that there is a need for further analysis of how renewable energy will eventually influence environmental certification.

Third, the findings indicate that greenhouse gas emissions are an important driver for ISO 14001 diffusion. Countries like China have higher levels of CO2 emissions and are under increasing pressure to reduce their environmental impacts. Thus, they are most likely to adopt ISO standards. This evidence underlines the role of regulatory and environmental pressures in the diffusion of responsible production measures by companies and governments, especially in countries with high pollution levels.

In sum, the study contributes to understanding how economic and environmental factors shape the diffusion of ISO 14001 certifications worldwide. The findings raise awareness of the need for integrated policies that advance economic growth and environmental sustainability. Governments and businesses can move forward with responsible production standards by incentivizing investment in green technologies and encouraging regulatory frameworks that work toward curbing pollution. Future studies in this field might touch upon a more specific look into an influence assessment of different factors on diverse economic sectors, and cross-country comparative studies of the dynamics of standards diffusion across countries at different economic and environmental development levels.

AUTHOR CONTRIBUTION

Writing – original draft: Aknur Zhidebekkyzy, Birganym Amangeldiyeva.
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Formal analysis and investigation: Birganym Amangeldiyeva.
Development of research methodology: Aknur Zhidebekkyzy, Birganym Amangeldiyeva.
Resources: Aknur Zhidebekkyzy.
Software and supervisions: Aknur Zhidebekkyzy.
Data collection, analysis and interpretation: Aknur Zhidebekkyzy, Birganym Amangeldiyeva.
Visualization: Birganym Amangeldiyeva.
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