UNIVERSIDAD DE GRANADA

Universidad de Granada

TESIS DOCTORAL:

MEASURING THE IMPACT OF TRANSBOUNDARY DISRUPTIVE CRISES ON ECO-INNOVATION AND FIRM PERFORMANCE THROUGH ADVANCED COMPOSITE INDICATOR CONSTRUCTION TECHNIQUES

Facultad de Ciencias Económicas y Empresariales

Departamento de Economía Financiera y Contabilidad

Programa de Doctorado en Ciencias Económicas y Empresariales

Mención de Doctorado Internacional

Doctorando:

Germán López Pérez

Directores:

José Luis Zafra Gómez (Universidad de Granada)

Isabel María García Sánchez (Universidad de Salamanca)

Granada, 2024

Editor: Universidad de Granada. Tesis Doctorales
Autor: Germán López Pérez
ISBN: 978-84-1195-628-4
URI: https://hdl.handle.net/10481/98080

A mi familia, en especial a Elena, a mis padres y a mi hermana. Gracias por serlo todo para mí.

AGRADECIMIENTOS

Quisiera dedicar unas palabras de agradecimiento a todas y cada una de las personas que han estado a mi lado durante la realización de esta Tesis Doctoral, y sin las cuales esto no hubiese sido posible.

En primer lugar, quisiera expresar mi más sincero agradecimiento a los miembros del Tribunal por acompañarme en uno de los días más importantes de mi vida, tanto en el ámbito académico como personal. Valoro enormemente vuestro esfuerzo y es un verdadero honor contar con la presencia de profesionales de tan alto nivel.

En segundo lugar, como no puede ser de otra manera, quiero agradecer a mis directores de Tesis, el Dr. D. José Luis Zafra Gómez y la Dra. Dña. Isabel María García Sánchez, por su apoyo constante y por haberme permitido comenzar mi carrera en el ámbito académico de la mano de dos profesionales de semejante calidad académica y humana. No puedo estar más feliz de haber contado con vuestro apoyo desde el principio.

Me gustaría dirigirme especialmente a D. José Luis Zafra Gómez, al que le estaré eternamente agradecido. Gracias por tu inmensa profesionalidad, por tu cercanía y por el cariño que me has mostrado en todo este tiempo. Por tu disponibilidad, tus consejos y tu forma de hacerme ver las cosas. Gracias por haber confiado en mí desde el primer momento y por haberme permitido contar con el mejor mentor que podría haber imaginado. Quisiera dirigirme también a Dña. Isabel María García Sánchez, de la Universidad de Salamanca. Ha sido un auténtico honor haber podido contar contigo como mentora en esta etapa tan importante de mi vida. Gracias por haberte mostrado siempre dispuesta a ayudar, por haberme guiado de una manera excelente y por atenderme siempre con una sonrisa. Sin duda, además de tu calidad como profesional, me has demostrado contar con una gran calidad humana. Por todo ello, gracias a los dos.

Por otro lado, quisiera agradecer al Dr. D. Víctor Giménez, de la Universidad Autónoma de Barcelona, por haber colaborado en la presente Tesis Doctoral y por haberme prestado su ayuda en el desarrollo de gran parte de la metodología desarrollada en este trabajo, así como al Dr. D. Juan Carlos Garrido Rodríguez, de la Universidad de Granada, por haberme ayudado con una profesionalidad impecable a comprender diversos aspectos estadísticos de esta Tesis Doctoral.

Quisiera extender mis agradecimientos a la Maynooth University, en Irlanda, perteneciente a la Alianza Europea de Universidades Arqus, y en especial a la School of Business, por haber sido mi casa durante estos meses. Gracias en especial al Dr. Danny Chow, de la Maynooth University, por haberme permitido realizar mi estancia investigadora con él, en una universidad cuyos rincones me han enamorado. Gracias por haberme hecho sentir como en casa a pesar de la distancia y por haberme mostrado cómo se trabaja en una universidad extranjera, además de darme consejos inmejorables sobre qué hacer en esos (pocos) ratos libres en ese maravilloso país.

Gracias también a la Facultad de Ciencias Económicas y Empresariales y, por supuesto, al Departamento de Economía Financiera y Contabilidad de la Universidad de Granada, así como a su actual director, D. José Luis Zafra Gómez, y a su actual secretaria, Dña. María del Carmen Pérez López, por haber sido mi hogar desde que comencé la carrera hasta el día de hoy y por habernos brindado confianza tanto a mí como al resto de compañeros. Me gustaría extender estos agradecimientos a todos los compañeros del departamento por haberme acogido de tal manera y por haberme hecho sentir como en casa en todo momento.

Quisiera agradecer en especial a D. Juan Carlos Garrido Rodríguez por haberse portado conmigo como un hermano mayor y por haberme aconsejado y ayudado en todo

momento, a Dña. Gemma Pérez López, a Dña. María del Carmen Pérez López, a Dña. Ana Plata y a D. David Ortiz, por haberse prestado a ayudar y por tratarme siempre con tanto cariño. Gracias por haberme demostrado tanta confianza y cercanía desde el primer día. A Dña. Celia Ordóñez Solana, por confiar en mí y por haberme mostrado un inmenso cariño a lo largo de todos estos años.

Por supuesto, me gustaría dar las gracias a mis compañeros y compañeras de asignatura, por hacerme sentir que algo tan complejo como dar clases en una universidad del tamaño de la Universidad de Granada parezca algo sencillo. En especial, a María del Carmen Pérez, a Celia Ordóñez, a María Elena Gómez y a Isabel Román, por haberme acompañado de la mejor manera posible en mi primera etapa como docente universitario, así como a Marian Navarro, Cristina Campos y Emilio de la Higuera, con los que he tenido el placer de colaborar en la redacción de algún que otro artículo.

No podía redactar esta sección sin agradecer a mis compañeros de pasillo. Gracias a todos y cada uno de ellos, en especial a Gemma Pérez, Juan Lara, Sara Rodríguez, Laura Alcaide, José Frías y Raquel Garde. Gracias a todos por esos cafés y por esos buenos ratos entre clases, investigaciones y tutorías. Aunque Juan me diese más de un quebradero de cabeza cada vez que ganaba su equipo de fútbol y perdía el mío, no cambiaría esos momentos por nada.

Además, quisiera mencionar a Pablo Povedano, Lorena Márquez, Elisabeth Zafra y Marta Garrido, del Departamento de Economía Financiera y Contabilidad, por haber estado conmigo en todo este proceso, por haber compartido buenos momentos y por haberos convertido en unos amigos con los que puedo hablar tanto de lo bueno como de lo malo. Nunca olvidaré que empecé esta aventura en el ámbito académico junto a vosotros.

Me gustaría centrarme ahora en todas aquellas personas que, fuera del ámbito académico, han estado conmigo en todo este tiempo, apoyándome de manera incondicional y dándome ánimos cuando más lo necesitaba. Por ello me gustaría agradecer a toda mi familia, en especial a mi tía Mari y a mi tía Paula, por haberme acompañado en cada momento especial de mi vida. A mis tíos y primos, ya sea de sangre o no, por estar tan orgullosos de mí y por mostrarme una admiración que solo un familiar podría mostrar. A todos mis amigos, a los de toda la vida y a los que han aparecido con el paso de los años, en especial a Bea, Andrea, Paula, Alberto y Juande, por ser familia y por estar siempre tan pendientes de mí.

A Álvaro, Elena, Inés y Lucía, así como al resto de la familia Marín y Garzón por haberme tratado como un hijo, hermano y primo más en vuestra familia, que ha pasado a ser parte de la mía. Por haberme acompañado todos estos años y por hacerme sentir enormemente agradecido por poder contar con la compañía de personas con semejante calidad humana. Gracias por todos los buenos momentos, y los que quedan.

También quisiera dar las gracias al mejor "hermano mayor" que podría haber imaginado. Gracias, Gilbert, por haberme acompañado en estos últimos once años en los que me has visto crecer, siempre confiando en tu "Ger". Jamás pensé que iba a tener tanta suerte de contar con una persona como tú como compañero de vida de mi hermana.

Finalmente, me gustaría agradecer a mis padres. Papá, mamá, gracias infinitas. No hay palabras que puedan expresar el agradecimiento y el amor que os tengo. Gracias por haber sido mi pilar fundamental desde que nací, por haberme hecho sentir siempre tan especial y por haberlo dado todo para poder tener todas las comodidades que he tenido a lo largo de toda mi vida. Sé que estáis enormemente orgullosos de mí, ya que me lo repetís día tras día con cualquier cosa que haga, pero además sé que sabéis que yo también lo

estoy de vosotros. Siempre es un buen momento para deciros lo feliz y orgulloso que me siento de tener a los mejores padres que se pueden tener, por haberme criado con tanto cariño, con tanta educación y con tan buenos valores. Papá, mamá, podéis estar orgullosos de vuestra labor como padres, porque creo que no podríais haberlo hecho mejor.

Gracias a mi hermana, Estefanía. Has sido y eres mi mayor referente, esa figura de hermana mayor de la que tanto presumo y que me hace sentir inmensamente agradecido con la vida por haber podido nacer en una familia como la nuestra y poder experimentar día tras día algo que tiene un valor incalculable: el amor de una hermana. Gracias por haberme guiado de la forma en la que lo has hecho, por haberme defendido en cada momento que lo requería y por haberme regalado momentos de películas, juegos y muchas, muchas risas. No me canso de decir que tengo la mejor hermana del mundo y que eres una de las personas que han hecho que hoy en día sea quien soy. Espero que estés orgullosa de tu "nene" al menos en una cuarta parte de lo que lo estoy yo de ti, que ya sería mucho.

Y, por supuesto, a ti, Elena. Desde que nos conocimos jamás llegué a imaginar que íbamos a construir una relación como la nuestra. Gracias infinitas por ser un pilar imprescindible en mi vida. Por comprenderme como lo haces, por regalarme tu sonrisa día tras día y por hacerme sentir el hombre más afortunado del mundo. Gracias por haber compartido conmigo estos ocho años de relación en los que hemos crecido juntos y en los que nos hemos permitido el lujo de celebrar la magia del día a día. Gracias por hacerme tan feliz, por hacerme ver la vida con otros ojos, por enseñarme a amar, por quererme como lo haces y por confiar en mí más que yo mismo. Tengo motivos suficientes para estar orgulloso de la persona que tengo a mi lado y con la que quiero compartir el resto de mi vida.

A todos y cada uno de vosotros, una vez más, gracias. Esta Tesis Doctoral no sería posible sin vuestro apoyo.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

RESUMEN

La creciente preocupación por el medio ambiente y el futuro de las próximas generaciones ha motivado un cambio en las preferencias de los consumidores y grupos de presión, lo que ha puesto en relieve la importancia de invertir en estrategias de crecimiento económico sostenible. Históricamente se ha instaurado un modelo de producción lineal donde los recursos naturales ingresan por un extremo del proceso productivo y emergen por el otro en forma de productos económicos. Sin embargo, ante los desafíos ambientales emergentes y la escasez de recursos, las empresas están asumiendo una mayor responsabilidad a través de estrategias de responsabilidad social corporativa, haciendo necesaria la aparición de una alternativa al modelo unidireccional: la economía circular, que pretende, a grandes rasgos, lograr un crecimiento social y económico de forma sostenible mediante el uso eficiente de los recursos.

La economía circular requiere de innovaciones en la producción, consumo y formulación de políticas. En este contexto surge el concepto de innovación ambiental o eco-innovación, que hace hincapié en la relación entre innovación y sostenibilidad. No obstante, cabe señalar que la eco-innovación es un concepto multidimensional que se encuentra en un proceso de continuo desarrollo y revisión y que abarca las dimensiones de productos, procesos, organización y marketing.

Además, las eco-innovaciones no solo reducen las prácticas contaminantes, sino que pueden traducirse en un alto rendimiento económico. Es por ello por lo que la adopción de estas prácticas está creciendo notablemente en los últimos años, impulsada por propuestas como el Plan de Eco-innovación o el Protocolo de Kioto.

Sin embargo, los investigadores que han elaborado estudios previos no han mostrado resultados concluyentes al respecto, por lo que es necesario profundizar en los

diversos factores que influyen en las aplicaciones de estrategias sostenibles por parte de las empresas, así como el impacto que éstas tienen sobre sus resultados. Por un lado, diversos autores afirman que las empresas que aplican estrategias sostenibles mejorarán aspectos tales como la reputación de dichas empresas o la satisfacción del cliente, además de conseguir una notable reducción de los costes y, por ende, una mejora en los resultados. Sin embargo, en la postura contraria, numerosos investigadores aseguran que la eco-innovación no siempre tiene un impacto positivo, ya que la fuerte inversión inicial o el alto grado de rotación por trabajador, podría desembocar en un empeoramiento del desempeño corporativo.

Adicionalmente, los recientes acontecimientos globales, como la pandemia de COVID-19 y el conflicto entre Rusia y Ucrania, han representado un gran desafío para las empresas que pretenden ser más sostenibles. Estos eventos han afectado particularmente a las empresas que operan en varios países, haciéndolas más vulnerables a riesgos ambientales, económicos y geopolíticos. De este modo, mientras que la pandemia ha generado una crisis sanitaria y económica sin precedentes, el conflicto en Ucrania ha incrementado la incertidumbre económica y ha impactado en las cadenas de suministro y los precios de los productos básicos en todo el mundo.

En este contexto, el análisis de la relación entre eco-innovaciones y resultados empresariales se ha vuelto un tema de investigación crucial. Para ello, se han desarrollado diferentes metodologías e indicadores para medir el desempeño ambiental corporativo. Aunque no existe un instrumento de medición único y globalmente aceptado, varios estudios han aplicado diferentes enfoques para evaluar este desempeño. Estos indicadores permiten identificar qué empresas y sectores son más ecoinnovadores, aunque los

procesos matemáticos utilizados en estos estudios pueden ser complejos y difíciles de replicar.

En base a estos antecedentes, la Tesis Doctoral se estructura en varios capítulos, cada uno de los cuales aborda uno de los tres objetivos principales establecidos para explorar la relación entre la eco-innovación y el rendimiento empresarial, así como para desarrollar nuevas metodologías en este campo.

En el Capítulo II, se desarrolla el primer objetivo, que consiste en comprender la relación entre eco-innovación y resultados empresariales. Para ello, se realiza una revisión sistemática de la literatura existente combinada con un análisis bibliométrico. Este enfoque permite obtener una visión global del estado actual del conocimiento en esta área e identificar las principales áreas de investigación. A través de esta revisión, se examinan las diferentes posturas y conclusiones a las que han llegado los investigadores respecto al impacto de la eco-innovación en los resultados. El capítulo también reflexiona sobre las posibles razones por las que existe falta de consenso en la literatura, analizando aquellos factores que podrían estar influyendo en las divergencias observadas. De este modo, se establece un marco de conocimiento que resulta de utilidad tanto para investigadores como para líderes empresariales interesados en aplicar estrategias de innovación ambiental en sus organizaciones.

Los resultados obtenidos en este capítulo conducen a varias conclusiones importantes. Por un lado, se observa un creciente interés en las estrategias de sostenibilidad y eco-innovación por parte de académicos, gobiernos y empresas en los últimos años. Por otro lado, aunque no hay consenso entre los investigadores sobre el impacto de las estrategias de eco-innovación en el desempeño empresarial, la mayoría

afirma que esta tiene un efecto positivo en la rentabilidad a corto y largo plazo y/o en el valor de mercado.

El Capítulo III está dedicado al segundo objetivo, que consiste en la creación de un sistema de clasificación innovador para evaluar la eco-innovación en múltiples dimensiones: productos, procesos y organizacionales. En este capítulo, se elabora un ranking multinivel y multidimensional utilizando una muestra de 4,761 empresas cotizadas de todo el mundo, obtenidas de la base de datos Refinitiv Eikon. Para la construcción de este ranking, se emplea el enfoque de dominancia de Pareto, una metodología que preserva la multidimensionalidad de los datos y es especialmente útil en escenarios de toma de decisiones multicriterio. Este enfoque permite comparar el desempeño ambiental de empresas, países y sectores de una manera exhaustiva y flexible, sin la necesidad de ponderar arbitrariamente los indicadores. Así, el capítulo proporciona un análisis detallado de cómo se posicionan diferentes empresas y regiones en términos de eco-innovación, destacando aquellas con mejores prácticas y señalando posibles áreas de mejora.

Los resultados principales derivados de este capítulo muestran que, desde un punto de vista macro, las regiones que lideran el ranking global son Francia, Finlandia, Uruguay, Tailandia y España. La presencia destacada de países europeos en los primeros puestos se explica por diversas iniciativas implementadas en Europa, como el Plan de Acción para la Eco-innovación y el Pacto Verde Europeo, que han promovido altos niveles de desempeño ambiental. Este análisis es aplicable a cada dimensión de eco-innovación, donde las regiones europeas y asiáticas siguen predominando en las posiciones más altas, con una mayor presencia europea en las dimensiones de producto y proceso, y una mayor presencia asiática en la dimensión organizacional. En cuanto a los

sectores mejor posicionados en el ranking, destacan los servicios públicos, los bienes de consumo no cíclicos y los sectores industriales. A nivel micro, se expone cuáles son las empresas mejor posicionadas, tomando como ejemplo una de ellas para mostrar qué tipo de decisiones está tomando para situarse en esa posición dentro del ranking. De este modo, el desarrollo y aplicación de este ranking basado en dominancias permite identificar de manera sencilla qué empresas, regiones e industrias presentan un mayor grado de eco-innovación, basándose en las variables seleccionadas y detalladas en la sección de metodología.

Finalmente, el Capítulo IV aborda el tercer objetivo, consistente en realizar un análisis exhaustivo de la relación entre eco-innovación y resultados empresariales en un contexto de crisis transfronterizas provocadas por eventos disruptivos, como la pandemia de COVID-19 y la guerra en Ucrania. Utilizando una muestra de 3,606 empresas internacionales de diversos sectores, y datos de panel del periodo 2018-2022, se examina cómo estos eventos han potenciado la inversión en innovaciones ambientales. Para ello, se ha creado una nueva variable de eco-innovación a partir de 19 indicadores de desempeño ambiental obtenidos de Refinitiv Eikon, aplicando la metodología Benefit of the Doubt (BoD), que optimiza la ponderación de las variables según las características individuales de cada empresa. Además, se emplean modelos de regresión específicos para datos de panel, que permiten capturar tanto las diferencias entre las empresas como las variaciones a lo largo del tiempo, ofreciendo una visión precisa del efecto de este tipo de innovaciones y los eventos disruptivos en los resultados empresariales. Este capítulo proporciona una comprensión integral de cómo las empresas ajustan sus estrategias en respuesta a cambios en su entorno, identificando los factores que impulsan el éxito en un contexto de sostenibilidad.

En este sentido, este análisis sugiere que tanto el COVID-19 como la guerra en Ucrania han influido positivamente en la aplicación de eco-innovaciones, sugiriendo que la aparición de estos eventos disruptivos ha fomentado el desarrollo y aplicación de estrategias medioambientales dentro de las empresas, mostrando así que estas crisis transfronterizas pueden verse como un factor que fomenta el camino hacia prácticas más sostenibles, permitiendo a las organizaciones ser más resilientes y adaptativas a entornos turbulentosl. Por otro lado, los hallazgos muestran que la eco-innovación tiene un efecto positivo y significativo en los resultados empresariales.

Esta Tesis Doctoral tiene implicaciones estadísticas importantes que revolucionan el análisis de la eco-innovación y su impacto en el rendimiento empresarial. En primer lugar, el estudio introduce un innovador sistema de clasificación basado en índices de dominancias, utilizando variables dicotómicas para evaluar eco-innovación en dimensiones de productos, procesos y organizacionales. Este enfoque, basado en el concepto de dominancia de Pareto, ofrece una comparación más matizada del desempeño ambiental, permitiendo una evaluación sin la necesidad de ponderaciones arbitrarias. Este avance metodológico proporciona una herramienta útil para comparar empresas, países y sectores de manera más flexible y precisa.

Además, la Tesis emplea la metodología Benefit of the Doubt para crear una nueva variable de eco-innovación. Esta técnica de agregación pondera de manera óptima 19 indicadores de desempeño ambiental, maximizando la precisión en la evaluación del desempeño relativo de las empresas. La aplicación de este modelo y la integración de esta nueva variable en un análisis de datos de panel permiten capturar variaciones tanto temporales como individuales, ofreciendo una visión más detallada del impacto de la eco-innovación en el rendimiento empresarial.

El estudio también valida la robustez de sus resultados mediante la aplicación de diferentes pruebas estadísticas. Esta variedad metodológica asegura que los resultados sean consistentes y fiables a través de diferentes enfoques, fortaleciendo la validez de las conclusiones obtenidas. La utilización de estos modelos permite una evaluación exhaustiva de la influencia de eventos disruptivos como la pandemia de COVID-19 y la guerra en Ucrania, así como un análisis preciso de la relación entre eco-innovación y resultados.

En este sentido, esta Tesis no solo introduce nuevas herramientas estadísticas para el análisis de la eco-innovación, sino que también valida sus hallazgos a través de una metodología rigurosa, ofreciendo una base sólida para futuras investigaciones y aplicaciones prácticas en el campo de la sostenibilidad.

UNIVERSIDAD
DE GRANADA

CHAPTER 1: INTRODUCTION

INTRODUCTION

Industrialization brought with it a series of technological and economic advances of great global relevance. However, these advances were accompanied by serious environmental problems (Hizarci-Payne et al., 2020; Nandi et al., 2021; Wang et al., 2021). Since then, a linear production model has been in use, in which natural resources enter from one end of the production system and emerge from the other in the form of economic products (George et al., 2015).

The application of this productive model presupposes the abundance of natural resources and their obtaining at low cost (Leder et al., 2020), an assumption that has proven to be unsustainable as environmental problems such as pollution or resource depletion have become more evident, especially in recent years (Wang et al., 2021). This, accompanied by waste accumulation and ecosystem degradation, has highlighted the need to rethink this linear approach and look for more sustainable alternatives (Krieger and Zipperer, 2022).

Thus, concern for the environment and the future of the next generations has become one of the main global priorities (United Nations, 1987; Leder et al., 2020; Zhong et al., 2022). This concern not only affects citizens, but also companies in all sectors, which are increasingly aware of the scarcity of resources and the need to stop pushing our planet to the limit (Nandi et al., 2021).

This concern became latent in 2015, when the United Nations established the Sustainable Development Goals (SDGs), thus setting a roadmap for countries to achieve, through the fulfillment of 17 major goals, economic and social development based on the principle of sustainability (United Nations, 2015; Ahmad et al., 2022).

In this context, citizens, managers, consumers and suppliers around the world (Nowicki et al., 2021; Krieger and Zipperer, 2022; Albitar et al., 2023) have led companies to increase their efforts in transforming their business model with the aim of mitigating the negative environmental impacts that may derive from their activity (Zhong et al., 2022; López-Pérez et al., 2023).

To achieve this transformation and in order to curb the negative impact of climate change, it is necessary to transition from a traditional or linear economy model to a circular economy (hereafter CE) model, which can be defined as an economic model that aims to carry out an efficient use of resources by minimizing waste, reducing closed loops and using more environmentally friendly technologies (Park et al., 2010; Morseletto, 2020).

The implementation of this model requires the application of a series of environmental innovations that play a crucial role in addressing societal challenges and contributing to the improvement of human well-being (Castellacci, 2023). These innovations are known as eco-innovations (hereafter EI), defined as those products,

production processes, or management and business methods whose main objective is to avoid or reduce environmentally harmful practices (OECD, 2009; Prieto-Sandoval et al., 2018; López-Pérez et al., 2023)

Interest in EI in the business environment has grown exponentially, which has led numerous authors to investigate how this type of innovation can impact business results, especially in recent years (López-Pérez et al., 2023; Wilke and Pyka, 2024).

On the one hand, we find authors who claim that companies that implement sustainable strategies will improve aspects such as reputation or customer satisfaction (Liao, 2018), in addition to achieving a significant reduction in costs and, therefore, an improvement in results (Marín-Vinuesa et al., 2018). On the other hand, we find authors who claim that EI does not always have a positive impact, since the high initial investment or the high degree of turnover per worker could considerably harm these results (Aibar-Guzmán & Frías-Aceituno, 2021).

As can be seen, previous studies on this subject have not been conclusive, so it is necessary to delve deeper into the various factors that influence the implementation of sustainable strategies by companies and the impact they have on their economic performance.

On the other hand, recent global events have posed a real challenge to those companies that want to implement EI and thus become more sustainable. These external events have mainly affected companies operating in different countries, as their continuous exposure to environmental, economic and geopolitical risks (Dreyfus & Nair, 2022, Chatterjee et al., 2024) make them more vulnerable to situations such as military

conflicts and various economic challenges, among others (Caldara & Iacoviello, 2022; Ahmad et al., 2022).

Among the different events that have occurred in recent years, the health and economic crisis caused by the COVID-19 pandemic, which began in late 2019 and started to spread globally in early 2020, has been one of the greatest challenges of recent decades worldwide, causing the death of millions of people and generating an unprecedented sense of uncertainty (Krammer, 2022; Gómez et al., 2024).

On the other hand, the conflict between Russia and Ukraine that started in February 2022 has provided an additional reason to generate even more uncertainty in economic terms, as it has triggered commodity prices (World Bank Group, 2022; Wang et al., 2023), as well as notably impacting the supply of raw materials and supply chains globally (Park et al., 2020; Ghadge et al., 2020; AlQershi et al., 2023).

This conflict has also been of particular concern to countries that depend on Russia for the consumption of fossil fuels such as coal, gas or oil, among which are the member countries of the European Union (hereafter EU) (Ali et al., 2024). In order to move away from this dependence, it has become necessary to search for other renewable energy sources and alternatives to fossil fuels, which, on the one hand, will allow these countries not to depend on Russia for energy production and, in addition, will allow them to achieve sustainable economic growth to address the various current and future climate problems (Han et al., 2022; Wang et al., 2023).

In this context, multinational enterprises (MNEs) must establish different strategies aimed at achieving the necessary resources that will allow them to mitigate potential risks that may affect the survival of the companies and thus be able to invest in

EI strategies, as well as achieve an optimal level of resilience (Khan et al., 2024; Grego et al., 2024).

To this end, some authors argue that companies need to adopt various innovations that will keep them prepared for future adversities, which will improve their competitiveness in the long term (Grego et al., 2024). Among these innovations, EI effectively responds to the growing concern about climate change, as it seeks to have companies carry out their activity using alternative products and processes to traditional ones in order to minimize their negative impact on the environment (Kemp & Pearson, 2007; Pan et al., 2020; López-Pérez et al., 2024).

In this context, numerous researchers claim that investing in sustainable strategies causes companies to experience less negative economic impact in crises such as that caused by SARS-Cov-2 or, more recently, the Russia-Ukraine war (Huang et al., 2020; Hermundsdottir et al., 2022).

Thus, those companies that implement eco-innovative strategies will be more resilient, allowing them to cope with events such as the COVID-19 pandemic and the war in Ukraine more effectively (Vai & Aarstad, 2024). Furthermore, some authors argue that the implementation of environmental innovations can translate into positive business performance outcomes, making EI an attractive alternative for companies as well as investors (Scarpellini et al., 2016; Garcia-Sanchez et al., 2020).

To analyze the implementation of EI strategies, several studies have applied indicators capable of measuring the degree of corporate environmental performance (Dong et al., 2014; Wang et al., 2021; Zaman et al., 2021), which will allow assessing which companies and/or initiatives are more eco-innovative. However, there is no single

and globally accepted measurement instrument within the field of corporate sustainability and EI (Amor-Esteban et al., 2020), so numerous studies can be found that use different methodologies to measure this degree of environmental performance (Amor-Esteban et al., 2020; García-Sánchez et al., 2021; Chaparro-Banegas et al., 2023). These methodologies, despite generating detailed indicators, usually employ highly complex mathematical processes that can make it difficult to replicate and understand them in the scientific and business environment.

Based on the above, this Doctoral Thesis formulates three main objectives in order to address the different research needs identified in the current scientific literature. First, it is of relevance to understand the relationship between EI and business performance. Therefore, the aim is to establish a knowledge framework to help researchers understand the direction of the literature. This framework is useful for business leaders who wish to implement environmental innovation strategies in their organizations. The establishment of a knowledge framework will provide relevant information to understand the lack of consensus among authors and thus explain the different factors that condition the impact of EI on business performance, as well as identify gaps in the literature, generate new lines of research and translate its application into practice.

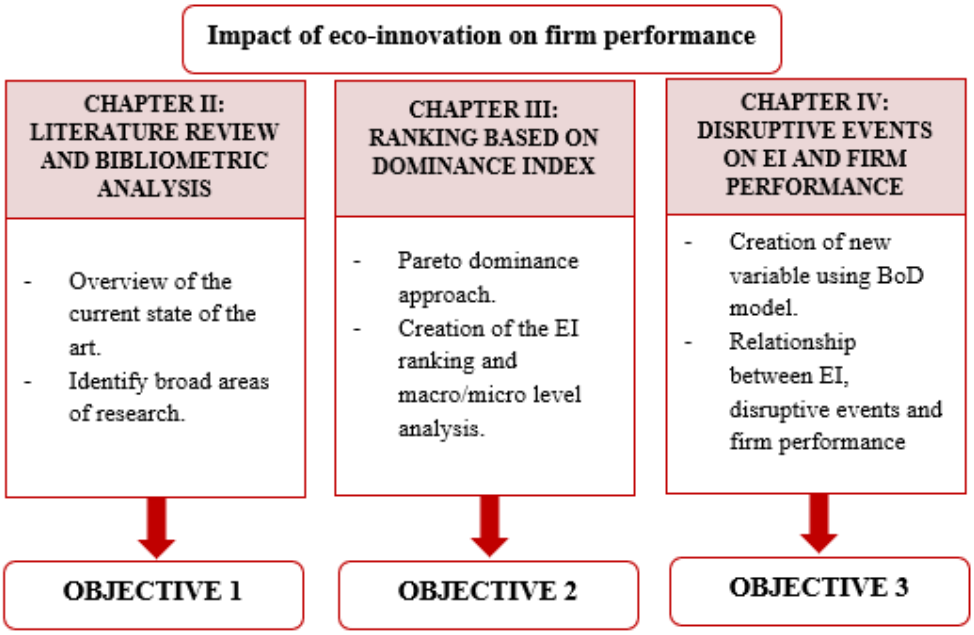
The second objective of this Doctoral Thesis is to develop an original and innovative ranking system based on a dominance index that uses dichotomous variables to evaluate EI in multiple dimensions: product, process and organizational. Unlike other traditional composite indicators, this ranking has been carried out by applying a novel methodology that takes advantage of the concept of Pareto dominance, which allows a more nuanced and flexible comparison of the degree of environmental performance of companies, countries and sectors without the need to weight the indicators arbitrarily.

Finally, a comprehensive analysis of the relationship between EI and business performance will be conducted using a sample of global companies, assessing whether and how disruptive events have influenced the implementation of these strategies. It will investigate whether EI implementation has intensified in response to such events, as well as the influence of these events on business decisions related to investment in green practices. This chapter seeks to provide a comprehensive view of how companies adjust their EI strategies in response to disruptive changes in the environment in order to better understand the drivers of business success in the context of sustainability.

In order to meet these objectives, this Doctoral Thesis has been structured as follows (see Figure 1). First, a systematic literature review combined with a bibliometric analysis has been carried out, which allows us to have an overview of the current state of the art and to identify major areas of research. After exposing the different positions that have been found in the systematic literature review, we reflect on the possible reasons for this. In order to achieve the establishment of a solid knowledge framework, it is necessary to answer a series of pre-established research questions that will be presented in Chapter II.

For the second objective, in Chapter III a multilevel and multidimensional ranking will be created using a sample of 4,761 listed companies from around the world obtained, again, from Refinitiv Eikon. The Pareto dominance approach is applied for the ranking, which offers several advantages over other methodologies by preserving the multidimensionality of the data, being particularly useful in multi-criteria decision-making scenarios, identifying optimal solutions without reducing the data to a single scalar value.

Figure 1: Structure of the Doctoral Thesis



Source: The author

Finally, for the third objective, Chapter IV conducts a comprehensive analysis using a sample composed of 3,606 international companies belonging to various sectors. Panel data corresponding to the period 2018-2022 were used, allowing us to capture both temporal variations and individual differences between firms.

In order to evaluate EI, a new variable is created from 19 environmental performance indicators obtained from the Refinitiv Eikon database. For this purpose, the Benefit of the Doubt (BoD) methodology is applied, which is an aggregation technique that allows optimal weighting of the variables according to the individual characteristics of each company, thus maximizing their relative environmental performance.

Finally, to analyze the relationship between EI, business performance and disruptive events such as the COVID-19 pandemic and the war in Ukraine, specific regression models for panel data are used. These models allow us to capture both differences between firms and variations over time, providing a more accurate picture of

the effects under study. Furthermore, in order to test the validity and robustness of the results obtained, additional statistical tests are applied.

UNIVERSIDAD DE GRANADA

CHAPTER II: A SYSTEMATIC LITERATURE REVIEW AND BIBLIOMETRIC ANALYSIS OF ECO-INNOVATION ON FINANCIAL PERFORMANCE: IDENTIFYING BARRIERS AND DRIVERS

1. INTRODUCTION

Industrialization has brought not only great advances but also serious environmental problems (Hizarci-Payne et al., 2020; Nandi et al., 2021; Wang et al., 2021). Since its onset, a linear production model has been in place in which resources have seemed infinite and can be obtained at low cost (Leder et al., 2020). In this model, natural resources enter at one end of the production process and emerge at the other in the form of economic products (George et al., 2015). Concern for the environment and the future of the next generations is growing (Leder et al., 2020; Zhong et al., 2022). The business world and society in general are increasingly aware that our planet has limited resources and that we are pushing the Earth to its limits (Nandi et al., 2021). As a result, consumer preferences and pressure groups are changing (Nowicki et al., 2021), leading to a search for balanced economic growth accompanied by sustainable practices (Tang et al., 2017).

This concern for the environment is not limited to advanced economies but is widespread. In Asian countries such as China, environmental concerns have become one

of the government's main priorities (Leder et al., 2020). Moreover, in recent years, there has been an increase in the number of academic papers published on sustainability (Çimen, 2021) reflecting the emerging interest in this topic in academia. In this context, the concept of "EI" emerges, defined as a set of techniques, processes, systems, and products that reduce or avoid harmful impacts on the environment (Vence & Pereira, 2018). In the area of business, a key issue is the relationship between EI and business performance. Much has been studied recently on this topic and on the impact that EI can have on business performance. However, the previous studies on this topic have not been conclusive, so it is necessary to delve deeper into the several factors that influence companies' applications of sustainable strategies and the impact they have on their performance.

Specifically, these previous studies have presented discrepancies in terms of the effect that green innovations or EI have on business performance. On the one hand, we find authors who claim that companies that apply sustainable strategies will improve aspects such as their reputation or customer satisfaction (Liao, 2018), in addition to achieving a significant reduction in costs and, therefore, an improvement in business results (Marín-Vinuesa et al., 2018). On the other hand, we find authors who claim that EI does not always have a positive impact, since the high initial investment or the high degree of turnover per worker could lead to poorer business performance (Aibar-Guzmán & Frías-Aceituno, 2021). In addition to the above, despite not improving business profitability, some authors claim that organizations that implement EI strategies will be better valued by investors, which will lead to an increase in their market value (García-Sánchez et al., 2019).

The analysis of this study establishes EI as the main topic, which is of relevance due to the growing concern for sustainability and environmental responsibility in companies. To understand the relationship between EI and business performance, it is essential to establish a knowledge framework that helps researchers understand the direction of the literature, as well as being of great use to business leaders who wish to apply environmental innovation strategies within their organizations. The establishment of this knowledge framework will provide relevant information to understand the lack of consensus among authors and thus explain the different factors that condition the impact of EI on business performance, as well as identifying literature gaps, generating new research lines, and transferring their application to practice.

In this context, the aim of this chapter is to establish a contextual framework, based on a bibliometric and bibliographic review, to guide researchers in the creation of a theoretical framework and the identification of possible lines of research. After explaining the various positions that have been found in the systematic literature review, we reflect on the possible reasons why this is the case. To achieve the establishment of a solid knowledge framework, it is necessary to answer a series of pre-established research questions. Considering that the main objective of this study is to analyze the impact of EI on business performance, the first research question is:

RQ1. How do EI strategies impact firm performance?

On the other hand, numerous studies can be found in academic literature that claim that not all companies have the same facilities when it comes to implementing environmental innovations, since it will depend on a series of factors (Doran & Ryan, 2012; Rexhäuser & Rammer, 2013; Xue et al., 2012). Therefore, the following research question is proposed:

RQ2. What are the barriers and drivers for companies to implement EI?

To complete the knowledge framework and obtain a complete view of the impact of EI on business performance, it is necessary to establish which factors can explain why, within those companies that implement EI strategies, some experience a positive impact and why others experience a negative impact. To this end, we establish the third research question:

RQ3. Are there any factors that condition the impact of EI on firm performance?

Although there are numerous studies that analyze the impact of EI on firm performance through a systematic literature review process, they are not conclusive, since they focus on answering this question without considering a series of external factors that can condition this impact. This work differs from previous studies by establishing a series of factors that could explain the lack of consensus in the literature and delving into the different barriers and drivers that serve to contextualize these conditioning factors, thus complementing the existing literature. However, a differentiating aspect of the present work is the methodology used to explain the impact of EI on firm performance, since it combines a systematic literature analysis with a bibliometric analysis, which allows us to obtain a broader view of the current situation of the academic literature in this field of research.

Thus, this study contributes to the existing literature on the impact of EI on business performance, as it summarizes the distinct positions in this research field, providing additional information on the conditioning factors of this impact resulting from bibliographic and bibliometric analysis. Moreover, this study provides useful information to both managerial and society in general to understand the barriers and drivers of implementing environmental innovations and show what is the possible impact of

applying this type of innovation. These implications are explained in greater depth in the conclusions section.

To achieve the above results, this study is structured as follows: In the following section, the research field and its relevance are contextualized, followed by the methodological design of our bibliometric and bibliographic review. In this sense, it is essential to identify the sources and keywords of this field of research, the key factors to address the main topics that have been developed throughout the period under study, and the main authors and journals interested in the subject. Thirdly, a systematic review of the literature is conducted to determine the drivers of and barriers to the implementation of EI, as well as its effect on corporate performance. Finally, the main conclusions, as well as the policy and managerial implications, are drawn. In addition, the limitations of the research and the future research directions are presented, which allow the researchers to identify the current picture of the field and the research gaps.

2. BACKGROUND AND JUSTIFICATION OF THE WORK

2.1. Towards circular economy

To alleviate global warming and the consequences of the linear economic model, companies are pursuing greener business strategies in which they conduct their activities under environmental approaches in their organization, planning, and production stage (Hizarci-Payne et al., 2020) to cope with different emerging environmental challenges and resource depletion (Abu Seman et al., 2019).

Companies are assuming greater responsibility through corporate social responsibility (CSR) strategies (Pan et al., 2020), making necessary the emergence of an alternative to the unidirectional model: the CE, which aims, broadly speaking, to make

society and the economy grow in a sustainable way (Aminoff & Pihlajamaa, 2020). Morseletto (2020) defines CE as "an economic model aimed at the efficient use of resources through waste minimization, long-term value retention, reduction of primary resources and closed loops of products, product parts and materials within the limits of environmental protection and socio-economic benefits" (p. 1). However, Prieto-Sandoval et al. (2018) and Kirchherr et al. (2017) have compiled various definitions of this concept, such as those of Peters et al. (2007) and Geng and Doberstein (2008), who focus mainly on the closing material loops, or Park et al. (2010), who refer to new technologies that enable environmental modernization. In addition, Kirchherr et al. (2017) compile the definitions of Stahel (2016) and the Ellen MacArthur Foundation (2012), who define CE as, respectively, a model that would change economic logic and as an industrial system whose goal is the elimination of waste.

In addition to defining CE, it is important to establish a set of objectives that such an economic model pursues. Following Morseletto (2020), we can establish the 10 main objectives of CE: reject, rethink, reduce, reuse, repair, renew, remanufacture, reconvert, recycle, and recover. Following the above, the author groups these objectives into three main strategies: useful application of materials, extending the useful life of products and parts, and the use and manufacture of smarter products.

However, setting these objectives is not enough to achieve the transformation to an effective CE, as this requires careful decisionmaking and scheduling of activities (Morseletto, 2020). There are few examples of circular businesses that have been successful in their economic development, mainly due to barriers such as technological complexity and lack of innovation (Aminoff & Pihlajamaa, 2020). Despite this, the number of countries that have taken steps to encourage the implementation of a CE has

grown in recent years (George et al., 2015). Among other countries, China has opted for this alternative to the conventional model to develop its economic activity, considering it a vital strategy to develop in the most sustainable way possible.

2.2. The relationship between eco-innovation and circular economy

In addition to the effort that must be made by all nations in the world, the change from a linear to a CE requires numerous agents to work hard to achieve changes in the different stages of the productive process and in various relevant sectors, thus achieving the transition to a sustainable economy (Durán-Romero et al., 2020). In this context, we find a key concept that makes the transition from a linear to a circular model possible and that we will analyze below: EI.

The transformation from a linear to a circular model requires innovations to make this change possible. CE requires innovations in production, consumption, and policymaking (Prieto-Sandoval et al., 2018). For this reason, companies are increasingly investing in new processes aimed at detecting and reducing environmental problems (Hojnik et al., 2018). This type of innovation is called "environmental innovation" or "EI"—a concept that emphasizes innovation and sustainability and was introduced in the third industrial revolution and extended during the fourth industrial revolution (Johl & Toha, 2021).

EI is a key strategy for linking sustainable development with the CE (Liu et al., 2019), emphasizing activities that are essential for companies to move towards environmental sustainability (Durán-Romero & Urraca-Ruiz, 2015; Maldonado-Guzmán et al., 2021). However, it should be noted that EI is a multidimensional concept whose implementation and development can be complex (Smol et al., 2017; Urbaniec &

Gerstlberger, 2011). In this sense, strategies aimed at the development of EIs are in a process of continuous development and revision (Buttol et al., 2011). These strategies have been studied throughout the academic literature as one of the fundamental elements in the development of new and more competitive technologies, as well as in the development of different business models (de Jesus et al., 2018; Maldonado-Guzmán et al., 2021).

EIs not only reduce polluting practices but, according to several authors, can also translate into high economic performance (Aldieri et al., 2019). This is why the adoption of these practices by both consumers and companies is growing notably (Hojnik et al., 2018), driven by proposals such as the EI Plan or the Kyoto Protocol (Bitencourt et al., 2020). To properly understand this concept, it is necessary to define what EI is, what types of EIs exist according to the literature, the drivers of EI, and how it affects business performance. Below, we present the methodological development to conduct the bibliometric study and the analysis of the literature on the above concepts.

3. METHODOLOGY

3.1. Data collection

To synthesize existing knowledge on the determinants of EI and its impact on corporate performance and to establish research gaps, a systematic literature review was designed. A systematic literature review can be defined as a literature review process whose objective is, using basic and reproductive methods, to identify, evaluate, and summarize primary studies related to a particular topic (Cerchione & Esposito, 2016). This review method is useful for compiling research efforts on emerging topics to identify challenges for future studies (Potrich et al., 2019). For this purpose, this work was structured in the following phases: (i) definition of the research question, (ii) selected

databases, (iii) identification of keywords, (iv) selection of included articles, and (v) data extraction and evaluation.

i. Before conducting the literature review, the status of the analyzed research field was examined (Turzo et al., 2022). To this end, the most repeated keywords were noted to establish the search equation to be used later for the review. Once the current situation of the research field was analyzed, it was observed that there were gaps in terms of the impact of EI on business results. In this sense, this work was motivated by the need to answer the following questions: How do EI strategies impact business performance? What are the barriers and drivers for companies to implement EI? Are there any factors that condition the impact of EI on firm performance? Once the research questions were established, inclusion criteria for articles in the review process were developed. This consisted of including those works that answered these questions and excluding those that, although they included the keywords defined in step (iii), were not relevant in answering the research questions posed.

ii. To answer these questions, we used Scopus and Web of Science (WOS) as the databases to search for scientific articles related to the CE, EI, and business performance as the main topics. We selected these databases as they are two of the most widely used in the scientific field due to the substantial number of journals that can be found through them and the quality of the results that can be obtained from them.

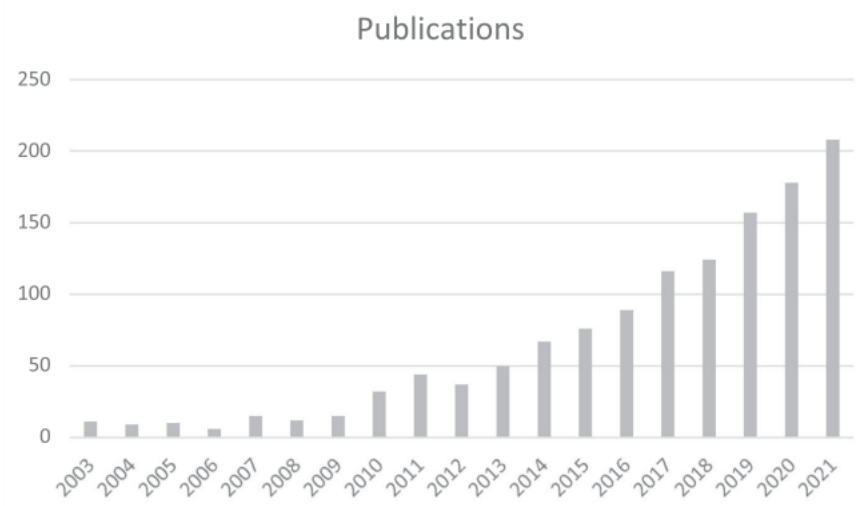
iii. To find the articles required to carry out this work and considering the most recurring keywords obtained from the analysis step, we entered a series of search equations in the search engine of each database, that is, a set of keywords that we must use to find the documents that will be useful to us for carrying out the research. This step in the review process is important because the proper definition of search terms will allow

us to find studies that are relevant to our research (Enciso-Alfaro & GarcíaSánchez, 2022). Between Scopus and WOS, a total of six search equations were used; their main keywords were "CE," "EI," "eco-design," and "firm performance."

iv. By entering the same search equations, we found more results in WOS, where we found a greater number of articles useful for this work. To avoid duplicates, we linked the six equations using the "OR" function of WOS and Scopus, with which we obtained a total of 1277 and 232 results, respectively.

Thanks to the tools offered by WOS, it was possible to gather useful information to be able to filter the search results. For example, we found that of the 1277 results obtained in this database, 83.79% were articles (1070). In addition, we were able to observe that the largest number of publications related to this topic began being published in 2010 and, from 2013, this number did not stop growing until the end of 2021 (see Figure 2).

Figure 2: Evolution of publications in WOS



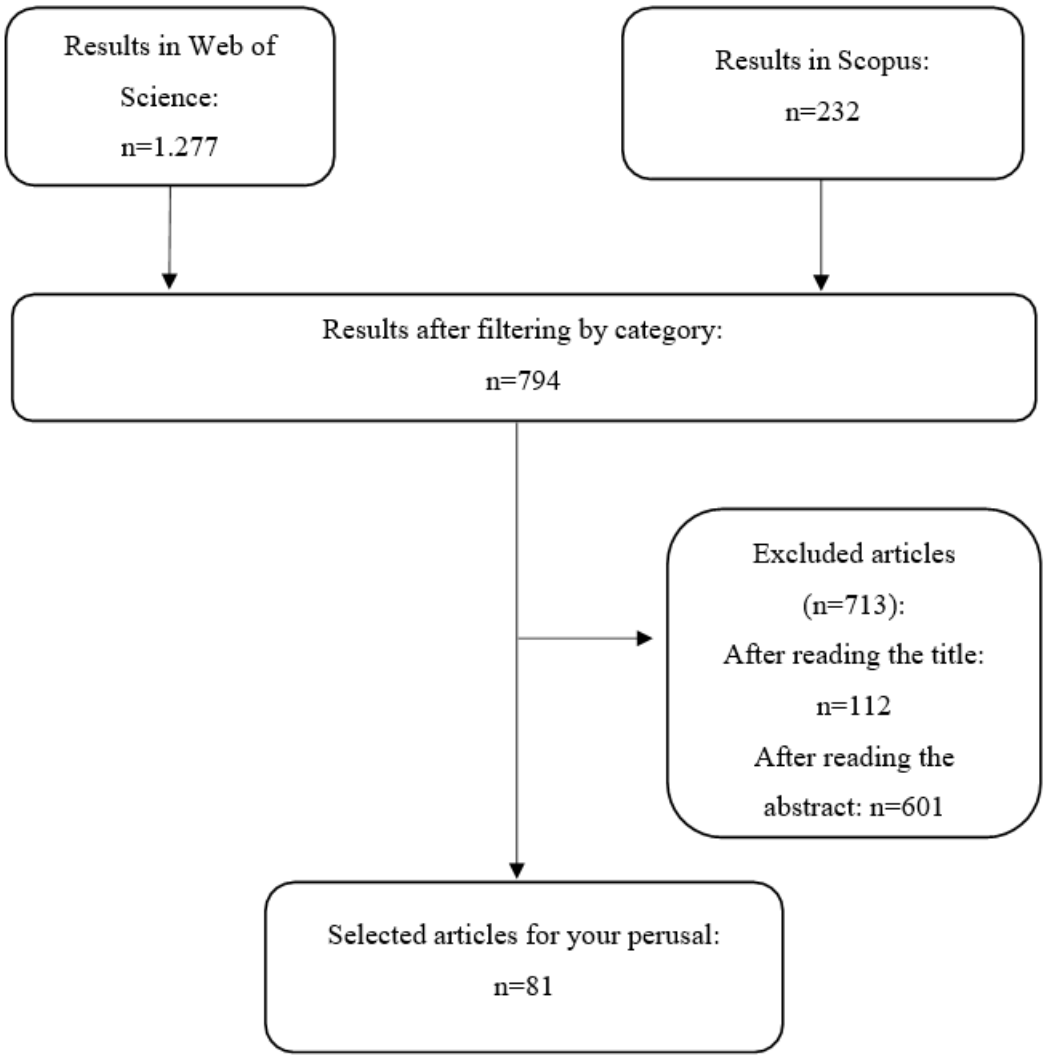
Source: Web Of Science

In addition to the above, we note that 98% of the documents that appear in the results after entering our search equations were published in English. Thanks to this information, we were able to establish filters to narrow down the results obtained, so we filtered by:

- Document type: articles
- Year of publication: 2010–2021
- Language: English
- Knowledge area: business

Once the results were filtered, we went from obtaining 1277 documents to 712 in WOS and from 232 to 82 in Scopus. The number of papers found in the first round of research was systematically reduced by a series of selection criteria (Abbate, Centobelli, Cerchione, Oropallo, & Riccio, 2023). During the literature review process, articles whose titles and abstracts suggested the inclusion of the keywords used in the search equation but were not related to the objectives established in the present study were excluded. Subsequently, a thorough reading of the selected articles was conducted, and those that did not substantially address the main objectives or research questions posed were excluded, considering them irrelevant for the present systematic review.

Figure 3: Item selection process



Source: The author

Firstly, of the 794 articles extracted from the previous process, a total of 713 were discarded once we determined that none of them met the objectives pursued by this study. Secondly, the titles of the papers derived from the previous process were carefully read, and 112 articles were excluded. Thirdly, and following Pittaway et al. (2004), 601 were excluded after we read the abstract. Finally, 81 articles were selected for further reading and analysis (see Figure 3).

In addition to the systematic review process, the snowball method (Abbate, Centobelli, Cerchione, Oropallo, & Riccio, 2023; Chen et al., 2020; Greenhalgh & Peacock, 2005) was used to include other studies that were not considered in the review process but that were considered relevant to contextualize this work, as well as to reinforce the methodological part. v. With the articles obtained a process of data extraction and analysis was conducted using the bibliometric analysis described in the following section.

3.2. Bibliometric analysis

Bibliometric analysis is a mathematical and statistical method that allows displaying the current state and evolution of a field of knowledge (Abejon & Garea, 2015). In this sense, bibliometric analysis has gained popularity in various fields of study in recent years (Donthu et al., 2021; Turzo et al., 2022). This analysis can provide a broader view of relevant literature and enable a more complete understanding of the most relevant studies, which is particularly useful in rapidly evolving research fields such as EI. In addition, bibliometric analysis is useful for determining emerging trends in research collaboration efforts, or in article and journal performance, among others (Campobasso & Boscia, 2022; Donthu et al., 2021).

Once the base of articles needed to study current knowledge was defined, the VOSviewer software, a program developed to build and visualize graphic maps (Van Eck & Waltman, 2010), was selected to conduct the bibliometric analysis to identify bibliometric networks in the field of EI and business performance. These networks can be determined for researchers, journals, and publications. They can be created by considering each of them individually, or built on citation, co-citation, and co-authorship relationships and bibliographic linkage (Ding & Yang, 2020). Additionally, the text

mining functionality allows identification and visualization of the co-occurrence networks of the main terms extracted from the analyzed scientific articles.

Regarding the researchers, Table 1 shows that the three most active authors are, in this order, Scarpellini, Portillo-Tarragona, and Valero-Gil, all of whom have published 10 or more articles on EI and corporate performance. Professor Scarpellini's eight articles represent 9.8% of the current knowledge on this topic measured by number of publications in relation to the 81 articles selected for further analysis, while Professors Portillo-Tarragona and Valero-Gil have authored five and four articles, respectively.

Table 1: Ranking of Authors with the most publications acording to WOS

Order	Author	No. of Publications	% out of 81 articles
1	Scarpellini S	8	9.877%
2	Portillo-Tarragona P	5	6.173%
3	Valero-Gil J	4	4.938%
4	Marín-Vinuesa LM	3	3.704%
5	Moneva JM	3	3.704%
6	Aranda-Uson A	2	2.469%
7	Carrillo-Hermosilla J	2	2.469%
8	Gallego-Alvarez I	2	2.469%
9	Garcia-Sanchez IM	2	2.469%
10	Hojnik J	2	2.469%

Source: Web Of Science

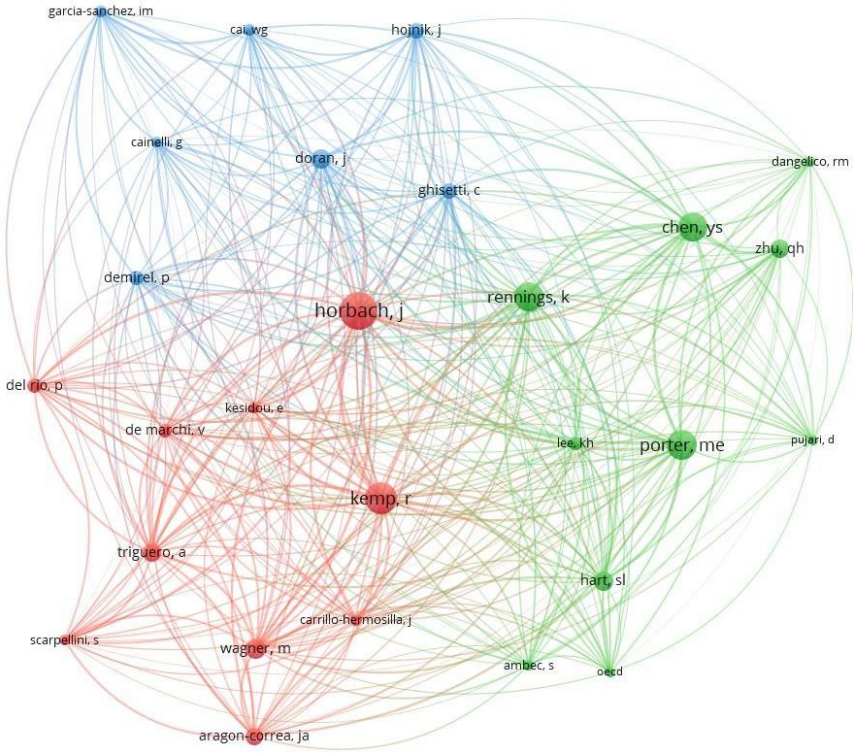
The map in Figure 4 shows how the different authors are related according to the co-citation that occurs between each of them. Co-citation analysis is a method that examines the frequency of citations of two or more documents (Small, 1973). If two documents appear together in the reference list of a third publication, they are considered as co-cited (Farrukh et al., 2020). The co-citation analysis is used to investigate the thematic similarities between publications within a specific research field, as well as to

study how the literature is structured through the cited publications (Farrukh et al., 2020; Khanra et al., 2022; Rao & Shukla, 2022).

Setting a minimum threshold of 20 citations per author, it was found that out of the 3834 authors resulting from the sample, 28 met the threshold. Thus, a total of three clusters were obtained, which are represented in Figure 4 in red (11 items), green (10 items), and blue (seven items), with Jens Horbach, René Kemp, and Klaus Rennings standing out with 75, 63, and 57 citations, respectively. This map was made, once again, based on the 81 articles selected for analysis.

In relation to the journals in which the most content related to our main topic is published, Table 2 summarizes the total frequencies for the total number of articles published. The most representative journal is the Journal of Cleaner Production, published by Elsevier, one of the world's leading scientific publishers, which has been in business since 1880. This journal published 29.6% of the articles identified regarding EI and corporate performance. To analyze the keywords of the research in question, we used VOSviewer's concurrence analysis to identify the number of times that each word appears in an article. The analysis of keywords is essential to describe the content and themes of the analyzed documents (Rao & Shukla, 2022).

Figure 4: Map of co-citations between authors created with VOSviewer



Source: Own elaboration using VOSviewer

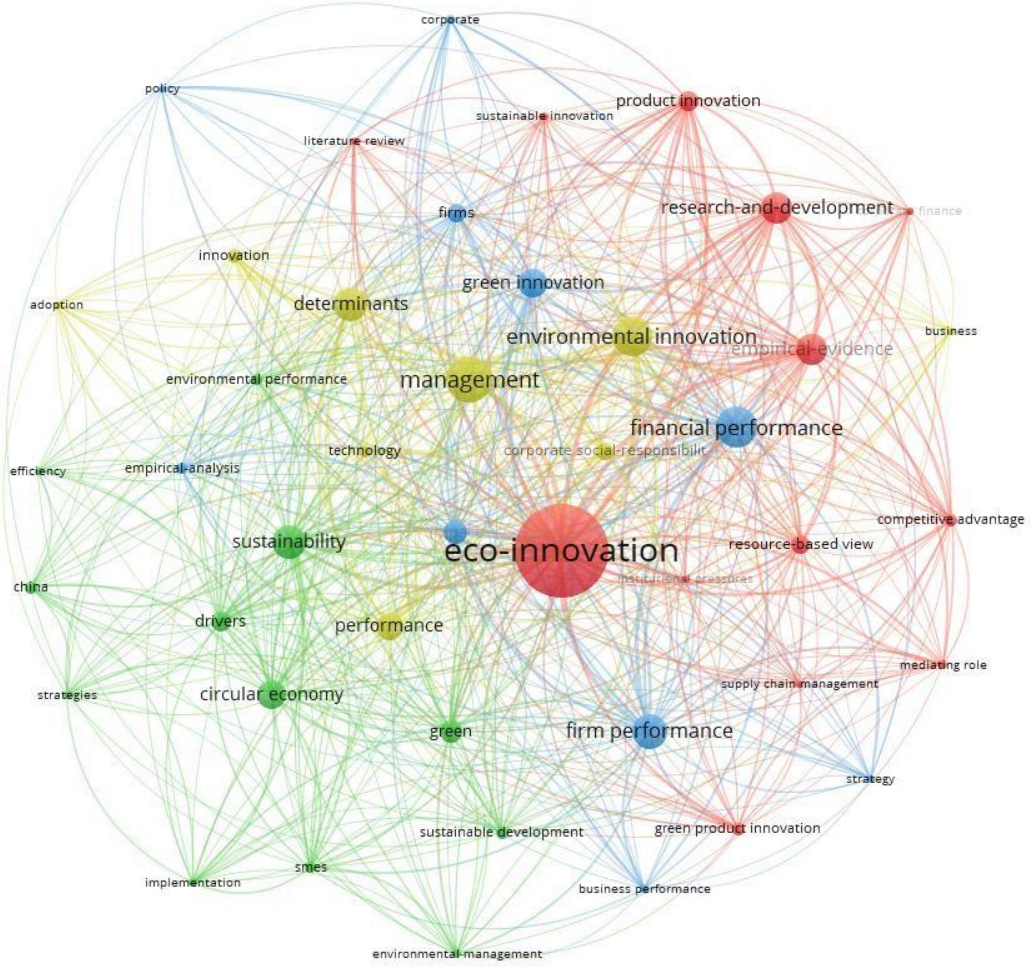
Table 2: Ranking of Journals According to WOS

Order	Journal	No. of publications
1	Journal of Cleaner Production	24
2	Business Strategy and the Environment	13
3	Sustainability	8
4	Cogent Business & Management	7
5	Journal of Business Research	3
6	Resources, Conservation and Recycling	3
7	Administrative Sciences	2
8	Corporate Social Responsibility and Environmental Management	2
9	Journal of Engineering and Technology Management	2
10	Current Opinion in Environmental Science & Health	1

Source: Web of Science

Through this analysis, the degree of co-occurrence of keywords and research domain concepts can be determined (Khanra et al., 2020). Then, after establishing a threshold of five (the word must appear at least five times), it is found that, out of the 493 keywords that appear in the sample, 44 meet the threshold established previously. Thus, a total of four clusters were obtained, which are represented in Figure 5 in red (13 items), green (12 items), blue (10 items), and yellow (nine items).

Figure 5: Map of keyword nodes created with VOSviewer



Source: VOSviewer

The analysis of the clusters derived from this bibliometric analysis is useful for establishing the main topics and the most relevant research areas of the analyzed studies

(Marzi et al., 2021) (Table 3). As can be seen, the most relevant keyword in this analysis is "EI," followed by "management" and "financial performance." Among the next seven, we find synonyms used to talk about EI such as "green innovation" and "environmental innovation," as well as keywords whose relevance has been highlighted throughout the work, such as "firm performance" and "sustainability."

Table 3: Clusters obtained from the bibliometric analysis of Keywords using VOSviewer

Cluster	**Items**	**Keywords**	**Co-occurrence**	**Topic**
Red (Cluster 1)	13	EI	58	Research on the development of EI strategies.
		empirical evidence	20	
		research-and-development	20	
Green (Cluster 2)	12	sustainability	21	Transition towards a sustainable and CE.
		CE	18	
		green	14	
Blue (Cluster 3)	10	financial performance	26	Impact of EI strategies on firm performance.
		firm performance	22	
		green innovation	18	
Yellow (Cluster 4)	9	management	29	Strategic management of EI and identification of barriers and drivers.
		environmental innovation	25	
		determinants	21	

Source: VOSviewer

In addition, Table 4 shows the strength of the connection between the keywords, where, once again, "EI" stands out. Thus, looking at Figure 5, the map allows us to visualize the most important nodes, which are larger, the connection between the terms, identified by color, and the proximity between them. These aspects reflect the frequency with which a specific keyword or topic has appeared (Campobasso & Boscia, 2022).

Table 4: Co-occurrence of Keywords with VOSviewer

Order	Keyword	Co-occurrence	Total bond strength
1	EI	58	378
2	management	29	193
3	financial performance	26	180
4	environmental innovation	25	169
5	firm performance	22	154
6	determinants	21	143
7	sustainability	21	127
8	empirical evidence	20	150
9	research-and-development	20	144
10	green innovation	18	134

Source: VOSviewer

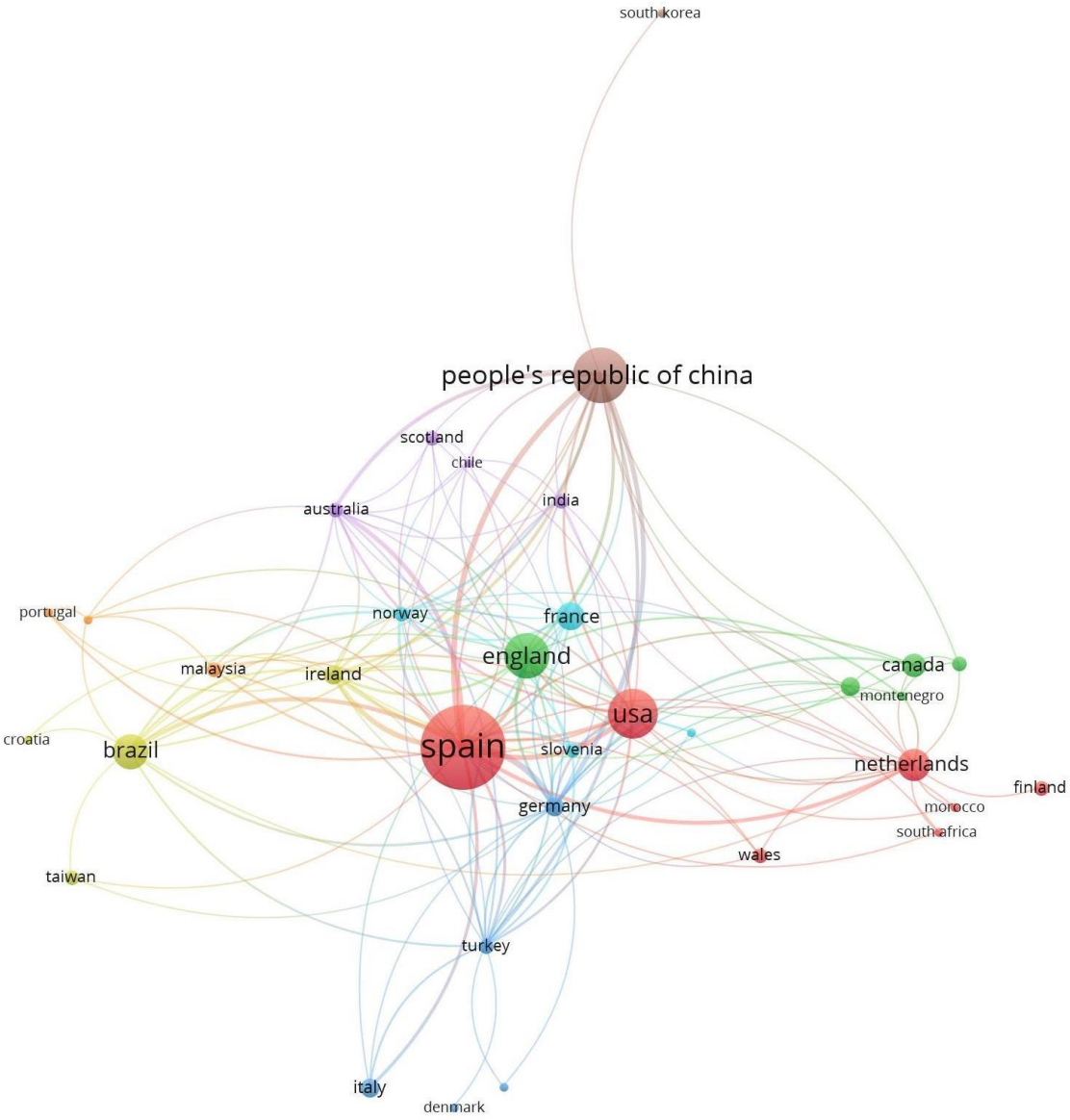
Figure 6: Choropleth map by number of publications

Source: The author

Finally, with the data collected from WOS, we created a choropleth map (Figure 6) according to the number of publications that allows, after the bibliometric analysis of the studies derived from the literature review, to identify the countries that are conducting the most studies related to the main topic of this study. As the map shows, the countries

where we found the most publications related to our search are, in this order, Spain, China, and the United States.

Figure 7: Country citation map created with VOSviewer



Source: VOSviewer

The map in Figure 7 shows the countries in which the most papers have been published and the interrelationship between them, considering the citations received by authors from other countries. In this respect, articles written by Spanish authors received citations mainly from China, England, the United States, Australia, and Germany. In the case of China, citations mainly came from England, Spain, Germany, Turkey, Australia,

and Ireland and mainly from Spain, Ireland, and China in the case of North America. Once the bibliometric analysis has been carried out, it is necessary to review the literature, which is developed in the following section and whose references are compiled in Table 5.

Table 5: Recapping table with the references analyzed in each section.

Section	References
4.1. Conceptualization of EI	Scarpellini et al., 2020 García-Sánchez et al., 2020 Vence and Pereira, 2018 Hall et al., 2013 Horbach, 2008 Pan et al., 2020 Carrillo-Hermosilla et al., 2010 Kemp & Pearson, 2008
4.2. Types of EI	Hofstra and Huisingh, 2014 Prieto-Sandoval et al., 2018 Vence and Pereira, 2018 Kemp & Pearson, 2008 Liao, 2018 Rodriguez-Rebés et al., 2021 Rodríguez-García et al., 2019 García-Granero et al., 2018
4.3. Drivers of and Barriers to EI	Bitencourt et al., 2020 Hojnik et al., 2018 Dorand and Ryan, 2012 Rizos et al., 2016 Kirchherr et al., 2018 Kayikci et al., 2021 Pacheco et al., 2017 Andries and Stephan, 2019
4.4. Impact of EI on Business Performance	Tang et al., 2017 Scarpellini et al., 2017

	Hizarci-Payne et al., 2020
	Rexhäuser and Rammer, 2013
	García-Sánchez et al., 2019
	Lopes-Santos et al., 2019
	Xue et al., 2012
	Lee and Min, 2015
	Benijts, 2014

Source: The author

4. LITERATURE REVIEW

4.1. Conceptualization of eco-innovation

Innovation and design are two words that must go together when we talk about one of the main drivers of business success (Scarpellini et al., 2020). Innovations become EIs, also known as green innovations, sustainable innovations, and environmental innovations (Hizarci-Payne et al., 2020), when they are inspired by an important concept in this field: eco-design. According to García-Sánchez et al. (2020), eco-design is the development and commercialization of technologies, products, and services that aim to reduce the impact they may have on the environment.

Hand in hand with eco-design, we find EI, a concept that has been discussed on numerous occasions throughout the existing literature and which consists of using techniques, processes, systems, and products in a way that reduces or avoids harmful impacts on the environment (Vence & Pereira, 2018). The term "EI" came into use around the mid-1990s; however, this key concept in transforming the linear model into a circular one (Scarpellini et al., 2020) has gained more interest in the last two decades (Hizarci-Payne et al., 2020).

Several definitions of EI can be found in the literature. Among them are those collected by Liao (2018) from Hall et al. (2013) and Horbach (2008), who state that

environmental innovation is a variant of innovation and consists of using techniques, processes, systems, and products in a way that reduces or avoids harmful impacts on the environment. On the other hand, Pan et al. (2020) and Carrillo-Hermosilla et al. (2010) define EI as, respectively, an important approach to address current environmental problems and as any innovation that reduces the negative impact of consumption and production on the environment.

However, although we have found several definitions of EI, we will use the one given by Kemp and Pearson (2007) in the "Final Report MEI Project About Measuring EI," as it is one of the definitions that has been repeated the most throughout he articles reviewed for this work. These authors define EI as exploitation, assimilation, or production that is novel for the company and that reduces negative impacts on the environment compared to other alternatives (Kemp & Pearson, 2007). As can be seen, there are slight differences between the definitions shown above. This is because some authors perceive EI to obtain competitive advantages, while others perceive it to achieve an environmental goal (Vence & Pereira, 2018). Therefore, it is necessary to conduct a preliminary study on the types of EI that exist, what motivates and restrains companies to apply these strategies, and, subsequently, to see what the impact of environmental innovations is on the business performance of the companies that apply them.

4.2. Types of eco-innovation

Although most of the authors reviewed in this chapter agree, throughout the literature review, we found several types of EI. Prieto-Sandoval et al. (2018) refer to four types of EIs based on Hofstra and Huisingh (2014). These are exploitative, restorative, cyclical, and regenerative EIs. Vence and Pereira (2018) compiled other types of EIs. In this compilation, we find authors such as Kemp and Pearson (2007), who presented in the

"Final Report MEI Project About Measuring EI" mentioned above and who cite four other typologies of EI referring to environmental technologies, organizational innovations, product, and service innovations, and, finally, green system innovations.

In addition to Kemp and Pearson, Vence and Pereira present five other types of EIs. Depending on the role they play in the market, EIs can be complementary, integrated, alternative product, macro-organizational, or general purpose. Although there are different classifications of the concept of EI, there are four types of environmental innovations that have been most repeated in our literature review, including those developed by authors such as Liao (2018), Rodríguez-Rebés et al. (2021), and Rodríguez-García et al. (2019), where three types of product, process, and organizational EIs are mentioned. In addition, García-Granero et al. (2018) refer to marketing EIs. These four types can be defined as follows:

• Product EIs: These refer to the use of new or improved goods or services (Liao, 2018). When a product is manufactured, the materials used can have a negative impact on the environment (García-Granero et al., 2018), so it is necessary to develop appropriate technologies to enable the manufacture of new products on the market that are beneficial to the environment (Rodríguez-García et al., 2019).

• Process EIs: When a company conducts its productive activities, not only does the product have an environmental impact, but so does the way in which the entity produces that product (García-Granero et al., 2018). Therefore, process EIs pursue the use of more environmentally friendly technologies when producing products and services (Rodríguez-García et al., 2019), which is why it is necessary to make efficient use of resources in the production process (Liao, 2018).

• Organizational EIs: These environmental innovations refer to how the organization and its employees conduct different activities, adopting environmental management models (Rodríguez-García et al., 2019). These EIs not only focus on important aspects such as research and development (R&D) but also pay special attention to the way companies manage their business (Liao, 2018).

• Marketing EIs: Within this typology of EIs, we find those that aim to reduce the negative environmental effects generated by companies in their marketing activities. Despite being a relevant activity to business performance, green innovation in marketing has received less attention than others (García-Granero et al., 2018).

Once the different typologies of environmental innovations or EIs have been set up, it is necessary to study what factors motivate or restrain companies in implementing these strategies.

4.3. Drivers of and barriers to eco-innovation

As we have seen, EI has been dealt with by numerous authors throughout the literature because of the relevance it is taking on in business. This interest in environmental innovation goes hand in hand with the different factors that drive this process of change. However, the motivation behind the implementation of EI strategies can be conditioned by a series of circumstances that can put a brake on its development.

Related to the drivers, there are several reasons why companies decide to invest in EI and implement such strategies. Throughout the literature review, we found different drivers that can determine whether such a strategy is conducted. In this regard, Bitencourt et al. (2020) state that investing in R&D will allow companies to develop cleaner technologies and thus encourage changes in both products and production processes. In

addition, market turbulence forces companies to be in a continuous process of differentiation, so this hostile environment motivates companies to generate competitive advantages over the rest of the companies in the sector. This results in consumers demanding environmentally friendly products, giving rise to the so-called "green value," which can be used to gain a competitive advantage (Hojnik et al., 2018).

On the other hand, Doran and Ryan (2012) state that regulatory pressure is one of the main drivers of EI. These regulations force companies to invest in EI to reduce pollution and avoid negative impacts on the environment. In addition, they consider that the generation of knowledge drives different economic agents to strengthen ties to favor the development of EI. Further, Hojnik et al. (2018) note that the so-called "green barriers" prevent companies from trading in other markets unless they comply with certain environmental requirements, which encourages the need to invest in EI.

In terms of firm size, Andries and Stephan (2019) state that when small firms adopt environmental measures voluntarily, they benefit economically more than large firms do. This is because the reputation that small firms achieve with these practices can benefit them in terms of increased demand or approval from their stakeholders, which will lead to an improvement in their business performance (Andries & Stephan, 2019). As we can see, the drivers of EI are diverse, with business motivations ranging from improving the company's reputation to reducing costs or simply complying with regulations (Hojnik et al., 2018).

Related to the barriers, it is important to mention that the drivers mentioned above cannot be applied to all types of companies, as there are several factors that condition the implementation of different EI strategies. Among these factors, Rizos et al. (2016) lists a series of difficulties that some companies face, such as the assessment of what the future

benefits will be compared to the costs they currently face, what the availability of technologies will be like, or how demand will act in terms of eco-friendly products. In addition, these authors identify several barriers that smaller versus larger firms face in adopting EI strategies. Although both types of firms face these difficulties, they do not face them under the same conditions.

Within these barriers we find that SMEs lack a large amount of capital, government support, and effective legislation. In addition, they lack sufficient information and technical and technological knowledge to be able to implement such strategies (Kirchherr et al., 2018). This is compounded by the administrative burdens faced by SMEs and the lack of an environmental culture within SMEs (Kayikci et al., 2021).

On the other hand, multinationals have the technology, finance, human resources, and know-how to be able to innovate, while SMEs lack a strong R&D department and will therefore rely on external agents to carry out innovation tasks (Jordan et al., 2014). Furthermore, we find that multinationals can adopt CE concepts and determine how to implement them; however, SMEs will need to rely on research institutes, agencies, and universities to enhance organizational learning and facilitate the adoption of sustainable practices (Pacheco et al., 2017). In addition, according to Andries and Stephan (2019), the main reason that smaller companies adopt environmental improvement programs is regulation, which forces them to introduce EIs in the same way as large companies even though they lack the necessary resources. For small firms, these innovations come at a high cost that they will not be able to compensate for with a higher volume of goods or services sold, something that large firms will be able to do (Andries & Stephan, 2019).

Having established the drivers of and barriers to EI, we will now analyze the different perspectives in the literature on the impact of the implementation of eco-innovative strategies on economic performance.

4.4. Impact of eco-innovation on business performance

So far, we have seen what EI is, what types exist, and what its main drivers and barriers are. Among the drivers of environmental innovation, we have found some related to management's conviction about potential cost savings or gaining a competitive advantage, among others. In this section, we will focus on the impact of EIs on the business performance of organizations that are committed to sustainable practices.

Despite the measures taken by many countries to implement environmental innovations (Liao, 2018), these have not always had the same impact in all cases. A meta-analysis of several articles published between 1978 and 2008 showed that 55% of these showed a positive effect, 15% negative, and 30% showed that EIs had no impact on outcomes (Tang et al., 2017). Today, more than a decade later, research still lacks clear evidence about the impact of EIs on business performance. However, out of these three academic approaches and after having reviewed the literature selected for this chapter, we find two main conflicting perspectives on whether organizations that invest in EI improve or worsen their business performance. According to Scarpellini et al. (2017), these two approaches are the following:

• Win–lose: Engaging in economic activities and protecting the environment entail additional costs, harming economic productivity and competitiveness (Scarpellini et al., 2017).

• Win–win: When companies improve their environmental performance, they reduce their costs and increase their sales (Scarpellini et al., 2016). Furthermore, through greening supply chains, companies can explore new market opportunities (Hojnik et al., 2018). Other authors, however, believe that while the impact of EIs on firm performance may be negative in the short term, in the long term, it will provide economic benefits.

4.4.1. Literature review on the positive effect of eco-innovation on business performance

That environmental innovation has a positive impact on the business performance of companies is a position that has been advocated by numerous authors. In fact, the predominant evidence in the literature focuses on the positive effect that EI has on business economic performance (Hojnik et al., 2018).

Innovation is one of the most important means of differentiating companies in an increasingly competitive environment, benefiting from the production of better and more innovative products, enhancing reputation to gain stakeholder support, increasing market share, and improving customer satisfaction, among other benefits (Liao, 2018). Furthermore, authors such as Liao (2018), Marín-Vinuesa et al. (2018), and Scarpellini et al. (2017) argue that EIs can lead to cost reductions and thus improve business performance. On the other hand, we find a position that, despite claiming that EI might have a negative effect in the short term, over time this effect will turn positive.

However, the effect that these innovations can have depends not only on time but also on the type of EI (Hojnik et al., 2018). As we have seen previously, there are several types of EIs according to the literature; of these, we highlighted four as the most recurrent. These are product, process, organizational, and marketing. Hizarci-Payne et al. (2020)

established the impact that each of these types of green innovations had on firms, stating that they all have a positive impact on business performance:

• Process EI: Companies that adopt novel and more environmentally friendly production systems and delivery mechanisms promote cost reduction and operational efficiency.

• Product EI: Acts such as modifying the composition of a product to prevent its impact from being harmful to the environment help the company to position the product in the market, improve its image or reputation, and gain an important competitive advantage.

• Organizational EI: When sustainable practices are promoted within the organization through a pro-environmental philosophy, a chain effect occurs that allows the company to comply with government regulations (and thus avoid having to pay penalties), meet the needs of its stakeholders, and increase the company's presence in the market, all of which contribute to improved business performance.

• Marketing EI: Green marketing or environmental marketing has emerged with the aim of meeting the needs of customers while reducing the negative impact that activities have on the environment. This approach to marketing can generate significant benefits for companies that apply it, such as improved performance and cost savings. In addition, the creation of green products can establish a brand image that enhances the company's market position and can help to build customer loyalty and win new customers.

4.4.2. Literature review on the negative effect of eco-innovation on business performance

In contrast to the previous position, there are authors who claim that EI does not always have a positive impact, as the successful implementation of this strategy requires a strong initial investment and a high degree of turnover per worker (Doran & Ryan, 2012), so the implementation of green innovations does not always result in a positive return for companies (Rexhäuser & Rammer, 2013).

In addition, EIs may not be beneficial in aspects such as the revenues, competitiveness, image, or performance of the companies that implement such strategies (García-Sánchez et al., 2020). Moreover, according to García-Sánchez et al. (2019), implementing environmental innovation strategies entails high costs that will harm both production and distribution in these companies. Following the same authors, a study conducted on more than 6000 international companies between 2002 and 2017 confirms that these strategies have a negative impact, especially in munificent environments.

Despite the above, even if the implementation of EI does not increase the current profitability capacity, García-Sánchez et al. (2019) found that investors will value these investments positively, thus causing an increase in their market value, this being an indicator of great relevance when considering the expectations that investors have about the possible profits that companies can obtain in the future.

The discrepancies observed about the impact that EIs have on business performance may be due to the fact that some studies have shown that this impact has been positive while others have shown that it has been negative; however, it must be considered that not all companies are the same, nor are the countries where these studies

are carried out or the environment in which these companies are located. Therefore, we will now discuss how numerous factors can affect the impact that these environmental innovation strategies can have on business performance.

4.4.3. Constraints on the impact of eco-innovation on business performance

As we observed in the previous section, it is generally accepted that EIs increase productivity, reduce costs, and allow companies to enter new markets, thus improving these companies' business performance (Marín-Vinuesa et al., 2018). However, we also observed that there is no consensus in the literature on the actual impact of environmental innovations on business performance (Lopes Santos et al., 2019). This may be due to several institutional factors that condition this impact and prevent a homogeneous assessment of how several types of EIs affect business performance. These factors are related to the level of economic development:

a. Emerging versus developed countries

Lopes Santos et al. (2019) showed that the level of development of the countries where firms were located positively or negatively influenced economic performance after implementing EI strategies. In this study, three indicators were analyzed: return on sales (ROS), return on assets (hereafter ROA), and return on equity (hereafter ROE). On the one hand, these authors found that EI activities are positively related to all three indicators in developed countries, despite declining revenues.

On the other hand, in emerging countries, it was observed that despite the decline in sales performance, asset performance and revenues increased, and revenues were higher than in developed countries during the study period.

b. Business environment

García-Sánchez et al. (2019) argued that companies operating in industries with greater resources enjoy greater growth, which does not imply that they need to promote pro-environmental practices to improve their economic situation. According to these authors, the abundance of resources implies a lower opportunity cost for firms operating in more competitive industries (Goll & Rasheed, 2004), so they are more likely to invest in EIs without worrying about the impact that such investments may have on their results (Xue et al., 2012). This is why the negative impact that EI strategies have on business performance will be greater in industries with greater resources (García-Sánchez et al., 2019), as they invest a greater amount of money without having to worry about the economic return that this will bring to the company.

On the other hand, we find that EI has a positive impact on the market value of companies that develop and apply such strategies. Recall that market value is a good indicator to establish how investors view the company in terms of its possible future growth (Nicolau & Santa-María, 2013), and it is a useful indicator to reflect the market's assessment of a company's results, which allows the measurement of its business performance (Lee & Min, 2015). However, this impact is not the same across industries and/or sectors.

According to García-Sánchez et al. (2019), companies that operate in sectors where there is a high level of munificence enjoy a better valuation by the market after implementing EI strategies as they have greater competitive opportunities and better conditions for growth. Furthermore, it should be considered that, in more favorable environments, companies will be able to enjoy greater tax incentives, as well as benefit from government subsidies, which will allow them to implement the necessary technologies to promote green energy (Benijts, 2014).

5. CONCLUSIONS AND IMPLICATIONS

The results obtained from this bibliometric and bibliographic study led us to the following conclusions. On the one hand, we find that interest in sustainability and EI strategies has grown in recent years both from academics and from governments and companies. On the other hand, this review shows that although researchers have not reached a consensus on the impact of EI strategies on business performance, most of them favor a positive impact on the profitability of these companies, in either the short or long term, while others think that the impact will not be positive for their profitability but will be positive for their market value. Furthermore, unlike Hojnik et al. (2018), Liao (2018), or Doran and Ryan (2012), after our analysis, we can see that the impact of EI can be different depending on a series of factors, so it cannot be stated that EI has a positive or negative impact in all cases. Therefore, we note that that the impact of EI on business performance varies according to the size of the company, the country where it is located, and the environment in which it is located. These results are in line with those obtained by Zheng and Iatridis (2022) and Hizarci-Payne et al. (2020).

Along these lines, we find that small companies face different barriers that hinder the implementation of sustainable strategies compared to large companies, which have more resources and can implement them with less difficulty. In addition, depending on whether the country in which the company is located is developed or emerging, the application of sustainable strategies will affect certain indicators in one way or another. In developed countries, ROS, ROA, and ROE will increase, while in emerging countries, only ROA and ROE will increase. On the other hand, companies with more resources will invest more in EI, as they are not as concerned about the economic return as companies in a less favorable environment for EI. Therefore, the negative impact will be greater on the economic performance of the former, as they invest more.

The conclusions obtained from the analysis conducted in this study provide information that can facilitate the understanding of the lack of consensus that can be observed in the existing literature in the field of EI and firm performance (Liao, 2018; Marín-Vinuesa et al., 2018; Tang et al., 2017), providing a series of external factors that can explain the reasons for these discrepancies (Hizarci-Payne et al., 2020; Zheng & Iatridis, 2022). In addition, the conclusions derived from both the bibliographic and bibliometric analyses allow us to outline a picture of the state of the art in this field of knowledge that can be of great use for researchers, as well as to help develop possible lines of research that can be carried out in future studies.

5.1. Contribution to theory

This study makes several contributions to the existing literature. Firstly, this study exposes and summarizes the different positions observed in the literature that refer to the impact of EI on firm performance in the two main scenarios (positive and negative impact), which broadens and deepens the previous literature. Secondly, the analysis presented in this study combines a systematic literature review with a bibliometric analysis to establish a contextual framework to guide researchers in understanding the current situation of this field of knowledge. Thirdly, the results obtained in the present work contribute to the theory of resources and capabilities (Penrose, 1995), since it has been shown that both resources and capabilities are key factors to companies when investing in EI strategies, highlighting that the companies that invest the most in this type of strategy are those that have the greatest resources. Related to the above, the present work contributes to the institutional theory regarding the impact that EI has on results, as they depend on both the firm's environment and its level of institutional development (Zhou et al., 2016).

5.2. Managerial and policy implications

In addition to the theoretical implications described in the previous section, this work contributes in a practical way to the development of different environmental strategies. In this sense, the barriers and drivers described in this study are of great relevance for managers who want to implement EI strategies within their company. In addition, the different positions summarized in this review process, as well as the factors that can condition the negative or positive economic impact, are of great relevance for managers and companies when it comes to knowing how, depending on the situation in which the organization finds itself, EI can influence both its results and the behavior of investors.

In addition to the above, the bibliometric analysis conducted in this study reflects the growing concern and the emerging interest in this topic, particularly in the last decade. This analysis provides relevant information for companies to visually and easily observe the concern that exists in continuing to advance in sustainability matters to efficiently address environmental problems such as waste of resources, generation of waste, energy expenditure, or greenhouse gas emissions, among others. Furthermore, the distinction between the four types of EI highlighted in the studies analyzed in the review process can help companies understand how this type of green innovations can be applied in different areas and stages of the production process, which can be a differentiating element within the market.

On the other hand, in the current environment in which environmental recovery and digital transformation towards a CE model are being highlighted through the establishment of the Sustainable Development Goals (SDGs), it is necessary to emphasize the impact that the implementation of different environmental innovations has with the

aim of improving the current climate crisis. Thus, this work should be considered when implementing the different actions aimed at sustainable economic growth, considering that EIs are essential to improve the different production models by reducing the carbon footprint, thus contributing to a more environmentally friendly economy.

5.3. Research limitations and future research directions

This study has few limitations that need to be highlighted. Firstly, systematic reviews may have several limitations, ranging from the selection of the database to the interpretation of the results. In this case, the literature review has been conducted by only considering two databases: Scopus and WOS, with the latter being more relevant. Although these databases are two of the most widely used globally, the selection of these databases may limit the scope of the review, as there may be relevant studies that are not published in these databases. In addition, the search equations applied in the systematic review process were conducted using general keywords, so we may have missed some papers that used more specific keywords. In addition, when selecting the studies analyzed in this chapter, a series of criteria were applied that may have excluded other studies with valuable information due to being published in a different period or language than the one selected.

On the other hand, the bibliometric analysis was conducted using a single software: VOSviewer. Despite being a widely used software by the scientific community and providing relevant information, there are other software tools that could have offered a more complete type of analysis. Despite these limitations, our study highlights the growing interest in the economic impact of companies' implementation of different environmental strategies. This analysis has focused on the impact of EI on business performance.

Although there is incipient and extensive literature on the subject, there are still many issues to be explored to clarify the current situation of the business environment in the context of sustainability, the CE, and environmental innovations. In this sense, we propose future lines of research with the aim of filling some of the gaps that exist in the current academic literature. Following Centobelli et al. (2020) and taking into account the clusters obtained from the bibliometric analysis, the selected articles can be classified into four main areas (Table 6): (1) research on the development of EI strategies, (2) transition towards a sustainable and CE, (3) impact of EI strategies on firm performance, and (4) strategic management of EI and identification of barriers and drivers.

Table 6: Main topics and future research avenues

Cluster	**Exemplary references**	**Future Research Avenues**
Red (Cluster 1): Research on the development of EI strategies.	Scarpellini et al. (2019) Lee and Min (2015) Dong et al. (2014)	-Analyze the role of government policies in promoting EI. -Study the integration of CE principles in EI strategies. -Analyze the economic impact of other green firm capabilities. -Investigate on the role of education in promoting the adoption of EIs.
Green (Cluster 2): Transition towards a sustainable and CE.	Duran-Romero et al. (2020) Gliedt et al. (2018) Rizos et al. (2016) George et al. (2015)	- Investigate innovation in technologies and business models that enable an effective transition towards a circular and sustainable economy. - Analyze the environmental, social, and economic impact of the transition towards a circular and sustainable economy.

		- Establish new indicators and measurement tools that allow evaluating progress towards a CE. - Determinate how the post-pandemic recovery funds and the war in Ukraine have changed the current scenario to observe the role of the CE in this new scenario. - Identify how the digital transition can help in the transition towards a sustainable economy model.
Blue (Cluster 3): Impact of EI strategies on firm performance.	Xue et al. (2019) Garcia-Granero et al. (2018) Tang et al. (2017)	- Analyze the long-term impact of EI. - Analyze the impact of EI in the current global context, after the COVID-19 crisis and the war in Ukraine. - Analyze the impact of EI strategies on poverty reduction, job creation, and biodiversity conservation.
Yellow (Cluster 4): Strategic management of EI and identification of barriers and drivers.	Rodriguez-Rebes et al. (2021) Nandi et al. (2021) Santos et al. (2019) Lin et al. (2019) Andries and Stephan (2019)	- Exploration of stakeholder involvement in EI management. - Analyze underdeveloped countries and how they are managing EI. - Establish new barriers and drivers in the current global context when it comes to implementing EIs. - Determinate how AI can help companies to implementing EI strategies. - Determinate how companies manage their investments in

	innovative technologies aimed at reducing their environmental impact.

Source: The author

5.3.1. Research on the development of eco-innovation strategies

EI can be defined as the exploitation, assimilation, or production novel to the firm that reduces negative impacts on the environment compared to alternatives (Kemp & Pearson, 2007). In this sense, the literature has focused on defining and studying the types of EI that exist. However, there is no solid literature analyzing how different countries are coming together to promote and develop EI strategies through government policies and awareness through the education system, so we propose to analyze the role of these institutions in promoting EI practices.

On the other hand, although there are numerous studies that analyze the relationship between EI and the CE (Abu Seman et al., 2019; Aldieri et al., 2019; Aminoff & Pihlajamaa, 2020), it is important to analyze how the different principles established in the CE relate to each type of EI (product, process, organizational, and marketing). In this sense, we propose as a future research avenue to investigate how organizations integrate the CE principles in their EI strategies. Moreover, no particular attention has been paid to other green firm capabilities such as green investment capability, green purchasing practices, or green digitalization capabilities (Khan et al., 2022). To fill these research gaps, we propose as a future line of research to study how the combination of these green firm capabilities (in line with EI) affects business performance, paying particular attention to the role of the digital transition on the path to sustainability within firms (Abbate, Centobelli, & Cerchione, 2023).

5.3.2. Transition towards a sustainable and circular economy

The area of research focuses on the CE, which is defined as an alternative economic model to the linear model whose objective lies in waste minimization, long-term value retention, reduction of primary resources, and closed product loops (Morseletto, 2020). The literature has focused on studying what this concept consists of and what impact it can have on organizations that apply this new economic model, relating it to a series of environmental innovations that justify this impact. However, most of these studies were conducted prior to the global instability that has arisen in the post-pandemic era (Casado-Aranda et al., 2021), aggravated by the war in Ukraine. Therefore, as a future line of research, we propose to analyze how the post-pandemic recovery funds and the war in Ukraine have changed the current scenario to observe the role of the CE in this new scenario.

On the other hand, the impact of the CE on firm performance has been analyzed by several authors (de Jesus et al., 2018; George et al., 2015; Leder et al., 2020); however, it is necessary to analyze the environmental and social impact of this transition. In this way, it would be necessary to establish new indicators and measurement tools to know how the transition to a circular economic model is being made and to see its impact on other different areas. Furthermore, the emerging growth of Industry 4.0 (Abbate, Centobelli, & Cerchione, 2023) makes necessary to research the role of this industry in the transition towards a more sustainable economic model, so we propose to analyze, in parallel, the digital transition with the transition towards the CE to establish a relationship between them.

5.3.3. Impact of eco-innovation strategies on firm performance

The literature has focused on studying the impact of EIs on business performance. Although most studies claim a positive impact, this is not conclusive. In addition, the impact of EI may vary over time since the global context is constantly changing. In this sense, studies that analyze the impact of EI on economic outcomes focusing on the short term, without having a more long-term perspective. To fill this research gap, we propose as a future line of research to analyze the impact of environmental strategies in the long term, which could eliminate the uncertainty that prevails in the literature instead of focusing on a short-term analysis that can lead to confusing results, with special emphasis on the current context of political and economic instability at the global level.

On the other hand, and in line with the research proposal in the previous section, we propose to analyze the impact of EI strategies in social and environmental terms, specifically on poverty reduction, job creation, and biodiversity conservation.

5.3.4. Strategic management of eco-innovation and identification of barriers and drivers

This area of research refers to the strategic management that companies conduct when implementing EI strategies, as well as the external factors that, together with the barriers and drivers that lead organizations to implement them, can condition the impact of these strategies on the results of companies that apply them. Regarding strategic management, there is a limited literature that analyzes the influence of institutional investors within listed companies when managing and implementing EI strategies. Although several authors have analyzed the environmental pressure of institutional investors when voting on executive say-on-pay (Ertimur et al., 2013; Obermann, 2019),

we are not aware of any literature that analyzes the influence of these investors when implementing specific EI strategies.

Regarding external factors that condition the impact of EI, this study sets out the size of the company, the environment in which it operates, and the level of development of the country in which it conducts its activity as conditioning factors. However, although there are studies that analyze the impact of EI on the results of companies located in developing countries, most of the studies that have been conducted focus on analyzing this impact in developed countries. Therefore, we propose to analyze this impact by prioritizing developing countries, since it is in these countries that most of the global production is located. In addition, we propose to study barriers and drivers different from those previously studied that have emerged on the current global context.

On the other hand, artificial intelligence (AI) is a concept that is awakening an emerging interest among academics (Bag et al., 2021; Nishant et al., 2020). Being a field in continuous change and growth, there is still much to study in this area. Therefore, as a future research line, we propose to establish a cause–effect relationship between the development of AI and the implementation of EI within organizations, to observe if this new technology is promoting such implementation and what is its economic impact.

UNIVERSIDAD DE GRANADA

CHAPTER III: COMPARATIVE ANALYSIS OF CORPORATE ENVIRONMENTAL PERFORMANCE IN TERMS OF ECO-INNOVATION: DEVELOPING A DOMINANCE INDEX (DMI) APPROACH.

1. INTRODUCTION

Climate change and its consequences have become an issue of great relevance due to the concern it arouses not only among citizens, but also among managers, consumers, and suppliers around the world (Krieger and Zipperer, 2022; Albitar et al., 2023). This concern, which has been growing since the 1980s (Flores-Rivera et al., 2023), coupled with the lack of natural resources and the various constraints that exist in this regard exacerbated by recent socio-economic and health crises, as well as changing consumer preferences, have made sustainability a crucial element in any business strategy (Nowicki et al., 2021).

In order to curb the negative impact of climate change, there have been increased efforts by companies, governments and society in general, where innovation has played a crucial role in addressing societal challenges and contributing to the improvement of human wellbeing (Castellacci, 2023). These efforts have been aimed at finding an alternative to the linear production model, as this poses a serious problem for sustainability as it does not take into account the scarcity of resources, which compromises future generations (Zhong et al., 2022; López-Pérez et al., 2023),

To alleviate the consequences of this model, the concept of CE (CE) arises, which can be defined as an economic model that aims to carry out an efficient use of resources by minimizing waste, reducing closed loops and using more environmentally friendly technologies (Park et al., 2010; Morseletto, 2020). For this model to be implemented, it is necessary to apply a series of environmental innovations or EIs, defined as those products, production processes or management and business methods whose main objective is to prevent or reduce environmentally harmful practices (OECD, 2009).

The interest in EI has grown exponentially, which has led numerous authors to investigate this type of innovation in the business sphere, especially in recent years (López-Pérez et al., 2023; Wilke and Pyka, 2024). In this context, several authors claim that investing in sustainable strategies means that companies experience less negative economic impact from crises such as the COVID-19 crisis or, more recently, the war in Ukraine (Huang et al., 2020; Hermundsdottir et al., 2022).

To analyze this type of strategy, numerous studies have established indicators capable of measuring the degree of corporate environmental performance (Dong et al., 2014; Wang et al., 2021; Zaman et al., 2021), which will make it possible to evaluate which companies and/or initiatives are the most eco-innovative. However, there is no single, globally accepted measurement instrument in the literature within the field of corporate sustainability and EI (Amor-Esteban et al., 2020), so numerous studies can be found that use different methodologies to measure this degree of environmental performance (Pavláková-Docekalová and Kocmanová, 2016; Amor-Esteban et al., 2020; García-Sánchez et al., 2021; Chaparro-Banegas et al., 2023). These methodologies, despite generating detailed indicators, often employ highly complex mathematical

processes that can hinder their replication and understanding within the scientific and business environment.

Thus, the aim of this study is to draw up a ranking based on dominance for the year 2020 that allows us to establish, by means of qualitative variables, which companies, sectors and countries have the highest level of performance in terms of EI. For this purpose, a sample of 4,761 listed companies from all over the world obtained from the Refinitiv Eikon database has been used to subsequently calculate the ranking in R-Studio. The aim is to show a more simplified and efficient approach that contributes to a broader understanding, which will allow a comparative analysis of the commitment to these practices at corporate, country and industry level.

2. ECO-INNOVATION AND CORPORATE ENVIRONMENTAL PERFORMANCE

Sustainability and its importance in business is a widely studied topic in the scientific literature (Liao, 2018; Hizarci-Payne et al., 2020; Çimen, 2021). Authors such as Aksu and Akman (2023) have addressed this topic as "corporate sustainability" or "business sustainability", defined as those actions carried out by organizations with the aim of meeting the needs of stakeholders without compromising future generations, emphasizing on environmental, economic and social dimensions (Çankaya and Sezen, 2015; Rafiaani et al., 2019; Aksu and Akman, 2023). In this line, authors such as Varsei et al. (2014) or Rajesh (2020) approach corporate sustainability as the incorporation of sustainable development objectives within business practices.

2.1. Exploring eco-innovations

The last decade has seen the emergence of a concept whose interest has grown significantly among academics and practitioners around the world: EI, also known as environmental innovation or green innovation (García-Sánchez et al., 2019; Zheng and Iatridis, 2021; López-Pérez et al., 2023). EI has been widely analyzed in the scientific literature, where several definitions of this concept can be found. Among these definitions, Kemp and Pearson (2007) and Pan et al. (2020) define EI as those activities that address environmental problems, whose environmental impact is lower compared to other alternatives, and which are novel for the company. This type of innovation is perceived as a potential factor that allows moving towards a CE through production cycles, innovative technologies in the production process and improvements in environmental policies. (Barbieri et al., 2016).

From a more specific point of view, several authors have classified EI into four broad categories based on its nature. Although EI has traditionally been classified into products and processes (Damanpour, 2010; Riaz et al., 2023), authors such as Carrillo-Hermosilla et al. (2010) or Hojnik and Ruzzier (2016), among others, classify this type of innovation into four broad categories: product, process, organizational and marketing. However, in this study, we will focus on analyzing the first three dimensions, as no representative variables for the marketing category have been found, which is in line with other previous studies (García-Granero et al., 2018).

2.2. Measurement Indicators of Environmental Performance

In order to analyze the degree of environmental performance carried out by companies, several authors have analyzed to what extent and in what way these companies carry out eco-innovative practices (García-Granero et al., 2018; Almeida and

Wasin, 2022; Albitar et al., 2023). In this context, there are several aspects that can motivate companies to carry out this type of practices. Flores-Rivera et al. (2023) divides these motivations into two main groups: external and internal, where the external ones refer to the incentives received from different stakeholders, as well as different governmental pressures, while the internal ones refer to specific characteristics of the companies, such as market value, financial performance, or the existence of an environmental committee, among others (Broccardo et al., 2019; Salo et al., 2020).

In this context, at the macro level, in 2010 the EI Observatory (EIO) developed an index called the EI Scoreboard (Eco-IS) which consists of measuring the degree of performance of EU Member States in relation to EI (EIO, 2012; Park et al., 2017). This index is a score consisting of 16 indicators grouped into five broad groups (see Table 7), which are used to calculate the score of each member state in terms of EI using the unweighted average of these indicators (Park et al., 2017).

In this line, several researchers have analyzed the degree of environmental performance of companies not only by country, but also by industry. Authors such as Pavláková-Docekalová and Kocmanová (2016) designed a Complex Performance Indicator (CPI) including environmental, social, economic and corporate governance aspects. Moreover, Amor-Esteban et al. (2020) analyzed from a broader point of view the commitment to Corporate Social Responsibility (CSR) at country and industry level using the CUR matrix, highlighting the commitment of Australia and European countries in matters of sustainability in comparison with the rest of the countries, as well as the industries with the best environmental performance, including the utilities sector and the oil and gas industry, among others.

Table 7: Eco-innovation Scoreboard components

Group	Indicators	Measuring Element
EI inputs	Governments environmental and energy R&D appropriations and outlays	Governments budget appropriations and outlays
	Total R&D personnel and researchers	Number of R&D personnel and researchers
	Total value of green early-stage investments	Total value of investments
EI activities	Firms having implemented innovation activities aiming at a reduction of material input per unit output	Number of firms having implemented innovation activities for material efficient
	Firms having implemented innovation activities aiming at a reduction of energy input per unit output	Number of firms having implemented innovation activities for energy efficiency
	ISO 14001 registered organizations	Number of ISO 14001 registered organizations
EI outputs	Eco-innovation related patents	Number of patents
	Eco-innovation related academic publications	Number of publications
	Eco-innovation related media coverage	Per number of electronic media
Environmental outcomes	Material productivity	GDP/Domestic material Consumption
	Water productivity	GDP/Water footprint
	Energy productivity	GDP/gross inland energy consumption
	GHG emissions intensity	CO2e/GDP
Socio-economic outcomes	Exports of products from eco-industries	% of total exports
	Employment in eco- industries and CE	% of total employment across all companies
	Revenue in eco-industries and CE	% of total revenue across all companies

Source: Park et al. (2017)

On the other hand, authors such as Aparicio et al. (2020) present the creation of composite indicators through an extended DEA with the introduction of the benefit of the

doubt (BoD) to assess the performance of decision-making units in the field of CSR, showing the way for analysts to observe how companies could improve their CSR performance with less effort. This combination of methodologies (DEA-BoD) has been widely used by various authors throughout the literature to develop composite indicators that attempt to explain complex realities (Giambona and Vasallo, 2013; Fukuyama et al., 2020; Gupta and Guha, 2024). Following the DEA model, Aparicio and Kapelko (2019) state that the companies that show the highest levels of efficiency in the field of CSR are those belonging to the manufacturing and mining sectors.

Something similar is done by García-Sánchez et al. (2021), who present a CEBIX composite index with the aim of assessing, based on 17 environmental initiatives, which countries and industries are the most developed in terms of CE (CE), placing France and the utilities sector as leaders in the shift towards a more environmentally friendly economy. Furthermore, García-Sánchez et al. (2021) state that business activity and its commitment to the CE should be enhanced through the application of eco-innovative practices.

At the corporate or micro level, several authors have investigated the degree of compliance of organizations in implementing environmental innovation strategies (Abu-Seman et al., 2019; Wang et al., 2021). Among these studies are papers such as Dong et al. (2014) who use different indicators to analyze the correlation between environmental performance and business competitiveness considering the typology of EI, placing organizational and product EI as the most influential.

On the other hand, numerous studies have used the "Environmental Innovation Score", present in the Refinitiv Eikon database, which is a score between 0 and 100 and reflects a company's ability to create new market opportunities with more

environmentally friendly technologies, as well as the ability to reduce costs and environmental burdens for its customers (Albitar et al., 2023). This Score has been used by authors such as Zaman et al. (2021), who examine the effect of EI on stock price downside risk. These authors used the Score directly from the database that Eikon calculates from twenty indicators related to organizational, product and process environmental innovations.

In addition, Albitar et al. (2023) analyze the impact of EI and climate governance on companies' commitment to climate change, using their own Score. In this way, these authors, in addition to selecting the Score that appears in Refinitiv Eikon, create their own EI index in which they add, unlike the study of Zaman et al. (2021), an eco-design variable. Eco-design consists of the development of products, services and technologies with the aim of reducing the environmental impact derived from business activity, this being a particularly relevant concept when analyzing environmental innovation strategies (García-Sánchez et al., 2020; López-Pérez et al., 2023).

So far, it can be observed how most of the studies covering the field of environmental innovation use methodologies that allow for analyses with quantitative and qualitative variables (Amor-Esteban et al., 2020; Zaman et al., 2021, among others). However, there are other methodologies used by various academics capable of creating aggregate indicators for qualitative analysis. Among these methods are crisp-set qualitative comparative analysis (csQCA) and fuzzy-set qualitative comparative analysis (fsQCA), which can explain complex patterns and various conditions that may be related to a particular outcome. In the case of csQCA, it allows defining various membership conditions as binary structures, using 0 when the condition is absent and 1 when the

condition is present (Wagemann and Schneider, 2010; Marx et al., 2013), while fsQCA does so by setting a membership score with continuous values between 0 and 1.

In relation to the latter, Chaparro-Banegas et al. (2023) use the fsQCA to detect those factors at the national level that were necessary or sufficient for European countries to pursue EI strategies. Similarly, Rhaiem and Doloreux (2022) applied this same model together with an empirical analysis using structural equations to observe the effect of technological factors and the search for knowledge in the field of EI.

In this sense, it can be observed how the degree of compliance in terms of environmental performance and, more specifically, EI has been widely analyzed in the scientific literature. However, the application of various methodologies throughout the literature shows diffuse results regarding the degree of corporate environmental performance in relation to the development and implementation of environmental strategies. In addition, these methods can have several disadvantages when analyzing this degree of performance, as they can be confusing and complicated to replicate when using complex mathematical and statistical models. For this reason, this study presents the elaboration of a ranking based on dominance through dichotomous variables that shows, in a simple and clear way, which are the companies that are best positioned in terms of EI. This ranking, in addition to being easily replicable and comprehensible, will allow for a comparative analysis at the macro level (by regions and industries) and at the corporate level.

3. ECO-INNOVATION RANKING BASED ON DOMINANCE ANALYSIS

3.1. Data collection

In order to develop our own indicator, it is necessary to carry out and exhaustive data collection. In this sense, we use the Thomson Reuters Eikon database, as it offers the possibility of downloading relevant information and setting customizable benchmarks, such as sector and country, which allows specific criteria to be applied when obtaining relevant information (Sanches-García et al., 2017).

With an approximate coverage of 80% of the world's market capitalization and data from 76 countries worldwide, Thomson Reuters Eikon is a useful tool where economic-financial and Environmental, Social and Governance (hereafter ESG) data, among others, can be consulted, allowing users to gather useful information for decision-making (Refinitiv, 2023). In addition to covering stocks, bonds and exchange rates, this database includes ESG data on thousands of companies obtained in real time from more than 70,000 sources, as well as more than 400 sustainable development indicators (see Table 8) (Sikacz and Wołczek, 2018; Refinitiv, 2023).

Once the database was selected, the information necessary for the development of this study was collected. To this end, the research was divided into three distinct phases in order to ensure the integrity and coherence of the analysis: (i) Identification and selection of the sample, (ii) ESG data download, (iii) Development of the indicator.

Table 8: Description of ESG dimensions.

Dimension	Pillar Score	Categories	Items
Environmental	The environmental pillar measures a company's impact on living and non-living natural systems, including the air, land and water, as well as complete ecosystems. It reflects how well a company uses best management practices to avoid environmental risks and capitalize on environmental opportunities in order to generate long term shareholder value.	Resource Use	38
		Emissions	83
		Innovation	34
Social	The social pillar measures a company's capacity to generate trust and loyalty with its workforce, customers and society, through its use of best management practices. It is a reflection of the company's reputation and the health of its license to operate, which are key factors in determining its ability to generate long term shareholder value.	Workforce	75
		Human Rights	9
		Community	23
		Product Responsibility	54
Governance	The corporate governance pillar measures a company's systems and processes, which ensure that its board members and executives act in the best interests of its long term shareholders. It reflects a company's capacity, through its use of best management practices, to direct and control its rights and responsibilities through the creation of incentives, as well as checks and balances in order to generate long term shareholder value.	Management	70
		Shareholders	39
		CSR Strategy	29
Total			454

Source: Refinitiv Eikon

3.2. Selection and description of variables

For the ESG variables, a multidimensional download was carried out covering environmental (E), social (S) and governance (G) data, so that the download was designed to obtain relevant data for each of the dimensions in order to obtain a larger number of

indicators that may be useful when developing the indicator. Table 9 shows some of the indicators that can be obtained within the Refinitiv Eikon platform.

Table 9: Example of selected variables by category

Environmental	Social	Governance
Policy Sustainable Packaging	Salary Gap	Policy Board Size
Energy Use Total	Number of Employees from CSR reporting	Audit Committee Independence
Policy Emissions	Human Rights Policy	CEO Board Member
VOC Emissions	Policy Forced Labor	CSR Sustainability Committee
GHG Emission Method	Policy Business Ethics	CSR Sustainability Reporting
Environmental Products	ISO 9000	GRI Report Guidelines
Eco-design Products	Healthy Food or Products	CSR Sustainability External Audit
ESG Assets Under Management	Nuclear weapons	ESG Reporting Scope
GMO Products	Firearms Producer	ESG Period Last Update Date
Animal Testing	Oil and Gas Producer Ownership Percent	Integrated Strategy in MD&A

Source: Refinitiv Eikon

Among all the variables obtained and based on studies that can be found in previous literature such as those of Zaman et al. (2021) and Albitar et al. (2023), those variables that best fit within the EI indicator were selected based on their definition. To this end, a total of 25 variables of a dichotomous nature were selected (see Appendix 1), with a value of 0 in the case of a negative response, i.e. not carrying out the initiative, and 1 in the case of an affirmative response, i.e. applying the initiative. These variables, defined in Annex 1, have been grouped into three large groups based on their definition

and their relationship with the definition of the different dimensions of EI found in the literature (see table 10).

Table 10: Variables selected by dimension for the elaboration of the eco-innovation indicator.

Dimension	Definition	Variables
Products	Development of new or improved products or services through more environmentally friendly materials selection processes and use of more environmentally friendly technologies.	Environmental Products Environmental Asset Under Management Product Environmental Responsible Use Renewable/Clean Energy Products Eco-Design Products Waste Reduction Initiatives Environmental Materials Sourcing e-Waste Reduction
Processes	Innovations focused on adopting production processes that are more respectful of the environment using clean technologies that enable the efficient use of resources.	Water Technologies Noise Reduction Nuclear
Organizational	The way in which the organization and its employees carry out various activities under environmental management models, with an emphasis on how companies manage their business with the environment in mind.	Equator Principles Environmental Project Financing Organic Products Initiatives CSR Sustainability Committee CSR Sustainability Reporting Environment Management Team Environment Management Training

	Environmental Supply Chain Management
	Green Buildings
	Policy Emissions
	Targets Emissions
	Environmental Restoration Initiatives
	Environmental Partnerships
	Env Supply Chain Partnership Termination

Source: Refinitiv Eikon

3.3. Eco-innovation Ranking

Once the variables have been selected, the companies, regions and industries with the highest environmental performance are analyzed. A common approach, especially among practitioners, for the calculation of composite indicators for a performance ranking, is to calculate the average value of a set of indicators after normalization. There are several problems with this method. Firstly, whether a weighted average is used, the weights for each indicator must be defined ex-ante, which may be difficult for all parties involved in the future use of the ranking to accept. Secondly, it is customary to assume that the pre-defined weights will apply equally to all entities to be assessed. Frequently, different entities may have different strategies, characteristics or priorities that may lead them to prioritize one or the other indicators, which would result in an unfair assessment. Thirdly, if, as in our case study, we are dealing with dichotomous indicators that only reflect whether a certain characteristic is met, calculating an average would implicitly assume a scale dimension for the indicators that would be incorrect. However, the literature offers a method often used for the calculation of composite indicators that solves

the first two problems described above and allows a ranking to be made. This is the model known as Benefit of the Doubt (Melyn and Moesen, 1991; Cherchye et al., 2007, Cherchye et al., 2008; De Witte and Rogge, 2011; Gaaloul and Khalfallah, 2014; Stumbriene et al., 2019). Giménez et al. (2024) exemplify different areas of their application for the calculation of composite indicators. These models assign endogenously and individually to each entity the most beneficial weights; however, they do not allow for the efficient treatment of dichotomous indicators as in our case.

The Pareto dominance approach offers distinct advantages over other composite indicator methodologies, especially when dealing with dichotomous variables. Unlike composite indicators that aggregate multiple criteria into a single index, Pareto dominance preserves the multidimensional nature of data, allowing for a more nuanced comparison of alternatives. This method is uniquely beneficial in decision-making scenarios where different attributes must be considered simultaneously, without losing the specificity of each criterion. For instance, in operations research and multicriteria optimization, Pareto dominance is pivotal because it does not impose a single scalar value but rather identifies non-dominated solutions that are optimal across multiple dimensions (Voorneveld, 2003).

This ensures that the inherent trade-offs between different criteria are maintained, providing a clearer picture of the optimal solutions without arbitrary weighting of the indicators (Branke et al., 2008). Furthermore, the robustness of Pareto dominance lies in its foundation on intuitive properties such as reflexivity, antisymmetry, and transitivity, making it a reliable method for various applications (Voorneveld, 2003). This method's capability to handle both positive and negative attributes simultaneously, while maintaining logical consistency and independence of duplicated states, further enhances

its applicability and effectiveness in evaluating complex, multidimensional data sets (Branke et al., 2008; Miettinen, 1999). Additionally, Pareto dominance has been extensively applied in fields such as economics and game theory, demonstrating its versatility and broad acceptance in the academic community (Sen, 1970; Milnor, 1954).

For this purpose, and for a 2020 sample of 4,671 listed companies from around the world and different sectors, an alternative approach based on the creation of a Dominance Index (DMI) is proposed to create an order ranking, especially useful when no objective criteria are available to determine weights or the relative importance of each indicator and some or all of them are dichotomous variables. The purpose of this ranking is based on the benchmarking methodology, as it aims to identify which are the most eco-innovative practices inside and outside the company in comparative terms (Björklund, 2010; Tsalis et al., 2020; Vanham and Mekonnen, 2021). The ranking has been calculated as follows:

(i) Firstly, an order is established for each EI dimension, so that these companies are ordered from lowest to highest based on the number of companies that dominate that company and for each of the variables, so that a company will be better positioned the fewer companies that dominate it.

(ii) Once it has been established how many companies dominate or are dominated for each of the companies in the sample, the different positions in the ranking are established. These positions are made sequentially, although there may be a situation in which two or more companies have the same values. In this case, these companies will have the same position, which explains why, despite having a sample of 4,671 companies, the ranking has 2,392 positions.

(iii) Finally, after establishing the order for each of the EI dimensions, the overall ranking is calculated. Although a similar procedure to the one described above is followed, the criteria are reversed when it comes to establishing which company is in the best or worst position. In other words, whereas in the ranking prepared for each dimension, variables with values 0 and 1 were considered to establish dominance, in this case the value obtained by the companies within the ranking is considered. Therefore, in this case, the best positioned company will not be the one with the highest values, but the one with the smallest value, as this would reflect a better position within the ranking.

From a formal and generalized point of view, the algorithm for calculating the ranking in EI would be the following. Consider I_j^k the indicator *j=1… J* for the entity *k=1… K*. The indicators can be grouped into *D* dimensions. A higher value I_j^k is assumed to be better. First, the ranking R_d is calculated for dimension $d \in D$. as follows:

1. Calculation of the number of companies that dominate company *k* *(*DB_k,). Company k is dominated by p if $I_j^p \geq I_j^k \ \forall j \in d$ with at least one indicator *p* satisfying $I_j^p > I_j^k$..

2. Calculation of the number of companies dominated by company *k* *(*DT_k). Company *p* is dominated by *k* if $I_j^p \leq I_j^k \ \forall j \in d$ with at least one indicator *p* that satisfies $I_j^p < I_j^k$.

3. To calculate the position in the ranking of the dimension d of company *k* (R_d^k), companies are ordered from the lowest to the highest value DB. In case of companies with equal *DB* value, they are ordered from highest to lowest *DT* value. If $DB_h = DT_h$ y $DB_b = DT_b$ for two companies $h \neq b$, then both are assigned the same position in the R_d ranking.

Once $R_d \forall d$ is obtained, the global ranking R_g is calculated as follows (in this case, a lower value of R_g is better):

1. Calculation of the number of companies that dominate company k according to their positions in R_d (DRB_k). Company k is dominated by p if $R_d^p \leq R_d^k \ \forall d \in D$ with at least one case satisfying $R_d^p < R_d^k$.

2. Calculation of the number of companies dominated by company k according to their positions in $R_d(DRT_k)$. Company p is dominated by k if $R_d^p \geq R_d^k \ \forall d \in D$ with at least one indicator p satisfying $R_d^p > R_d^k$.

3. For calculation of the ranking position in the overall ranking $R_g$of company k (R_g^k) companies are ordered from the lowest to the highest value DRB. In cases of companies with the same DRB value, they are ordered from the highest to lowest DRT value. If $DRB_h = DRT_h$ and $DRB_b = DRT_b$ for two companies $h \neq b$, then they are both assigned the same position in the ranking R_g.

4. RESULTS AND DISCUSSION

After applying the method described above and creating a ranking based on dominance, we obtained relevant results that allow us to carry out a comparative analysis, both at country/sector level and at corporate level. In addition to obtaining this global ranking, this methodology allows us to obtain a differentiated ranking according to the dimensions of EI in products, processes, and organization.

4.1. Macro-level analysis

4.1.1. Regions

From a macro-level point of view, it can be observed that the countries that dominate in more aspects of EI are France, Finland, Uruguay, Thailand and Spain, while

the countries with the lowest presence in EI are Monaco, Panama, Qatar, Omar and Bahrain (see table 11). These results, which are graphically represented in Figure 8, are in line with studies such as those carried out by Amor-Esteban et al. (2020) and García-Sánchez et al. (2021), among others, who place European and Asian countries among the top countries with the best environmental performance, as is the case in the results shown in this study.

Table 11: Eco-innovation Ranking by regions.

Ranking	Country	Freq	%	Ranking	Country	Freq	%
1	France	103	2,21%	**33**	Hungary	4	0,09%
2	Finland	29	0,62%	**34**	Norway	38	0,81%
3	Uruguay	2	0,04%	**35**	Chile	32	0,69%
4	Thailand	31	0,66%	**36**	United Arab Emirates	6	0,13%
5	Spain	36	0,77%	**37**	Russia	13	0,28%
6	Turkey	10	0,21%	**38**	South Africa	44	0,94%
7	Italy	54	1,16%	**39**	Jersey	4	0,09%
8	Macau	3	0,06%	**40**	Luxembourg	15	0,32%
9	India	89	1,91%	**41**	China	373	7,99%
10	Portugal	9	0,19%	**42**	Bermuda	24	0,51%
11	Japan	359	7,69%	**43**	Brazil	11	0,24%
12	Kazakhstan	2	0,04%	**44**	Canada	195	4,17%
13	Taiwan	112	2,40%	**45**	Indonesia	34	0,73%
14	Germany	113	2,42%	**46**	Kuwait	5	0,11%
15	Hong Kong	100	2,14%	**47**	Israel	17	0,36%
16	Belgium	38	0,81%	**48**	United States of America	1732	37,08%
17	Austria	23	0,49%	**49**	Guernsey	14	0,30%
18	Korea; Republic (S. Kor..	112	2,40%	**50**	Australia	52	1,11%
19	Malaysia	34	0,73%	**51**	Egypt	5	0,11%
20	Netherlands	44	0,94%	**52**	Cyprus	3	0,06%

21	Greece	12	0,26%	**53**	Saudi Arabia	11	0,24%
22	Mexico	39	0,83%	**54**	Zimbabwe	1	0,02%
23	Ireland; Republic of	34	0,73%	**55**	Morocco	2	0,04%
24	Philippines	20	0,43%	**56**	Cayman Islands	5	0,11%
25	Denmark	30	0,64%	**57**	Peru	23	0,49%
26	Singapore	34	0,73%	**58**	New Zealand	20	0,43%
27	Switzerland	89	1,91%	**59**	Malta	4	0,09%
28	Sweden	105	2,25%	**60**	Monaco	4	0,09%
29	Colombia	11	0,24%	**61**	Panama	1	0,02%
30	United Kingdom	244	5,22%	**62**	Qatar	7	0,15%
31	Poland	22	0,47%	**63**	Oman	4	0,09%
32	Argentina	22	0,47%	**64**	Bahrain	3	0,06%

Source: The author

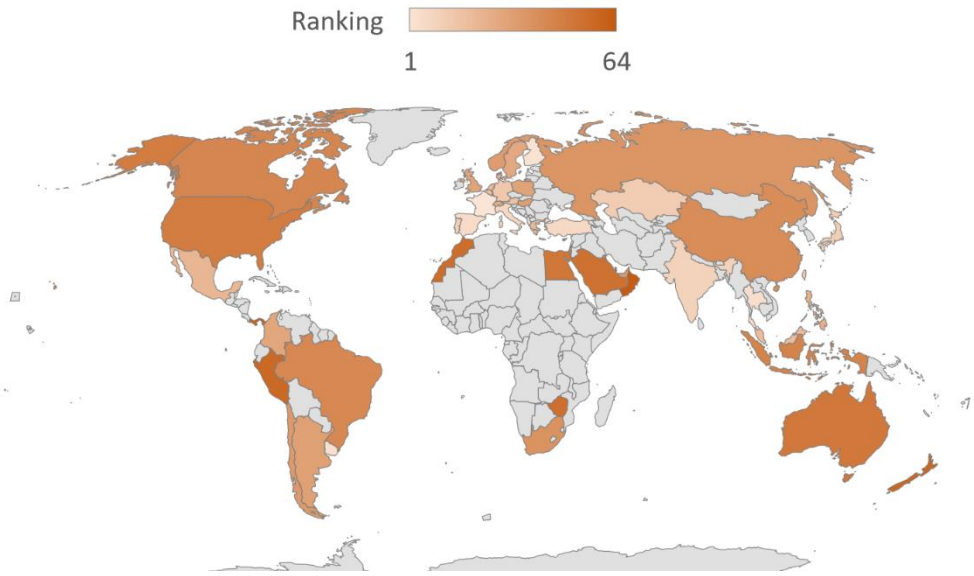
The leading position of European countries in the ecological transition is a topic that has been widely analyzed in the scientific literature and has been verified by authors such as Horbach (2016) or Qureshi et al. (2022), among others, who place the European Commission (EC) as a body of special relevance in the ecological transition, having an active role in the systematic encouragement to promote EI strategies and green technologies (Tobelmann and Wendler, 2020; Azeem Qureshi). In this context, the ranking position of European countries may be due to the initiatives that have been carried out in the EU (EU) with the aim of improving the environmental performance of its member countries.

In 2009, the first EU Renewable Energy Directive came into force, marking the beginning of a remarkable increase in the total capacity of solar PV systems (Kougias et al., 2021). Two years later, in 2011, the term "EI" became part of the European Commission's agenda when it funded the EI Action Plan (Eco-AP), which encourages the

acceleration of these innovations to foster productivity, efficiency and competitiveness, as well as contribute to preserving the environment (European Commission, 2011). Since then, this concept has been at the center of several reports and official documents (Colombo et al., 2019).

Another major initiative is the European Green Deal (EGD), whose main objective is to transform the EU into a modern, resource-efficient, and competitive economy with zero net greenhouse gas emissions by 2050 (European Commission, 2019). Furthermore, the EU's commitment to contribute to the green transition has recently been underlined by the post-pandemic recovery plans, allocating more than 35% of these funds and of the EU budget to green initiatives for the period 2021-2027 (European Commission, 2021).

Figure 8: Choropleth map according to average ranking position per regions



Source: The author

Moving on to analyze the position of these countries from a more specific point of view, table 12 shows the position of the top 15 countries in terms of EI, differentiating between the three typologies analyzed in this study. As can be seen, none of the countries

shown in this table has the same position in the ranking for the three dimensions of EI. As in the global ranking shown above, most of the countries in the top positions are European and Asian.

Table 12: Eco-innovation ranking by regions and dimensions.

Ranking	Product	Process	Organizational
1	France	Kazakhstan	Uruguay
2	Finland	Finland	Turkey
3	India	Turkey	Thailand
4	Italy	Korea; Republic (S. Kor..	France
5	Thailand	Japan	Portugal
6	Japan	France	Finland
7	Macau	Poland	Macau
8	Austria	Austria	Malaysia
9	Hong Kong	Germany	Spain
10	Taiwan	Sweden	Taiwan
11	Greece	Argentina	Mexico
12	Netherlands	Netherlands	Philippines
13	Belgium	Switzerland	Italy
14	Spain	Spain	India
15	Portugal	India	Colombia

Source: The author

Among these countries, Europeans have a higher presence for the product and process dimensions (60% in both cases), while in the organizational EI dimension, Asian countries have a higher presence, with 33% European versus 47% Asian countries. Furthermore, it is interesting how Kazakhstan ranks first in terms of process EI, which is in line with studies such as that of Gaukhar et al. (2020), who emphasize the efforts that this country has been making in recent years to achieve sustainable development objectives and thus improve the country's environmental situation, as well as the study by Davidenko et al. (2024), who ensure a change in the behavior of Kazakhstan's companies

to carry out their economic and production activities in a conscious manner in order to reduce their negative impact on the environment.

4.1.2. Industries

In addition to the previous analysis, and after grouping the different sectors into eleven broad categories (see Appendix 2), our results allow us to observe which industries are best positioned in our ranking of dominance and which, therefore, have a higher degree of environmental performance in terms of EI (see table 8). Thus, the top five industries include utilities, consumer non-cyclicals, industrials, basic materials and financial, with the industrial sector being the most frequent (17.15%). These results are in line with authors such as Aparicio and Kapelko (2019) and Amor-Esteban et al. (2020), among others, placing a large part of these industries as those with the highest environmental performance. These, in addition to presenting this degree of performance, are particularly relevant industries due to the strong impact they have on the lives of citizens (Amor-Esteban et al., 2020).

Another striking industry is the energy industry, which is ranked 8th in the ranking and has a presence of 6.85%. This industry is of great relevance, as the level of energy consumption is essential for a country's economic and social development (Sohail et al., 2021; Liu et al., 2023). Add to this the fact that most of this energy is generated by fossil fuels, and we are faced with an industry whose environmental impact is significant and negative, leading to environmental degradation (Lei et al., 2021; Liu et al., 2023).

Table 13: Eco-innovation Ranking by industries.

Ranking	Industry	Freq	%
1	Utilities	89	1,91%
2	Consumer Non-Cyclicals	313	6,70%
3	Industrials	801	17,15%
4	Basic Materials	467	10,00%
5	Financial	301	6,44%
6	Consumer Cyclicals	720	15,41%
7	Technology	688	14,73%
8	Energy	320	6,85%
9	Real Estate	408	8,73%
10	Healthcare	553	11,84%
11	Academic & Educational Services	11	0,24%

Source: The author

Add to this the fact that most of this energy is generated by fossil fuels, and we are faced with an industry whose environmental impact is significant and negative, leading to environmental degradation (Lei et al., 2021; Liu et al., 2023). In addition, the conflict in Ukraine that began in February 2022 has led to strict restrictions by the West on Russia, one of the largest exporters of fossil fuels, forcing these countries to look for more environmentally friendly alternatives that do not interfere with the achievement of the 2030 Agenda (Allam et al., 2022). This makes the energy industry one of the most interesting for future studies analyzing environmental performance in the post-conflict period between Russia and Ukraine.

Table 14: Eco-innovation Ranking by industries and dimensions.

Ranking	Product	Process	Organizational
1	Utilities	Industrials	Consumer Non-Cyclicals
2	Financial	Consumer Non-Cyclicals	Utilities
3	Technology	Consumer Cyclicals	Basic Materials
4	Industrials	Basic Materials	Consumer Cyclicals
5	Basic Materials	Technology	Industrials
6	Consumer Cyclicals	Financial	Technology
7	Consumer Non-Cyclicals	Healthcare	Energy
8	Real Estate	Utilities	Financial
9	Energy	Academic & Educational Services	Real Estate
10	Healthcare	Real Estate	Healthcare
11	Academic & Educational Services	Energy	Academic & Educational Services

Source: The author

From a more specific point of view, table 9 shows the ranking of sectors by EI dimensions. In the case of the first five sectors at the global level (see table 8), it can be seen how the industrial sector, and the basic materials sector are in the top five industries in the three EI dimensions, with the industrial sector ranking first in terms of process EI and the basic materials sector ranking third in terms of organizational EI. As in the overall ranking, the energy industry occupies an unfavorable position in the rankings for all three dimensions, especially in the process EI dimension, where it ranks last.

4.2. Micro-level analysis

Table 15: Eco-innovation Ranking by companies.

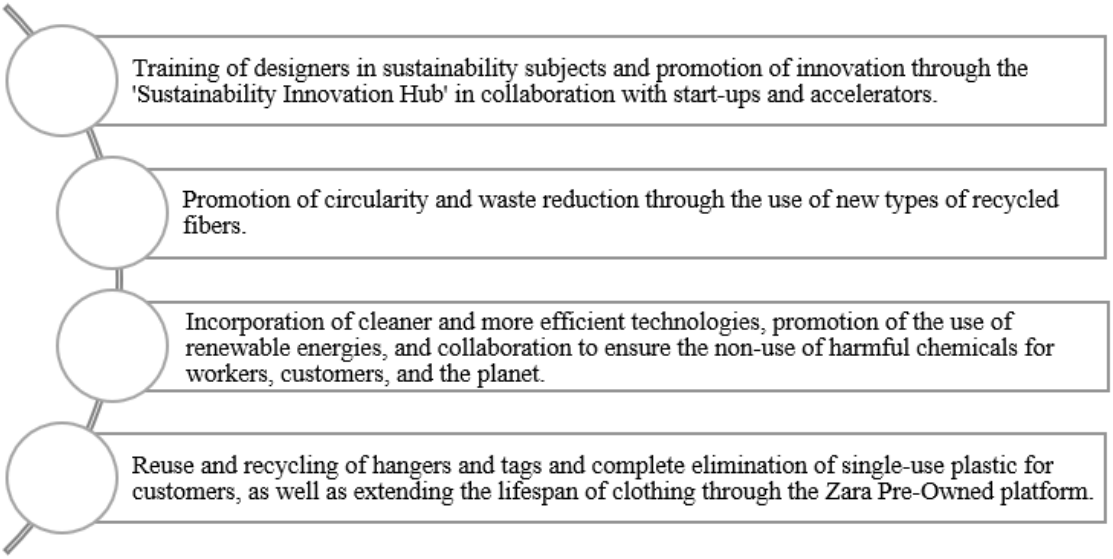
Company	Dominated by	Dominating to	Ranking
Koninklijke Philips NV	0	4537	**1**
Hitachi Ltd	0	4381	**2**
General Electric Co	0	4381	**2**
Volvo AB	0	4314	**3**
Mitsubishi Electric Corp	0	4293	**4**
Home Depot Inc	0	4249	**5**
Goldman Sachs Group Inc	0	4078	**6**
Arcelik AS	1	4467	**7**
UPM-Kymmene Oyj	1	4465	**8**
Fosun International Ltd	1	4062	**9**
Mirae Asset Securities Co Ltd	1	4057	**10**
Industria de Diseño Textil SA	1	4045	**11**
Kering SA	1	4045	**11**
Abb Ltd	1	4040	**12**
EIDP Inc	1	4020	**13**
Owens Corning	2	4397	**14**
Panasonic Holdings Corp	2	4150	**15**

Source: The author

Finally, table 10 shows the top 15 most eco-innovative companies according to our ranking. All of them are characterized by a higher dominance in the EI variables presented in the methodological section and by being dominated by a smaller number of

companies. As can be seen, Hitachi Ltd and General Electric Co are positioned in position 2, as they share the same values in terms of dominance. Among these companies is Industria de Diseño Textil SA, better known as Inditex, being the only Spanish company that appears in this top 15 and which is interesting to analyze, as it specifies in detail what its actions are in terms of EI, as well as the different phases it carries out to comply with its main environmental objectives, which allows us to observe clearly and simply what actions it carries out to reduce its environmental impact. To this end, as it specifies on its website, Inditex is committed to "a new cycle" (see illustration 2) to achieve the reduction of emissions and the efficient use of water and energy, as well as to obtaining innovative, organic or recycled raw materials that allow the achievement of the different objectives established for the coming years.

Figure 9: Inditex initiatives for sustainable development



Source: https://www.inditex.com/itxcomweb/es/sostenibilidad#un-nuevo-ciclo

These targets include reducing water consumption in the supply chain by 25% by 2025, having 5 million hectares protected and regenerated through proper management to improve biodiversity by 2030, or achieving net zero emissions by 2040 by reducing its carbon footprint by at least 90% compared to 2018, among others (Inditex, 2024).

5. CONCLUSIONS

In this study, a DMI is developed using dichotomous variables that respond to the different eco-innovative initiatives carried out by companies around the world and for the year 2020, which allows us to carry out a comparative analysis of the different companies in terms of environmental performance through a dominance-based ranking, both at the macro and corporate levels. In addition to the ranking in global terms, our methodology allows us to carry out an analysis of environmental performance for each of the dimensions of EI that can be found in the scientific literature, i.e. product, process and organizational. In this way, the main results obtained from this study allow us to observe in a simple way which companies, regions and industries have a higher degree of EI based on the variables that have been selected for the analysis and which are detailed in the methodology section.

The main results show that, from a macro point of view, the regions at the top of the global ranking are mainly France, Finland, Uruguay, Thailand and Spain. The presence of European countries at the top of the ranking can be explained by the different initiatives that have been carried out within the European continent to enable its member countries to achieve adequate levels of environmental performance. These initiatives include the EI Action Plan and the European Green Pact, among others. This analysis can be extrapolated for each dimension of EI, where European and Asian regions continue to predominate in the top positions, with a greater European presence in the product and

process dimensions, compared to a greater Asian presence in the organizational dimension.

As for the best positioned sectors in the ranking, as in previous studies, the utilities, consumer non-cyclicals and industrial sectors stand out. It is worth highlighting the energy sector, which is at the bottom of the ranking, which is particularly noteworthy given that it is one of the most important industries for the development of a country. The same happens in the different dimensions of EI, where other sectors such as basic materials or the financial sector stand out, while the energy sector remains at the bottom of the ranking, especially in the process dimension. Finally, at the corporate level, this study shows the position of the top 15 companies in terms of EI, among which Koninklijke Philips NV, Hitachi Ltd and General Electric Co, among others, stand out. In addition, we highlight Inditex as the only Spanish company within this top 15, standing out for the different sustainable actions it carries out and which it clearly details on its website.

Thus, the present study has several contributions to the previous literature from a theoretical and practical point of view. In terms of its theoretical implications, the applied methodology allows for an alternative analysis of environmental performance in EI matters in a simpler and more replicable way compared to methodologies applied in previous literature within this field of study. Secondly, 25 detailed variables have been introduced for each dimension of EI, which allows for a more exhaustive and complete analysis, unlike previous studies that analyze the degree of environmental performance from a global point of view. Finally, in addition to being able to establish a global ranking at regional, industry and corporate level, one of the main contributions of this study lies in the comparative analysis for each dimension of EI, showing at macro and corporate

level which are the most eco-innovative regions, industries, and companies for each of these dimensions. From a practical point of view, the ranking presented in this study can be very useful for policy makers and managers around the world, as it projects which countries and companies have a better and worse position in terms of EI. In this way, the results of this study can be relevant for those who want to know the specific situation of each region, industry, and company in terms of environmental performance, as well as to see which dimensions and aspects need to be improved.

Despite the usefulness of this study, it is important to note that it has certain limitations. Firstly, despite having carefully selected the variables used for the creation of our indicator, the Refinitiv Eikon database contains a wide range of ESG variables that could be equally relevant and that have not been considered for this analysis. In addition, Refinitiv Eikon has been the only platform used for the selection of these variables, without exploring other databases such as Bloomberg or Morningstar, among others, which would limit us when considering different or complementary variables. Furthermore, the analysis has been carried out exclusively for the year 2020, which does not allow us to carry out a comparative analysis for different years. Finally, despite the usefulness of the indicator and the fact that it shows results in line with previous studies, the methodology used to obtain it is relatively simple as it does not consider complex aspects such as the weights of each of the variables.

In this context, future studies could analyze the degree of environmental performance in terms of EI beyond the analysis of a single year. Analyzing the pre- and post-pandemic period would be interesting to observe the evolution of these regions, industries and companies within the ranking presented in this study. Furthermore, analyzing this situation for the period after the conflict between Russia and Ukraine would

be of great relevance, especially for the energy sector, as it has been one of the most affected by this conflict. Regarding the dimensional analysis of EI, authors such as Filiou et al. (2023) or Tsolakis et al. (2023) highlight the importance of Artificial Intelligence (AI) in matters of sustainability, as it promotes aspects such as the production of green patents or sustainable development. In this line, future research can be aimed at analyzing the impact of AI in the different dimensions of EI, with special emphasis on the production process, which would allow measuring how the development of new technologies can contribute to an improvement in corporate environmental strategies.

UNIVERSIDAD DE GRANADA

CHAPTER IV: IMPACT OF DISRUPTIVE EVENTS ON ECO-INNOVATION IMPLEMENTATION AND FIRM PERFORMANCE

1. INTRODUCTION

The growing quest to meet current needs without compromising future generations has made sustainable development a crucial aspect of any economy in the world (United Nations, 1987). This commitment became latent in 2015, when the United Nations established the Sustainable Development Goals (SDGs), thus setting a roadmap for countries to achieve, through the fulfillment of 17 major goals, economic and social development based on the principle of sustainability (United Nations, 2015; Ahmad et al., 2022). This concern for the environment has led numerous companies to increase their efforts to transform their business model with the aim of mitigating the negative environmental impacts that may result from their activity (Zhong et al., 2022; López-Pérez et al., 2023). To achieve this transformation, and as seen in chapter two of this PhD Thesis, it is necessary to change the traditional or linear economy model into a CE model, which is achieved through environmental innovations or EI (Prieto-Sandoval et al., 2018; López-Pérez et al., 2023).

However, recent global events have posed a real challenge to those companies that want to apply EIs and thus become more sustainable. These external events have mainly affected companies operating in different countries, as their continuous exposure to environmental, economic and geopolitical risks (Dreyfus & Nair, 2022, Chatterjee et al., 2024) make them more vulnerable to situations such as military conflicts and economic challenges, among others (Caldara & Iacoviello, 2022; Ahmad et al., 2022).

Among the different events that have occurred in recent years, the health and economic crisis caused by the COVID-19 pandemic, which began in late 2019 and started to spread globally in early 2020, has been one of the greatest challenges of recent decades worldwide, causing the death of millions of people and generating an unprecedented sense of uncertainty (Krammer, 2022; Gómez et al., 2024).

On the other hand, the conflict between Russia and Ukraine that began in February 2022 has provided an additional reason to generate even more uncertainty in economic terms, as it has triggered commodity prices (World Bank Group, 2022; Wang et al., 2023), as well as significantly impacting the supply of raw materials and supply chains globally (Park et al., 2020; Ghadge et al., 2020; AlQershi et al., 2023). This conflict has also been of particular concern to countries that depend on Russia for the consumption of fossil fuels such as coal, gas or oil, including the member countries of the EU (Ali et al., 2024).

In order to move away from such dependence, it has become necessary to search for other sources of energy that are renewable and that represent an alternative to fossil fuels which, on the one hand, will allow these countries not to depend on Russia for energy production and, on the other hand, will allow them to achieve sustainable economic growth that will make it possible to address the different current and future climate problems (Han et al., 2022; Wang et al., 2023).

In this context, multinational enterprises (MNEs) have to establish different strategies aimed at achieving the necessary resources that will allow them to mitigate potential risks that may affect the survival of the companies and be able to invest in EI strategies, as well as achieve an optimal level of resilience (Khan et al., 2024; Grego et al., 2024). To this end, some authors argue that companies need to adopt various innovations that keep them prepared for future adversities, which will improve their long-term competitiveness (Kennedy et al., 2017; Grego et al., 2024).

Among these innovations, EIs respond effectively to the growing concern about climate change, as they seek to make companies conduct their business using alternative products and processes to traditional ones in order to minimize their negative impact on the environment (Kemp & Pearson, 2007; Pan et al., 2020; López-Pérez et al., 2023). Thus, those companies that pursue eco-innovative strategies will be more resilient, enabling them to cope with events such as the COVID-19 pandemic or the war in Ukraine more effectively (Vai and Aarstad, 2024). Furthermore, some authors argue that the implementation of environmental innovations can translate into positive business performance outcomes, making EEs an attractive alternative for companies as well as investors (Scarpellini et al., 2016; Garcia-Sanchez et al., 2020).

In this sense, the main objective of this chapter is to analyze the impact of crises arising in turbulent periods on EI and this, in turn, on business results. The definition of the previous objective allows us to consider two specific objectives. First, the aim is to examine how these crises have affected the adoption and adaptation of EI strategies. This will make it possible to analyze how the adverse conditions resulting from these events have modified firms' priorities and approaches to environmental innovations. In this way, it will be possible to observe the degree to which such events have driven or constrained

the integration of sustainable practices and innovative technologies into their business models, which will allow us to provide a comprehensive view of how companies can adapt their strategies to become more resilient and sustainable in the face of future global challenges. Secondly, we aim to analyze the impact of EI on business performance especially considering the context of the global crises caused by the COVID-19 pandemic and the war conflict between Russia and Ukraine.

These objectives will be carried out through a comprehensive analysis of a sample of 3,606 listed companies globally, using Refinitiv Eikon to collect data for the period 2018-2022. To do so, we will proceed to download environmental performance data to create a new EI variable using the Benefit of Doubt model. Subsequently, after downloading various economic-financial variables that will be used to control the models, a quantitative analysis will be carried out through regressions for panel data, which will allow us to evaluate and contrast the hypotheses raised throughout this chapter.

Finally, to ensure the validity and reliability of the results obtained, a robust check will be carried out that will include additional tests and consideration of possible external factors that may influence the results. This check will seek to ensure that the conclusions derived from the panel data regression are robust and applicable in a broader context.

Thus, the study developed in this chapter makes several contributions to previous scientific literature. Our findings show that disruptive events have boosted EI adoption, suggesting that turbulent environments can act as catalysts to implement this type of strategies, thus strengthening corporate resilience. Moreover, EI is not only observed to improve corporate financial performance as shown by studies such as Driessen et al. (2013) or Zhao et al. (2021), among others, but it is also shown to offer competitive advantages in the face of global crises such as COVID-19 and the war in Ukraine.

On the other hand, this chapter makes a valuable methodological contribution through the creation of a new EI variable using the BoD model. This innovative approach not only responds to the need for a more accurate and flexible assessment of the development of EI strategies in companies, but also allows us to capture the differences between them in different contexts. Thus, this new variable provides an enriching tool for future studies by providing an advanced methodology, extending the limits of previous knowledge in this field and improving the understanding of the impact of EI on corporate performance, thus complementing previous studies such as those conducted by Zhen and Iatridis (2022) or Abeysekera (2023), among others.

2. THEORETICAL FRAMEWORK

The impact of EI on business performance is a topic that has been widely analyzed in the scientific literature. However, and as specified in the second chapter of this doctoral thesis, there is discrepancy regarding the impact of this type of innovation on corporate economic and financial performance (López-Pérez et al., 2023).

Thus, researchers such as Driessen et al. (2013) or Zhao et al. (2021), among others, point out that EI does not always have a positive impact, as high initial investment or high staff turnover could deteriorate business performance. Despite these assertions, most researchers claim that sustainable strategies improve aspects such as reputation and customer satisfaction, reduce costs and thus improve business performance (Liao, 2018; Marín-Vinuesa et al., 2018). Along these lines, Zheng and Iatridis (2022), after analyzing a sample of more than 124,000 companies, conclude that their study provides strong evidence that evidences a positive impact of EI on all types of business performance.

As can be seen, there are discrepancies in the scientific literature when determining the impact of these innovations on corporate results, which may be due to the influence of external factors that have not been taken into account in the different studies (López-Pérez et al., 2023). In this context, in the last decade global events have acted as catalysts for profound changes in corporate behavior. These events, known in the literature as disruptive events (Hoffman, 1999), are characterized by their ability to radically alter the environment in which organizations operate, which has been instrumental in forcing a re-evaluation of traditional strategies, processes and business models (Hoffman, 1999; Tettamanzi et al., 2022).

In this sense, in addition to the external factors mentioned in chapter two of this Doctoral Thesis (country, environment and company size), it is crucial to consider the influence of these disruptive events when assessing the impact of any business strategy on the bottom line (Boin, 2019; Räisänen et al., 2023), as they often trigger economic, social and even humanitarian crises.

These crises are characterized by their ability to easily transcend geographical, political, cultural, public and legal boundaries, making them difficult for managers to classify, contain and manage (Boin, 2019; Räisänen et al., 2023). These crises, which spill over borders and evolve rapidly, are known as transboundary crises, and generate confusion about their causes and consequences (Boin and Lodge, 2016). Moreover, they are perceived as serious threats that require urgent action under conditions of great uncertainty, which makes their management even more difficult (Ansell et al., 2010; Cabane and Lodge, 2023).

Among the most significant transboundary crises in recent years can be highlighted the pandemic caused by COVID-19 and the situation of geopolitical

instability arising from the armed conflict between Russia and Ukraine, which have significantly impacted recent global business dynamics (Bucea-Manea-Ţoniş et al., 2021; Al-Amosh & Khatib, 2023). In this regard, in relation to the first crisis and despite the fact that the magnitude of COVID-19 has varied depending on the size, location and sector in which the firm is framed (Abeysekera, 2023) has led to a general sense of uncertainty and instability worldwide (Kuckertz & Brändle, 2022; Abeysekera, 2023).

Simultaneously, the outbreak of the war in Ukraine in February 2022 has had a significant impact on geopolitical stability and the supply chain at the global level (Appiah-Otoo & Chen, 2023; Balsalobre-Lorente et al., 2023).. Thus, companies have had to cope with adverse events resulting from this war, including the disruption in the procurement of certain raw materials due to price increases (Feng et al., 2023).This has created additional challenges for those organizations that want to invest in environmental innovation strategies. In this context, the emergence of these transboundary crises has highlighted the importance of implementing sustainable strategies that foster innovation in order to cope with adverse situations and that do not jeopardize long-term business growth (Al Amosh & Khatib, 2023)..

2.1. COVID-19

Some authors argue that COVID-19 has been able to slow down the efforts of organizations to move towards a sustainable economy, since crises of such relevance can disrupt environmental practices in all types of companies, harming SMEs in particular (Zhang & Fang, 2022). (Zhang & Fang, 2022). As a consequence of the pandemic, companies have experienced a worsening of their performance, leading them to liquidity problems and budget constraints (Hermundsdottir et al., 2022).. Thus, authors such as

Guderian et al. (2021) state that the negative impact of COVID-19 has slowed down the different activities aimed at developing environmental innovation strategies.

In this context, several researchers argue that the impact of COVID-19 has led companies to face major economic challenges, which has led to the search for the survival of the company itself in the face of economic crises of such magnitude (Awan et al., 2021).. In this line, Zou et al. (2020) state that companies have reduced their efforts to invest in investment and development (R&D) with the main objective of surviving the negative situation caused by the pandemic. On the other hand, Carroll (2021) o Tampakoudis et al. (2021) state that the potential gains from investing in ESG activities during the pandemic were lower than the costs of investing in them. In addition, the financial pressures that arose in this crisis limit companies from allocating economic resources to the development of sustainable strategies, so they tend to wait until their economic-financial situation improves (Humphreys & Trotman, 2022; Klymenko & Lillebrygfjeld Halse, 2022).. Thus, there are numerous works in the literature that support the idea that companies had to allocate their economic resources in a more secure way in order to adapt to the provoked crisis situation.

However, other authors argue that the onset of the pandemic caused by COVID-19 has significantly encouraged companies to boost their efforts in the field of innovation as a strategic response to the crisis. (Abeysekera, 2023)The adoption of innovations has become a crucial aspect for the survival of organizations in the post-covida era (Adusei et al., 2023). (Adusei et al., 2023).. In this regard, Kitsis & Chen (2021) argue that the application of EIs, as well as their dynamism and quality, has become a crucial and non-negotiable strategy in the development of competitive business strategies.

In this context, several experts argue that the pandemic has boosted the implementation of sustainable strategies within the business community (Loia & Adinolfi, 2021). The EU, for example, is committed to sustainable development by allocating more than 35% of the funds of the post-pandemic recovery plans and of the European budget for 2021-2027 to green initiatives. Therefore, the role of governments, policy makers and banks during this crisis has been crucial, as it has enhanced the reduction of the negative economic impacts resulting from the pandemic through the development and implementation of recovery measures aimed at mitigating the immediate negative impacts (Al Amosh & Khatib, 2023)..

Regarding the relationship between COVID-19 and the development of environmental strategies by companies with business performance, some authors argue that those companies that implemented EI strategies are better able to adapt to changes in their environment because they are more flexible and, therefore, better able to adapt to crises such as the one that occurred during the pandemic (Hermundsdottir et al., 2022). (Hermundsdottir et al., 2022). In addition, authors such as Zhang & Fang, (2022) demonstrated that companies implementing sustainable measures showed a lower propensity to suffer negative economic impacts during COVID-19. Linked to the above, Ding et al., (2021) observed that environmentally concerned companies suffered a smaller drop in their stock price during the pandemic due to the trust placed in them by stakeholders (Huang et al., 2022).. Therefore, it can be observed that there are several authors who argue that organizations that implemented environmental innovation and sustainability practices were better prepared to face adverse external events.

2.2. War in Ukraine

On February 24, 2022, the conflict between Russia and Ukraine broke out, generating negative economic consequences such as a drop in the supply of agricultural products or increased volatility in the price of energy, among others (Balsalobre-Lorente et al., 2023; Feng et al., 2023).. As a result of the conflict, considered the most important in Europe since World War II, many countries have imposed significant trade restrictions with Russia, which has triggered a domino effect that has awakened a feeling of uncertainty in many investors around the world, in addition to influencing the economic performance of importing and exporting countries, mainly, of oil (Adekoya et al., 2023)as well as energy price volatility, even leading to a doubling of natural gas prices and a 60% increase in oil prices (Balsalobre-Lorente et al., 2023). (Balsalobre-Lorente et al., 2023).. In addition, the war between Russia and Ukraine led to a drop in the supply of agricultural products, which significantly affected the food sector. (Feng et al., 2023).

In this sense, authors such as Lim et al. (2022) state that this event has had a negative impact on companies, threatening them in terms of sustainable growth due to the increasing inflation rate and the reduction of their purchasing power. As a result, companies have seen their revenues decline, which, together with the increase in expenses, has led to a decrease in profits. (Prohorovs, 2022)(Prohorovs, 2022), hindering the prospects of achieving the Sustainable Development Goals (hereafter SDGs) (Balsalobre-Lorente, 2022). (Balsalobre-Lorente et al., 2023; Pereira et al., 2022).. Derived from the above, it can be expected that, as happened with COVID-19, companies will be forced to allocate a lower percentage of their resources to environmental strategies such as EI (Zou et al., 2020; Awan et al., 2021).

However, several experts have argued that this conflict can motivate companies to invest in more environmentally friendly strategies. Along these lines, authors such as Allam et al., (2022) or Schnitkey et al. (2022), have shown the concern of countries, especially in Europe, regarding their dependence on Russian imports, which has led different nations to seek alternative sources of energy imports (Balsalobre-Lorente et al., 2023).. However, this concern is not only transferred to European countries. Allam et al. (2022) state that the war between Russia and Ukraine has significantly influenced gas and oil supply chains and prices in the G7 and BRICS countries.

In this regard, numerous authors highlight the efforts being made by the affected nations to reduce this dependence, primarily on Russian oil and gas (Adekoya et al., 2023; Kuzemko et al., 2022; Pereira et al., 2022).. To achieve this independence, the European Commission has raised the renewables target for 2023, committing to double solar power capacity by 2025 (Kuzemko et al., 2022; European Commission, 2022). On the other hand, the United States banned trading with Russia in relation to oil, liquefied natural gas and coal, which will necessitate the search for clean and environmentally friendly energy alternatives that do not interfere with the achievement of the 2030 Agenda (Allam et al., 2022).. For this reason, it has been observed how this event has aggravated the environmental challenges of companies, accelerating the realization of sustainable investments with different scopes such as innovative energy efficiency projects or the substitution of fossil energies by renewable energies. In this way, it can be observed how the search to dispense with dependence on resources from another country derived from the conflict implies the need to develop innovative and sustainable environmental strategies.

Based on these events, companies have had to make strategic decisions in order to adapt to the environment generated by these disruptive events. This approach is in line with the *Contingency Theory*, which states that those companies that align their organizational resources with the environmental context in which they operate will adapt better than those that do not in the face of adverse external situations. (McKiernan, 1996; Robert Baum & Wally, 2003). The *Contingency* Theory (Fiedler, 1951) explains the decision making carried out by organizations based on internal and external determinants in a particular situation, understanding internal factors as those occurring within an organization and external factors as those occurring outside it (Childs et al., 2022)The COVID-19 and the conflict between Russia and Ukraine fall within the second typology.

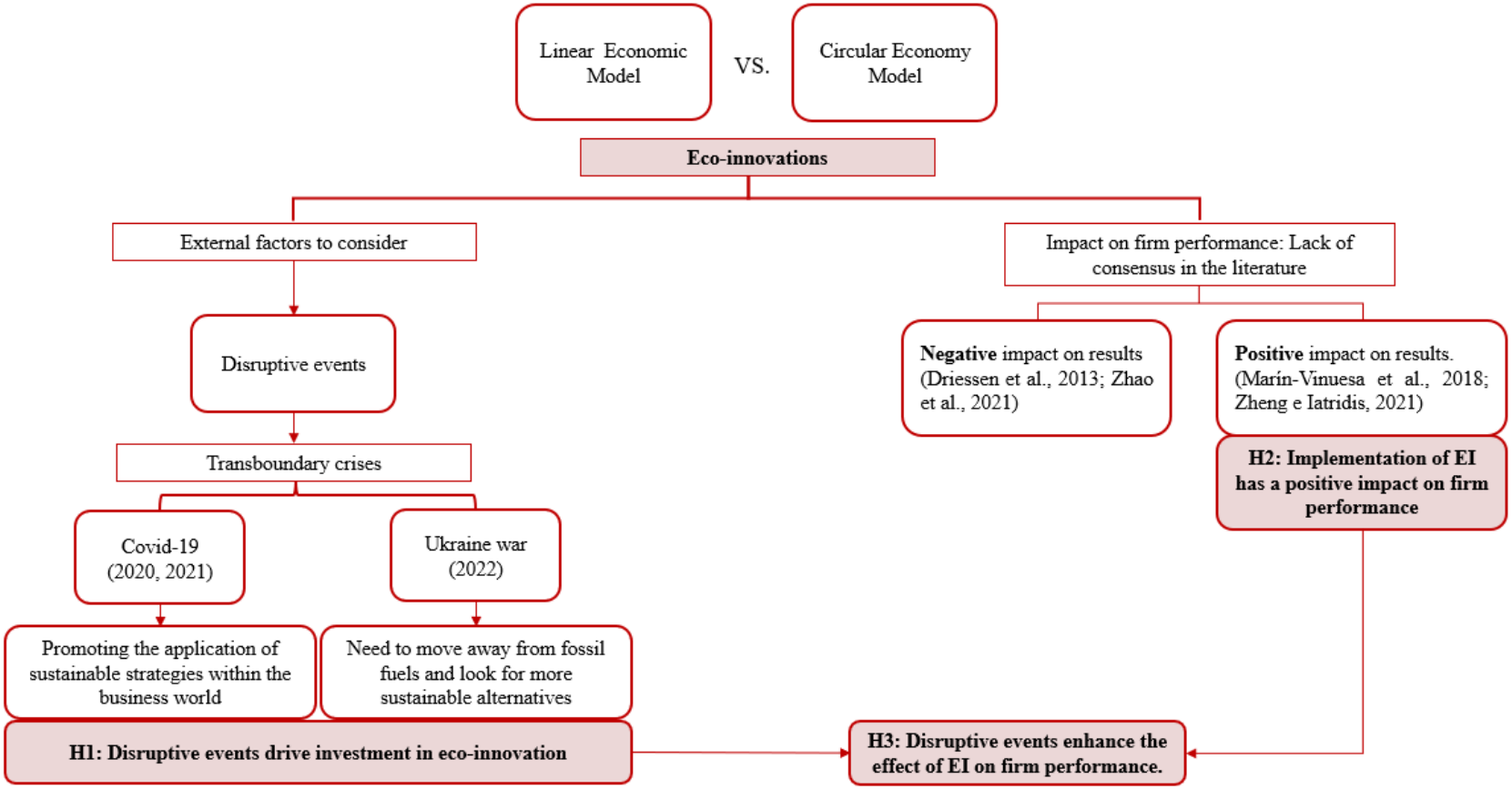
Based on the above and on this theory, the following hypotheses are proposed (see Figure 10):

H1: Disruptive events drive investment in EI.

H2: Implementation of EI has a positive impact on firm performance.

H3: Disruptive events enhance the effect of EI on firm performance.

Figure 10. Hypothesis Statement



Source: The author

3. METHODS

Data collection and variables

In order to test the hypotheses, it is necessary to carry out an exhaustive data collection to establish which items are appropriate to measure EI as completely as possible. For this purpose, as in chapter three, the Refinitiv Eikon database has been used. Based on 19 of the environmental items offered by the platform (see appendix 3), a new EI variable was created.

The Benefit of Doubt (BoD) model was used to obtain this item. This model, which considers only outputs and represents a variant of the nonparametric frontier models used to measure efficiency (Cooper et al., 2007; Giménez et al., 2024), has been used in the literature to construct composite indicators (CI) in different contexts (Lauer et al., 2004; Despotis, 2005; Cherchye et al., 2008), making it possible to analyze complex phenomena that cannot be evaluated with a single variable, globalizing processes with multiple stages and sub-indicators (Maricic et al., 2019).

Unlike other models for CI creation, the BoD proposes an alternative approach using data envelopment analysis (DEA) methods to obtain endogenous weights without prior information (Wang et al., 2015).

Thus, following Giménez et al. (2024), we have a sample of *K* firms and a set of *J* positive sub-indicators to be maximized ($y \in \mathrm{R}_{+}^{J}$) and *H* negative sub-indicators to be minimized ($y \in \mathrm{R}_{+}^{H}$). In order to measure the performance of each of the evaluated firms, the following directional distance function or DDF is used (Chambers et al., 1996; Oh, 2010; Giménez et al., 2024):

$$D_{(y,b)} = \max (\beta \mid (y + \beta g_{y,} b - \beta g_b))$$

This function, using the vector g = $(g_{y,} g_b) \epsilon R_+^{J+H}$ determines the maximum simultaneous increase and decrease, measured by β of the sub-indicators *y* and *b*. Although different methodologies have been used in the literature to determine the computation of $D_{(y,b)}$, in this study we are going to follow, once again, Giménez et al. (2024), who started from a nonparametric frontier model based on Oh (2010) in which inputs will not be considered. Thus, $D_{(y,b)}$ is calculated by the following linear program for firm *o*:

$$Max\ \theta(y_{oj,} b_{oh}) = \beta$$

s.t. $\Sigma_{k=1}^{k} \lambda_k y_{kj} \geq y_{oj} + \beta g_y \qquad j = 1 \ldots J,$

$\Sigma_{k=1}^{k} \lambda_k b_{kh} \leq b_{oh} - \beta g_b \qquad h = 1 \ldots H$

$\lambda_k \geq 0 \qquad k = 1 \ldots K.$

In this linear program, y_{kj} y b_{kh} represent the sub-indicators to maximize (*j*) or minimize (*h*) for company *k*, where y_{oj} y b_{oh} are the observed levels of each sub-indicator for the evaluated firm. In addition, β represents the maximum simultaneously achievable increase or decrease in the sub-indicators to maximize or minimize (Giménez et al., 2024).

In this context and to perform the CI calculation, the Shepard output distance is used (Fusco, 2015; Rogge et al., 2017; Giménez et al., 2024):

$$CI(y_{oj}, b_{oh}) = \frac{1}{1 + \theta(y_{oj}, b_{oh})}$$

Where $CI(y_{oj}, b_{oh}) \leq 1$, i.e., the new EI variable will obtain a minimum value of 0 and a maximum value of 1. In this case, if a company obtains $CI(y_{oj}, b_{oh}) = 1$In this case, if a company obtains 1, it means that it has obtained the highest level of efficiency or, better said, it has reached the maximum level of EI.

Once the EI variable was obtained, we proceeded to obtain economic performance variables that allow us to establish a relationship between environmental and economic-financial variables. In this way, and following authors such as Lopes-Santos et al. (2019) or Khan et al. (2021)**,** among others, the ROA, ROE and Return on Investments (hereafter ROI) variables were downloaded.

These variables of accounting origin will be key to establish a relationship between EI and business performance. In addition, control variables related to firm size (SZ), corporate governance (GovS), investment in research and development (R&D), capital expenditures (CE) and working capital (WC) have been used. In addition, a dichotomous variable of origin called EU has been established, which takes the value 1 if the company belongs to a European country and 0 otherwise. These values have been applied from 2019 onwards, as this was the year in which the European Green Pact was implemented, promoting sustainability among EU member countries (European Commission, 2020).

In addition, for each of the three Hypotheses, it is necessary to obtain data that reflect relevant information in relation to the disruptive events that we will use in this Doctoral Thesis and that, as previously specified, will be the pandemic caused by COVID-19 and the war in Ukraine. For the first disruptive event and based on works such as Klumpp et al. (2022) and Giménez et al. (2024) we have proceeded to download the

deaths caused by the SARS-Cov-2 virus. For this purpose, the data provided by https://ourworldindata.org/ for the years 2020-2022 have been used.

On the other hand, and in relation to the second disruptive event, i.e. the war in Ukraine (see Table 16), a categorical and gradual variable has been created to capture the complexity and scope of the war in Ukraine at a global level. In this sense and for the year 2022, category 1 is composed of non-EU countries. These countries are not directly involved in the Russia-Ukraine conflict, but may experience significant side effects such as disruption of global supply chains, fluctuations in energy prices or changes in international trade flows, among others (Lin et al., 2023; Arndt et al., 2023; Derindere-Köseoğlu et al., 2024).

China is in category 2, as it is in an intermediate position between European and non-European countries in terms of impact and relationship with this war. This intermediate position is justified by two main aspects. On the one hand, China has a significant economic relationship with Russia, including relevant trade and energy agreements (Liu et al., 2023; Xing et al., 2023). On the other hand, China has shown a cautious stance on the conflict, seeking a balance between maintaining its relationship with Russia while aiming to maintain stable economic relations with Europe and other parts of the world (Blank, 2022; Chang-Liao, 2023). Thus, the Asian country's position reflects a situation of indirect relationship with the conflict, although it is significantly influenced.

Finally, category 3 is made up of countries belonging to the EU. This value is justified on several grounds, including the direct impact of the conflict, direct economic and political effects, and regional politics and security (Darmayadi and Megits, 2023). First, European countries are directly involved in the crisis due to geographical proximity

and the development and implementation of policies in support of Ukraine, both at the humanitarian, military and economic levels.

Second, European countries face direct consequences such as disruption of energy supplies, rising living costs due to inflation, and significant impact on the security and stability of member countries, which means that European economies are experiencing, among other things, high volatility in commodity prices (Lin et al., 2023; Henderson, 2024). Third, the myriad Russian threats and challenges in terms of security, migration and regional cooperation place Europe as a region where political and defense decisions have been influenced by the situation in Ukraine (Genschel, 2022; Tian et al., 2023).

3.2. Statistical models

Once all the variables have been defined, it is necessary to establish statistical models to analyze the relationship between them and to contrast the hypotheses previously established. To do this, a series of necessary steps must be carried out to apply these models.

3.2.1. Descriptive statistics

Table 17 presents the descriptive statistics of the variables that will be used for the design of the models that will be shown later. On the one hand, the mean values and standard deviations of the numerical and percentage variables can be observed, while on the other hand, the frequency of the dichotomous variable used in this study can be observed (percentage of observations taking the value 1 for said variable).

Table 16: Variables definition

Variable	Abb	Definition	Data Source
Return on Assets	ROA	Net operating profit for the period divided by the total asset (%)	Refinitiv Eikon
Return on Equity	ROE	Net operating profit for the period divided by the total equity (%)	Refinitiv Eikon
Return on Investment	ROI	Net operating profit for the period less adjusted taxes divided by the invested capital (%)	Refinitiv Eikon
EI	EI	Continuous variable created with BoD where 0 is the minimum value and 1 is the maximum value.	Own elaboration using BoD
EU	EU	Dichotomous variable that takes the value 0 if it is a non-European country and 1 if it is a European country for years 2019-2022, when the European Green Deal started.	Own elaboration
Size	SZ	Firm size as measured by the natural logarithm of total assets	Refinitiv Eikon
Governance Pillar Score	GovS	The corporate governance pillar measures a company's systems and processes, which ensure that its board members and executives act in the best interests of its long-term shareholders. It reflects a company's capacity, through its use of best management practices, to direct and control its rights and responsibilities through the creation of incentives, as well as checks and balances in order to generate long term shareholder value.	Refinitiv Eikon
Research and Development	R&D	Represents expenses for research and development of new products and services by a company in order to obtain a competitive advantage.	Refinitiv Eikon
Capital Expenditures	CE	Capital Expenditures represents the sum of Purchase of Fixed Assets, Purchase/Acquisition of Intangibles and Software Development Costs for the defined fiscal period.	Refinitiv Eikon
Working Capital	WC	This item is defined as the difference between Current Assets and Current Liabilities for the fiscal period. Available for Industrial and Utility companies.	Refinitiv Eikon
Covid	Cov	Numerical variable measured by the number of deaths per Covid for the years 2020-2022	Our World in Data
Ukraine War	War	Categorical and stepwise variable where 1 = non-European countries 2= China and 3 = European countries.	Own creation

Source: The author, Refinitiv Eikon and Our World in Data

Table 17: Descriptive statistics

Variable	Mean	Std. dev.
ROA (%)	3.19	7.05
ROE (%)	6.74	14.39
ROI (%)	4.23	9.20
EI	0.80	0.31
SZ	22.22	1.58
GovS (%)	51.42	22.47
R&D	7.46	9.55
CE	19.14	4.38
WC	15.93	8.24
COVID	59999.28	137483.50
WAR	0.29	0.66
Frequency (%)		
EU	14.00	

Descriptive statistics are very useful to know, in a generalized and summarized way, relevant information on each of the variables**.** In relation to the profitability variables, it can be observed that ROA has a mean value of 3.19%, while ROE has a mean value of 6.74% and 4.23% in the case of ROI, which shows that, on average, the companies generate a reasonable profitability for the data of the sample analyzed. However, we note that the standard deviations are considerably high, suggesting that there is considerable variability among these companies.

In relation to the EI variable, it can be observed that the mean is 0.80, which indicates that, on average, the listed companies analyzed are achieving an optimal level of EI. Regarding company size, measured by the natural logarithm of total assets, it can be observed how there is a standard deviation of 1.58, which suggests that the size of the analyzed companies is comparable, which makes sense considering that all the companies are listed.

The Governance Pillar Score (GovS) variable shows that the companies have an average score of 51.42, which places them at an intermediate level in terms of corporate

governance, indicating ample room for improvement. On the other hand, companies show significant variability in R&D investment (mean of 7.46) and in working capital (mean of 15.93), reflecting different approaches to innovation and operational management. In contrast, average investment in capital expenditures stands at 19.14, showing more constant investments, underlining the importance of maintaining and expanding productive capacity.

In relation to disruptive events, it can be observed how the Covid variable has a mean value of 60,000 deaths per year, while it has an extremely high standard deviation. This high variability indicates an uneven impact of COVID-19 among the different regions studied, which can significantly influence highly relevant aspects such as the demand for products and services or the supply chain, among others.

The War variable, with a mean value of 0.29 and a standard deviation of 0.66, suggests that most of the observations correspond to non-EU countries, with a smaller number of observations coming from China or Europe. This is highly relevant, as the geopolitical context significantly influences the economic and political stability of a country, which affects business decisions.

These data are supported by the EU variable, which shows a mean value of 0.14, reflecting that 14% of the sample corresponds to companies belonging to EU countries. It should be noted that this percentage corresponds to a total of 3,606 companies from all over the world, so the remaining 86% corresponds to companies from non-EU countries, with a greater presence of US companies.

On the other hand, the correlation matrix depicted in Table 18 shows that the profitability measures (ROA, ROE, ROI) are highly correlated with each other and are

positively associated with firm size (SZ) and capital expenditures (CE). In addition, EI presents a positive and moderate relationship with profitability, suggesting that higher EI may be associated with better financial performance. As for R&D investment, it shows a slight and negative correlation with profitability indicators, which could indicate that R&D investments do not always result in an immediate financial return.

Table 18: Correlation matrix

Variable	ROA (%)	ROE (%)	ROI (%)	EI	EU	SZ	GovS	R&D	CE	WC	COVID	WAR
ROA (%)	1											
ROE (%)	0.8080***	1										
ROI (%)	0.9396***	0.8261***	1									
EI	0.1953***	0.1887***	0.1894***	1								
EU	0.0461***	0.0603***	0.0487***	0.1356***	1							
SZ	0.1541***	0.2036***	0.1716***	0.3948***	0.0378***	1						
GovS	0.0086	-0.0052	0.0070	0.0281***	0.0795***	0.0077	1					
R&D	-0.0439***	-0.0516***	-0.0413***	0.0360***	-0.0546***	0.0730***	-0.0165*	1				
CE	0.1365***	0.1410***	0.1431***	0.2675***	-0.0965***	0.4691***	-0.0287***	0.1846***	1			
WC	0.0895***	0.0643***	0.0965***	0.0241***	-0.0470*	-0.0174	-0.0095***	0.2344***	0.0489***	1		
COVID	-0.0608***	-0.0573***	-0.0486***	-0.0834***	-0.1337***	-0.0965***	-0.0224**	-0.0120	-0.1178***	0.0291***	1	
WAR	0.0128	0.0176*	0.0154*	0.1049***	0.2290***	0.0388***	0.0032	0.0185*	0.0050	-0.0132	-0.1884***	1

Note: *p < 0.1 **p<0.05 ***p<0.001

As for the variables related to disruptive effects, it can be observed that both have a relatively low correlation with the profitability variables, having a negative effect in the case of COVID-19 and a positive effect in the case of war. In the case of the EI variable, it can be observed how COVID-19 has a negative correlation, indicating that the impact of the pandemic might have reduced the ability of firms to eco-innovate, while the war in Ukraine would have the opposite effect.

3.2.2. Tests for the choice of statistical models

In order to choose the statistical model to be used in this chapter, it is necessary to apply various statistical tests that will facilitate the choice of the model that best fits the data analyzed and, therefore, the one that should be applied when testing the previously stated hypotheses (see Figure 11).

3.2.2.1. Breusch-Pagan test

The Breusch-Pagan test is used to verify the presence of heteroscedasticity in a model, which will determine whether a pooled model or one with random effects should be used (Toha and Johl, 2021). Following Breusch and Pagan (1980), the null and alternative hypothesis are stated as follows:

- Null Hypothesis (H_0): Model errors have constant variance (homoscedasticity), represented as. $H_0: \sigma^2 = 0$

- Alternative Hypothesis (H_1): Model errors have non-constant variance (heteroscedasticity), represented as. $H_0: \sigma^2 > 0$

Therefore, first of all, it will be necessary to know whether it is more convenient to use a random effects model or a pooled model:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \gamma_i + \in_{it}$$

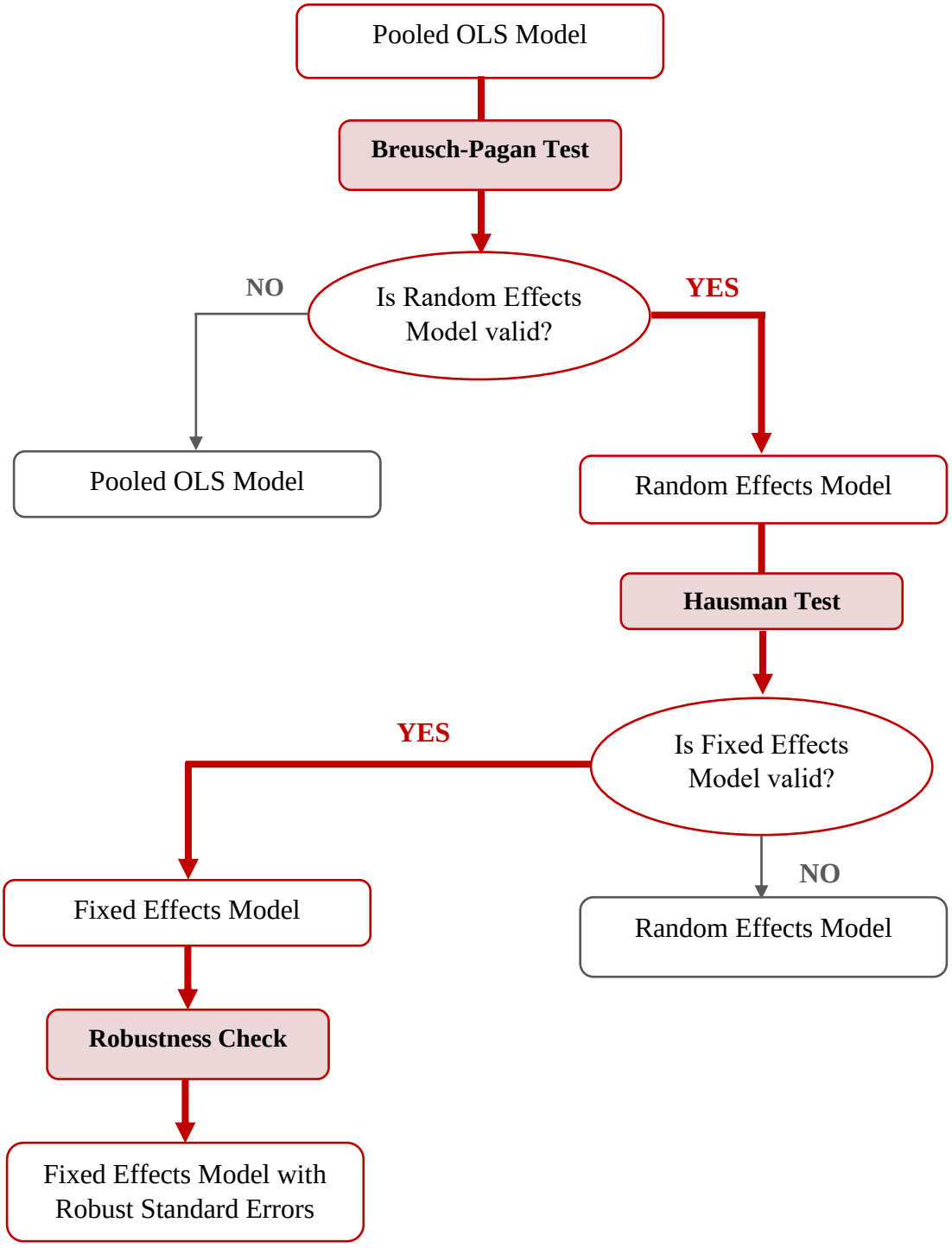
Where y_{it} is the dependent variable, x_{it} is the independent variable, γ_i captures the unobserved effects specific to each unit (in the case of a random effects model), and $\in_{it}$ is the error term.

Secondly, it is necessary to establish a regression of the squared residuals of the previous model on the explanatory variables:

$$\hat{\in}^2_{it} = \alpha_0 + \alpha_1 x_{it} + u_{it}$$

Where $\hat{\in}^2_{it}$ are the squared residuals of the initial model and x_{it} are the explanatory variables of the model. The test follows a chi-square distribution with k degrees of freedom, where k is the number of explanatory variables in the regression of squared residuals (Breusch and Pagan, 1980). In this context, the results derived from our analysis and reflected in Tables 19, 20 and 21 show that, for a sample of 14,424 observations, models with random effects are preferable in all models.

Figure 11: Statistical steps to choose the correct model



Source: The author

3.2.2.2.2. Hausman test

Once the Breusch-Pagan test has been performed, it is necessary to carry out the Hausman test, used to decide whether a fixed effects model is preferable to a random effects model (Hausman, 1978). This test compares the estimators of both models to determine which is more consistent, establishing whether or not the effects are correlated with the observable variables (Blasco and Moya, 2005). To do this, the model must first be estimated using fixed effects:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \alpha_{it} + \in_{it}$$

Where α_{it} captures the unit-specific fixed effects and subsequently estimate the model using random effects:

$$y_{it} = \beta_0 + \beta_1 x_{it} + u_{it} + \in_{it}$$

Where u_{it} captures the random effects specific to each unit. We then proceed to compare the estimated coefficients in both models. This is calculated as:

$$H = \left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right)' [Var\left(\hat{\beta}_{FE}\right) - Var\left(\hat{\beta}_{RE}\right)]^{-1} \left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right)$$

Where $\hat{\beta}_{FE}$ is the vector of estimated coefficients of the fixed effects model, $\hat{\beta}_{RE}$ is the vector of estimated coefficients of the random effects model, and $Var\left(\hat{\beta}_{FE}\right)$ y $Var\left(\hat{\beta}_{RE}\right)$ are the variance-covariance matrices of the estimators of the fixed and random effects model, respectively.

The test statistic follows a chi-square distribution with k degrees of freedom, where k is the number of estimated parameters in the model. In this context, the results

reflected in Tables 19 and 20 reflect that, for all models, it is preferable to use models with fixed effects rather than models with random effects.

In addition to the variables described above, the country and industry effects were controlled for in the pooled OLS and random effects model by applying categorical variables due to the existence of more than one country/industry. These variables were not included for the analysis using the fixed-effects model, since this model eliminates invariant characteristics by controlling for differences between units that do not change over time.

Table 19: Comparison of statistical models for Hypothesis H1

	EI					
	Pooled OLS model		**Random effects**		**Fixed effects**	
Var.	**Coef.**	**Std.err**	**Coef.**	**Std.err.**	**Coef.**	**Std.err**
COVID	-1.06e-07***	1.56e-08	5.13e-08***	1.10e-08	9.06e-08***	1.13e-08
WAR	0.016***	0.003	0.023***	0.002	0.025***	0.002
L.EU	0.087***	0.007	0.041***	0.008	0.025**	0.012
L.SZ	0.060***	0.002	0.067***	0.002	0.086***	0.009
L.GovS	0.002**	0.001	0.001	0.001	-0.001	0.001
L.R&D	-0.003	0.002	0.002	0.003	0.001	0.007
L.CE	0.007***	0.005	0.004***	0.006	0.002	0.008
L.WC	0.001***	0.002	0.001	0.003	-0.002	0.004
_cons	-0.713***	0.032	-0.791***	0.052	-1.139***	0.201
Breusch-Pagan test	87.95 [0.000]					
Hausman test				90.17 [0.000]		

Note: *p < 0.1 **p<0.05 ***p<0.001

Table 20: Comparison of statistical models for Hypothesis H2

	ROA						ROE					
	Pooled OLS model		**Random effects**		**Fixed effects**		**Pooled OLS model**		**Random effects**		**Fixed effects**	
Var.	**Coef.**	**Std.err**	**Coef.**	**Std.err.**	**Coef.**	**Std.err**	**Coef.**	**Std.err**	**Coef.**	**Std.err.**	**Coef.**	**Std.err**
L.EI	3.154***	0.192	1.008***	0.158	0.455***	0.171	5.102***	0.393	1.813***	0.350	0.731*	0.386
COVID	-1.28e-06***	4.01e-07	5.88e-07***	2.06e-07	1.14e-06***	2.08e-07	-1.80e-06**	8.21e-07	1.28e-06***	4.62e-07	2.49e-06***	4.70e-07
WAR	-0.175**	0.084	-0.044	0.036	0.0839**	0.037	-0.290*	0.171	-0.101	0.082	0.181**	0.084
L.EU	0.805***	0.175	0.886***	0.182	1.0754***	0.217	2.335***	0.358	2.147***	0.396	2.386***	0.491
L.SZ	0.260***	0.043	0.219***	0.066	-1.8055***	0.168	1.158***	0.088	1.015***	0.136	-3.597***	0.379
L.GovS	-0.001	0.002	-0.001	0.002	0.001	0.002	-0.012**	0.005	-0.004	0.003	-0.002	0.003
L.R&D	-0.066***	0.006	-0.041***	0.009	-0.020	0.014	-0.140***	0.012	-0.093***	0.019	-0.035	0.033
L.CE	0.124***	0.015	0.054***	0.014	0.007	0.015	0.202***	0.031	0.096***	0.030	0.003	0.035
L.WC	0.087***	0.007	0.048***	0.007	0.033***	0.008	0.144***	0.014	0.081***	0.015	0.051***	0.018
_cons	-8.301***	0.861	-4.157***	1.419	42.094***	3.718	-27.689***	1.762	-19.895***	2.902	84.897***	8.386
Breusch-Pagan test	142.28 [0.000]						129.66 [0.000]					
Hausman test				306.19 [0.000]						261.20 [0.000]		

Note: *p < 0.1 **p<0.05 ***p<0.001

Table 20: Continuation of comparison of statistical models for Hypothesis H2

	ROI					
	Pooled OLS model		**Random effects**		**Fixed effects**	
Var.	**Coef.**	**Std.err**	**Coef.**	**Std.err.**	**Coef.**	**Std.err**
L.EI	3.6982***	0.2515	1.2037***	0.2102	0.5420**	0.2276
COVID	-6.80e-07	5.24e-07	9.78e-07***	2.73e-07	1.63e-06***	2.77e-07
WAR	-0.1648	0.1097	-0.0326	0.0488	0.1286***	0.0496
L.EU	1.2610***	0.2287	1.3922***	0.2412	1.6990***	0.2896
L.SZ	0.4895***	0.0563	0.4283***	0.0867	-2.1970***	0.2235
L.GovS	-0.0015	0.0033	-0.0004	0.0020	0.0004	0.0021
L.R&D	-0.0880***	0.0081	-0.0536***	0.0119	-0.0260	0.0194
L.CE	0.1640***	0.0200	0.0667***	0.0185	0.0036	0.0207
L.WC	0.1231***	0.0093	0.0636***	0.0096	0.0390***	0.0111
_cons	-14.0124***	1.1254	-8.3941***	1.8553	51.6222***	4.9400
Breusch-Pagan test	140.49 [0.000]					
Hausman test				284.14 [0.000]		

Note: *p < 0.1 **p<0.05 ***p<0.001

3.2.2.3. Definition of models

Once the previous tests have been carried out, it is concluded that the most appropriate method to estimate our models and to be able to test the Hypotheses formulated is a regression with panel data and fixed effects. Therefore, the models designed for testing the Hypotheses are as follows:

(1) $EI_{it} = \beta_0 + \beta_1 Covid_{it} + \beta_2 War_{it} + \beta_3 EU_{it-1} + \beta_4 SZ_{it-1} + \beta_5 GovS_{it-1} + \beta_6 R\&D_{it-1} + \beta_7 CE_{it-1} + \beta_8 WC_{it-1} + \alpha_{it} + \in_{it}$

(2) $ROA/ROE/ROI_{it} = \beta_0 + \beta_1 EI_{it-1} + \beta_2 Covid_{it} + \beta_3 War_{it} + \beta_4 EU_{it-1} + \beta_5 SZ_{it-1} + \beta_6 GovS_{it-1} + \beta_7 R\&D_{it-1} + \beta_8 CE_{it-1} + \beta_9 WC_{it-1} + \alpha_{it} + \in_{it}$

(3) $ROA/ROE/ROI_{it} = \beta_0 + \beta_1 (Covid * EI) + \beta_2 (War * EI) + \beta_3 Covid_{it} + \beta_4 War_{it} + \beta_5 EI_{it-1} + \beta_6 EU_{it-1} + \beta_7 SZ_{it-1} + \beta_8 GovS_{it-1} + \beta_9 R\&D_{it-1} + \beta_{10} CE_{it-1} + \beta_{11} WC_{it-1} + \alpha_{it} + \in_{it}$

Each of the models is designed to test each of the previously stated hypotheses. Thus, model (1) has the EI variable as the dependent variable, since it tries to explain whether the disruptive events have influenced the application of this type of innovations. Therefore, the independent variables are the disruptive events Covid and War, in addition to having EU, SZ, GovS, R&D, CE and WC as control variables. In this way, Hypothesis H1 can be tested.

In the same way, model (2) has been designed to test Hypothesis H2. For this purpose, the financial performance metrics ROA, ROE and ROI have been established as dependent variables. The EI variable is established as an independent variable, which allows us to evaluate the impact of this type of strategies on business results, which is what we intend to test in Hypothesis H2. In addition, Covid, War, EU, SZ, GovS, R&D, CE and WC are included as control variables to adjust for the effects of other factors that may influence business performance. The same model will be applied for each of the profitability indicators individually, so we will obtain three results derived from this first model.

On the other hand, in model (3), which has the same dependent variables as model (2), the interaction between Covid and War with the EI variable is introduced. This interaction allows us to evaluate whether the effect of EI on business results is modified in the presence of these disruptive events. Additionally, the same control variables as in model (2) are maintained to adjust for the effects of these factors. In this way, hypothesis H3 can be tested.

Table 21: Comparison of statistical models for Hypothesis H3

	ROA						ROE					
	Pooled OLS model		**Random effects**		**Fixed effects**		**Pooled OLS model**		**Random effects**		**Fixed effects**	
Var.	**Coef.**	**Std.err**	**Coef.**	**Std.err.**	**Coef.**	**Std.err**	**Coef.**	**Std.err**	**Coef.**	**Std.err.**	**Coef.**	**Std.err**
COVID#EI	4.22e-06***	9.49e-07	3.39e-07	5.14e-07	-4.13e-07	5.21e-07	5.60e-06***	1.98e-06	1.28e-06	1.15e-06	9.94e-09	1.18e-06
WAR#EI	1.005**	0.422	0.023	0.214	-0.197	0.215	1.989**	0.881	0.188	0.481	-0.265	0.486
COVID	-4.71e-06***	8.19e-07	5.87e-07	4.33e-07	1.39e-06***	4.40e-07	-7.44e-06***	1.71e-06	6.87e-07	9.73e-07	2.34e-06**	9.93e-07
WAR	-0.965**	0.383	0.022	0.194	0.250	0.196	-1.908**	0.799	-0.109	0.437	0.399	0.442
L.EI	2.244***	0.208	0.988***	0.158	0.436**	0.171	3.611***	0.433	1.677***	0.350	0.661*	0.387
L.EU	0.790***	0.167	0.982***	0.179	1.087***	0.218	2.475***	0.348	2.380***	0.390	2.417***	0.492
L.SZ	-1.539***	0.080	-1.243***	0.128	-0.436	0.297	-1.487***	0.167	-1.233***	0.268	-0.231	0.669
L.GovS	-.0007	0.002	-0.001	0.002	0.001	0.002	-0.011**	0.005	-0.004	0.003	-0.002	0.004
L.R&D	-0.106***	0.005	-0.075***	0.008	-0.019	0.014	-0.208***	0.012	-0.156***	0.018	-0.033	0.033
L.CE	0.114***	0.014	0.042***	0.013	0.007	0.015	0.195***	0.030	0.076**	0.030	0.003	0.035
L.WC	0.056***	0.001	0.039***	0.007	0.034***	0.008	0.090***	0.014	0.062***	0.015	0.054***	0.018
_cons	-13.034***	0.870	-14.457***	1.475	133.203***	28.370	-37.646***	1.814	-38.056***	3.046	290.405***	63.972
Breusch-Pagan test	134.30 [0.000]						123.25 [0.000]					
Hausman test			52.75 [0.000]						166.72 [0.000]			

Note: *p < 0.1 **p<0.05 ***p<0.001

Table 21: Continuation of comparison of statistical models for Hypothesis H3

	ROI					
	Pooled OLS model		**Random effects**		**Fixed effects**	
Var.	**Coef.**	**Std.err**	**Coef.**	**Std.err.**	**Coef.**	**Std.err**
COVID#EI	3.64e-06***	1.24e-06	3.64e-08	6.82e-07	-7.57e-07	6.92e-07
WAR#EI	1.025*	0.554	-0.092	0.284	-0.348	0.286
COVID	-4.28e-06***	1.07e-06	1.22e-06**	5.75e-07	2.14e-06***	5.85e-07
WAR	-0.963*	0.502	0.160	0.257	0.433*	0.260
L.EI	2.708***	0.272	1.188***	0.209	0.534**	0.228
L.EU	1.337***	0.218	1.563***	0.236	1.764***	0.290
L.SZ	-1.570***	0.105	-1.213***	0.168	-0.096	0.394
L.GovS	-0.001	0.003	-0.001	0.002	0.001	0.002
L.R&D	-0.138***	0.007	-0.097***	0.011	-0.025	0.019
L.CE	0.158***	0.019	0.053***	0.018	0.003	0.020
L.WC	0.083***	0.008	0.052***	0.009	0.041***	0.011
_cons	-21.337***	1.140	-22.688***	1.931	117.795***	37.687
Breusch-Pagan test	132.86 [0.000]					
Hausman test				172.05 [0.000]		

Note: *p < 0.1 **p<0.05 ***p<0.001

4. RESULTS AND DISCUSSION

4.1. Main results

Table 22 shows the results obtained after applying model (1) in order to test Hypothesis H1. The findings obtained after applying this model show that the disruptive events analyzed have a positive and highly significant impact on the implementation of EI strategies. These results indicate that both geopolitical conflicts and global health crises, such as the one caused by SARS-Cov-2, boost investment in environmental innovations. This supports Hypothesis H2 and aligns with studies such as Demirel and Kesidou (2011) and Zhang and Fang (2022), which argue that crises can catalyze a shift towards more sustainable and environmentally friendly practices in firms, driven by the need for resilience and adaptation.

Table 22: Main results using fixed-effects model for model (1)

	EI	
Var.	**Coef.**	**Std. Err**
COVID	9.06e-08***	1.13e-08
WAR	.0256239***	.0020082
L.EU	.0258053**	.0118382
L.SZ	.0862249***	.0090879
L.GovS	-.0000168	.0000872
L.R&D	.0011489	.000796
L.CE	.001296	.0008496
L.WC	-.0002328	.000456
_cons	-1.139623***	.201416
R-square	0.1776	
sigma_u	.23743355	
sigma_e	.15714918	
rho	.69537812	

Note: *p < 0.1 **p<0.05 ***p<0.001

Table 23 shows the results obtained after applying model (2). In this sense, it can be observed that the adoption of EI strategies has a significant and positive impact on business profitability, confirming that the implementation of EIs can improve business performance. This finding is in line with previous research such as Hizarci-Payne et al. (2020) and Horbach et al. (2012), among others, who claim that investments in environmental or sustainable innovations can contribute to better economic performance due to reduced operating costs and improvements in resource efficiency. Thus, Hypothesis H2 is accepted.

Furthermore, our study reveals that COVID-19 and the war in Ukraine had a positive and significant effect on the profitability of the companies in the sample analyzed. These findings go against the findings of works such as Shen et al. (2021) or Bongiovanni and Fiandrino (2024), who state that COVID-19 had a significant and negative impact on business performance.

Table 23: Main results using fixed-effects model for model (2)

	ROA		ROE		ROI	
Var.	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
L.EI	0.4550***	0.1713	0.7314*	0.3865	0.54203**	0.2276
COVID	1.14e-06***	2.08e-07	2.49e-06***	4.70e-07	1.63e-06***	2.77e-07
WAR	0.0839**	0.0373	0.1813**	0.0842	0.1286***	0.0496
L.EU	1.0754***	0.2179	2.3864***	0.4916	1.6990***	0.2896
L.SZ	-1.8055***	0.1682	-3.5975***	0.3795	-2.1970***	0.2235
L.GovS	0.0001	0.0016	-0.0024	0.0036	0.0004	0.0021
L.R&D	-0.0200	0.0146	-0.0352	0.0330	-0.0260	0.0194
L.CE	0.0073	0.01564	0.0025	0.0352	0.0036	0.0207
L.WC	0.0332***	0.0083	0.0516***	0.0189	0.0390***	0.0111
_cons	42.0945***	3.7181	84.8973***	8.3860	51.6222***	4.9400
R-square	0.0687		0.0793		0.0721	
sigma_u	7.5509		15.5226		13.5977	
sigma_e	2.8933		6.5258		3.8362	
rho	0.8719		0.8498		0.9262	

Note: *p < 0.1 **p<0.05 ***p<0.001

In relation to the war in Ukraine, Kumar and Symss (2024) or Hatab and Lagerkvist (2024), state that periods of political instability such as those experienced during the war in Ukraine have a negative effect on global economies, markets and stability, generating financial stress in companies and leading to a worsening of business performance.

However, it should be noted that our analysis is based on companies belonging to 64 countries around the world and 11 different sectors (see chapter three). In this context, the COVID-19 pandemic could have significantly benefited various sectors, including the technology sector, accelerating the digitization of various business and personal activities. Thus, technology companies such as Alphabet, Amazon or Meta, which offer digital services, cloud storage and e-commerce services, experienced a significant increase in demand.

On the other hand, the increase in demand for medical equipment, hospital supplies and pharmaceuticals due to the health emergency caused companies in the healthcare sector to experience a massive increase in their business results. In addition, the non-cyclical consumer goods sector, which includes essential consumer goods such as food, beverages or personal care, among others, benefited significantly from the increase in consumption of these products due to the confinements and the need to stock up.

In relation to the war in Ukraine, the geopolitical conflict had a significant impact on energy supply, especially in Europe, where oil and natural gas prices increased. As a result, energy companies located outside the affected areas benefited from an increased demand for alternative energy sources to the main supplier, Russia, with the United States being one of the countries that benefited the most. This is of vital importance considering that more than 37% of the companies analyzed in this study are U.S. companies.

Thus, our results show that the disruptive events analyzed, despite having severely impacted the results of companies belonging to various sectors (Awan et al., 2021; Lim et al., 2022), have positively influenced those industries that found opportunities to thrive and use changes in demand trends as a factor to improve their results, which is in line with studies such as Wu et al. (2023) or Yahya et al. (2023), among others.

As the last hypothesis to be tested, model (3) was applied to accept or refute hypothesis H3. This hypothesis aims to evaluate the impact of the interaction between the COVID and WAR variables with the EI variable on business results, thus being able to see whether the influence of EI on results has been enhanced by the presence of the transboundary crises selected in this chapter.

Table 24: Main results using fixed-effects model for model (3)

	ROA		**ROE**		**ROI**	
Var.	**Coef.**	**Std.err**	**Coef.**	**Std.err**	**Coef.**	**Std.err**
COVID#EI	-4.92e-07	5.22e-07	-1.87e-07	1.18e-06	-8.98e-07	6.93e-07
WAR#EI	-0.2230	0.2160	-0.3304	0.4872	-0.3940	0.2869
COVID	1.53e-06***	4.41e-07	2.67e-06***	9.94e-07	2.33e-06***	5.85e-07
WAR	0.2826	0.1965	0.4767	0.4434	0.4796*	0.2611
L.EI	0.4696***	0.1719	0.7387*	0.3878	0.5686**	0.2284
L.EU	1.0814***	0.2180	2.3919***	0.4917	1.7098***	0.2896
L.SZ	-1.8091***	0.1683	-3.5998***	0.3796	-2.2036***	0.2236
L.GovS	0.0001	0.0016	-0.0024	0.0036	0.0005	0.0021
L.R&D	-0.0206	0.0146	-0.0362	0.0330	-0.0271	0.0194
L.CE	0.0065	0.0156	0.0014	0.0353	0.0022	0.0208
L.WC	0.0333***	0.0083	0.0516***	0.0189	0.0392***	0.0111
_cons	42.1777***	3.7189	84.9617***	8.3881	51.7724***	4.9407
R-square	0.0247		0.081		0.073	
sigma_u	9.8212		15.534		9.821	
sigma_e	3.8440		6.526		3.844	
rho	0.8671		0.849		0.867	

Note: *p < 0.1 **p<0.05 ***p<0.001

In this sense, the results shown in Table 24 show that, contrary to what authors such as Hermundsdottir et al. (2022) or Huang et al. (2022) argue, the positive influence of EI on potential outcomes was not enhanced by the disruptive events, but quite the opposite. In addition to presenting a negative coefficient, indicating this detrimental impact, it is worth mentioning that the interacting variables that have been proposed to test hypothesis H3 are not significant. For this reason, this hypothesis has to be rejected, suggesting that the pandemic caused by COVID-19 and the war in Ukraine have not enhanced the effect of EI on business results.

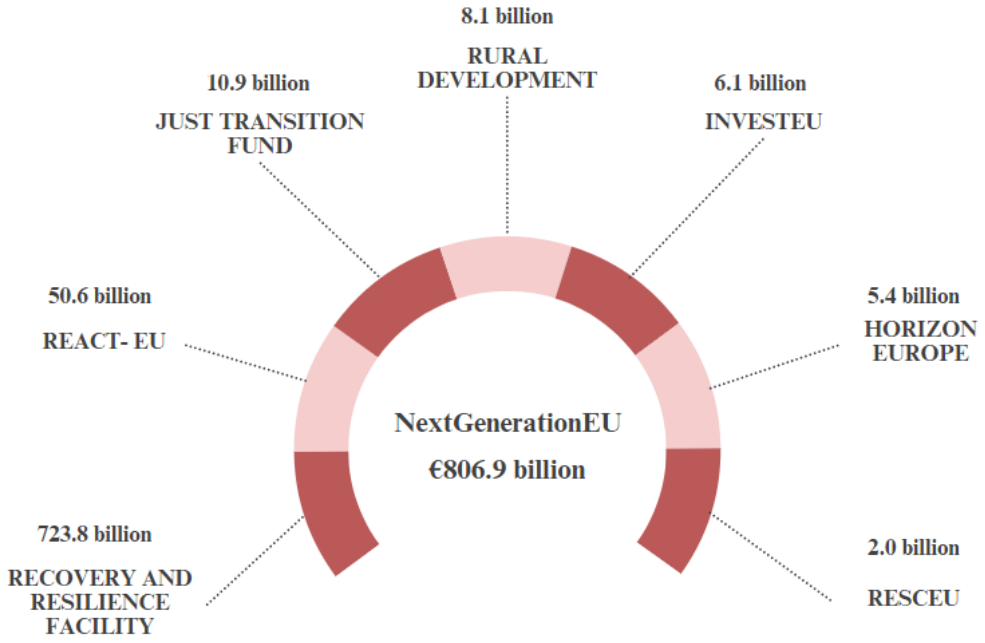
Finally, it can be observed how in each of the two Hypotheses raised, EU membership shows a positive and significant effect on the adoption of these innovations, highlighting an inclination in favor of investment in sustainable strategies by EU member countries, as also pointed out by Melece and Hazners (2017), Sikandar et al. (2023) or Costantini et al. (2023).

For more than a decade, the EU has increased its efforts to promote the green transition. In 2011, the EI Action Plan (Eco-AP) was established to turn environmental innovation into an engine for growth and jobs (European Commission, 2011). However, the turning point came in 2019 when the European Green Pact was launched, presenting itself as a comprehensive strategy that seeks to achieve climate neutrality by 2050. This Pact promotes a sustainable, modern and competitive economy that includes ambitious policies on energy, transport and emissions reduction (European Commission, 2019).

In this context, it is particularly relevant to note that the European Green Pact was launched at the beginning of COVID-19. To counteract these effects, the EU implemented a recovery plan composed of the *NextGenerationEU* program, earmarking €806.9 billion for post-pandemic recovery that will foster resilience, R&D investments and just transition, among others (European Commission, 2020). In addition, the Multiannual Financial Framework 2021-2027, with a budget of more than €1.2 trillion, allocates around 30% of the funds to boost the transition to a sustainable, net-zero emission economy.

On the other hand, the *Fit for 55* packages, presented in 2021, is focused on reducing greenhouse gas emissions by 55% by 2030, where the transport and energy sectors are presented as key sectors. In addition, the EU proposes the Social Climate Fund to mitigate the social impact of these transformations (Erbach and Jensen, 2022). In this context, it is logical to see how EU countries have key incentives to invest in EIs.

Figure 12: Distribution of NextGeneration EU Funds.



Source: NextGeneration EU Funds

4.2. Robustness check

To ensure the validity and reliability of the results obtained, a robust analysis will be carried out, which will include additional testing and consideration of possible external factors that may influence the results. This robust analysis will seek to ensure that the conclusions derived from the panel regression are robust and applicable in a broader context.

In studies using panel data, fixed effects models are commonly applied to control for unobserved unit-specific heterogeneities (such as individuals, firms, or countries) (Papke and Wooldridge, 2023). However, to ensure that the results of these models are reliable, it is essential to assess the presence of problems such as heteroskedasticity and adjust the model according to the findings (Stock and Watson, 2008; Verardi and Wagner, 2011).

Considering that the fixed effects model is $y_{it} = \beta_0 + \beta_1 x_{it} + \alpha_{it} + \in_{it}$ this model assumes that the fixed effects α_{it} are correlated with x_{it} and is therefore eliminated by transforming α_{it} by transforming within the individual differences of the panel units (Verardi and Wagner, 2011; Vogelsang, 2012). To determine whether heteroscedasticity exists in the model, the Wald test for heteroscedasticity has to be performed. Heteroscedasticity implies that the variance of the error term is not constant across observations. $\in_{it}$ is not constant across observations.

In this sense, following Vogelsang (2012) and considering the null hypothesis. $H_0 : R\beta = r$, the Wald test can be defined as:

$$Wald = \left(R\hat{\beta} - r\right)' [R\hat{V}(\hat{\beta}R']^{-1} (R\hat{\beta} - r),$$

where $\left(R\hat{\beta} - r\right)$ is the difference between the constrained and estimated values and $[R\hat{V}(\hat{\beta}R']^{-1}$ represents the inverse matrix of the variance of the constraints.

The heteroscedasticity test statistic follows a distribution of χ^2. In our case, the probability value Prob > χ^2 = 0.0000 in all cases, suggesting that the null hypothesis of homoscedasticity is rejected. Since the hypothesis H_0 was rejected, the results indicate the presence of heteroscedasticity, so applying the fixed effects model without taking this problem into account could lead to inconsistencies in the variance of the estimators. To correct for this, the fixed effects model has to be estimated by adjusting the robust standard errors, which are consistent in the face of heteroscedasticity.

The adjustment is performed through the robust variance-covariance matrix of White (1982), which adjusts the standard errors of the model coefficients and allows estimating a robust variance in the face of heteroscedasticity (Bera et al., 2002):

$$\hat{V}(\hat{\beta}) = (X'X)^{-1}(\sum_{i=1}^{N} X_i \hat{u}_{it} X_i)(X'X)^{-1} ,$$

where X is the matrix of explanatory variables, $\hat{u}_{it}$ the estimated residuals of the model and $\hat{V}(\hat{\beta})$ is the robust variance-covariance matrix of the estimators. $\hat{\beta}$.

This adjustment ensures that the standard errors obtained are consistent even in the presence of heteroscedasticity. Thus, the hypothesis tests and confidence intervals for the coefficients are reliable, even when the error variance is not constant across panel units.

4.2.1. Robustness check for hypotheses H1 and H2

Table 25: Robustness check using White variance-covariance matrix for model (1)

	White variance-covariance matrix		**Tobit model**	
		EI		
Var.	Coef.	Robust Std. Err	Coef.	Std. Err
COVID	9.06e-08***	1.22e-08	5.92e-08***	1.30e-08
WAR	0.0256***	0.0018	0.0244***	0.0022
L.EU	0.0258***	0.0066	0.0431***	0.0099
L.SZ	0.0862***	0.0145	0.0832***	0.0030
L.GovS	-0.0001	0.0001	0.0001	0.0001
L.R&D	0.0011	0.0009	0.0006	0.0004
L.CE	0.0012	0.0011	0.0042***	0.0008
L.WC	-0.0002	0.0004	0.0005	0.0004
_cons	-1.1396***	0.3224	-1.1530***	0.06504
R-square	0.1776			
sigma_u	0.2374		0.2646	
sigma_e	0.1571		0.1765	
rho	0.6953		0.6920	
Log likelihood			-1979.8818	

Note: *p < 0.1 **p<0.05 ***p<0.001

Thus, after verifying the presence of heteroscedasticity in the fixed effects model using the Wald heteroscedasticity test and after correcting for this problem by estimating robust standard errors, the results of the fixed effects model are robust and statistically valid for model (1), where an additional analysis is performed using the Tobit model in which the country and industry effect is controlled. This model is used to facilitate

efficient and consistent estimates of the coefficients by applying the maximum likelihood method (Martínez-Ferrero et al., 2015). Thus, it is confirmed that disruptive events encourage the implementation of EI strategies as stated in Hypothesis H1.

On the other hand, the same steps have been followed to check the heteroscedasticity and robustness of model (2), which allows us to verify the validity of the results obtained after applying this model. Thus, Table 25 shows that the results are consistent, suggesting that, after correcting for heteroscedasticity problems, the analyzed companies that implemented EI strategies experienced an improvement in their results.

Table 26: Robustness check using White variance-covariance matrix for model (2)

	ROA		**ROE**		**ROI**	
Var.	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
L.EI	.4550448***	.1713692	.731404*	.3865116	.5420387**	.2276863
COVID	1.14e-06***	2.08e-07	2.49e-06***	4.70e-07	1.63e-06***	2.77e-07
WAR	.0839608**	.0373561	.1813852**	.0842542	.128611***	.0496325
L.EU	1.075444***	.2179759	2.386457***	.4916297	1.699088***	.2896093
L.SZ	-1.80554***	.1682729	-3.597577***	.379528	-2.197012***	.2235724
L.GovS	.0001104	.0016057	-.002452	.0036215	.0004954	.0021333
L.R&D	-.0200101	.0146552	-.0352739	.0330537	-.0260268	.0194713
L.CE	.0073413	.0156443	.0025657	.0352846	.0036118	.0207855
L.WC	.0332806***	.0083966	.0516289***	.018938	.0390823***	.011156
_cons	42.09454***	3.718151	84.89737***	8.386037	51.62225***	4.940048
R-square	0.0687		0.0793		0.0721	
sigma_u	7.5509477		15.522606		13.597741	
sigma_e	2.893381		6.5258243		3.836262	
rho	.87197049		.84980345		.92627372	

Note: *p < 0.1 **p<0.05 ***p<0.001

4.2.2. Robustness check for hypothesis H3: an exploratory analysis

Similarly, Table 27 shows the robustness of model (3) for hypothesis H3. However, the results obtained are not conclusive, as there are several variables that differ in terms of the level of significance with respect to the main results. In this context, it should be noted that the present analysis has been conducted for the years 2018-2022, as specified at the beginning of the chapter, which might not fully capture the influence of the war in Ukraine, as well as other economic and geopolitical factors that have emerged

during the year 2023, which would lead us to incorporate additional analysis that would yield significant results.

Table 27: Robustness check using White variance-covariance matrix for model (3)

	ROA		**ROE**		**ROI**	
Var.	**Coef.**	**Robust Std. Err**	**Coef.**	**Robust Std. Err**	**Coef.**	**Robust Std. Err**
COVID#EI	-4.92e-07	4.63e-07	-1.87e-07	1.20e-06	-8.98e-07	6.66e-07
WAR#EI	-0.223*	0.0199	-0.330	0.423	-0.394*	0.159
COVID	1.53e-06***	4.08e-07	2.67e-06**	1.06e-06	2.33e-06***	5.88e-07
WAR	0.282	0.183	0.476	0.388	0.479**	0.239
L.EI	0.469**	0.219	0.738*	0.445	0.568**	0.286
L.EU	1.081***	0.239	2.391***	0.675	1.709***	0.362
L.SZ	-1.809***	0.274	-3.599***	0.634	-2.203***	0.353
L.GovS	0.001	0.002	-0.002	0.005	0.001	0.002
L.R&D	-0.020**	0.009	-0.036	0.025	-0.027**	0.012
L.CE	0.006	0.019	0.001	0.035	0.002	0.024
L.WC	0.033***	0.011	0.051*	0.026	0.039***	0.014
_cons	42.177***	6.097	84.961***	1.403	51.772***	7.824
R-square	0.0712		0.0815		0.073	
sigma_u	9.821		15.534		9.821	
sigma_e	3.844		6.526		3.844	
rho	0.867		0.849		0.867	

Note: *p < 0.1 **p<0.05 ***p<0.001

Therefore, it is necessary to analyze the effect that these disruptive events have had on EI and on business results in the medium-long term since, in line with authors such as Aibar-Guzmán and Frías-Aceituno (2021), this relationship does not have an immediate effect, as the influence of these events requires a broader temporal analysis, especially the war in Ukraine, since it arose during the last period analyzed.

In this sense, and due to the time limitations encountered in the analysis of this hypothesis, it has not been possible to carry out an exhaustive validation of the hypothesis. Therefore, we propose its implementation as a preliminary exploratory analysis, to serve as a precedent for a more rigorous examination in future research. This approach will allow the hypothesis to be addressed with the level of detail necessary in subsequent studies, thus ensuring greater robustness in the results.

5. CONCLUSIONS AND IMPLICATIONS

This chapter has examined the impact of EI on business performance during turbulent periods, as well as the influence of COVID-19 and the war in Ukraine on this performance and on the implementation of environmental innovation strategies. For this purpose and using the fixed effects model as the main model after applying Breusch-Pagan and the Hausman test, three models corresponding to three different Hypotheses have been developed. In addition to this main analysis, a robust analysis has been performed including additional tests such as the Wald test and the White test, to guarantee the validity and robustness of the results obtained.

The results show that, using the fixed effects model, the two Hypotheses put forward in this study are accepted. First, Hypothesis H1 is accepted by observing that both COVID-19 and the war in Ukraine have positively influenced the implementation of EI, suggesting that the occurrence of these disruptive events has encouraged the development and implementation of environmental strategies within companies, thus showing that crises can be seen as a factor that encourages the path towards more sustainable practices that allow companies to be more resilient and adaptive to turbulent environments. Furthermore, the application of EI has a significant and positive influence on the results of the analyzed companies, suggesting that the companies that applied this type of innovations observed an improvement in their business results, thus accepting Hypothesis H2.

In this context, the present study makes several practical and theoretical contributions. From a theoretical point of view, the findings obtained in this chapter provide robustness to the results obtained by previous studies related to the positive influence of EI on business performance. In this sense, the results obtained after the application of the different models show that the application of EI is particularly

beneficial in contexts of transboundary crises caused by disruptive events. Moreover, these events have a positive influence on the application of this type of innovation. On the other hand, *Contingency Theory* argues that the management and effectiveness of certain strategies depend on contextual factors.

Thus, the present study finds significant evidence of the impact of positive EI on business performance along with the effect of disruptive events that enhance EI. Furthermore, the use of the BoD model for the creation of a new EI variable allows researchers to observe a new way of measuring environmental performance in firms, enabling them to conduct new analyses that contribute to the elucidation of discrepancies that exist in this field of study.

From a practical point of view, the results obtained from the analysis suggest that the implementation of environmental innovation strategies not only has direct benefits on economic and financial performance but is also a key tool for managing risk and strengthening resilience in times of crisis. These findings provide corporate leaders with insight into how, in an increasingly volatile world where transboundary crises are the order of the day, incorporating EI into the strategic core of companies makes them better prepared for unforeseen challenges, ensuring not only their survival, but also their long-term success.

However, this study has some limitations that should be considered when interpreting the results and that should be commented on. First, the variability of the results obtained between the different models may be due to the different assumptions that each of the models makes about the data analyzed. In this sense, endogeneity or unobserved heterogeneity may be factors influencing the results depending on the model applied. In addition, some models may be more sensitive to outlier or censored data and

capture nonlinear effects differently, as well as complex interactions between variables. This is especially relevant in turbulent contexts such as the transboundary crises caused by the COVID-19 pandemic or the war in Ukraine as major disruptive events, which may explain the discrepancies between the results obtained.

On the other hand, the analysis has been conducted for a sample of 3,606 listed companies from around the world and across industries, which may dilute the specific effects that EI strategies and disruptive events could have on different industries. This generalist approach could lead to an average approach in which the particularities of each sector are not adequately reflected in the results. In addition, the present analysis has been conducted for the years 2018-2022, as specified at the beginning of the chapter, which might not fully capture the influence of the war in Ukraine, as well as other economic and geopolitical factors that have emerged during 2023. This limitation could be observed in the exploratory analysis conducted for hypothesis H3, the results of which are reflected in Table 27. This preliminary analysis, which will allow us to continue with this analysis in future stages, is proposed as a future line of research to be considered within the scope of the study.

In addition, future research may be aimed at deepening the understanding of how EI may influence different industrial sectors and national contexts in relation to the global crises described in this study. Furthermore, the relationship between EI and digital transformation is a topic of relevance in the current global context, as it would allow observing how the application of advanced technologies such as artificial intelligence (AI) and big data could eventually enhance the development and implementation of strategies aimed at sustainable development.

On the other hand, it is interesting to carry out a comparative analysis between countries to observe how different policies, regulations and economic contexts influence the adoption and effectiveness of this type of innovation. This could help identify best practices and policies that facilitate the implementation of EI around the world.

In relation to the last limitation presented in this chapter, analyzing the impact that disruptive events have had on the adoption of EI by the year 2023 is of particular relevance, taking into account the emergence of new transboundary crises that have not been taken into account in this study, such as the Israeli-Palestinian conflict.

UNIVERSIDAD
DE GRANADA

CHAPTER V: CONCLUDING REMARKS

1. CONCLUSIONS AND IMPLICATIONS

Throughout this doctoral thesis, three main objectives have been set to address the emerging need to establish a clear relationship between EI and business performance. To this end, a knowledge framework has been established to understand where science is heading in this field of study and what are the main factors that condition the impact of EI on business performance. In addition, an innovative classification system has been developed based on a DMI capable of assessing EI from a multidimensional and multilevel perspective. Finally, a comprehensive analysis has been conducted on how transboundary crises triggered by disruptive events have influenced both EI and performance, exploring the intensification of EI in response to these events and how they impact corporate strategic decisions.

In this context, the findings obtained throughout this Thesis lead us to some highly relevant conclusions. On the one hand, Chapter II concludes that, although there is no unanimous consensus on the influence of EI, most researchers highlight a positive impact, either in terms of profitability or in the market value of companies. This chapter concludes

with a series of external factors that can have a significant influence on this impact, such as the size of the company, the country and the environment in which the company operates. Thus, larger companies with more resources are more likely to invest in sustainability strategies, as are those that operate in an economic and institutional context that encourages the implementation of these initiatives.

Chapter III, which analyzes environmental performance in terms of EI at the regional, industry and company levels, concludes that Europe and Asia are the leading regions in terms of EI, especially in the product and process dimensions. It is worth noting that industries such as energy are lagging in this aspect, highlighting the need to improve their performance. At the corporate level, Koninklijke Philips and Hitachi stand out as having a high level of EI.

Finally, Chapter IV, after conducting a statistical analysis of the impact of EI on business performance considering the influence of disruptive events such as COVID-19 and the war in Ukraine for the period 2018-2022, presents three main conclusions. Firstly, it can be observed that both COVID-19 and the war in Ukraine have had a positive and significant impact on the implementation of EI, indicating that the transboundary crises caused by these events have led companies to invest in EI, reinforcing the idea that turbulent periods can be an opportunity to advance corporate sustainability. Secondly, the study shows that the implementation of EI has a positive and significant effect on firm performance. Finally, the results obtained in the last hypothesis raised show that the pandemic caused by COVID-19 and the war in Ukraine have not enhanced the effect of EI on business results, thus rejecting hypothesis H3.

In this context, this doctoral thesis makes a significant contribution to the previous literature from a theoretical and practical point of view. From a theoretical point of view,

this study presents, through a systematic review and a bibliometric analysis, a contextual framework to guide researchers in understanding the impact of EI on business performance, establishing resources, capabilities and the institutional environment as key elements when implementing this type of strategies. In this way, it contributes to the Resources and Capabilities theory, as well as to the Institutional theory.

On the other hand, the application of novel methodologies such as the creation of an innovative dominance-based classification system, as well as a new EI variable using the BoD model, presents a highly relevant contribution to previous literature. Furthermore, the findings obtained show that the external context and events such as the pandemic caused by COVID-19 and the war between Russia and Ukraine significantly influence the development, implementation and effectiveness of environmental strategies, thus contributing to the Contingency theory.

From a practical point of view, establishing the various factors that can influence the relationship between EI and business performance provides simple and clear guidelines for business managers to understand how such innovations can influence both the performance of their companies and the behavior of investors. Moreover, the establishment of a classification system at the regional, industry (macro-level) and company (micro-level) levels is of particular relevance to policymakers and managers who are interested in understanding and improving the environmental performance of companies from a broad, multidimensional point of view.

Finally, by stressing that EI not only improves economic performance, but also strengthens business resilience, managers of companies whose characteristics resemble those of the sample analyzed can see how, in the face of unforeseen situations, eco-

innovative strategies can position organizations to face these types of challenges and ensure their success in the medium and long term.

2. LIMITATIONS AND FUTURE LINES OF RESEARCH

Despite making a significant contribution from both a theoretical and practical point of view, this doctoral thesis has a series of limitations that must be considered and that have been developed in the conclusion's sections of the different chapters. Thus, the systematic review was based exclusively on Scopus and WOS, which could have excluded relevant studies not included in these sources. In addition, the use of general keywords in the search, as well as the selection criteria applied, could have removed valuable research from this study. Furthermore, the bibliometric analysis was performed with VOSviewer, which limited the possibility of performing an alternative analysis with other bibliometric tools.

In relation to the selection of variables for the creation of the EI ranking, it was based on the Refinitiv Eikon database, which may have restricted the analysis by not considering other databases such as Bloomberg or Morningstar, among others, widely used in the literature. In addition, the fact that the ranking was based on the year 2020 prevents its comparison over different periods, which would allow for a more comprehensive analysis.

Finally, regarding the statistical analysis between EI and corporate results, as well as the influence of disruptive events on both, it is important to highlight that such analysis was performed on a global sample of listed companies belonging to various sectors, which could dilute the specific effects of EI and disruptive events in particular sectors, as well as not capturing other events that have arisen ex post, such as the Israeli-Palestinian conflict in 2023.

In this context, several lines of research that could be developed in the future can be identified. Firstly, and in relation to bibliometric analysis, there are several key areas, such as the role of government policies, CE and education in the promotion of EI strategies, as well as their economic impact. On the other hand, it is of particular relevance to analyze how technological innovations facilitate businesses to move towards CE and sustainability, as well as to measure their environmental impact. In addition, analyzing how AI can help companies in implementing EI strategies is a particularly relevant topic considering the constant evolution of this type of tools.

Secondly, in relation to the creation of the dominance-based ranking, it would be interesting to extend the time horizon to several years, which will allow us to observe significant changes in periods before and after the disruptive events analyzed in this thesis. In this way, identifying trends in the evolution of environmental performance in regions, industries and companies around the world can be interesting to observe how organizations act taking into account the context in which they are framed. Regarding the multidimensional analysis of EI, AI is again interesting, as studies could be conducted on how this technology can influence the development of each of the EI areas, especially in the process dimension.

Finally, and in relation to the statistical analysis developed in Chapter IV, performing a specific analysis of EI on business performance may shed light on this field of study, as it will be possible to study in a more comprehensive way how disruptive events have influenced specific regions and industries. Moreover, based on the previously stated limitation, analyzing this effect in years beyond 2022, where the effects of the Russia-Ukraine conflict and the Israeli-Palestinian conflict could be better observed, could yield results that will substantially enrich those obtained in this study.

UNIVERSIDAD
DE GRANADA

REFERENCES

REFERENCES

Abbate, S., Centobelli, P., & Cerchione, R. (2023). The digital and sustainable transition of the Agri-Food Sector. *Technological Forecasting and Social Change*, *187*, 122222. https://doi.org/10.1016/j.techfore.2022.122222

Abbate, S., Centobelli, P., Cerchione, R., Oropallo, E., & Riccio, E. (2022). Investigating healthcare 4.0 transition through a Knowledge Management Perspective. *IEEE Transactions on Engineering Management*, 1–14. https://doi.org/10.1109/tem.2022.3200889

Abejón, R., & Garea, A. (2015). A bibliometric analysis of research on arsenic in drinking water during the 1992–2012 period: An outlook to treatment alternatives for arsenic removal. *Journal of Water Process Engineering*, *6*, 105–119. https://doi.org/10.1016/j.jwpe.2015.03.009

Abeysekera, I. (2023). Innovation and business performance in Australia: Role of entrepreneurship and intrapreneurship in a crisis. *Frontiers in Psychology*, *14*, 1126313. https://doi.org/10.3389/fpsyg.2023.1126313

Abu Seman, N., Govindan, K., Mardani, A., Zakuan, N., Mat Saman, M., Hooker, R., & Ozkul, S. (2019). The mediating effect of green innovation on the relationship between green supply chain management and environmental performance. *Journal of Cleaner Production*, *229*, 115–127. https://doi.org/10.1016/j.jclepro.2019.03.211

Adekoya, O. B., Asl, M. G., Oliyide, J. A., & Izadi, P. (2023). Multifractality and cross-correlation between the crude oil and the European and non-European stock markets during the Russia-Ukraine war. *Resources Policy*, *80*, 103134. https://doi.org/10.1016/j.resourpol.2022.103134

Adusei, E., Demah, E., & Mensah, H. K. (2023). Does going intellectually green matter? Accentuating the role of eco-innovation speed and quality in a competitive post-Covid 19 emerging market. *International Journal of Innovation Science*. https://doi.org/10.1108/IJIS-01-2023-0019

Ahmad, M., & Wu, Y. (2022). Combined role of green productivity growth, economic globalization, and eco-innovation in achieving ecological sustainability for OECD economies. *Journal of Environmental Management*, *302*, 113980. https://doi.org/10.1016/j.jenvman.2021.113980

Aibar-Guzmán, B., & Frías-Aceituno, J. (2021). Is It Necessary to Centralize Power in the CEO to Ensure Environmental Innovation? *Administrative Sciences*, *11*(1), 27. https://doi.org/10.3390/admsci11010027

Aksu, B., & Akman, G. (2023). How eco-innovation determinants and eco-innovation strategy influences sustainability performance of smes? mediating role of eco-innovation strategy. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-023-01360-3

Al Amosh, H., & Khatib, S. F. (2023). ESG performance in the time of COVID-19 pandemic: cross-country evidence. *Environmental Science and Pollution Research*, *30*(14), 39978-39993. https://doi.org/10.1007/s11356-022-25050-w

Albitar, K., Al-Shaer, H., & Liu, Y. S. (2023). Corporate commitment to climate change: The effect of eco-innovation and climate governance. *Research Policy*, *52*(2), 104697. https://doi.org/10.1016/j.respol.2022.104697

Aldieri, L., Kotsemir, M., & Vinci, C. (2019). The role of environmental innovation through the technological proximity in the implementation of the sustainable

development. Business Strategy And The Environment, 29(2), 493-502. https://doi.org/10.1002/bse.2382

Ali, S., Ghufran, M., Ashraf, J., Xiaobao, P., & ZhiYing, L. (2024). The role of public and private interventions on the evolution of green innovation in China. *IEEE Transactions on Engineering Management, 71*, 6272-6290. https://doi.org/10.1109/TEM.2023.3280574

Allam, Z., Bibri, S. E., & Sharpe, S. A. (2022). The rising impacts of the COVID-19 pandemic and the Russia–ukraine war: Energy transition, climate justice, global inequality, and supply chain disruption. *Resources*, *11*(11), 99. https://doi.org/10.3390/resources11110099

Almeida, F., & Wasim, J. (2022). Eco-innovation and Sustainable Business Performance: Perspectives of smes in Portugal and the UK. *Society and Business Review*, *18*(1), 28–50. https://doi.org/10.1108/sbr-12-2021-0233

AlQershi, N., Saufi, R. B. A., Ismail, N. A., Mohamad, M. R. B., Ramayah, T., Muhammad, N. M. N., & Yusoff, M. N. H. B. (2023). The moderating role of market turbulence beyond the COVID-19 pandemic and Russia-Ukraine crisis on the relationship between intellectual capital and business sustainability. *Technological Forecasting and Social Change*, *186*, 122081. https://doi.org/10.1016/j.techfore.2022.122081

Aminoff, A., & Pihlajamaa, M. (2020). Business experimentation for a circular economy - Learning in the front end of innovation. *Journal Of Cleaner Production*, *275*, 124051. https://doi.org/10.1016/j.jclepro.2020.124051

Amor-Esteban, V., Galindo-Villardón, M. P., & García-Sánchez, I. M. (2020). Bias in composite indexes of CSR practice: An analysis of CUR matrix

decomposition. *Corporate Social Responsibility and Environmental Management*, *27*(4), 1914-1936. https://doi.org/10.1002/csr.1936

Andries, P., & Stephan, U. (2019). Environmental Innovation and Firm Performance: How Firm Size and Motives Matter.*Sustainability*, *11*(13),3585. https://doi.org/10.3390/su11133585

Ansell, C., Boin, A., & Keller, A. (2010). Managing transboundary crises: Identifying the building blocks of an effective response system. *Journal of contingencies and crisis management*, *18*(4), 195-207. https://doi.org/10.1111/j.1468-5973.2010.00620.x

Appiah-Otoo, I., & Chen, X. (2023). Russian-Ukrainian war degrades the total environment. *Letters in Spatial and Resource Sciences*, *16*(1), 32. https://doi.org/10.1007/s12076-023-00354-8

Arellano, M., & Bond, S. R. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277–297.

Arndt, C., Diao, X., Dorosh, P., Pauw, K., & Thurlow, J. (2023). The Ukraine war and rising commodity prices: Implications for developing countries. *Global Food Security*, *36*, 100680. https://doi.org/10.1016/j.gfs.2023.100680

Awan, U., Arnold, M. G., & Gölgeci, I. (2021). Enhancing green product and process innovation: Towards an integrative framework of knowledge acquisition and environmental investment. *Business Strategy and the Environment*, *30*(2), 1283-1295. https://doi.org/10.1002/bse.2684

Bag, S., Pretorius, J. H., Gupta, S., & Dwivedi, Y. K. (2021). Role of institutional pressures and resources in the adoption of big data analytics powered artificial

intelligence, sustainable manufacturing practices and circular economy capabilities. *Technological Forecasting and Social Change*, *163*, 120420. https://doi.org/10.1016/j.techfore.2020.120420

Balsalobre-Lorente, D., Sinha, A., & Murshed, M. (2023). Russia-Ukraine conflict sentiments and energy market returns in G7 countries: Discovering the unexplored dynamics. *Energy Economics*, *125*, 106847.https://doi.org/10.1016/j.eneco.2023.106847

Baltagi, B. H., & Liu, L. (2008). Testing for random effects and spatial lag dependence in panel data models. *Statistics & Probability Letters*, *78*(18), 3304-3306. https://doi.org/10.1016/j.spl.2008.06.014

Barbieri, N., Ghisetti, C., Gilli, M., Marin, G. and Nicolli, F. (2016), A survey of the literature on environmental innovation based on main path analysis. *Journal of Economic Surveys, 30*, 596-623. https://doi.org/10.1111/joes.12149

Baum, J. R., & Wally, S. (2003). Strategic decision speed and firm performance. *Strategic management journal*, 1107-1129.

Benijts, T. (2014). A Business Sustainability Model for Government Corporations. A Belgian Case Study. *Business Strategy And The Environment*, *23*(3), 204-216. https://doi.org/10.1002/bse.1784

Bitencourt, C., de Oliveira Santini, F., Zanandrea, G., Froehlich, C., & Ladeira, W. (2020). Empirical generalizations in eco-innovation: A meta-analytic approach. *Journal Of Cleaner Production*, *245*, 118721. https://doi.org/10.1016/j.jclepro.2019.118721

Björklund, M. (2010). Benchmarking tool for improved corporate social responsibility in purchasing. *Benchmarking: An International Journal*, *17*(3), 340–362. https://doi.org/10.1108/14635771011049335

Blank, S. (2022). Russia, China, and information war against Ukraine. *The Journal of East Asian Affairs*, 39-72.

Blasco, A. y Moya, I. (2005) "Un método de análisis económico-financiero explicativo de la eficiencia temporal de las grandes empresas del sector agroalimentario español", *Revista española de estudios agrosociales y pesqueros*, 206:163-186

Boin, A. (2019). The transboundary crisis: Why we are unprepared and the road ahead. *Journal of Contingencies and Crisis Management, 27*(2), 94–99. https://doi.org/10.1111/1468-5973.12241

Boin, A. and Lodge, M. (2016), designing resilient institutions for transboundary crisis management: A time for public administration. *Public Administration, 94*, 289-298. https://doi.org/10.1111/padm.12264

Bongiovanni, A., & Fiandrino, S. (2024). Does firm environmental performance mitigate the market reaction to COVID-19 uncertainty?. *Research in International Business and Finance, 68*, 102193. https://doi.org/10.1016/j.ribaf.2023.102193

Branke, J. (Ed.). (2008). Multiobjective optimization: Interactive and evolutionary approaches (Vol. 5252). *Springer Science & Business Media*. https://doi.org/10.1007/978-3-540-88908-3

Broccardo, L., Truant, E., & Zicari, A. (2019). Internal corporate sustainability drivers: What evidence from family firms? A literature review and research agenda. *Corporate Social Responsibility and Environmental Management, 26*, 1–18. https://doi.org/10.1002/csr.1672

Bucea-Manea-Țoniș, R., Prokop, V., Ilic, D., Gurgu, E., Bucea-Manea-Țoniș, R., Braicu, C., & Moanță, A. (2021). The relationship between eco-innovation and smart working as

support for sustainable management. *Sustainability*, *13*(3), 1437. https://doi.org/10.3390/su13031437

Buttol, P., Buonamici, R., Naldesi, L., Rinaldi, C., Zamagni, A., & Masoni, P. (2011). Integrating services and tools in an ICT platform to support eco-innovation in smes. Clean Technologies and Environmental Policy, 14(2), 211–221. https://doi.org/10.1007/s10098-011-0388-7

Cabane, L., & Lodge, M. (2023). Un-solvable crises? Differential implementation and transboundary crisis management in the EU. *West European Politics*, *47*(3), 491–514. https://doi.org/10.1080/01402382.2023.2282284

Caldara, D., & Iacoviello, M. (2022). Measuring geopolitical risk. *American Economic Review*, *112*(4), 1194-1225. https://doi.org/10.1257/aer.20191823

Campobasso, F., & Boscia, V. (2022). Sustainability Frontiers of Strategic Risk Management and firm survival: The Altman score effectiveness. A bibliometric analysis. *Business Strategy and the Environment.* https://doi.org/10.1002/bse.3336

Çankaya, S. Y., & Sezen, B. (2015). Moderator effect of environmental uncertainty on the relationship between ecologic innovation and sustainability performance. International *Journal of Management Economics and Business*, *11*(24), 111–134. https://doi.org/10.17130/ijmeb.2015.11.24.741

Carrillo-Hermosilla, J., del Río, P., & Könnölä, T. (2010). Diversity of eco-innovations: Reflections from selected case studies. *Journal Of Cleaner Production*, *18*(10-11), 1073-1083. https://doi.org/10.1016/j.jclepro.2010.02.014

Carroll, A. B. (2021). Corporate social responsibility (CSR) and the COVID-19 pandemic: Organizational and managerial implications. *Journal of Strategy and Management*, *14*(3), 315-330. https://doi.org/10.1108/JSMA-07-2021-0145

Casado-Aranda, L., Sánchez-Fernández, J., & Viedma-del-Jesús, M. (2021). Analysis of the scientific production of the effect of COVID-19 on the environment: A bibliometric study. *Environmental Research*, *193*, 110416. https://doi.org/10.1016/j.envres.2020.110416

Castellacci, F. (2023). Innovation and social welfare: A new research agenda. *Journal of Economic Surveys*, *37*(4), 1156-1191. https://doi.org/10.1111/joes.12537

Centobelli, P., Cerchione, R., Chiaroni, D., Del Vecchio, P., & Urbinati, A. (2020). Designing business models in Circular Economy: A Systematic Literature Review and Research Agenda. Business Strategy and the Environment, 29(4), 1734–1749. https://doi.org/10.1002/bse.2466

Cerchione, R., & Esposito, E. (2016). A systematic review of Supply Chain Knowledge Management Research: State of the art and research opportunities. *International Journal of Production Economics*, *182*, 276–292. https://doi.org/10.1016/j.ijpe.2016.09.006

Chambers, R. G., Chung, Y., & Färe, R. (1996). Benefit and distance functions. *Journal of Economic Theory*, *70*(2), 407-419. https://doi.org/10.1006/jeth.1996.0096

Chang-Liao, N. C. (2023). The limits of strategic partnerships: Implications for China's role in the Russia-Ukraine war. *Contemporary Security Policy*, *44*(2), 226-247. https://doi.org/10.1080/13523260.2023.2174702

Chaparro-Banegas, N., Mas-Tur, A., Park, H. W., & Roig-Tierno, N. (2023). Factors driving national eco-innovation: New routes to sustainable development. *Sustainable Development*, *31*(4), 2711-2725. https://doi.org/10.1002/sd.2541

Chatterjee, S., Chaudhuri, R., Vrontis, D., Dana, L. P., & Kabbara, D. (2024). Developing resilience of MNEs: From global value chain (GVC) capability and performance perspectives. *Journal of Business Research*, *172*, 114447. https://doi.org/10.1016/j.jbusres.2023.114447

Chen, X., Laurent, S., Onur, O. A., Kleineberg, N. N., Fink, G. R., Schweitzer, F., & Warnke, C. (2020). A systematic review of neurological symptoms and complications of COVID-19. Journal of Neurology, 268(2), 392–402. https://doi.org/10.1007/s00415-020-10067-3

Cherchye, L., Knox Lovell, C. A., Moesen, W., & Van Puyenbroeck, T. (2007). One market, one number? A composite indicator assessment of EU Internal Market Dynamics. *European Economic Review*, *51*(3), 749–779. https://doi.org/10.1016/j.euroecorev.2006.03.011

Cherchye, L., Moesen, W., Rogge, N., Van Puyenbroeck, T., Saisana, M., Saltelli, A., … Tarantola, S. (2008). Creating composite indicators with DEA and robustness analysis: the case of the Technology Achievement Index. *Journal of the Operational Research Society*, *59*(2), 239–251. https://doi.org/10.1057/palgrave.jors.2602445

Childs, M., Turner, T., Sneed, C., & Berry, A. (2022). A contingency theory approach to understanding small retail business continuity during Covid-19. *Family and Consumer Sciences Research Journal*, *50*(3), 216-230. https://doi.org/10.1111/fcsr.12434

Çimen, Ö. (2021). Construction and built environment in circular economy: A comprehensive literature review. *Journal of Cleaner Production*, 305, 127180. https://doi.org/10.1016/j.jclepro.2021.127180

Colombo, L. A., Pansera, M., & Owen, R. (2019). The discourse of eco-innovation in the European Union: An analysis of the eco-innovation action plan and horizon 2020. *Journal of Cleaner Production*, *214*, 653–665. https://doi.org/10.1016/j.jclepro.2018.12.150

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data envelopment analysis: a comprehensive text with models, applications, references and DEA-solver software* (Vol. 2, p. 489). New York: springer.

Costantini, V., Delgado, F. J., & Presno, M. J. (2023). Environmental innovations in the EU: A club convergence analysis of the eco-innovation index and driving factors of the clusters. *Environmental Innovation and Societal Transitions*, *46*. https://doi.org/10.1016/j.eist.2023.100698

Damanpour, F. (2010). An integration of research findings of effects of firm size and market competition on product and Process Innovations. *British Journal of Management*, *21*(4), 996–1010. https://doi.org/10.1111/j.1467-8551.2009.00628.x

Darmayadi, A., & Megits, N. (2023). The impact of the Russia-Ukraine war on the European Union economy. *Journal of Eastern European and Central Asian Research (JEECAR)*, *10*(1), 46-55. https://doi.org/10.15549/jeecar.v10i1.1079

Davidenko, L., Sherimova, N., Kunyazova, S., Amirova, M., & Beisembina, A. (2024). Sustainable economy: The eco-branding of an industrial region in Kazakhstan. *Sustainability*, *16*(1), 413. https://doi.org/10.3390/su16010413

de Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2018). Eco-innovation in the transition to a circular economy: An Analytical Literature Review. *Journal of Cleaner Production, 172*, 2999–3018. https://doi.org/10.1016/j.jclepro.2017.11.111

De Witte, K., & Rogge, N. (2011). Accounting for exogenous influences in performance evaluations of teachers. *Economics of Education Review*, *30*(4), 641–653. https://doi.org/10.1016/j.econedurev.2011.02.002

Demirel, P., & Kesidou, E. (2011). Stimulating different types of eco-innovation in the UK: Government policies and firm motivations. *Ecological Economics*, *70*(8), 1546-1557. https://doi.org/10.1016/j.ecolecon.2011.03.019

Derindere Köseoğlu, S., Mercangöz, B. A., Khan, K., & Sarwar, S. (2023). The impact of the Russian-Ukraine war on the stock market: a causal analysis. *Applied Economics*, *56*(21), 2509–2519. https://doi.org/10.1080/00036846.2023.2188168

Despotis, D. K. (2005). A reassessment of the human development index via data envelopment analysis. *Journal of the Operational Research Society*, *56*(8), 969–980. https://doi.org/10.1057/palgrave.jors.2601927

Ding, W., Levine, R., Lin, C., & Xie, W. (2021). Corporate immunity to the COVID-19 pandemic. *Journal of financial economics*, *141*(2), 802-830. https://doi.org/10.1016/j.jfineco.2021.03.005

Ding, X., & Yang, Z. (2020). Knowledge mapping of platform research: a visual analysis using VOSviewer and CiteSpace. *Electronic Commerce Research.* https://doi.org/10.1007/s10660-020-09410-7

Dong, Y., Wang, X., Jin, J., Qiao, Y., & Shi, L. (2014). Effects of eco-innovation typology on its performance: Empirical evidence from chinese enterprises. *Journal of*

Engineering and Technology Management, *34*, 78–98. https://doi.org/10.1016/j.jengtecman.2013.11.001

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Doran, J., & Ryan, G. (2012). Regulation and firm perception, eco-innovation and firm performance. *European Journal Of Innovation Management*, *15*(4), 421-441. https://doi.org/10.1108/14601061211272367

Dreyfus, D., & Nair, A. (2022). The impact of operational disruptions on performance in surgical settings: Moderating roles of risk management infrastructure and information exchange. *International Journal of Operations & Production Management, 42*(7), 930–958.

Driessen, P. H., Hillebrand, B., Kok, R. A. W., & Verhallen, T. M. M. (2013).Green new product development: The pivotal role of product green-ness. IEEE Transactions on Engineering Management, 60(2), 315–326. https://doi.org/10.1109/TEM.2013.2246792

Durán-Romero, G., & Urraca-Ruiz, A. (2015). Climate change and eco-innovation. A patent data assessment of Environmentally Sound Technologies. Innovation, 17(1), 115–138. https://doi.org/10.1080/14479338.2015.1011062

Durán-Romero, G., López, A., Beliaeva, T., Ferasso, M., Garonne, C., & Jones, P. (2020). Bridging the gap between circular economy and climate change mitigation policies through eco-innovations and Quintuple Helix Model. *Technological Forecasting And*

EIO. Methodological Report; Eco-Innovation Observatory, 2012. Available online: http://www.undocuments.net/wced-ocf.htm (accessed on 25 January 2024)

Ellen MacArthur Foundation, 2012. Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition. Available at. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf.

Enciso-Alfaro, S., & García-Sánchez, I. (2022). Corporate Governance and Environmental Sustainability: Addressing the dual theme from a bibliometric approach. Corporate Social Responsibility and Environmental Management, 30(3), 1025–1041. https://doi.org/10.1002/csr.2403

Erbach, G., & Jensen, L. (2022). Fit for 55 package. *EPRS, European Parliament*.

Ertimur, Y., Ferri, F., & Oesch, D. (2013). Shareholder votes and Proxy advisors: Evidence from say on pay. *Journal of Accounting Research, 51*(5), 951–996. https://doi.org/10.1111/1475-679x.12024

European Commission (2011). Innovation for a Sustainable Future – the Eco-innovation Action Plan (Eco-AP), COM(2011) 899 final. Available at https://www.eea.europa.eu/policy-documents/the-eco-innovation-action-plan

European Commission (2020). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committe and the Committee of the Regions Europe's moment: Repair and Prepare for the Next Generation, COM (2020) 456 final. Available at https://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:52020DC0456&from=EN

European Commission (2022). Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: EU Save Energy, European Commission, Brussels.

European Commission, (2011). Eco-innovation action plan. Available online at. http://ec.europa.eu/environment/ecoap/faq/index_en.htm [Last accessed on 8th February 2024].

European Commission, (2019). The European green deal. Available online at. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_es [Last accessed on 8th February 2024].

European Commission, (2021). Recovery Plan for Europe. https://ec.europa.eu/info/strategy/recovery-plan-europe_en. Available online at. [Last accessed on 8th February 2024).

European Commission, Directorate-General for Budget, (2021). *The EU's 2021-2027 long-term budget and NextGenerationEU : facts and figures*, Publications Office of the European Union. **https://data.europa.eu/doi/10.2761/808559**

Farrukh, M., Meng, F., Wu, Y., & Nawaz, K. (2020). Twenty-eight years of business strategy and the Environment Research: A Bibliometric analysis. Business Strategy and the Environment, 29(6), 2572–2582. https://doi.org/10.1002/bse.2521

Feng, F., Jia, N., & Lin, F. (2023). Quantifying the impact of Russia–Ukraine crisis on food security and trade pattern: evidence from a structural general equilibrium trade model. *China Agricultural Economic Review*, *15*(2), 241-258. https://doi.org/10.1108/CAER-07-2022-0156

Fiedler, F.E. (1951). A method of objective quantification of certain countertransference attitudes. *Journal of Clinical Psychology, 7*(2), 101–107

Flores-Rivera, C., Serrano-Bedia, A. M., & García-Piqueres, G. (2023). Motivations and outcomes of environmental corporate sustainability in family and non-family Mexican

firms: The mediating role of eco-innovation strategy. *Corporate Social Responsibility and Environmental Management*, *31*(1), 357–374. https://doi.org/10.1002/csr.2574

Fukuyama, H., Hashimoto, A., & Weber, W. L. (2020). Environmental efficiency, energy efficiency and aggregate well-being of Japanese prefectures. *Journal of Cleaner Production*, *271*, 122810. https://doi.org/10.1016/j.jclepro.2020.122810

Fusco, E. (2015). Enhancing non-compensatory composite indicators: A directional proposal. *European Journal of Operational Research*, *242*(2), 620-630. https://doi.org/10.1016/j.ejor.2014.10.017

Gaaloul, H., & Khalfallah, S. (2014). Application of the "benefit-of-the-doubt" approach for the construction of a Digital Access Indicator: A Revaluation of the "Digital Access Index." *Social Indicators Research*, *118*(1), 45–56. https://doi.org/10.1007/s11205-013-0422-8

García-Granero, E., Piedra-Muñoz, L., & Galdeano-Gómez, E. (2018). Eco-innovation measurement: A review of firm performance indicators. *Journal Of Cleaner Production*, *191*, 304-317. https://doi.org/10.1016/j.jclepro.2018.04.215

García-Sánchez, I. M., Somohano-Rodríguez, F. M., Amor-Esteban, V., & Frías-Aceituno, J. V. (2021). Which region and which sector leads the circular economy? CEBIX, a multivariant index based on business actions. *Journal of Environmental Management*, *297*, 113299. https://doi.org/10.1016/j.jenvman.2021.113299

García-Sánchez, I., Gallego-Alvarez, I., & Zafra-Gómez, J. (2019). Do the eco-innovation and ecodesign strategies generate value added in munificent environments? Business Strategy and the Environment, 29(3), 1021–1033. https://doi.org/10.1002/bse.2414

García-Sánchez, I., Gallego-Alvarez, I., & Zafra-Gómez, J. (2020). Do inde- pendent, female and specialist directors promote eco-innovation and eco-design in agri-food firms? *Business Strategy and the Environment, 30*(2), 1136–1152. https://doi.org/10.1002/bse.2676

Gaukhar, K., Rakhmetova, A., & Assanova, M. (2020). Financing of eco-innovations: Sources and trends in Kazakhstan. *International Journal of Energy Economics and Policy*, *11*(1), 173–179. https://doi.org/10.32479/ijeep.10762

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'. *International Journal Of Sustainable Development & Amp; World Ecology*, *15*(3), 231-239. https://doi.org/10.3843/susdev.15.3:6

Genschel, P. (2022). Bellicist integration? The war in Ukraine, the European Union and core state powers. *Journal of European Public Policy*, *29*(12), 1885-1900. https://doi.org/10.1080/13501763.2022.2141823

George, D., Lin, B., & Chen, Y. (2015). A circular economy model of economic growth. *Environmental Modelling & Amp; Software*, *73*, 60-63. https://doi.org/10.1016/j.envsoft.2015.06.014

Ghadge, A., Wurtmann, H., & Seuring, S. (2019). Managing climate change risks in global supply chains: a review and research agenda. *International Journal of Production Research*, *58*(1), 44–64. https://doi.org/10.1080/00207543.2019.1629670

Giambona, F., & Vassallo, E. (2013). Composite indicator of Social Inclusion for European countries. *Social Indicators Research*, *116*(1), 269–293. https://doi.org/10.1007/s11205-013-0274-2

Giménez, V., Prior, D., Thieme, C., & Tortosa-Ausina, E. (2024). International comparisons of COVID-19 pandemic management: What can be learned from activity analysis techniques? *Omega*, *122*, 102966. https://doi.org/10.1016/j.omega.2023.102966

Goll, I., & Rasheed, A. (2004). The Moderating Effect of Environmental Munificence and Dynamism on the Relationship Between Discretionary Social Responsibility and Firm Performance. *Journal Of Business Ethics*, *49*(1), 41-54. https://doi.org/10.1023/b:busi.0000013862.14941.4e

Gómez, J., Krammer, S. M., Pérez-Aradros, B., & Salazar, I. (2024). Resilience to the pandemic: The role of female management, multi-unit structure, and business model innovation. *Journal of Business Research*, *172*, 114428. https://doi.org/10.1016/j.jbusres.2023.114428

Greenhalgh, T., & Peacock, R. (2005). Effectiveness and efficiency of search methods in systematic reviews of complex evidence: Audit of Primary Sources. BMJ, 331(7524), 1064–1065. https://doi.org/10.1136/bmj.38636.593461.68

Grego, M., Magnani, G., & Denicolai, S. (2024). Transform to adapt or resilient by design? How organizations can foster resilience through business model transformation. *Journal of Business Research*, *171*, 114359. https://doi.org/10.1016/j.jbusres.2023.114359

Guderian, C. C., Bican, P. M., Riar, F. J., & Chattopadhyay, S. (2021). Innovation management in crisis: patent analytics as a response to the COVID-19 pandemic. *R&D Management*, *51*(2), 223-239. https://doi.org/10.1111/radm.12447

Gupta, R., & Guha, A. (2024). Construction of sub-country level environment policy stringency index: A study on Indian states. *Social Indicators Research*. https://doi.org/10.1007/s11205-023-03281-9

Gurka, M. J., Kelley, G. A., & Edwards, L. J. (2012). Fixed and random effects models. *Wiley Interdisciplinary Reviews: Computational Statistics*, *4*(2), 181-190. https://doi.org/10.1002/wics.201

Hall, P., O'Brien, T., & Woudsma, C. (2013). Environmental innovation and the role of stakeholder collaboration in West Coast port gateways. *Research In Transportation Economics*, *42*(1), 87-96. https://doi.org/10.1016/j.retrec.2012.11.004

Han, J., Raghutla, C., Chittedi, K. R., Tan, Z., & Koondhar, M. A. (2022). How natural resources affect financial development? Fresh evidence from top-10 natural resource abundant countries. *Resources Policy*, *76*, 102647. https://doi.org/10.1016/j.resourpol.2022.102647

Hansen, L. P. (1982). Large sample properties of generalized method of moments estimators. Econometrica: Journal of the Econometric Society, 1029–1054.

Hatab, A. A., & Lagerkvist, C. J. (2024). Perceived business risks and observed impacts of the Russian-Ukraine war among small-and medium-sized agri-food value chain enterprises in Egypt. *Food Policy*, *127*, 102712. https://doi.org/10.1016/j.foodpol.2024.102712

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the econometric society*, 1251-1271.

Henderson, J. (2024). The Impact of the Russia-Ukraine War on Global Gas Markets. *Current Sustainable/Renewable Energy Reports*, *11*(1), 1-9. https://doi.org/10.1007/s40518-024-00232-x

Hermundsdottir, F., Haneberg, D. H., & Aspelund, A. (2022). Analyzing the impact of COVID-19 on environmental innovations in manufacturing firms. *Technology in Society*, *68*, 101918. https://doi.org/10.1016/j.techsoc.2022.101918

Hizarci-Payne, A., Ipek, I., & Kurt Gümüs, G. (2020). How environmental innovation influences firm performance: A meta-analytic review. *Business Strategy and the Environment*, *30*(2), 1174–1190. https://doi. org/10.1002/bse.2678

Hoffman, A. J. (1999). Institutional evolution and change: Environmentalism and the US chemical industry. *Academy of management journal*, *42*(4), 351-371.

Hofstra, N., & Huisingh, D. (2014). Eco-innovations characterized: a taxonomic classification of relationships between humans and nature. *Journal Of Cleaner Production*, *66*, 459-468. https://doi.org/10.1016/j.jclepro.2013.11.036

Hojnik, J., Ruzzier, M., & Manolova, T. (2018). Internationalization and economic performance: The mediating role of eco-innovation. *Journal Of Cleaner Production*, *171*, 1312-1323. https://doi.org/10.1016/j.jclepro.2017.10.111

Horbach, J. (2008). Determinants of environmental innovation-New evidence from German panel data sources. *Research Policy*, *37*(1), 163-173. https://doi.org/10.1016/j.respol.2007.08.006

Horbach, J. (2016). Empirical determinants of eco-innovation in European countries using the Community Innovation Survey. *Environmental Innovation and Societal Transitions*, *19*, 1–14. https://doi.org/10.1016/j.eist.2015.09.005

Horbach, J., Rammer, C., & Rennings, K. (2012). Determinants of eco-innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull. *Ecological economics*, *78*, 112-122.https://doi.org/10.1016/j.ecolecon.2012.04.005

Huang, W., Chen, S., & Nguyen, L. T. (2020). Corporate Social Responsibility and organizational resilience to COVID-19 crisis: An empirical study of Chinese firms. *Sustainability*, *12*(21), 8970. https://doi.org/10.3390/su12218970

Huang, Y., Ahmad, M., Ali, S., & Kirikkaleli, D. (2022). Does eco-innovation promote cleaner energy? Analyzing the role of energy price and human capital. *Energy*, *239*, 122268. https://doi.org/10.1016/j.energy.2021.122268

Humphreys, K. A., & Trotman, K. T. (2022). Judgment and decision making research on CSR reporting in the COVID-19 pandemic environment. *Accounting & Finance*, *62*(1), 739-765. https://doi.org/10.1111/acfi.12805

Johl, S. K., & Toha, M. A. (2021). The nexus between proactive eco-innovation and firm financial performance: A circular economy perspective. Sustainability, 13(11), 6253. https://doi.org/10.3390/su13116253

Jordan, N., Lemken, T., & Liedtke, C. (2014). Barriers to Resource Efficiency Innovations and Opportunities for Smart Regulations - the Case of Germany. *Environmental Policy And Governance*, n/a-n/a. https://doi.org/10.1002/eet.1632

Kayikci, Y., Kazancoglu, Y., Lafci, C., & Gozacan, N. (2021). Exploring barriers to smart and sustainable circular economy: The case of an automotive eco-cluster. *Journal Of Cleaner Production*, *314*, 127920. https://doi.org/10.1016/j.jclepro.2021.127920

Kemp, R., & Pearson, P. (2007). Final report MEI project about measuring eco-innovation. UM Merit, Maastricht, 10.

Kennedy, S., Whiteman, G., & van den Ende, J. (2017). Radical Innovation for Sustainability: The Power of Strategy and Open Innovation. *Long Range Planning*, *50* (6), 712–725. https://doi.org/10.1016/j.lrp.2016.05.004

Khan, H., Ozkan, K. S., Deligonul, S., & Cavusgil, E. (2024). Redefining the organizational resilience construct using a frame based methodology: A new perspective from the ecology based approach. *Journal of Business Research*, *172*, 114397. https://doi.org/10.1016/j.jbusres.2023.114397

Khan, P. A., Johl, S. K., & Akhtar, S. (2021). Firm sustainable development goals and firm financial performance through the lens of green innovation practices and reporting: a proactive approach. *Journal of Risk and Financial Management*, *14*(12), 605.

Khan, S. A., Yu, Z., Umar, M., & Tanveer, M. (2022). Green capabilities and green purchasing practices: A strategy striving towards sustainable operations. *Business Strategy and the Environment*, *31*(4), 1719–1729. https://doi.org/10.1002/bse.2979

Khanra, S., Dhir, A., & Mäntymäki, M. (2020). Big data analytics and enterprises: A bibliometric synthesis of the literature. *Enterprise Information Systems, 14*(6), 737–768. https://doi.org/10.1080/17517575.2020. 1734241

Khanra, S., Kaur, P., Joseph, R. P., Malik, A., & Dhir, A. (2022). A resource-based view of green innovation as a strategic firm resource: Present status and future directions. *Business Strategy and the Environment*, *31*(4), 1395–1413. https://doi.org/10.1002/bse.2961

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). *Ecological Economics*, *150*, 264-272.https://doi.org/10.1016/j.ecolecon.2018.04.028.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation And Recycling*, *127*, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005

Kitsis, A. M., & Chen, I. J. (2021). Do stakeholder pressures influence green supply chain Practices? Exploring the mediating role of top management commitment. *Journal of Cleaner Production*, *316*, 128258. https://doi.org/10.1016/j.jclepro.2021.128258

Klumpp, M., Loske, D., & Bicciato, S. (2022). COVID-19 health policy evaluation: integrating health and economic perspectives with a data envelopment analysis approach. *The European Journal of Health Economics*, *23*(8), 1263-1285. https://doi.org/10.1007/s10198-021-01425-7

Klymenko, O., & Lillebrygfjeld Halse, L. (2022). Sustainability practices during COVID-19: an institutional perspective. *The International Journal of Logistics Management*, *33*(4), 1315-1335. https://doi.org/10.1108/IJLM-05-2021-0306

Kougias, I., Taylor, N., Kakoulaki, G., & Jäger-Waldau, A. (2021). The role of photovoltaics for the European Green Deal and the recovery plan. *Renewable and Sustainable Energy Reviews*, *144*, 111017. https://doi.org/10.1016/j.rser.2021.111017

Krammer, S. M. (2022). Navigating the New Normal: Which firms have adapted better to the COVID-19 disruption?. *Technovation*, *110*, 102368. https://doi.org/10.1016/j.technovation.2021.102368

Krieger, B., & Zipperer, V. (2022). Does Green Public Procurement Trigger Environmental Innovations? *Research Policy*, *51*(6), 104516. https://doi.org/10.1016/j.respol.2022.104516

Kuckertz, A., & Brändle, L. (2021). Creative reconstruction: A structured literature review of the early empirical research on the COVID-19 crisis and entrepreneurship. *Management Review Quarterly*, *72*(2), 281–307. https://doi.org/10.1007/s11301-021-00221-0

Kumar, N., & Symss, J. (2024). Corporate cash holding and firm's performance in times of Ukraine war: a literature review and way forward. *Journal of Chinese Economic and Foreign Trade Studies*. https://doi.org/10.1108/JCEFTS-10-2023-0053

Kuzemko, C., Blondeel, M., Dupont, C., & Brisbois, M. C. (2022). Russia's war on Ukraine, European energy policy responses & implications for sustainable transformations. *Energy Research & Social Science*, *93*, 102842. https://doi.org/10.1016/j.erss.2022.102842

Lauer, J. A., Lovell, C. K., Murray, C. J., & Evans, D. B. (2004). World health system performance revisited: the impact of varying the relative importance of health system goals. *BMC health services research*, *4*, 1-8. https://doi.org/10.1186/1472-6963-4-19

Leder, N., Kumar, M., & Rodrigues, V. (2020). Influential factors for value creation within the Circular Economy: Framework for Waste Valorisation. *Resources, Conservation And Recycling*, *158*, 104804. https://doi.org/10.1016/j.resconrec.2020.104804

Lee, K., & Min, B. (2015). Green R& amp;D for eco-innovation and its impact on carbon emissions and firm performance. *Journal Of Cleaner Production*, *108*, 534-542.https://doi.org/10.1016/j.jclepro.2015.05.114

Lei, W., Liu, L., Hafeez, M., & Sohail, S. (2021). Do economic policy uncertainty and financial development influence the renewable energy consumption levels in China? *Environmental Science and Pollution Research*, *29*(5), 7907–7916. https://doi.org/10.1007/s11356-021-16194-2

Liao, Z. (2018). Corporate culture, environmental innovation and financial performance. *Business Strategy and the Environment, 27*, 1368–1375. https://doi.org/10.1002/bse.2186

Lim, W. M., Chin, M. W. C., Ee, Y. S., Fung, C. Y., Giang, C. S., Heng, K. S., ... & Weissmann, M. A. (2022). What is at stake in a war? A prospective evaluation of the Ukraine and Russia conflict for business and society. *Global Business and Organizational Excellence*, *41*(6), 23-36. https://doi.org/10.1002/joe.22162

Lin, F., Li, X., Jia, N., Feng, F., Huang, H., Huang, J., ... & Song, X. P. (2023). The impact of Russia-Ukraine conflict on global food security. *Global Food Security*, *36*, 100661. https://doi.org/10.1016/j.gfs.2022.100661

Liu, P., Gao, X., Yu, L., & Sohail, M. T. (2022). Determinants of China's renewable energy industry development: Do eco-innovation and Financial Inclusion matter? *Environmental Science and Pollution Research*, *30*(4), 10505–10515. https://doi.org/10.1007/s11356-022-22817-z

Liu, W., Chen, X., & Zhang, J. (2023). The Russia-Ukraine conflict and the automotive energy transition: Empirical evidence from China. *Energy*, *284*, 128562. https://doi.org/10.1016/j.energy.2023.128562

Liu, X., Guo, P., & Guo, S. (2019). Assessing the eco-efficiency of a circular economy system in China's coal mining areas: Emergy and data envelopment analysis. Journal of Cleaner Production, 206, 1101–1109. https://doi.org/10.1016/j.jclepro.2018.09.218

Loia, F., & Adinolfi, P. (2021). Teleworking as an eco-innovation for sustainable development: Assessing collective perceptions during COVID-19. *Sustainability*, *13*(9), 4823. https://doi.org/10.3390/su13094823

Lopes-Santos, D., Valente Rezende, M., & Cruz Basso, L. (2019). Eco-innovation and business performance in emerging and developed economies. Journal of Cleaner Production, 237, 117674. https://doi.org/10.1016/j.jclepro.2019.117674

López Pérez, G., García Sánchez, I. M.,& Zafra Gómez, J. L. (2023). A systematic literature review and bibliometric analysis of eco-innovation on financial performance: Identifying barriers and drivers. *Business Strategy and the Environment*, *33*(2), 1321–1340. https://doi.org/10.1002/bse.3550

Maldonado-Guzmán, G., Garza-Reyes, J. A., & Pinzón-Castro, Y. (2021). Eco-innovation and the circular economy in the automotive industry. Benchmarking: An International Journal, 28(2), 621–635. https://doi.org/10.1108/bij-06-2020-0317

Maricic, M., Egea, J. A., & Jeremic, V. (2019). A hybrid enhanced scatter search—Composite I-distance indicator (eSS-CIDI) optimization approach for determining weights within composite indicators. *Social Indicators Research, 144*(2), 497–537. https://doi.org/10.1007/s11205-018-02056-x

Marín-Vinuesa, L., Scarpellini, S., Portillo-Tarragona, P., & Moneva, J. (2018). The Impact of Eco-Innovation on Performance Through the Measurement of Financial Resources and Green Patents. *Organization & Amp; Environment*, *33*(2), 285-310.https://doi.org/10.1177/1086026618819103

Martínez-Ferrero, J., García-Sánchez, I. M., & Cuadrado-Ballesteros, B. (2015). Effect of financial reporting quality on sustainability information disclosure. *Corporate social responsibility and environmental management*, *22*(1), 45-64. https://doi.org/10.1002/csr.1330

Marzi, G., Ciampi, F., Dalli, D., & Dabic, M. (2021). New product development during the last ten years: The ongoing debate and future avenues. *IEEE Transactions on Engineering Management*, *68*(1), 330–344. https://doi.org/10.1109/tem.2020.2997386

McKiernan, P. 1996. Historical Evolution of Strategic Management. Aldershot:Dartmouth.

Melece, L., & Hazners, J. (2017). Factors infuencing Latvian small and medium enterprises towards eco-innovation. Engineering for Rural Development, 16, 1466–1473. https://doi.org/10.22616/ERDev2017.16.N333

Melyn, W., & Moesen, W. (1991). Towards a synthetic indicator of macroeconomic performance: unequal weighting when limited information is available. *Public economics research papers*, 1-24.

Miettinen, K. (1999). Nonlinear multiobjective optimization (Vol. 12). *Springer Science & Business Media.*. https://doi.org/10.1007/978-1-4615-5563-6

Milnor, J. (1954). Games Against Nature in RM Thrall, CH Coombs, and RL Davis (Eds.) Decision Processes. New York: Wiley, 49, 59.

Morseletto, P. (2020). Targets for a circular economy. Resources, Conservation And Recycling, 153, 104553. https://doi.org/10.1016/j.resconrec.2019.104553

Nandi, S., Sarkis, J., Hervani, A., & Helms, M. (2021). Redesigning Supply Chains using Blockchain-Enabled Circular Economy and COVID-19 Experiences. *Sustainable Production And Consumption, 27*, 10-22. https://doi.org/10.1016/j.spc.2020.10.019

Nicolau, J., & Santa-María, M. (2013). The effect of innovation on hotel market value. *International Journal Of Hospitality Management, 32*, 71-79. https://doi.org/10.1016/j.ijhm.2012.04.005

Nishant, R., Kennedy, M., & Corbett, J. (2020). Artificial Intelligence for Sustainability: Challenges, opportunities, and a research agenda. International Journal of Information Management, 53, 102104. https://doi.org/10.1016/j.ijinfomgt.2020.102104

Nowicki, P., Ćwiklicki, M., Kafel, P., & Wojnarowska, M. (2021). Credibility of certified environmental management systems: Results from focus group interviews. Environmental Impact Assessment Review, 88, 106556. https://doi.org/10.1016/j.eiar.2021.106556

Obermann, J. (2019). Let's talk about money! assessing the link between firm performance and Voluntary Say-on-pay votes. *Journal of Business Economics, 90*(1), 109–135. https://doi.org/10.1007/s11573-019-00931-8

OECD. (2009). Sustainable manufacturing and eco-innovation. Framework, practices and measurement. Synthesis report. Accessed February 06, 2022 https://www.oecd.org/innovation/inno/43423689.pdf

Oh, D.-h. (2010). A metafrontier approach for measuring an environmentally sensitive productivity growth index. *Energy Economics, 32*(1), 146-157. https://doi.org/10.1016/j.eneco.2009.07.006

Pacheco, D., ten Caten, C., Jung, C., Ribeiro, J., Navas, H., & Cruz-Machado, V. (2017). Eco- innovation determinants in manufacturing SMEs: Systematic review and research directions. *Journal Of Cleaner Production*, *142*, 2277-2287. https://doi.org/10.1016/j.jclepro.2016.11.049

Pan, X., Sinha, P., & Chen, X. (2020). Corporate social responsibility and eco-innovation: The triple bottom line perspective. *Corporate Social Responsibility And Environmental Management*, *28*(1), 214-228. https://doi.org/10.1002/csr.2043

Papke, L. E., & Wooldridge, J. M. (2023). A simple, robust test for choosing the level of fixed effects in linear panel data models. *Empirical Economics*, *64*(6), 2683-2701. https://doi.org/10.1007/s00181-022-02337-y

Park, C.Y., Kim, K., Roth, S., (2020). Global Shortage of Personal Protective Equipment Amid COVID-19: Supply Chains, Bottlenecks, And Policy Implications (No. 130). Asian Development Bank.

Park, J., Sarkis, J., & Wu, Z. (2010). Creating integrated business and environmental value within the context of China's circular economy and ecological modernization. *Journal Of Cleaner Production*, *18*(15), 1494-1501. https://doi.org/10.1016/j.jclepro.2010.06.001

Park, M., Bleischwitz, R., Han, K., Jang, E., & Joo, J. (2017). Eco-innovation indices as tools for measuring eco-innovation. *Sustainability*, *9*(12), 2206. https://doi.org/10.3390/su9122206

Penrose, E. (1995). The firm in theory. The Theory of the Growth of the Firm, 9–30. https://doi.org/10.1093/0198289774.003.0002

Pereira, P., Zhao, W., Symochko, L., Inacio, M., Bogunovic, I., & Barcelo, D. (2022). The Russian-Ukrainian armed conflict will push back the sustainable development goals. *Geography and Sustainability*, *3*(3), 277-287. https://doi.org/10.1016/j.geosus.2022.09.003

Peters, G.P., Weber, C.L., Guan, D., & Hubacek, K. (2007). China's growing CO(2) emissions - a race between increasing consumption and efficiency gains. *Environmental Science & Technology*. 41 (17), 5939-5944. https://doi.org/10.1021/es070108f

Pittaway, L., Robertson, M., Munir, K., Denyer, D., & Neely, A. (2004). Networking and innovation: A systematic review of the evidence. *International Journal of Management Reviews*, *5-6*(3-4), 137–168. https://doi.org/10.1111/j.1460-8545.2004.00101.x

Potrich, L., Cortimiglia, M., & de Medeiros, J. (2019). A systematic literature review on firm- level proactive environmental management. *Journal Of Environmental Management*, *243*, 273-286. https://doi.org/10.1016/j.jenvman.2019.04.110

Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal Of Cleaner Production*, *179*, 605-615. https://doi.org/10.1016/j.jclepro.2017.12.224

Prohorovs, A. (2022). Russia's war in Ukraine: Consequences for European countries' businesses and economies. *Journal of risk and financial management*, *15*(7), 295. https://doi.org/10.3390/jrfm15070295

Qureshi, M. A., Ahsan, T., & Gull, A. A. (2022). Does country-level eco-innovation help reduce corporate CO2 emissions? evidence from Europe. *Journal of Cleaner Production*, *379*, 134732. https://doi.org/10.1016/j.jclepro.2022.134732

Rafiaani, P., Dikopoulou, Z., Van Dael, M., Kuppens, T., Azadi, H., Lebailly, P., & Van Passel, S. (2019). Identifying social indicators for sustainability assessment of CCU technologies: A modified multi-criteria decision making. *Social Indicators Research, 147*(1), 15–44. https://doi.org/10.1007/s11205-019-02154-4

Räisänen, H., Eronen, J. T., & Hukkinen, J. I. (2023). Imagining the next pandemic: Finnish preparedness for chronic transboundary crises before and during COVID-19. *Risk, Hazards & Crisis in Public Policy, 14*(2), 226–246. https://doi.org/10.1002/rhc3.12271246

Rajesh, R. (2020). Exploring the sustainability performances of firms using environmental, social, and governance scores. *Journal of Cleaner Production, 247*, 119600. https://doi.org/10.1016/j.jclepro.2019.119600

Rao, P. K., & Shukla, A. (2022). Sustainable strategic management: A Bibliometric analysis. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3344

Refinitiv. (2023). Sustainable Finance and ESG Investing. Recuperado de https://www.refinitiv.com/es/sustainable-finance/esg-investing?utm_content=Company%20Data-ES-EMEA-G-ES-Phrase&utm_source=google&utm_medium=cpc&utm_campaign=748967_BAUSpanishGenericPaidSearch2023&elqCampaignId=20645&utm_term=datos%20esg&gad_source=1&gclid

Rexhäuser, S., & Rammer, C. (2013). Environmental Innovations and Firm Profitability: Unmasking the Porter Hypothesis. *Environmental And Resource Economics*, *57*(1), 145-167. https://doi.org/10.1007/s10640-013-9671-x

Riaz, A., Ali, F., Ashfaq, K., Bhatti, A., & Rehman, S. U. (2023). Eco-innovation of food processing and manufacturing smes. *British Food Journal*, *125*(8), 2988–3006. https://doi.org/10.1108/bfj-04-2022-0352

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., & Kafyeke, T. et al. (2016). Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers. *Sustainability*, *8*(11), 1212. https://doi.org/10.3390/su8111212

Rodríguez-García, M., Guijarro-García, M., & Carrilero-Castillo, A. (2019). An Overview of Ecopreneurship, Eco-Innovation, and the Ecological Sector. *Sustainability*, *11*(10), 2909. https://doi.org/10.3390/su11102909. https://doi.org/10.3390/su11102909

Rodríguez-Rebés, L., Navío-Marco, J., & Ibar-Alonso, R. (2021). Influence of organisational innovation and innovation in general on eco-innovation in European companies. *Journal Of Intellectual Capital*, *22*(5), 840-867. https://doi.org/10.1108/jic-06-2020-0203

Rogge, N., De Jaeger, S., & Lavigne, C. (2017). Waste performance of NUTS 2-regions in the EU: A conditional directional distance benefit-of-the-doubt model. *Ecological Economics*, *139*, 19-32. https://doi.org/10.1016/j.ecolecon.2017.03.021

Rosenthal, U. (1989). P.'t Hart (Eds.), Coping with Crisis: The Management of Disasters, Riots and Terrorism, Charles C. *Thomas, Springfield*.

Salo, H. H., Suikkanen, J., & Nissinen, A. (2020). Eco-innovation motivations and ecodesign tool implementation in companies in the Nordic textile and information technology sectors. *Business Strategy and the Environment*, *29*(6), 2654–2667. https://doi.org/10.1002/bse.2527

Sanches-Garcia, A., Mendes-Da-Silva, W., & Orsato, R. J. (2017). Sensitive Industries produce better ESG performance: Evidence from emerging markets. *Journal of Cleaner Production, 150,* 135–147. https://doi.org/10.1016/j.jclepro.2017.02.180

Scarpellini, S., Marín-Vinuesa, L., Aranda-Usón, A., & Portillo-Tarragona, P. (2020). Dynamic capabilities and environmental accounting for the circular economy in businesses. *Sustainability Accounting, Management And Policy Journal*, *11*(7), 1129-1158. https://doi.org/10.1108/sampj-04-2019-0150

Scarpellini, S., Valero-Gil, J., & Portillo-Tarragona, P. (2016). The "economic-finance interface" for eco-innovation projects. *International Journal Of Project Management*, *34*(6), 1012- 1025. https://doi.org/10.1016/j.ijproman.2016.04.005

Scarpellini, S., Valero-Gil, J., Moneva, J., & Andreaus, M. (2020). Environmental management capabilities for a "circular eco-innovation". *Business Strategy And The Environment*, *29*(5), 1850-1864. https://doi.org/10.1002/bse.2472

Scarpellini, S., Valero-Gil, J., Rivera-Torres, P., & Garcés-Ayerbe, C. (2017). Analysis of thegeneration of economic results in the different phases of the pro-environmental change process. Journal Of Cleaner Production, 168, 1473-1481. https://doi.org/10.1016/j.jclepro.2017.09.114

Schnitkey, G., Paulson, N., Zulauf, C., Swanson, K., Colussi, J., & Baltz, J. (2022). Nitrogen fertilizer prices and supply in light of the Ukraine-Russia conflict. *farmdoc daily*, *12*(45).

Sen, A.K. (1970). Collective Choice and Social Welfare. Holden-Day, San Francisco.

Shen, H., Fu, M., Pan, H., Yu, Z., & Chen, Y. (2021). The impact of the COVID-19 pandemic on firm performance. In *Research on Pandemics* (pp. 81-98). Routledge.

Sikacz, H., & Wołczek, P. (2017). Analiza ESG spółek z indeksu RESPECT – podsumowanie badań. Zeszyty Naukowe SGGW, Polityki Europejskie, Finanse I Marketing, 18(67), 170–180. https://doi.org/10.22630/PEFIM.2017.18.67.32

Sikacz, H., & Wołczek, P. (2018). ESG analysis of companies included in the respect index based on Thomson Reuters Eikon Database. *Research Papers of Wroclaw University of Economics*, (520), 115–127. https://doi.org/10.15611/pn.2018.520.10

Sikandar, H., Kohar, U. H. A., Sanda, G., et al. (2024). Eco-innovation in small and medium enterprises (SMEs): A systematic literature review. *Journal of the Knowledge Economy*, *15*(4), 5841–5863. https://doi.org/10.1007/s13132-023-01367-w

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science*, *24*(4), 265–269. https://doi.org/10.1002/asi.4630240406

Smol, M., Kulczycka, J., & Avdiushchenko, A. (2017). Circular economy indicators in relation to eco-innovation in European regions. *Clean Technologies and Environmental Policy*, *19*(3), 669–678. https://doi.org/10.1007/s10098-016-1323-8

Social Change, *160*, 120246. https://doi.org/10.1016/j.techfore.2020.120246

Sohail, M. T., Ullah, S., Majeed, M. T., Usman, A., & Andlib, Z. (2021). The shadow economy in south asia: Dynamic effects on clean energy consumption and environmental pollution. *Environmental Science and Pollution Research*, *28*(23), 29265–29275. https://doi.org/10.1007/s11356-021-12690-7

Stahel, W. (2016).The circular economy. *Nature*, *531*(7595), 435-438. https://doi.org/10.1038/531435a

StataCorp. (2023). Stata: Software de estadísticas y análisis de datos. Recuperado de https://www.stata.com/

Stock, J. H., & Watson, M. W. (2008). Heteroskedasticity-robust standard errors for fixed effects panel data regression. *Econometrica*, *76*(1), 155-174. https://doi.org/10.1111/j.0012-9682.2008.00821.x

Stumbriene, D., Camanho, A. S., & Jakaitiene, A. (2019). The performance of education systems in the light of Europe 2020 strategy. *Annals of Operations Research*, *288*(2), 577–608. https://doi.org/10.1007/s10479-019-03329-5

Tampakoudis, I., Noulas, A., Kiosses, N., & Drogalas, G. (2021). The effect of ESG on value creation from mergers and acquisitions. What changed during the COVID-19 pandemic?. *Corporate Governance: The International Journal of Business in Society*, *21*(6), 1117-1141. https://doi.org/10.1108/CG-10-2020-0448

Tang, M., Walsh, G., Lerner, D., Fitza, M., & Li, Q. (2017). Green Innovation, Managerial Concern and Firm Performance: An Empirical Study. *Business Strategy And The Environment*, *27*(1), 39-51. https://doi.org/10.1002/bse.1981

Tettamanzi, P., Venturini, G., & Murgolo, M. (2022). Sustainability and financial accounting: A critical review on the ESG dynamics. *Environmental Science and Pollution Research*, *29*(12), 16758–16761. https://doi.org/10.1007/s11356-022-18596-2

Tian, N., Lopes da Silva, D., Béraud-Sudreau, L., Liang, X., Scarazzato, L., & Assis, A. (2023). Developments in Military Expenditure and the Effects of the War in Ukraine. *Defence and Peace Economics*, *34*(5), 547-562. https://doi.org/10.1080/10242694.2023.2221877

Tsalis, T. A., Nikolaou, I. E., Konstantakopoulou, F., Zhang, Y., & Evangelinos, K. I. (2020). Evaluating the corporate environmental profile by Analyzing Corporate Social Responsibility Reports. *Economic Analysis and Policy*, *66*, 63–75. https://doi.org/10.1016/j.eap.2020.02.009

Turzo, T., Marzi, G., Favino, C., & Terzani, S. (2022). Non-financial reporting research and practice: Lessons from the last decade. *Journal of Cleaner Production*, *345*, 131154. https://doi.org/10.1016/j.jclepro.2022.131154

UNCCS. (2015). Climate Action Now: Summary for Policymakers 2015.

United Nations General Assembly (March 20, 1987) "Report of the world commission on environment and development: our common future; Transmitted to the General Assembly as an Annex to document A/42/427 – Development and International Co-operation: Environment; Our Common Future, Chapter 2: Towards Sustainable Development; Paragraph 1". United Nations General Assembly

Urbaniec, M., & Gerstlberger, W. (2011). Innovation in environment-oriented networks. Management of Environmental Quality: An International Journal, 22(6), 686–704. https://doi.org/10.1108/14777831111170812

Vai, F. J., & Aarstad, J. (2024). How eco-innovative firms were affected by and responded to the unexpected external shock of the COVID-19 pandemic. *Cleaner Production Letters*, *6*, 100057. https://doi.org/10.1016/j.clpl.2024.100057

Van Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Vanham, D., & Mekonnen, M. M. (2021). The scarcity-weighted water footprint provides unreliable water sustainability scoring. *Science of The Total Environment*, *756*, 143992. https://doi.org/10.1016/j.scitotenv.2020.143992

Varsei, M., Soosay, C., Fahimnia, B., & Sarkis, J. (2014). Framing sustainability performance of supply chains with multidimensional indicators. *Supply Chain Management: An International Journal*, *19*(3), 242–257. https://doi.org/10.1108/scm-12-2013-0436

Vence, X., & Pereira, Á. (2018). Eco-innovation and Circular Business Models as drivers for a circular economy. *Contaduría Y Administración*, *64*(1), 64. https://doi.org/10.22201/fca.24488410e.2019.1806

Verardi, V., & Wagner, J. (2011). Robust estimation of linear fixed effects panel data models with an application to the exporter productivity premium. *Jahrbücher für Nationalökonomie und Statistik*, *231*(4), 546-557. https://doi.org/10.1515/jbnst-2011-0407

Vogelsang, T. J. (2012). Heteroskedasticity, autocorrelation, and spatial correlation robust inference in linear panel models with fixed-effects. *Journal of Econometrics*, *166*(2), 303-319. https://doi.org/10.1016/j.jeconom.2011.10.001

Voorneveld, M. (2003). Characterization of pareto dominance. *Operations Research Letters*, *31*(1), 7-11. https://doi.org/10.1016/S0167-6377(02)00189-X

Wang, H. (2015). A generalized MCDA–DEA (multi-criterion decision analysis–data envelopment analysis) approach to construct slacks-based composite indicator. *Energy*, *80*, 114-122. https://doi.org/10.1016/j.energy.2014.11.051

Wang, M., Li, Y., Li, J., & Wang, Z. (2021). Green process innovation, green product innovation and its economic performance improvement paths: A survey and structural model. *Journal Of Environmental Management*, *297*, 113282. https://doi.org/10.1016/j.jenvman.2021.113282

Wang, S., Xu, L., Yu, S., & Wang, S. (2023). Russia-Ukraine war perspective of natural resources extraction: a conflict with impact on sustainable development. *Resources Policy*, *85*, 103689. https://doi.org/10.1016/j.resourpol.2023.103689

Wilke, U., & Pyka, A. (2024). Sustainable innovations, knowledge and the role of proximity: A systematic literature review. *Journal of Economic Surveys*, 1–26. https://doi.org/10.1111/joes.12617

World Bank Group - International Development, Poverty, Sustainability. Retrieved June 2nd, 2024, from https://www.worldbank.org/en/home.

Wu, J., Zhan, X., Xu, H., & Ma, C. (2023). The economic impacts of COVID-19 and city lockdown: Early evidence from China. *Structural change and economic dynamics*, *65*, 151-165. https://doi.org/10.1016/j.strueco.2023.02.018

Xing, X., Xu, Z., Chen, Y., Ouyang, W., Deng, J., & Pan, H. (2023). The impact of the Russia–Ukraine conflict on the energy subsector stocks in China: A network-based approach. *Finance Research Letters*, *53*, 103645. https://doi.org/10.1016/j.frl.2023.103645

Xue, Ray, & Sambamurthy (2012). Efficiency or Innovation: How Do Industry Environments Moderate the Effects of Firms' IT Asset Portfolios? *MIS Quarterly*, *36*(2), 509. https://doi.org/10.2307/41703465

Yahya, H. (2023). The role of ESG performance in firms' resilience during the COVID-19 pandemic: Evidence from Nordic firms. *Global Finance Journal*, *58*, 100905. https://doi.org/10.1016/j.gfj.2023.100905

Zaman, R., Atawnah, N., Haseeb, M., Nadeem, M., & Irfan, S. (2021). Does corporate eco-innovation affect stock price crash risk? *The British Accounting Review*, *5*3(5), 101031. https://doi.org/10.1016/j.bar.2021.101031

Zhang, D., & Fang, Y. (2022). Are environmentally friendly firms more vulnerable during the COVID-19 pandemic?. *Journal of Cleaner Production*, *355*, 131781. https://doi.org/10.1016/j.jclepro.2022.131781

Zhao, W., Feng, T., Xin, X., & Hao, G. (2021). How to respond to competitors' green success for improving performance: The moderating role of organizational ambidexterity. *Business Strategy and the Environment*,*30*(1), 489–506. https://doi.org/10.1002/bse.2633

Zheng, L., & Iatridis, K. (2022). Friends or foes? A systematic literature review and meta-analysis of the relationship between Eco-innovation and firm performance. Business Strategy and the Environment, 31(4), 1838–1855. https://doi.org/10.1002/bse.2986

Zhong, Q., Wen, H., & Lee, C. (2022). How does economic growth target affect corporate environmental investment? Evidence from heavy-polluting industries in China. Environmental Impact Assessment Review, 95, 106799. https://doi.org/10.1016/j.eiar.2022.106799

Zhou, K. Z., Gao, G. Y., & Zhao, H. (2016). State ownership and firm innovation in China: An integrated view of institutional and efficiency logics. *Administrative Science Quarterly*, *62*(2), 375–404. https://doi.org/10.1177/0001839216674457

Zou, P., Huo, D., & Li, M. (2020). The impact of the COVID-19 pandemic on firms: a survey in Guangdong Province, China. *Global health research and policy*, *5*, 1-10. https://doi.org/10.1186/s41256-020-00166-z

APPENDICES

Appendix 1: Definition of the items selected for analysis

Item	Definition
Environmental Products	Does the company report on at least one product line or service that is designed to have positive effects on the environment or which is environmentally labeled and marketed?
Environmental Asset Under Management	Does the company report on assets under management which employ environmental screening criteria or environmental factors in the investment selection process?
Product Environmental Responsible Use	Does the company report about product features and applications or services that will promote responsible, efficient, cost-effective and environmentally preferable use?
Renewable/Clean Energy Products	Does the company develop products or technologies for use in the clean, renewable energy (such as wind, solar, hydro and geo-thermal and biomass power)?
Eco-Design Products	Does the company report on specific products which are designed for reuse, recycling or the reduction of environmental impacts?
Waste Reduction Initiatives	Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out total waste?
Environmental Materials Sourcing	Does the company claim to use environmental criteria (e.g., life cycle assessment) to source or eliminate materials?
e-Waste Reduction	Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out e-waste?
Water Technologies	Does the company develop products or technologies that are used for water treatment, purification or that improve water use efficiency?
Noise Reduction	Does the company develop new products that are marketed as reducing noise emissions?
Nuclear	Does the company construct nuclear reactors, produce nuclear energy or is active in another way in the nuclear energy industry?
Equator Principles	Is the company a signatory of the Equator Principles (commitment to manage environmental issues in project financing)?
Environmental Project Financing	Does the company claim to evaluate projects on the basis of environmental or biodiversity risks as well?

Organic Products Initiatives	Does the company report or show initiatives to produce or promote organic food or other products?
CSR Sustainability Committee	Does the company have a CSR committee or team?
CSR Sustainability Reporting	Does the company publish a separate CSR/H&S/Sustainability report or publish a section in its annual report on CSR/H&S/Sustainability?
Environment Management Team	Does the company have an environmental management team?
Environment Management Training	Does the company train its employees on environmental issues?
Environmental Supply Chain Management	Does the company use environmental criteria (ISO 14000, energy consumption, etc.) in the selection process of its suppliers or sourcing partners?
Green Buildings	Does the company report about environmentally friendly or green sites or offices?
Policy Emissions	Does the company have a policy to improve emission reduction?
Targets Emissions	Has the company set targets or objectives to be achieved on emission reduction?
Environmental Restoration Initiatives	Does the company report or provide information on company-generated initiatives to restore the environment?
Environmental Partnerships	Does the company report on partnerships or initiatives with specialized NGOs, industry organizations, governmental or supra-governmental organizations, which are focused on improving environmental issues?
Env Supply Chain Partnership Termination	Does the company report or show to be ready to end a partnership with a sourcing partner, if environmental criteria are not met?

Source: Refinitiv Eikon

Appendix 2: Grouping of industries according to the Refinitiv Eikon classification

Industry	**Components**
Academic & Educational Services	- Professional & Business Education - Schools, Colleges & Universities - Miscellaneous Educational Service Providers
Basic Materials	- Chemicals - Mineral Resources - Applied Resources
Consumer Cyclicals	- Automobiles & Auto Parts - Cyclical Consumer Products - Retailers
Consumer Non-Cyclicals	- Food & Beverages - Personal & Household Products & Services - Food & Drug Retailing - Consumer Goods Conglomerates
Energy	- Energy – Fossil Fuels - Renewable Energy - Uranium
Financial	- Banking & Investment Services - Insurance - Collective Investments - Investment Holding Companies
Healthcare	- Healthcare Services & Equipment - Pharmaceuticals & Medical Research
Industrials	- Industrial Goods - Industrial & Commercial Services - Transportation
Real Estate	- Residential & Commercial REITs - Real Estate Operations
Technology	- Technology Equipment - Software & IT Services - Financial Technology (Fintech) & Infrastructure - Telecommunications Services
Utilities	- Multiline Utilities - Water & Related Utilities - Natural Gas Utilities - Electric Utilities & IPPs

Source: Refinitiv Eikon

Appendix 3: Definition of the variables obtained for the creation of the EI variable through the BoD

Variable	Definition
EnvironmentManagementTeamScor	Does the company have an environmental management team? In scope are any team that performs the functions dedicated to environmental issues; an individual or team at any level composed of employees, even if the name of the team is different performing implementation of the environmental strategy; it is important to understand that the members of the team include employees of the company, who are operational on a day to day basis and are not the board committees (directors).
EnvMatSourcingScore	Does the company claim to use environmental criteria (e.g., life cycle assessment) to source or eliminate materials?
GreenBuildingsScore	Does the company report about environmentally friendly or green sites or offices? Office/green site where the company engages in some operations; LEED/BREEAM certifications for its own building; major refurbishments to improve the environmental aspects of sites/buildings/offices; the building has to be operational at least at the end of the fiscal year; if building is under construction then grade as "false".
EnvSupplyChainManagementScore	Does the company use environmental criteria (ISO 14000, energy consumption, etc.) in the selection process of its suppliers or sourcing partners? Data can also be on existing suppliers who were selected using some environmental criteria.
EnvSupplyChPartnerTermScore	Does the company report or show to be ready to end a partnership with a sourcing partner, if environmental criteria are not met?
PolicyEmissionsScore	Does the company have a policy to improve emission reduction? In scope are the various forms of emissions to land, air or water from the company's core activities; processes, mechanisms or programs in place as to what the company is doing to reduce emissions in its operations; systems or a set of formal, documented processes for controlling emissions and driving continuous improvement.
eWasteReductionScore	Does the company report on initiatives to recycle,

	reduce, reuse, substitute, treat or phase out e-waste? Any initiatives which the company has put in place to reduce e-waste; e-waste is used as a generic term embracing all types of waste containing electrically powered components; e-waste may contain hazardous materials which require special handling and recycling methods; includes all products covered under WEEE (waste electrical and electronic equipment) regulations like fluorescent tubes, sodium lamps, computers, mobiles, telephones, fax machines, copiers, printers, washing machines, dryers, refrigerators, air-conditioners, televisions, VCR/DVD/CD players, wi-fi sets, radios, drills, electric saws, sewing machines, batteries, toner cartridges.
EnvRestInitiativeScore	Does the company report or provide information on company-generated initiatives to restore the environment? Any initiatives to restore the environment like restoration, rehabilitation, clean up and remediation activities; company's own operation disturbing the environment and restoring the same later is not qualified as restoration initiatives.
EnvironmentalProductsScore	Does the company report on at least one product line or service that is designed to have positive effects on the environmental or which is environmentally labeled and marketed? In focus are the products and services that have positive environmental effects, or marketed as which solve environment problems.
NoiseReductionScore	Does the company develop new products that are marketed as reducing noise emissions? Products that have been specifically designed to reduce noise emissions or marketed as emitting less noise; in scope include also those companies which are retailing such products which are emitting less noise.
EnvironmentalAssetsUnderMgtS	Does the company report on assets under management which employ environmental screening criteria or environmental factors in the investment selection process? Relevant to asset management companies; SRI (socially responsible investment) and ethical funds are under our consideration.
EqPrincOrEnvProjFinancingScore	Is the company a signatory of the Equator Principles (commitment to manage environmental issues in project financing) or does it claim to evaluate

	projects on the basis of environmental or biodiversity risks as well?
NuclearProductionScore	Percentage of total energy production from nuclear energy. Relevant to companies involved in the generation of electricity; nuclear production = energy produced from nuclear/total energy * 100
OrganicProductsInitiativesSco	Does the company report or show initiatives to produce or promote organic food or other products? Relevant for companies in food industries, agricultural produce, and chemicals (organic fertilizers), textile & apparels (which use biodegradable materials including organic fibers); in scope data also include on the companies that are involved in promoting organic food in their retail chain.
RenCleanEnergyProdScore	Does the company develop products or technologies for use in the clean, renewable energy (such as wind, solar, hydro and geo-thermal and biomass power)? In scope, we also include data on the financing of renewable energy projects; if a utility company is deriving at least 25% of the power produced or revenue from clean technologies or energy.
WaterTechnologiesScore	Does the company develop products or technologies that are used for water treatment, purification or that improve water use efficiency? In scope are the products or services addressing water purification or greater water conservation or efficiency; also includes companies providing technologies/software to detect water leaks.
CSRSustainabilityCommitteeSco	Does the company have a CSR committee or team? Board level or Senior management committee responsible for decision making on CSR strategy.
CSRSustainabilityReportingSco	Does the company publish a separate CSR/H&S/Sustainability report or publish a section in its annual report on CSR/H&S/Sustainability? Any separate extra-financial report in which the company reports on the environmental and social impact of its operations; web-based non-financial reports are also considered if data is updated yearly; integrated annual report with sustainability data is qualified information; CSR section from the annual report must consist of substantial data; exceptionally,

	if company report quantitative data exclusively in less than 5 pages can also be considered; CSR reports published bi-annually, current year when there is no report then data measure is answered “False”; data only on community-focused report whit community-related activities of the company, answer is “False”.
EcoDesignScore	Does the company report on specific products which are designed for reuse, recycling or the reduction of environmental impacts? Products that have been specifically designed with the goal of being recycled, reused or which are disposed of without negatively impacting the environment; there must be some discussion of environmental concerns during the product design. Based on this definition, the Score has been created using the variables Renewable/Clean Energy Products, Environmental Materials Sourcing and e-Waste reduction.

Source: Refinitiv Eikon