



VILNIUS GEDIMINAS TECHNICAL UNIVERSITY
FACULTY OF MECHANICS
DEPARTMENT OF MECHANICAL AND MATERIALS ENGINEERING

Irvin Koricki

**KEY PERFORMANCE INDICATORS (KPIS) OF INNOVATIONS
WITH FOCUS ON SUSTAINABILITY
INOVACIJŲ PAGRINDINIAI SĖKMĖS RODIKLIAI SU ORIENTACIJA
Į TVARUMĄ**

Master's degree Thesis

Industrial Engineering and Innovation Management study programme, state code 6211EX056
Production and Manufacturing Engineering study field

Vilnius, 2025



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OBJECTIVES FOR MASTER THESIS

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For student Irvin Koricki

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THE OBJECTIVES:

Tasks to achieve the goal:

The main goal is to develop and propose a structured model of key performance indicators of innovations for industrial companies with focus on sustainability based on scientific literature' analysis and conducted empirical research.

Objectives:

- Conduct a scientific literature analysis on innovation KPIs, focusing on sustainability.
- Analyze empirical studies conducted by other researchers and select a methodology for the empirical part of the study.
- Conduct empirical research to identify the most significant innovation KPIs related to sustainability.
- Develop and propose a structured model of innovation KPIs for industrial companies with a focus on sustainability.

Academic Supervisor Associated Professor Rūta Banelienė

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Annotation This master's thesis develops a Key Performance Indicators (KPIs) framework for innovations, focusing on sustainability. A literature review is performed to analyze existing KPI frameworks and create a theoretical foundation. The empirical research methodology for the thesis was designed based on the reviewed empirical studies, and the empirical part of the thesis was chosen to work with secondary data and modeling using EViews software. A panel database for simulation was created using Eurostat, OECD, Transparency International, and World Bank data for 27 European Union countries over 11 years. First, regression analysis and the least squares method (LSM) were used to examine the significance of environmental, social, and governance (ESG) indicators in a broad simulation. In the second step, the most significant KPIs were identified, and a structured model of innovation KPIs for industrial companies with a focus on sustainability was developed and proposed. Thesis consists of 6 sections: introduction, literature analysis, methodology, empirical research, conclusions & recommendations and references. Scope of the thesis – 70 pages excluding the appendixes, 19 figures, 10 tables, 58 literature sources.

Keywords: KPI, innovation, sustainability, manufacturing, environment, model.

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INTRODUCTION

In the modern world it is becoming a necessity for a successful business to incorporate innovations. Innovative ideas help business to stay competitive & relevant in the marketplace. It is important to note, that currently more than ever it is necessary that innovations offer sustainable solutions, emphasising the need to address the global environmental challenges. To help incorporate this matter successfully, businesses are becoming more reliant on the Key Performance Indicators (KPIs) to measure the effectiveness of the innovations with the focus on sustainability.

Relevance of the research. The research of key performance indicators for sustainable innovations could provide businesses detailed information how to determine the effectiveness of innovative solutions on sustainability. This would be very helpful for companies who are trying to make an environmental impact. In addition, identifying KPIs of innovations with focus on sustainability could act as a guide for businesses in aligning their ideas with social and environmental goals. It is important to note, that today investors & stakeholders are becoming increasingly interested in the sustainability development. Research on key performance indicators for sustainable innovations could help companies to emphasise their objectives for sustainable business practices, which could lead to increased interest from stakeholders, who could potentially invest into such projects. Furthermore, there are becoming more regulations issued by the government to promote environmental awareness. Companies, who could implement KPIs in respect to the issued regulations can help the business to stay compliant.

Research problem. One of the main problems is that companies often settle for their short term goals, rather than strive for long term sustainable ideas. Key performance indicators will be required to Find the sweet spot Where the sustainable innovations could align with companies short term goals. In addition, relevance of the chosen KPIs may be influenced by the global events or economic changes. In this case, external events have to be taken into account when preparing the study. Last but not least, innovations rapidly develop alongside with the raise of new technologies. This factor makes it quite challenging for researches to keep up with all the latest news and trends. In such instance applicable KPIs should be developed to stay relevant longterm.

Research object. It is necessary to analyse the already existing sustainability KPIs. Furthermore, it is very important to understand the main areas of sustainability, that are critical

for determining success of innovations. Moreover, estimating the applicability of chosen KPI across different industries, as sustainable solutions might vary in the wide world of business.

Research goal. The main goal is to develop and propose a structured model of key performance indicators of innovations for industrial companies with focus on sustainability based on scientific literature' analysis and conducted empirical research.

Objectives:

1. Conduct a scientific literature analysis on innovation KPIs, focusing on sustainability.
2. Analyze empirical studies conducted by other researchers and select a methodology for the empirical part of the study.
3. Conduct empirical research to identify the most significant innovation KPIs related to sustainability.
4. Develop and propose a structured model of innovation KPIs for industrial companies with a focus on sustainability.

The research “Key Performance Indicators of innovations with focus on sustainability” was presented at the 28th Lithuanian Junior Researchers Conference “Science - Future of Lithuania” Mechanics, material science, industrial engineering and management, on 25 of April, 2025 in Vilnius. This annual conference is an opportunity for young scientists to collaborate, share their knowledge and ideas. In addition, the conference raises discussions regarding the innovation and sustainable development on a global scale. Using this platform, the research highlights the implications the manufacturing sector faces in relation to the environment and offers a tool for measuring and driving innovation. The study was peer reviewed, approved and validated by the leading experts and professors, that attended the conference. This has further confirmed the credibility of the research.

1. THEORETICAL FRAMEWORK: KEY PERFORMANCE INDICATORS, INNOVATION AND SUSTAINABILITY

1.1. Performance measurement: KPIs

As more and more companies are integrating sustainable and innovative solutions, it is becoming increasingly important to be able to measure their effect. To understand what KPIs companies are integrating for their performance measurement, a number of literature is reviewed.

The research “Key performance indicators: contemporary challenges to industrial small and medium enterprises” prepared by Baneliene in 2021, offers a detailed review into challenges companies face and a practical approach to integrating KPIs. Following a detailed analysis of the value chains, balanced scorecards and strategy maps, a KPI model is formed for SMEs (Baneliene, 2021):

- Inbound logistics: timeliness & quality;
- Operations: quality ratio; overall equipment effectiveness; labor productivity;
- Outbound logistics: timely delivery;
- Marketing & Sales: sales; revenue; market share; growth rate;
- Service: complaints from key customers which have not been resolved within 2 hours; key customer enquiries that have not been responded to over 24 hours; damage return rate from the past-time perspective;
- Human resource management:
 - Past timeframe: number of initiatives implemented after the staff-satisfaction survey;
 - Present timeframe: staff in vital positions who have handed in their notices in the last hour; key position job offers issued to candidates, which have been outstanding for more than three days;
 - Future timeframe: the number of vacant places at an important in-house course; the number of abandonments to be actioned in the next 30, 60, or 90 days.
- Technology development: innovation metrics;
- Procurement: stock level;

- Sustainability: reduced cost of energy; use of renewables; ratio of products and services designed for circularity versus all categories of products, as well as services by value and by the mass of materials; and recycled inputs.

It is important to note, the model was created with a strong emphasis on 3P framework (People, Process, Products) and adapting the Porter's Value Chain Model. In addition, Baneliene highlights that KPIs should be multi-dimensional, including various indicators ranging from human resources, finances, operations, procurement, technological development and more.

Another reviewed paper - "The Role of Sustainability Key Performance Indicators (KPIs) in Implementing Sustainable Strategies", prepared by Ivo Hristiv and Antonio Chirico in 2019 provides a Sustainability Balanced Scorecard framework, which helps to implement sustainability focused KPIs into business strategies. Following an in-depth literature review, and conducting interviews with managers from Italy, authors identified a set of KPIs for each sustainability dimension (Hristiv and Chirico, 2019):

- Environmental – as stated by researchers, such sustainability dimensions seek to preserve the natural resources, minimize non-renewable resource use with the intention to help the environment. The explored KPIs are focused on gas emissions, renewable resource consumption & waste.
- Social – authors claim that this dimension of sustainability is mainly focused on equitable citizen welfare. The identified indicators by the researchers would be occupational health & safety, social innovations, voluntary activities, employee satisfaction & promotion.
- Economic – writers state that this sustainability dimension prioritizes achieving lasting growth in economic indicators, which generates factors as employment, revenue, resource efficiency. The KPIs described for this dimension would be gross margin ratio, costs related to environmental protection, financial indicators.

In addition, main goals for each sustainability dimension were identified, after which authors of the research conducted the frequency of stated goals (refer to Figure 1.1.)

Table 1.1. Frequency distribution of key performance indicators

Goal	Freq	%	KPI	Freq	%
Renewable energy sources	25	100	Renewable sources rate	25	100
Reduction superfluous materials	23	92	Efficiency materials use rate	23	100
Reduction greenhouse gasses	22	88	Emissions greenhouse gasses rate	18	72
Environment's safeguard governmental policies	16	64	Waste reduction rate	16	64
Lifestyles towards natural recourses	16	64	Recycled materials used rate	16	64
Inclusion of all society members in the development of sustainable goals	21	84	Integration rate	21	84
Stakeholder's relationship	18	72	Stakeholder's satisfaction rate	15	60
Participation to the social initiative	18	72	Total participation social initiatives at national & local level	14	56
Inclusion of employees in the decision proc.	15	60	Employee integration rate	11	44
Social marketing policies	14	56	Customer satisfaction index	10	40
Trend of the financial indicators	25	100	ROI related to sustainable investments	25	100
Products quality	24	96	Check on products quality	21	84
Revenues invested in training, R&D, marketing & communication	20	80	Revenues invested rate	15	60
Technology process	20	80	Ratio of investments to IT and web (total sales)	14	56
The quality of the process	18	72	Suitability and quality of the post-sale technical assistance rate	12	48

Source: prepared by author based on Hristiv & Chirico (2019).

In the final step of their research, writers created a Sustainability Perspective, where they selected the most relevant KPIs for the value creation process, using the Sustainability Balanced Scorecard framework. The proposed perspective highlights the importance of aligning the sustainability dimensions to the strategy, with defined goals, KPIs, measures and other factors contributing for the long-term success (Hristiv and Chirico, 2019).

Table 1.2. The sustainability perspective

ENVIRONMENTAL		
STRATEGIC GOAL	KPI	MEASUREMENT
To improve the use of the renewable sources	Renewable sources rate	Renewable sources/other sources
To reduce superfluous recourses consumption	Efficiency resources use rate	Energy used per thousand product units (kWh/1000 product units), total consumption of water and other resources per thousand products (l/1000 product units)
To reduce GHG emissions	Total direct or indirect GHG emissions by weight	CO2/1000 products units
Environment's safeguard	Waste reduction rate	% of waste generated per thousand product units
To improve the effort to greeness	% of reuseable/recycled material	Recycled material used/tot material used
SOCIAL		
STRATEGIC GOAL	KPI	MEASUREMENT
Inclusion of all society members in developing sustainable goals	Integration rate	questionnaire
Stakeholders relationship	Stakeholders satisfaction rate	questionnaire
To participate at the social initiatives	n. social initiatives at national and local level	Tot social initiatives at national and local level
To increase employees satisfaction	Employee satisfaction rate	questionnaire
Social marketing policies	Customer satisfaction rate	Cost analysis
ECONOMIC		
STRATEGIC GOAL	KPI	MEASUREMENT
To increase return of investment	ROI related to environmental protection	Cost analysis
To increase the revenues associated to sustainability dimensions	% additional revenue	Financial reporting
To enhance technology process	% of investments in environmental technology	Investments in environmental technology/tot investments
To guarantee the quality of the process	% of production sites with environmental certification, environmental information accuracy rate, environmental information availability rate	survey

Source: prepared by author based on Hristiv & Chirico (2019).

Finally, the article “Five KPIs that businesses use to measure sustainability”, written by researcher Tom Swallow in 2022, explores the way companies use Key Performance Indicators to measure their success of implementing sustainable ideas. In the research, Tom Swallow

emphasises 5 KPIs that are being used by the businesses to create actionable insights on sustainability (Swallow, 2022):

1. Carbon Footprint. This is one of the most important KPIs, as it provides broader information about the greenhouse gases emissions by the company, company's suppliers and the customers. By measuring the emissions, businesses can analyse how their presence or services impact the environment and climate change.

2. Consumption of energy. This Key Performance Indicator is a great way for companies to get insights on the use of energy. This could lead to the determination of ways to use less coal generated energy, resulting in cost savings for the company & less emissions spread out into the environment. Digital tools, such as industrial internet of things (IIoT), are actively being used for analysis of production energy consumption.

3. Supply Chain Miles. Businesses emit gasses not only because of their production, but also due to logistics. Companies continuously are trying to improve their supply chain and make it more eco-friendly by using alternative powered transportation and other solutions. By using such KPI businesses analyse their supply chain mileage and the effect of different logistic methods.

4. Waste reduction & recycling rates. In modern world waste reduction and sourcing of materials is becoming more crucial, companies are trying to keep up with the trend by monitoring their wastes management. In this way businesses ensure that not only their production is sustainable, but that they also fall into the circular economy.

5. Social impact. As the consumer behaviour fluctuates, companies must react and recall the information provided to the suppliers. Environmental, Social, Governance provides great analysis on the social impact to the businesses. Such article can be very beneficial to the master thesis as it illustrates the importance of the mentioned KPIs for businesses, which provide valuable information on the performance of sustainable ideas. In addition, it gives examples of successful companies like EcoVadis, which made a huge contribution to environmental and global causes.

All in all, the reviewed texts provide a comprehensive details about how innovation and sustainability are interconnected, and establishing KPI frameworks to measure them. Baneliene's practical framework for SMEs offers a structures approach into their performance metrics, while Hristiv and Chirico's study provides a sustainability perspective, involving economic, environmental and social indicators. Shallow's article highlights 5 indicators: carbon footprint. consumption of energy, supply chain miles, waste reduction, recycling rates

and social impact, all of which contribute to companies long term success and sustainability goals.

1.2. Sustainable innovation and its measurement

To lay the foundation for the thesis research, it is necessary to understand what is innovation and sustainability. These two topics are very common in today's society, and are often interconnected, as scientists try to innovate, in order to solve many of the environmental problems.

Sustainable innovation is discussed in the essay “What is sustainable innovation?”, prepared by Ju Young Lee in 2021. In the essay researcher defines the meaning of sustainable innovations, by stating that it is the fundamental improvement of products, services, which contribute to environmental causes (Lee, 2021). Often such solutions are very beneficial to the business itself. As an example, Lee mentions of already existing sustainable innovations, such as:

- Bio-bean – startup based in Britain, which specializes in turning coffee waste into bio-fuel. One of their main products are coffee logs, contributing to a circular economy.
- Fairphone – Dutch startup company that focuses on the sustainable smartphone production. This includes using recycled materials & fair labor.

It is important to note, that author in his writing examines how sustainable innovations differ from traditional innovations (Lee, 2021). Researcher distinguished 3 main differences:

1. Long-term focus. Sustainable innovations, unlike the traditional ones, focus on the future results. Main aspects climate change and human rights.
2. System thinking. Businesses who use sustainable solutions find themselves collaborating with other organizations, stakeholders & broader systems.
3. Cultural Embedding. Sustainable innovations thrive in businesses where this is embedded into the companies culture.

As mentioned earlier, there are lots of benefits of the implementation of sustainable innovations into the company. Researcher states that such businesses are more likely to survive crises, producing more and impactful patents. Also, Lee noted that sustainable businesses attract more talented employees (Lee, 2021). In the paper, a model is created to illustrate the

methods how sustainable innovation could be achieved. Lee established 3 ways (refer to Figure 1.1.):

- Operational optimization – improving the existing processes, which could reduce emissions and negative social impacts from the company.
- Organizational transformation – producing products and providing services that can leave a positive impact on the environment and society.
- Systems building – working together with other organizations towards positive impacts on a broader scale.

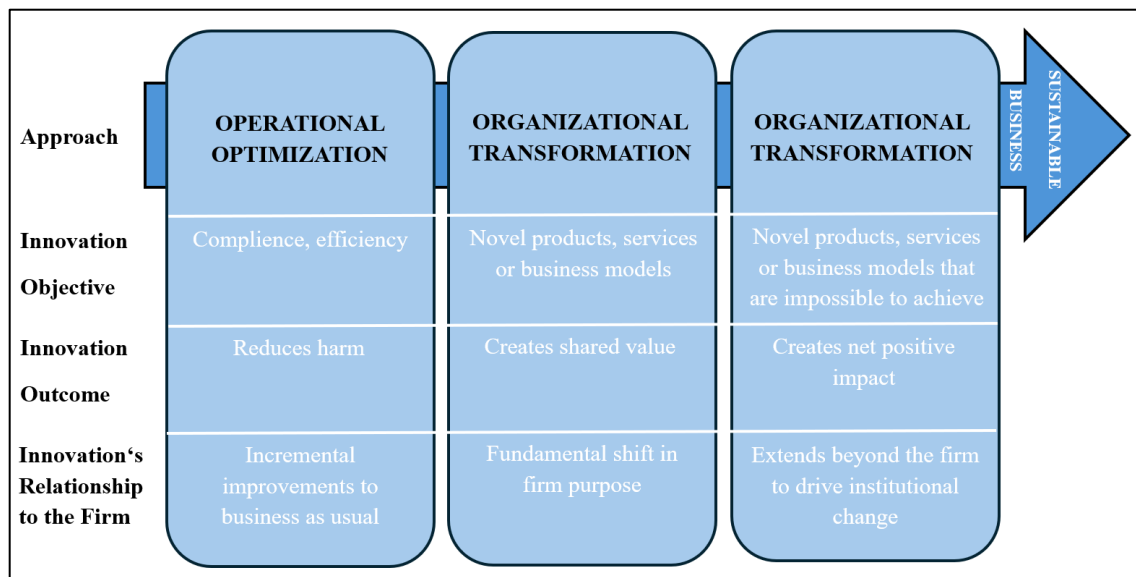


Figure 1.1. Three types of sustainable innovation methods

Source: prepared by author based on Adams et al. (2015).

Another research “Innovation Policy and Sustainable Development”, prepared by Manish Anand and Shailly Kedia, studies how innovation, technology, and sustainable technologies are inter-connected. For an easier illustration, authors provide a schematic, demonstrating how important the technological development is to the economy, its effect on the global environment and social factors (refer to Figure 1.2.). Researchers note, that the innovations are never a simple predictable process, as it involves a lot of participating elements. Manish Anand and Shailly Kedia highlight that the main challenge to develop innovative solutions is little to now funding and lack of motivation to focus on environmental issues (Anand and Kedia, 2015).

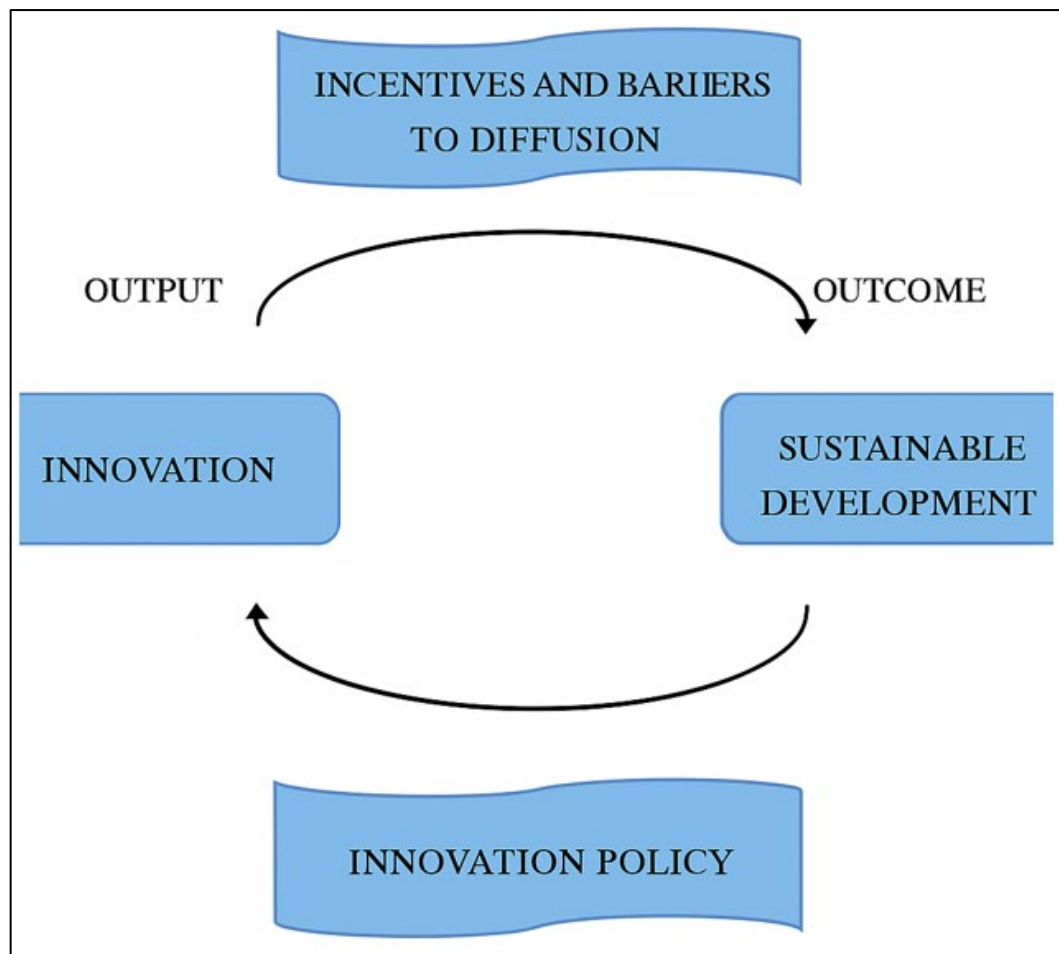


Figure 1.2. Interdependencies between innovation and sustainable development

Source: prepared by author based on Anand & Kedia (2015).

In the paper, an analysis of patent data has been performed, which reveals possible areas of cooperation across countries with various innovation agendas (Anand and Kedia, 2015). For sustainable growth, the case of India emphasizes the necessity of systemic and organizational innovation as well as a strong R&D strategy (see Figure 1.3.). This brings attention to the fact that countries with high income have a bigger concentration of advanced technologies, innovations.

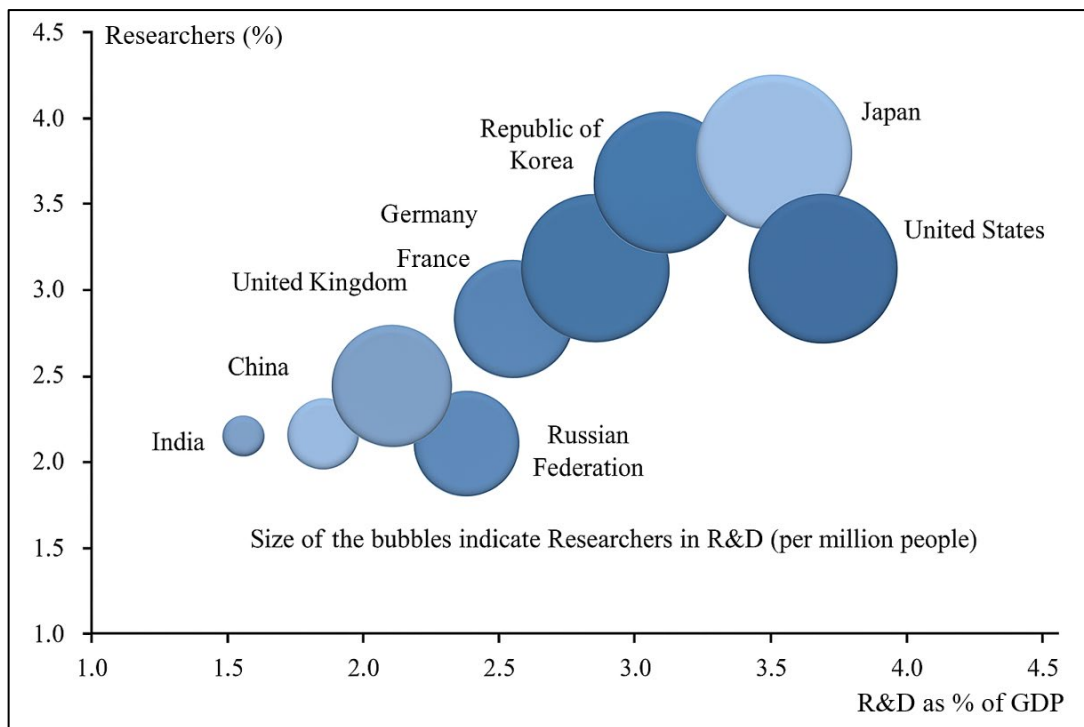


Figure 1.3. R&D as a percentage of GDP and researchers

Source: prepared by author based on Anand & Kedia (2015).

For a company to be successful and innovative, it has to be able to track its innovation output. One applicable indicator could be the green patents. The role of green patents on innovation is discussed by Eduardo Gomes Salgado and Rosangela Aparecida da Silva Franchi in their publishing „Green Technologies: The Role of Green Patents for Innovation, Preservation and Sustainable Development“. In the text, the authors state that the green patents have the ability to drive technological advancement and improve environmental awareness (Salgado and Franchi, 2023). In their research, the writers have noted that green patents - inventions that have a positive affect on the environment – are directly affecting the development of sustainable technologies. One of the main research findings is that green patents significantly reduce the time required for environmentally friendly inventions to enter the market. In addition, the legal protection provided by the green patents attracts more inventors and society to create, as well as attracting investments into sustainable research and development (Salgado and Franchi, 2023).

Another effective way to measure company's innovation output, is to track its high technology exports. This has been confirmed by the research „Role of Innovation in Hi-Tech-Exports of a Nation“, conducted by Tejinder S. Sara, Faye Hall Jackson & Leo T. Upchurch.

Using a regression analysis for their empirical model, the researchers have confirmed that the innovative capability of a country is significantly determined by the share of high-technology exports of nations manufactured products. As high technology sectors are usually leaders in environmental friendly innovation – providing efficient energy usage, renewable materials and other solutions – export of such products is a great indication of countries ability to expand the sustainable solutions globally (Sara et al., 2012). This is one of the many reasons why databases like Organisation for Economic Co-operation and Development (OECD) and The World Bank highlight this indicator as a measurement of innovation, as it reflects the competitiveness of a country's knowledge intensive industries on a global scale

In summary, reviewed texts confirm that there is a strong connection between the innovation and sustainability, both of which address social and environmental issues. Lee mentions that sustainable innovation keeps companies competitive, integrates long-term planning. Author even mentioned multiple success stories of companies like Bio-bean or Fairphone. In addition, the study by Anand & Kedia highlights the importance of R&D, investments to drive sustainability and innovation. Additionally, both green patents and hi-tech exports serve to be great indicators for a country's innovation output. Green patents provide legal protection for inventors to create eco-friendly technologies, attracting investors and helping products reach markets faster. Meanwhile, hi-tech exports demonstrate a nation's ability to commercialise sustainable innovation globally. Companies could be including both of the mentioned indicators to measure their innovation performance and the environmental impact, ensuring a company stays competitive.

1.3. Environment, society and governance

As described in the publication „What is ESG (environmental, social and governance)?“ by writers Gillis, Mathis and Stedman it is a: „framework used to assess an organization's business practices and performance on various sustainability and ethical issues. It also provides a way to measure business risks and opportunities in those areas.“ According to the publishing, ESG is composed of 3 pillars (Gillis et al., 2024):

- Environmental – factors that consider the organisation's environmental impacts, any risks or opportunities related to environmental issues. Such factors include greenhouse gas emissions, energy consumption and efficiency, management of waste, deforestation and etc.

- Social – factor that refers to the company's impact on its stakeholders, people, culture and communities. This is done through fair pay for employees, diversity programs, workplace health and safety, data protection, etc.
- Governance – factor that examines how the organisation is led and managed, how it complies with regulations. Some examples of this would be the financial transparency, ethical business practices, whistleblower programs and more.



Figure 1.4. 3 ESG pillars and indicators

Source: prepared by author based on Gillis et al. (2024).

Once the organisation defines its ESG goals, it is important to consistently monitor and report the collected data. Currently, there are several ESG reporting frameworks for structured data collection & analysis:

- International Financial Reporting Standards Foundation (IFRS) Sustainability Disclosure Standards;
- Sustainability Accounting Standards Board (SASB) Standards;
- Climate Disclosure Standards Board (CDSB) Framework;
- Global Reporting Initiative (GRI) Standards;
- Task Force on Climate-related Financial Disclosures (TCFD) Recommendations;
- Carbon Disclosure Project (CDP);

- Streamlined Energy and Carbon Reporting;
- U.N. Guiding Principles Reporting Framework;

As stated in the article „What is environmental, social and governance (ESG)?” by authors Tom Krantz and Alexandra Jonker, there are several regulations that have been implemented help companies to enforce ESG factors. Author has highlighted Corporate Sustainability Reporting Directive (CSRD), which is a European Union legislation, that requires organizations to report the environmental & sustainable affects of their activities (Krantz and Jonker, n.d.). The Sustainable Finance Disclosure Regulation (SFDR) is mentioned as also a potential factor for standardized reporting of ESG data.

All in all, it is safe to say that ESG is a significant framework that could assist in evaluating the organizations sustainability and social affects, which is well established by a reporting system and numerous regulations.

1.4. ESG as a KPI framework for innovation and sustainability

In an article „ESG and Innovation: Driving Sustainable Solutions“, published by a GENECAPSULE representative ANANDV, the topic of ESG impact on innovative sustainability has been explained. In the article, ESG is described as a catalyst for innovations through the following factors (ANANDV, 2024):

- Circular Economy
- Renewable Energy solutions
- Sustainable Supply Chains
- Social Innovations

Similar take on ESG is expressed by iRISCARBON, a company that has more than 18 years of experience in regulatory reporting, involved in assisting more than 1.5 million companies worldwide. In their publishing „Harnessing the Power of ESG Reporting to Foster Innovation and Growth: A Catalyst for a Sustainable Future“ it is expressed how ESG Reporting can unlock innovation and fuel growth in the following ways (iRISCARBON, 2024):

- Market differentiation – causing customer curiosity by differentiating the brand with a strong ESG performance;
- Attracting talent – having a transparent ESG reporting could attract Millennials and Gen Z talent;

- Access to capital – ESG reporting could demonstrate to investors a commitment to a responsible business, focused on sustainability;
- Cost reduction opportunities – such as minimizing energy consumption and associated costs;
- Enhanced risk management – building resilience to potential disruptions through proactive ESG reporting through sustainable solutions;
- Operational Efficiency – ESG reporting leading to a more holistic view of operations, highlighting weaknesses.

The idea, of introducing ESG as a KPIs to track organisations affects on sustainability, is widely discussed in a writing, published by ADEC ESG. ADEC is a company with more than 30 years of environmental and social sustainability experience, that specialises in helping organisations to grow and operate by integrating ESG management & reporting. In the writing, it is stated, that „ESG KPIs, specifically, gauge performance on environmental, social and governance topics such as greenhouse gas emissions, water consumption, waste, diversity and human rights, and execute policy and oversight“ (ADEC, n.d.). Furthermore, ADEC formed a list of potential ESG KPIs for each pillar:

- Environmental:
 - Energy consumption
 - Fuel consumption
 - Water consumption
 - Greenhouse gas emissions
 - Resource efficiency metrics (energy, water, other materials)
- Social:
 - Worker health and safety incidents
 - Diversity and inclusion metrics
 - Compensation equality metrics
 - Metrics related to human rights and labor policies
- Governance:
 - Board and management diversity metrics
 - Executive compensation
 - Transparency of environmental, social and governance policies
 - Disclosure and reporting programs

The list of ESG based KPIs not only has the possibility of changing the organisations profit-centric approach to sustainable one, but in addition – drive innovation. Due to this multiple companies have already incorporated them as their KPI and seen great success. One of such companies is Toyota Boshoku – a world’s premium interior, filtration and powertrain component manufacturer. In 2021, the company has implemented ESG KPIs alongside with other KPIs to measure social and economic value. The results are being followed up at their CSV Promotion Meeting, held twice a year.

Table 1.3. Toyota Boshoku ESG KPIs

NON-FINANCIAL TARGETS (ESG KPIS)			
	MAJOR KPI	TARGETS FOR 2030	Realize „I like Toyota Boshoku“
E Environment	Production of GHG emissions reduction ratio (total volume) NEW	Down 50% (compared to FY2020)	
	reduction ratio (total volume) NEW	Down 30% (compared to FY2020)	
	Scope 3 emissions Number of products developed taking recyclability into consideration	Under consideration	
S Society	Number of AI/IoT-based „people-friendly“ advanced technologies installed NEW	Under consideration	
	Ratio of people who take regular exercise (aged 40 or more) NEW	80%	
	Ratio of female managers NEW	5%	
	Ratio of local employees in presidents of overseas entities NEW	30%	
G Governance	Degree of implementation of the Toyota Boshoku Group Guiding Principles	90%	
	Number of serious cyber security incidents	0	

Source: prepared by author based on Toyota Boshoku (2021).

For each pillar, Toyota Boshoku has identified major KPIs and their targets for 2030. For environmental aspect (Toyota Boshoku, 2021):

- Environment: plan to reduce the production of GHG emissions reduction ratio by 50%, scope 3 emissions total volume by 30% & consider the number of products developed by recycling.
- Society: a consideration of the number AI/IoT based „people-friendly“ technologies installed; 30% of people who take regular exercise (aged over 40); 5% of female managers; 80% of local employees in presidents of overseas entities.
- Governance: 90% degree of implementation of the Toyota Boshoku Group Guiding Principles and an aim for 0 serious cyber security incidents.

Another successful company with integrated ESG KPIs is Nestle – a multinational food and drink processing conglomerate corporation. The organisation has selected 9 ESG KPIs, that they consider strategically important for their business. The 9 KPIs include:

1. GHG emissions reduction;
2. Water use reduction in factories ;
3. Percentage of key ingredients produced sustainably;
4. Percentage of deforestation-free for primary supply chain;
5. Percentage of plastic packaging designed for recycling;
6. Percentage of virgin plastic reduction;
7. Number of servings of affordable nutrition with micronutrient fortification;
8. Number of young people around the world with access to economic opportunities;
9. Women in the top 200+ senior executive positions.

In summary, by implementing ESG, organisations attract talent & investors, differentiate themselves in the market and foster a long-term success while driving innovation and sustainability. Toyota Boshoku and Nestle are great examples how companies across different industries are using ESG KPIs and create sustainable innovation.

1.5. ESG in manufacturing and industrial engineering

As manufacturing sector is affecting the environment with air, water pollution and resource usage, in addition to the ever increasing topics of worker safety and supply chain management, the idea of ESG implementation is becoming more and more significant. In the

article „The evolving role of ESG in manufacturing“, published by Sheynin on AlphaSense - a market intelligence and search platform, that is working closely with the world's leading companies and financial institutions – the topic of ESG importance in the manufacturing sector is being discussed.

In the writing, the author notes different ways in which ESG has been shaping the manufacturing industry, and how companies are willingly moving towards ESG-led growth (Sheynin, 2024). AlphaSense has highlighted the 6 key trends:

1. Smart manufacturing and sustainability. To stay ahead of the competition, companies are rapidly digitising and integrating new technologies such as AI. This helps to improve the productivity and efficiency. However, it was noted that smart manufacturing has a positive effect on sustainability. Companies that have successfully integrated new technologies are more likely to hit their ESG goals with less effort. Some of the new technology examples that compliment ESG are:

- Improved data utilization - determine opportunities and weaknesses;
- Smart manufacturing - waste reduction, decrease energy consumption.

2. Supply chain transparency and ethical sourcing. As supply chains can have a substantial impact on the environment due to ways the raw material is extracted and its transportation, it is becoming more important to implement ESG practices. By making the supply chains more transparent, companies can identify their negative impacts and work on ways to make their sourcing more ethical. This is also critical in ensuring fair labour conditions and worker safety. This will not just align with the environmental regulations, but also will be more appealing to stakeholders and investors.

3. Integration of circular economy principles. ESG has changed the way companies are designing their products. Nowadays, companies are moving to the circular economy models, designing their products with the possibility of refurbishing, remanufacturing them. This in return reduces waste and saves the world's natural resources. By meeting ESG targets, companies are moving to the sustainable growth and together driving innovation.

4. Emphasis on innovation. Manufacturing companies by leveraging the advanced technologies, such as IoT, AI, advanced analytics, are reducing their carbon footprints, optimising their efficiency and resource usage. By providing their employees with online trainings, they reduce the carbon emissions that would occur if employees would have traveled. By incorporating circular economy, companies manufacture products from recyclable

materials. All of these innovations help the companies to stay competitive, while at the same time hitting their ESG goals.

5. Addressing labour shortages. As manufacturing sector has been facing persistent labour shortages, the ESG implementation has improved the attractiveness of the company to the workers. By focusing on the societal pillar of the ESG, companies have improved their work safety, health and overall satisfaction. In addition, it improves the work and life balance of the employees, promotes culture diversity and inclusion. In this way companies fix their problem of labour shortages and keep their workers satisfied and motivated.

6. Aligning with customers ESG goals. For manufacturing companies, the consumer desires play a major role in the product development. As more and more people are becoming aware of the environment and their impact as a consumer, they tend to require more sustainable and environmentally friendly solutions to meet their needs. As an example with electric cars was shown in the article - manufacturing companies will develop electric vehicles not only to meet their ESG goals, but also because today's consumer is willing to buy the electric car to help the environment. Moreover, in the article, the writers point out several companies that have been committed to the ESG practices and have successfully implemented them into their operations (Sheynin, 2024). The listed companies are:

1. Nike. Nike, the world renowned fitness company, is regarded as the pioneer of the ESG initiatives. Some of their key objectives are:

- Reducing carbon emissions by focusing on renewable energy sources;
- Reducing waste by 10% per unit;
- Reducing fresh water usage by 25% per kilogram from textile dyeing and finishing;
- Adopting clean chemistry alternatives for ten priority chemistries across the supply chain;

2. Siemens. The largest industrial company in Europe, recently has taken their ESG commitment to another level with their DEGREE framework, which stands for:

- Decarbonisation;
- Ethics;
- Governance;
- Recourse efficiency;
- Equity;
- Employability.

In addition to this framework, Siemens have assigned Judith Weise - one of the top Chief Sustainability Officers - as their Sustainability Officer and Chief People.

3. Unilever. The international consumer goods company was awarded with a score of a 90 out of 100 by the S&P Dow Jones Sustainability Index in 2020, based on 27 ESG metrics. Currently Unilever is working on reducing their environmental footprint by 50% by the year of 2030.

4. L'Oréal. The company has been a leader in ESG initiatives within the beauty industry for many years. One of the ways they are doing so, is by introducing their product impact labeling system, which improves transparency and educates the customers about the value of sustainable product alternatives.

5. Nestle. As already mentioned in a previous literature, the global food company is an example of a successful company hitting their ESG goals. In 2020 they have announced their plan to half their GHG emissions by 2030 and achieving net zero by 2050.

All in all, it is clear that implementing the ESG principles within the manufacturing companies have become a necessity. As mentioned in the article by AlphaSense, ESG implementation leads the companies to becoming more technologically advanced, appealing to investors and customer, and keeping their competitive edge. Companies like Nike, Siemens, L'Oréal, Unilever and Nestle are great examples that ESG implementation through carbon emission reduction, renewable energy adoption, waste minimisation, water usage efficiency and transparency - drives innovation, also reflecting the focus on sustainability.

1.6. Governance impact on sustainable innovation

The governance pillar has a huge effect on fostering innovation and sustainability within a country. The factors such as low corruption, strong rule of law and effective governance all create the perfect environment for technological prosperity and environmental awareness.

In the scientific paper „The Impact of Corruption on Economic Growth and Innovation in an Economy in Developed European Countries, Anna Pluskota explores the relationship between corruption and innovation in the EU countries. In this research, Pluskota taken on an empirical research to test the association. Following the analysis, it has been concluded that there is a correlation between corruption and innovation. However, the relationship is not linear, but actually, a parabola – a low level of corruption can actually be beneficial for the innovation, while high levels of corruption can negatively affect innovation (Pluskota, 2020). Pluskota

explains that due to corruption, there are limited investments in research and development, technologies in the sectors where long term planning is required – are diffused (Pluskota, 2020). In addition, in another article „Rule of law, corruption and transparency impacts on green growth of East Asian economies“ published by authors Weiyu Gu, Weifeng Yan and Shiqin Yu, the governance quality, transparency and the rule of law were examined for their influence on sustainability. In the performed empirical analysis, a significant impact of the rule of law, institutional transparency has been noted to have a positive affect on the environment. Also, corruption has been highlighted as a catalyst for hindering the environmental performance (Gu et al., 2024). In the same way as in the previous literature, it is stated that corruption disrupts the investments into green technologies, and removes the power from environmental regulations (Gu et al., 2024). Moreover, the article highlights that countries with robust legal frameworks are more likely to encourage eco-friendly development due to efficient resource allocation and transparency (Gu et al., 2024). Furthermore, in the publishing „Does corruption affects business innovation? Insights from emerging countries“, authors Marilen Gabriel Pirtea, Gabriela Lucia Sipos and Alin Ionescu provide additional empirical data which serves as evidence that institutional corruption has a negative affect on business innovation across 110 emerging economies over a 13-year period. The research stands out as they have introduced multidimensional perspective on corruption, assessing not just its presence, but also the depth, functional role in administrative interactions. On the other hand, the innovation was measured through factors like adoption of international quality certifications and digital communication practices. Following their analysis it has been determined that corruption created an unstable environment that affects long-term projects, their investments, especially for sustainable development (Pirtea et al., 2019). The findings confirm that the inclusion of governance related indicators is crucial to address the innovation output and sustainability concerns.

All in all, based on the reviewed literature, it is clear that low corruption index, rule of law and government effectiveness all have an impact on innovation and sustainability. All these factors play into efficient resource allocation, funding, and long term planning – all necessary factors for green innovation development.

1.7. Education and employment impact on sustainable innovation

It is believed that countries with better quality of the education, especially in the science, technology, engineering and maths fields, as well as countries with higher employment rates, tend to innovate more and have a stronger environmental awareness.

In the article „Innovation and employment“, Marco Vivarelli has highlighted a strong relationship between the employment and different types of innovation. Specifically, product and process innovations were examined. At the conclusion of the study, it was clear that R&D-intensive product innovation, especially in the high-technology sectors, has created new job opportunities with new company and startup creation (Vivarelli, 2007). On the other hand, process innovation was noted to be removing job positions (Vivarelli, 2007). To mitigate this, more investments and demand expansions is required to mitigate the affect on the labour demand. However, one of the major findings of the reserach was that the educated, skilled labour & R&D personnel are key for companies to stay competetive and drive innovation (Vivarelli, 2007). Similar findings were emphasized in an another publishing „Why STEM Education is Vital for Developing Innovative Solutions in Sustainable Goods Transportation“ by April Miller on the website EARTH.ORG. In the article, the important role of STEM education has been highlighted for the environmental problems, particularly, in the transportation sector (Miller, 2023). As transportation of products and recourses is a big part of manufacturing, this publishing is considered relevant to the thesis. The author stated that the people receiving STEM education gain problem-solving skills, which assists them in developing innovative sollutions, such as advanced technologies, energy efficiency, alternative, sustainable fuels and many more (Miller, 2023). So by having a more STEM oriented labour fource, ompanies could benefit from their employee literacy, creative thinking and teamwork to ensure suatainable innovation. Considering these findings, it is clear that governments should invest more into education. This is confirmed in a publishing „The Impact of Education Expenditure on Environmental Innovation“ published in Heliyon by Chanxi Yang and Zhongzheng Fang. In their research, the authors have performed empirical analysis with panel data to find evidence between education investments and sustainable technologies. As a finding, the authors state that education spending, especially in STEM fields improves labour force and helps companies to achieve their environmental goals (Yand and Fang, 2024). The results of their research confirm that higher levels of education expenditure are related to improved output of green patents, as well as R&D focused sollutions. Moreover, the study

suggests that R&D investments and investments into education work together and further accelerate innovation outcomes (Yand and Fang, 2024).

All in all, it is safe to say that quality of education, particularly in the STEM fields and employment to positively contribute to innovation and sustainability. The reviewed literature confirmed that skilled labour force provides literacy, technical skills and creative thinking for companies, which further drives innovation and sustainable solutions. The publishing by Chanxi Yang & Zhongzheng Fang has further insisted on education expenditure and R&D investments are both enablers of technological advancements and green solutions.

1.8. KPI framework based on the reviewed literature

All in all, it is safe to say that there is a growing emphasis on integrating the sustainability and innovation into performance measurement systems, especially in the manufacturing sector. Following the literature review, it was noted that companies are starting to move away from the traditional financial KPIs to environmental, social and governance focused indicators. Such transition ensures the companies are meeting their longterm goals and stakeholder expectations.

Table 1.4. KPI Framework based on the reviewed literature

KPI FRAMEWORK BASED ON REVIEWED LITERATURE		
ENVIRONMENTAL	SOCIAL	GOVERNANCE
GHG emissions per employee (tons)	Graduates in tertiary education, in science, math, computing, engineering, manufacturing, construction (per 1000 of population aged 20-29)	Gross domestic expenditure on research and development in manufacturing sector (% of gross domestic product)
Final energy consumption per capita (kilograms of oil equivalent)	Young people neither in employment nor in education and training (%)	Corruption perception index (score)

Table 1.4. continuation

Environmental taxes per employee (million euro)	Employed ICT specialists (% of total employment)	Business enterprise expenditure on research and development in manufacturing sector (% of gross domestic product)
Recycling rate of municipal waste (%)	Employment in technology and knowledge-intensive sectors (% of total employment)	Government effectiveness indicator, score
	Research and development personnel (% of population in the labour force)	Rule of law indicator, score
		Development of environment related technologies (inventions per person)
		Government expenditure on education (% of GDP)

Source: prepared by author.

The reviewed literature provides empirical evidence that innovation drives sustainability, as well as improves companies competitiveness and performance. In addition, literature indicates that there are performance and sustainability metrics developed by companies, however the issue is that there is still no universally accepted set of sustainability-focused innovation KPI. Furthermore, the literature confirmed that green patents and high-technology exports have a big influence on the country's or company's innovation capabilities, while low corruption, transparency and strong institutions assist in sustainable development. Moreover, education, especially in STEM fields creates a well prepared workforce to develop longterm innovate, sustainability focused solutions

Finally, based on the reviewed literature and the mentioned existing KPI frameworks and their indicators, a theoretical framework has been created.

2. EMPIRICAL BACKGROUND: METHODOLOGY AND RESEARCH DESIGN

2.1. Overview of methods used by researchers

Performing a review of used methodologies in literature is a crucial step of the research, as it provides insights into how the research can be approached, what are the different analysis options available. By reviewing different approaches to similar studies tools and different designs of the studies can be observed, which could be implemented. Most critically, limitations and strenghts can be indentified, which assists in choosing the appropriate method for the thesis.

One of quite commonly used research methods is primary research. This is implemented through surveys and questionnaires, in order to adress a topic, get more insights. Primary research was incorporated in the study “Case Studies on Sustainability-Oriented Innovations and Smart Farming Technologies in the Wine Industry“. The data has been collected through consultations with stakeholders and expert surveys. In the analysis, authors used the KPI framework based on the environmental, social and economic indicators, with both quantative and qualitative methods were incorporated. Quantative methods analised pesticide use, production costs, while qualitative evaluated wine quality. All of these incorporated methods provides a lot of details for assessment, but also may contain biased answers from interviews, as it heavily relies on stakeholder and expert judgments (Kasimati et al., 2024). Additionally, the research is very narrow geographically and sectoraly, as it studies only the farming technologies in wine industry of Italy. By changing the settings, like reviewing a different country or a different sector, results may be different. Another research that implemented primary research, is titled „Procedure for Selecting Key Performance Indicators for Sustainable Manufacturing“. In this paper, authors present a procedure how to select KPIs for sustainable manufacturing. As research method, the researchers conducted consultations with experts, where different indicators were ranked and evaluated (Kibira et al., 2017). While such approach provides critical insights and expertise from field specialists, there are also limitations. Mainly, the data is not backed by empirical validation though existing industry data, which could confirm whether any bias was present during the consultations. Finally, primary research with questionnaires has been used in the study “Key performance indicators for sustainable manufacturing evaluation in automotive companies“. The authors were aiming to identify a set

of indicators by gathering the information directly from industry professionals. This method has advantages, as it ensures that the indicators are closely aligned with the current trends and practices within the industry (Yusof and Amrina, 2011). However, the scope is restricted, as well as the possibility of bias or gaining feedback from personnel only based on their perceptions, not the actual metrics and outcomes.

On the other hand, secondary research offers a large scale, robust data which is collected from government sources, previous studies. Specifically for KPI model identification, this research is especially beneficial as indicator relevance and impacts can be validated. In a study „A Novel Dataset about Corporate Social Responsibility and Performance Indicators“ by Cano and Vogli (2023) secondary research is implemented with using the CSREU dataset, which accompanies performance data from 115 European companies. The data is collected from Global Reporting Initiative database. Eventually, a structured dataset is established for use in econometric research (Cano and Vogli, 2023). Such approach is very robust, as GRI is an internationally recognised framework, providing credibility to the proposed dataset. Similarly, a secondary research was used in the study "The Link between Sustainable Innovation and Industrial Performance: The Case of the United States" by Adubofour et al. (2024), where the relationship between sustainable innovation and industrial performance metrics was assessed. In the paper, 94 U.S. industries over the period from 2014 to 2022 were analysed with panel data regression. The secondary data for the research was collected from databases such as Bloomberg, Capital IQ, Morningstar and Compustat. Such approach ensures studies statistical reliability with factual data. The study showed that the sustainable innovation improved the performance in the United States manufacturing sectors, with positive effects on ROIC and ROE metrics (Adubofour et al., 2024). Lastly, secondary research is chosen in the study „Exploring how green innovation moderates the relationship between innovation strategies and CSR performance in the African States“ by Omonijo and Zhang (2024). In the research, data collected from World Bank Indicators and other accessible databases has been structured into panel data. The scope of the research covered the time period of 2014-2023, focusing on Chinese companies in African countries. Relationships between innovation strategies and Corporate Social Responsibility have been reviewed by using objective indicators such as patent numbers, market value and green product development. It was concluded that green innovation significantly moderated the connection of innovation strategies and CSR in Africa (Omonijo and Zhang, 2024). It is worth noting that the study showed firms with green innovation practices have stronger positive effects on CSR outcomes. Such usage of secondary research method ensured that the outcomes are reliable and easily comparable on a large scale.

All in all, different methodologies and tools used in the literature were reviewed for innovation and sustainability KPI development. It is noted that primary and secondary researches are often used due to the insights that they both provide. Primary research offers very specific details, often received from consulting or interviewing field experts. However, primary research is prone to bias, which may affect the results. In addition, primary research is usually very case specific, making the collected data very difficult to generalize. On the other hand, secondary research offers robust and reliable results, based on statistics.

Table 2.1. Methodology comparison in reviewed literature

Study Title	Research Method	Tools Used	Strengths	Limitations
Case Studies on Sustainability-Oriented Innovations and Smart Farming Technologies in the Wine Industry	Primary	Consultations Surveys	Detailed insights Real-world context Mixed KPI evaluation	Bias Narrow geographic/sector scope
Procedure for Selecting Key Performance Indicators for Sustainable Manufacturing	Primary	Consultations	Expert-driven selection Structured KPI prioritization	Lack of empirical validation Bias
Key Performance Indicators for Sustainable Manufacturing Evaluation in Automotive Companies	Primary	Questionnaires	Industry-aligned indicators Current trend relevance	Subjectivity Perception-based responses
A Novel Dataset about Corporate Social Responsibility and Performance Indicators	Secondary	CSREU dataset GRI data	Reliable Standardized framework Ready for econometric use	Self-reported data
The Link between Sustainable Innovation and Industrial Performance: The Case of the United States	Secondary	Bloomberg Capital IQ Morningstar Compustat	High statistical reliability Long-term Sectoral trends	Dependent on available data Lacks detail
Exploring how green innovation moderates the relationship between innovation strategies and CSR performance in the African States	Secondary	World Bank Indicators	Cross-national comparability Objective metrics Broad scope	Limited to Chinese firms in Africa Lacks firm-level detail

Source: prepared by author.

Choosing the appropriate method comes down to data availability, scope of the research and the necessity for details.

2.2. Research design

For this research, a panel data regression analysis is implemented in order to study the relationship of the ESG based KPI and innovation output over a 11 year period from 2012 to 2022 across 27 European countries. The aim was to achieve as big of a time frame that would cover all of the indicators identified during the literature review. The decision to analyze the 27 European Union countries was made due to following factors:

- European Union is a diverse and at the same time closely interconnected economic bloc, where each country commits to sustainable development, environmental awareness and transparent governance. EU is known for implementing different policies which emphasize innovation and sustainability. This makes them an excellent subject to analyse how all of the policies and outcomes translate into the manufacturing sector.
- The data availability and harmonization between the EU countries. Databases like Eurostat offer high-quality data covering huge periods of time, which are frequently updated with the latest developments.
- Focusing solely on European Union countries ensures that the countries are comparable, as they all have similar regulations, economic structures and data collection standards.

Due to this panel data structure, the following hypothesis is raised for testing: *„ESG-based indicators, particularly from the environmental, social, and governance pillars, have a statistically significant impact on output in the manufacturing sector of EU-27 countries.“* This hypothesis is inspired by the performed literature review in the previous chapter, which confirmed the relationship of the environmental, social and governance based indicators on the innovation outcomes, specifically in the manufacturing sector.

The conceptual framework identified following the literature review consists of a total of 16 indicators, each falling under one of the ESG pillars:

Environmental:

- Recycling rate of municipal waste (%)
- Final energy consumption per capita (kilograms of oil equivalent)
- GHG emissions per employee (tons)
- Environmental taxes per employee (million euro)

Social:

- Young people neither in employment nor in education and training (%)

- Graduates in tertiary education (STEM fields per 1000 people aged 20-29)
- Employed ICT specialists (% of total employment)
- Employment in technology and knowledge-intensive sectors (% of total employment)
- Research and development personnel (% of labour force)

Governance:

- Corruption Perception Index (score)
- Government expenditure on education (% of GDP)
- Government effectiveness indicator (score)
- Government rule of law indicator (score)
- Gross domestic expenditure on R&D in manufacturing (% of GDP)
- Business enterprise expenditure on R&D in manufacturing (% of GDP)
- Development of environment-related technologies (inventions per person)

From the list of the indicators, combinations of indicators are going to be selected and tested to analyse their affect and relationship with each other. Initial model will consist of 7 most effective indicators. The model of 7 KPI will depend on the following factors:

- R-squared – a statistical measure which is used in regression analysis to understand how well the chosen variables explain the variation in the dependent variable. In our case, independent variables are the chosen indicators, while the dependent variable will be the innovation output indicator. The standard is set for the model to have at least an indication of 0.90 R-squared to explain 90% of the variation.
- Adjusted R-squared – it is the R-squared, but in order to prevent overfitting, it corrects the number of predictors used, so the model does not look good only because it used too many variables. The standard is set for the model to have at least an indication of 0.90 Adjusted R-squared.
- Durbin-Watson statistic – a test in a regression analysis to observe autocorrelation in the errors of a model. If DW value is below 1.5, it means there is a strong autocorrelation, if the value is above 2.5 – strong negative autocorrelation. In case a model depicts a DW out of the range of 1.5-2.5, the reason for it should be justified, as ESG KPI of innovations and sustainability are often interconnected.

These factors are crucial for model creation, as they confirm its reliability and robustness. Then, only 4 key indicators will be left for the following reasons:

- 1) Degrees of freedom. As there will be only 27 cross-sectional items over a span of 10 years, too many independent variables would overfit the model and negatively affect the statistical results, making coefficients unreliable.
- 2) Multicollinearity. As a lot of ESG indicators are strongly related to one-another, including a lot of them in a regression model can lead to multicollinearity and affect the results. So in order to maintain reliability of the model, the indicator number is limited.

The 4 indicators will be chosen depending on the following reasons:

- P value – probability value, assisting in determining whether the indicator is statistically significant. For an indicator in a model to be verified, p-value should be 0.05 or lower, ensuring that the indicator is significant.
- Models R-squared, Adjusted R-squared and DW statistic.

For model and indicator selection method, please refer to Figure 2.1.

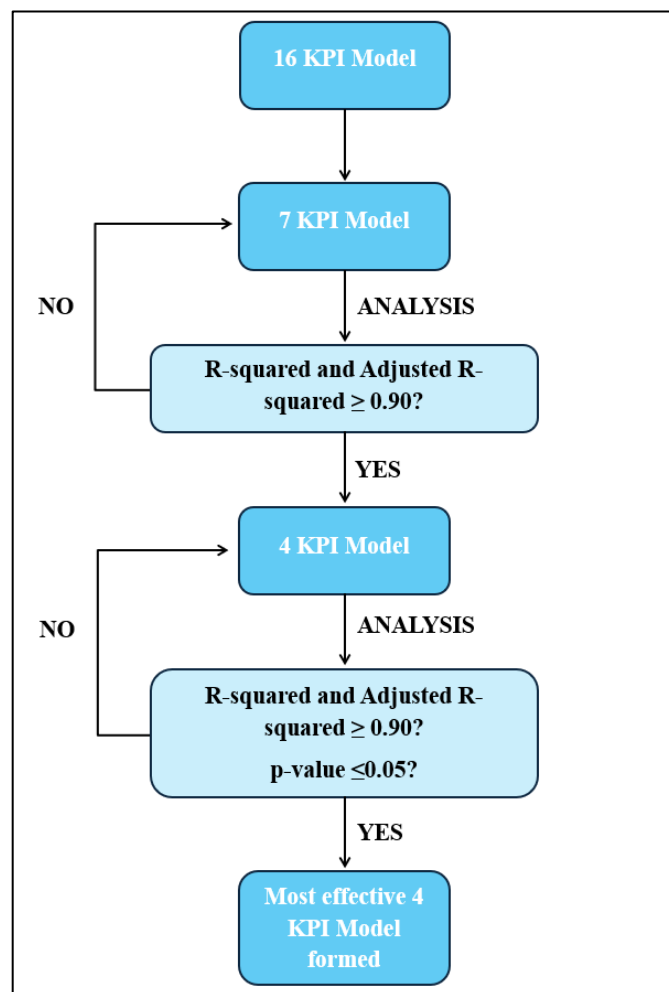


Figure 2.1. Model development flowchart

Source: prepared by author.

For innovation output measurement, the gross value added (GVA) of the manufacturing sector, as a percentage of gross domestic product (GDP) is chosen. This is due to the following reasons (Solow, 1957):

- GVA illustrates the contribution of the manufacturing sector to the economy, which serves as an indicator of industrial innovation;
- Technological advancements and innovation usually results in better productivity and value creation, which means having an impact on GVA;
- The data for the indicator is widely available and standardized between countries.

To analyse the chosen indicators, data has to be collected. To ensure credibility of the data, the information has been collected from comprehensive databases such as:

- Eurostat – offers standardized data for specifically European Union countries. With its easy to use interface, the data can be easily collected and compared between countries, and included into the panel data.
- OECD – provides critical data that could be compared between international countries. The data focuses on the economies of the countries, society and environmental aspects – all aspects very relevant to ESG and the research.
- World Bank Group – offers data related to economic indicators, as well as innovation outputs and sustainability trackings.
- Transparency International – gives data related to governance-related indicators, such as corruption index, which is crucial in comparing the transparency between the countries.

The mentioned databases provide crucial information regarding macroeconomic, environmental, social, governance and other indicators in the EU.

Table 2.2. A fragment of the statistics formed in a panel data set

TIME	COUNTRY	MGVA_GDP	RR	FEC_cap	GHG_emp	YNE	YE	ICT	TE	RDP	ET_emp	CI	GERD_GDP	BERD_GDP	DERT_cap	EE	GEI	GRI
2012	Austria	17,30	57,70	792,00	7022,88	6,80	:	3,60	3,50	1,54	0,66	69,00	2,93	:	48,79	5,48	1,56	1,86
2013	Austria	17,10	57,70	815,00	6946,67	7,30	22,20	3,70	3,80	1,55	0,65	75,00	2,98	1,31	39,37	5,55	1,67	1,45
2014	Austria	17,20	56,30	730,00	6824,36	7,70	23,00	3,60	4,10	1,63	0,65	41,00	3,11	:	43,18	5,45	-0,03	-0,12
2015	Austria	17,20	56,90	767,00	6881,83	7,50	21,90	4,00	4,00	1,65	0,65	46,00	3,07	1,35	42,07	5,46	0,68	0,15
2016	Austria	17,70	57,60	792,00	6676,20	7,70	22,10	4,20	4,30	1,7	0,61	66,00	3,13	:	39,05	5,48	1,38	1,09
2017	Austria	17,40	57,80	791,00	6798,58	6,50	22,00	4,40	4,40	1,71	0,66	49,00	3,07	1,41	42,24	5,37	0,92	1,02
2018	Austria	17,30	57,70	739,00	6325,17	6,80	22,80	4,50	4,20	1,79	0,73	90,00	3,11	:	43,62	5,23	1,99	1,88
2019	Austria	17,10	58,20	753,00	6485,87	7,10	23,40	4,30	4,00	1,86	0,75	64,00	3,14	1,46	48,80	5,22	0,95	1,15
2020	Austria	16,60	62,30	781,00	6341,62	8,00	24,40	4,50	4,10	1,84	0,63	90,00	3,21	:	46,51	5,57	2,21	1,94
2021	Austria	17,00	62,50	866,00	6712,15	8,50	25,00	4,50	4,50	1,94	0,77	71,00	3,26	1,61	33,06	5,49	1,37	1,44
2022	Austria	16,20	62,60	762,00	6089,05	8,10	24,30	5,00	5,00	2,02	0,70	79,00	3,18	:	21,95	4,77	1,53	1,67
2012	Belgium	12,60	53,40	762,00	8198,57	12,30	:	4,30	4,70	1,38	1,08	36,00	2,27	0,95	18,16	6,26	0,28	0,39
2013	Belgium	12,70	52,80	814,00	8227,31	12,70	13,00	4,20	4,40	1,38	1,07	55,00	2,32	0,95	19,65	6,63	0,61	0,61
2014	Belgium	12,60	53,80	664,00	8244,61	12,00	14,00	4,20	4,40	1,48	1,03	69,00	2,36	0,91	21,11	6,59	1,54	1,73
2015	Belgium	12,60	53,50	730,00	8206,53	12,20	13,30	4,20	4,40	1,57	1,05	42,00	2,43	0,93	20,50	6,45	0,45	0,43
2016	Belgium	12,20	53,50	729,00	8184,44	9,90	14,30	4,20	4,30	1,59	1,22	49,00	2,53	0,99	22,09	6,46	0,83	0,78
2017	Belgium	12,40	53,90	715,00	8146,61	9,30	13,60	4,90	4,60	1,67	1,34	54,00	2,68	1,05	21,45	6,43	0,83	0,84
2018	Belgium	12,30	54,40	704,00	8062,54	9,20	14,00	5,20	4,90	1,77	1,34	80,00	2,86	1,12	24,34	6,38	1,66	1,79
2019	Belgium	12,40	54,70	653,00	7897,44	9,30	14,20	5,00	5,10	1,85	1,39	57,00	3,15	1,19	19,87	6,33	1,24	1,34
2020	Belgium	12,00	51,40	657,00	7340,68	9,20	15,70	5,00	5,10	1,92	1,21	84,00	3,37	1,27	21,90	6,80	1,84	1,85
2021	Belgium	10,70	55,50	708,00	7419,76	7,40	16,40	5,60	5,70	2,33	1,30	58,00	3,41	1,11	21,82	6,36	0,66	0,82
2022	Belgium	12,20	54,70	604,00	6606,73	6,60	16,40	5,60	5,80	2,41	1,32	63,00	3,29	:	13,84	:	1,00	1,04
2012	Bulgaria	14,10	25,00	322,00	2637,04	21,50	:	2,50	3,20	0,51	0,24	44,00	0,60	0,06	2,48	3,48	-0,17	0,09
2013	Bulgaria	12,80	28,50	313,00	2642,02	21,60	14,60	2,50	3,40	0,53	0,27	46,00	0,63	0,05	1,77	4,06	0,78	0,49
2014	Bulgaria	13,00	23,10	306,00	2658,10	20,20	14,20	2,50	3,30	0,59	0,27	61,00	0,79	0,09	2,27	4,07	1,02	1,01
2015	Bulgaria	13,60	29,40	314,00	2946,51	19,30	14,60	2,90	3,70	0,69	0,28	65,00	0,95	0,21	2,40	3,91	1,06	1,04
2016	Bulgaria	14,40	31,80	327,00	3184,58	18,20	13,90	3,00	3,90	0,78	0,30	88,00	0,77	0,19	1,94	3,39	1,91	1,93
2017	Bulgaria	14,00	34,60	341,00	3247,23	15,30	14,30	3,10	3,60	0,71	0,29	69,00	0,74	0,18	1,51	4,08	1,57	1,83
2018	Bulgaria	13,30	31,50	332,00	3304,29	15,00	13,60	3,30	3,90	0,8	0,31	75,00	0,76	0,18	1,83	4,05	1,70	1,46
2019	Bulgaria	13,30	34,60	327,00	3338,29	13,70	14,00	3,10	3,90	0,86	0,42	41,00	0,84	0,15	1,51	4,20	-0,01	-0,15
2020	Bulgaria	12,90	35,20	364,00	3284,49	14,40	13,10	3,30	4,20	0,87	0,45	48,00	0,85	0,15	2,14	4,51	0,68	0,18
2021	Bulgaria	11,20	28,20	369,00	3435,26	13,90	14,40	3,50	4,50	0,85	0,47	63,00	0,77	0,13	1,03	4,73	1,36	1,03
2022	Bulgaria	13,20	24,60	331,00	3431,23	12,30	14,60	3,80	4,80	0,91	1,21	48,00	0,75	0,13	1,10	:	0,92	1,02
2012	Cyprus	4,20	12,80	405,00	2935,40	16,00	:	2,60	2,90	0,57	0,44	80,00	0,44	0,02	2,31	5,90	1,62	1,81

Source: prepared by author based on Eurostat (2024a-o), OECD (2024), World Bank Group (2024a-b) and Transparency International (2024).

All data is harmonized in terms of units, countries and time span. The data is collected in a Panel Data structure.

As a tool for this research, the software Eviews is going to be used. Eviews is a powerful, modern statistical software, which is very easy to use with their user friendly interface. The subject software was chosen for the following reasons:

- Ability to analyse complex panel data, allowing fixed and random effect usage;
- Accurate estimation and robustness;
- Wide offer of capabilities, such as graphs, charts, residual plots and more.

Comparing Eviews to its competitors such as Stata R, or SPSS, Eviews was chosen for its user friendly interface, ability to test multiple models with different econometric techniques (fixed and random effects). Also, Eviews functions particularly great with panel data, which is used in this research.

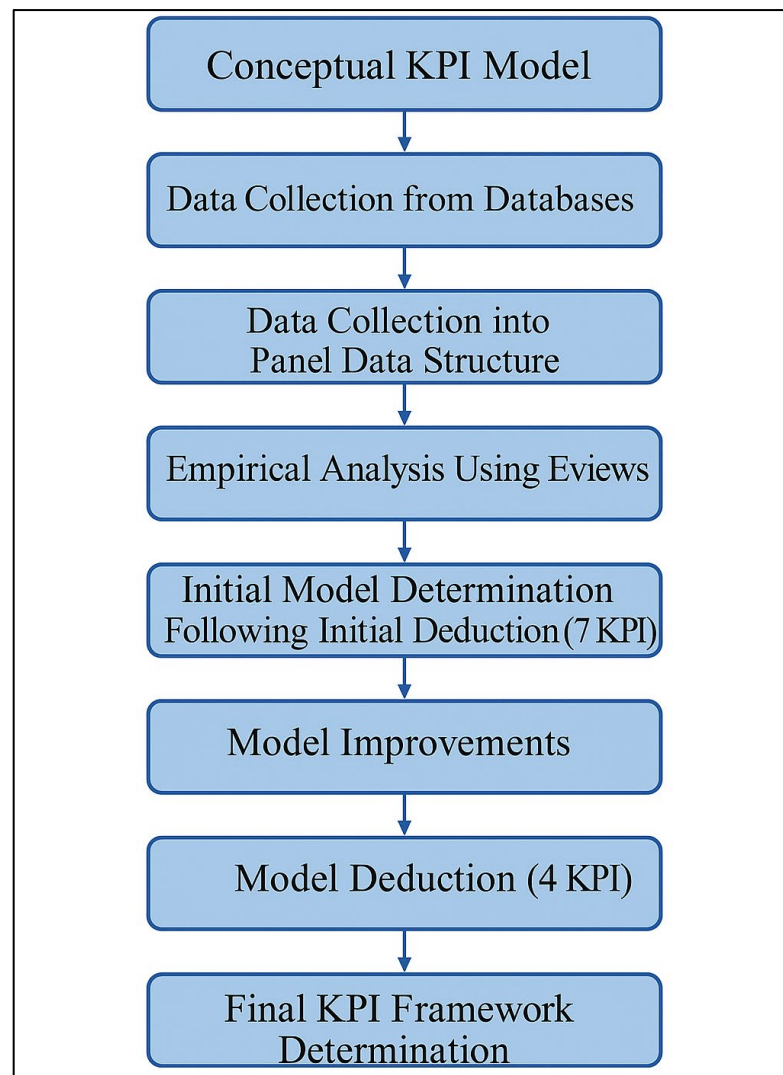


Figure 2.2. Methodology flowchart

Source: prepared by author.

All in all, the described methodology confirms a reliable approach in order to study all of the aspects of ESG indicators and their relationship with the output in the European Union manufacturing sector. By gathering the data from reliable databases, structuring it in panel data, implementing the usage of Eviews software - valuable insights for the thesis will be achieved.

3. ANALYSIS OF ESG-BASED KPI ON THE OUTPUT IN MANUFACTURING SECTOR OF THE EUROPEAN UNION

While the literature analysis is very beneficial to form a conceptual framework and provide a foundation to the research, the empirical part of the study is key, as it ensures that the findings and outcomes are practical, and based on the real data. This provides credibility and robustness to the thesis. Furthermore, it will illustrate the significance and overall relationships of the chosen indicators. Considering this, in this part of the master thesis, an empirical analysis is going to be conducted to investigate the relationship between the ESG-based indicators and the gross value added in the manufacturing sector of 27 EU countries from 2012 to 2022. The data for the conceptual model (formed from literature analysis) is going to be gathered from reliable databases such as Eurostat, OECD, World Bank. With the implementation of the least data regression technique using the EViews software, the hypothesis “ESG-based indicators, particularly from the environmental, social, and governance pillars, have a statistically significant impact on output in the manufacturing sector of EU-27 countries.” is going to be tested.

3.1. Initial empirical research

Once all data is collected and the panel model prepared, the file is being uploaded into EViews. Then, it is ensured that the missing data is represented as „.“. Furthermore, the column with years is specified as „date“ data type.

Excel Read - Step 3 of 4

Text representing NA:

Column info

Click in preview to select column for editing

Name:

Description:

Data type:

TIME	COUNTRY	mGVA	GDP	RR	FEC	cap	GHG	emp	YNE	YE	ICT	TE	RDP	ET	emp
2012	Austria	17.3	57.7	792	7022.88	6.8	3.6	3.5	1.54	C					
2013	Austria	17.1	57.7	815	6946.67	7.3	22.2	3.7	3.8	1.55	C				
2014	Austria	17.2	56.3	730	6824.36	7.7	23	3.6	4.1	1.63	C				
2015	Austria	17.2	56.9	767	6881.83	7.5	21.9	4	4	1.65	C				
2016	Austria	17.7	57.6	792	6676.2	7.7	22.1	4.2	4.3	1.7	C				
2017	Austria	17.4	57.8	791	6798.58	6.5	22	4.4	4.4	1.71	C				
2018	Austria	17.3	57.7	739	6325.17	6.8	22.8	4.5	4.2	1.79	C				
2019	Austria	17.1	58.2	753	6485.87	7.1	23.4	4.3	4	1.86	C				

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Figure 3.1. Data type identification for time column

Source: prepared by author.

The country column is specified as „character“.

Excel Read - Step 3 of 4

Text representing NA:

Column info

Click in preview to select column for editing

Name:

Description:

Data type:

TIME	COUNTRY	mGVA	GDP	RR	FEC	cap	GHG	emp	YNE	YE	ICT	TE	RDP	ET	emp
2012	Austria	17.3	57.7	792	7022.88	6.8	3.6	3.5	1.54	C					
2013	Austria	17.1	57.7	815	6946.67	7.3	22.2	3.7	3.8	1.55	C				
2014	Austria	17.2	56.3	730	6824.36	7.7	23	3.6	4.1	1.63	C				
2015	Austria	17.2	56.9	767	6881.83	7.5	21.9	4	4	1.65	C				
2016	Austria	17.7	57.6	792	6676.2	7.7	22.1	4.2	4.3	1.7	C				
2017	Austria	17.4	57.8	791	6798.58	6.5	22	4.4	4.4	1.71	C				
2018	Austria	17.3	57.7	739	6325.17	6.8	22.8	4.5	4.2	1.79	C				
2019	Austria	17.1	58.2	753	6485.87	7.1	23.4	4.3	4	1.86	C				

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Figure 3.2. Data type identification for country column

Source: prepared by author.

And all of the variable columns are identified as „number“.

Excel Read - Step 3 of 4

Text representing NA:

Column info: Click in preview to select column for editing

Name:

Description:

Data type:

TIME	COUNTRY	mGVA_GDP	RR	FEC_cap	GHG_emp	YNE	YE	ICT	TE	RDP	ET_emp
2012	Austria	17.3	57.7	792	7022.88	6.8		3.6	3.5	1.54	C
2013	Austria	17.1	57.7	815	6946.67	7.3	22.2	3.7	3.8	1.55	C
2014	Austria	17.2	56.3	730	6824.36	7.7	23	3.6	4.1	1.63	C
2015	Austria	17.2	56.9	767	6881.83	7.5	21.9	4	4	1.65	C
2016	Austria	17.7	57.6	792	6676.2	7.7	22.1	4.2	4.3	1.7	C
2017	Austria	17.4	57.8	791	6798.58	6.5	22	4.4	4.4	1.71	C
2018	Austria	17.3	57.7	739	6325.17	6.8	22.8	4.5	4.2	1.79	C
2019	Austria	17.1	58.2	753	6485.87	7.1	23.4	4.3	4	1.86	C

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Figure 3.3. Data type identification for variables columns

Source: prepared by author.

In the following step, the basic structure is set up as „dated panel“, while the cross section ID series are identified as „country“ and the date series as „time“.

Excel Read - Step 4 of 4

Import method:

Structure of the Data to be Imported

Basic structure:

Frequency:

Import options:

Panel identifier series

Cross section ID series:

Date series:

	TIME	COUNTRY	MGVA_GDP	RR	FEC_CAP	GHG
1	2012	Austria	17.3	57.7	792	
2	2013	Austria	17.1	57.7	815	
3	2014	Austria	17.2	56.3	730	
4	2015	Austria	17.2	56.9	767	
5	2016	Austria	17.7	57.6	792	
6	2017	Austria	17.4	57.8	791	
7	2018	Austria	17.3	57.7	739	
8	2019	Austria	17.1	58.2	753	
9	2020	Austria	16.6	62.3	781	
10						

Cancel < Back Next > Finish

Figure 3.4. Dated Panel setup

Source: prepared by author.

After uploading and setting up the data to Eviews the equation specification is being formed. The equation is as follows (see Formula 3.11).

$$MGVA_{GDP} = \beta_1 + \beta_2 RR + \beta_3 FEC_{CAP} + \beta_4 GHG_{EMP} + \beta_5 YNE + \beta_6 YE + \beta_7 ICT + \beta_8 TE + \beta_9 RDP + \beta_{10} ET_{EMP} + \beta_{11} CI + \beta_{12} GERD_{GDP} + \beta_{13} BERD_{GDP} + \beta_{14} DERT_{CAP} + \beta_{15} EE + \beta_{16} GEI + \beta_{17} GRL + \varepsilon \quad (3.1.)$$

Where:

β_n - regression coefficient;

$MGVA_{GDP}$ – gross value added of the manufacturing sector, as a percentage of gross domestic product (%);

RR – recycling rate of municipal waste (%);

FEC_{CAP} – final energy consumption per capita (kg);

GHG_{EMP} – GHG emissions per employee in tons (kg);

YNE – young people neither in employment nor in education and training (%);

YE – graduates in tertiary education, in science, math, computing, engineering, manufacturing, construction per 1000 of population aged 20-29 (graduates);

ICT – employed ICT specialists (% of total employment);

TE – employment in technology and knowledge-intensive sectors (% of total employment);

RDP – research and development personnel (% of population in the labour force);

ET_{EMP} – environmental taxes per employee (million euro);

CI – corruption perception index (score);

$GERD_{GDP}$ – gross domestic expenditure on research and development in manufacturing sector (%);

$BERD_{GDP}$ – business enterprise expenditure on research and development in manufacturing sector (%);

$DERT_{CAP}$ – development of environment related technologies (inventions per person);

EE – government expenditure on education (% of GDP);

GEI – government effectiveness indicator (score);

GRL – government rule of law indicator (score);

ε – residual.

For panel options, fixed effects is being used. This is due to the reason that in this study, country-specific control is being prioritised. In addition, the study aims to analyse effects in the country over time, not across all of the countries. Finally, the Hausman test was performed to

justify this effect decision. To avoid the biased coefficient estimation, Least Squares estimation method has been applied. Least Squares will effectively address the unobserved, time-invariant heterogeneity across the countries by introducing dummies or demeaning the data. Once everything is set up, the equation is estimated.

Dependent Variable: MGVA_GDP Method: Panel Least Squares Date: 05/01/25 Time: 18:14 Sample: 2012 2022 Periods included: 11 Cross-sections included: 26 Total panel (unbalanced) observations: 198				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	20.66318	2.303938	8.968637	0.0000
RR	0.037800	0.014511	2.604845	0.0101
FEC_CAP	-0.004660	0.001972	-2.363645	0.0193
GHG_EMP	-0.000263	0.000239	-1.097114	0.2743
YNE	-0.035073	0.044620	-0.786030	0.4330
YE	0.021601	0.032317	0.668413	0.5049
ICT	-0.508451	0.230000	-2.210654	0.0285
TE	-0.302516	0.255985	-1.181775	0.2391
RDP	-0.353186	0.868682	-0.406577	0.6849
ET_EMP	-0.857587	0.839743	-1.022466	0.3081
CI	0.001291	0.011756	0.109839	0.9127
GERD_GDP	0.360449	0.689423	0.522827	0.6018
BERD_GDP	-1.245862	1.151390	-1.082050	0.2809
DER_T_CAP	0.009564	0.019344	0.494389	0.6217
EE	0.053495	0.142821	0.374559	0.7085
GEI	-0.259982	0.341157	-0.762061	0.4472
GRL	0.102505	0.381552	0.268652	0.7886
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.980621	Mean dependent var	14.34899	
Adjusted R-squared	0.975527	S.D. dependent var	4.826268	
S.E. of regression	0.755010	Akaike info criterion	2.461660	
Sum squared resid	88.92623	Schwarz criterion	3.159171	
Log likelihood	-201.7043	Hannan-Quinn criter.	2.743989	
F-statistic	192.5312	Durbin-Watson stat	0.871924	
Prob(F-statistic)	0.000000			

Figure 3.5. Experimental model results

Source: prepared by author.

Following multiple tests and different combinations with the most effective 7 indicators, an initial model has been developed.

$$MGVA_{GDP} = \beta_1 + \beta_2 RR + \beta_3 FEC_{CAP} + \beta_4 GHG_{EMP} + \beta_5 YNE + \beta_6 YE + \beta_7 ET_{EMP} + \beta_8 CI + \varepsilon \quad (3.2.)$$

Dependent Variable: MGVA_GDP				
Method: Panel Least Squares				
Date: 05/01/25 Time: 18:25				
Sample: 2012 2022				
Periods included: 11				
Cross-sections included: 27				
Total panel (unbalanced) observations: 259				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.97454	2.095045	5.715648	0.0000
RR	0.009860	0.015187	0.649220	0.5169
FEC_CAP	-0.002776	0.002181	-1.272956	0.2043
GHG_EMP	0.000692	0.000224	3.083278	0.0023
YNE	-0.073152	0.049700	-1.471862	0.1425
YE	0.134036	0.037930	3.533796	0.0005
ET_EMP	-0.781928	0.654316	-1.195031	0.2333
CI	-0.007900	0.004889	-1.615755	0.1075
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.961591	Mean dependent var	14.00386	
Adjusted R-squared	0.955958	S.D. dependent var	5.221325	
S.E. of regression	1.095755	Akaike info criterion	3.142586	
Sum squared resid	270.1530	Schwarz criterion	3.609505	
Log likelihood	-372.9649	Hannan-Quinn criter.	3.330315	
F-statistic	170.6988	Durbin-Watson stat	0.454228	
Prob(F-statistic)	0.000000			

Figure 3.6. Model results: 7 KPIs model

Source: prepared by author.

After improving the model by removing the variables that have a probability of more than 0.05, the model estimation is repeated.

$$MGVA_{GDP} = \beta_1 + \beta_2 FEC_{EMP} + \beta_3 GHG_{EMP} + \beta_4 YE + \beta_5 EPE + \varepsilon \quad (3.3.)$$

Dependent Variable: MGVA_GDP				
Method: Panel Least Squares				
Date: 04/20/25 Time: 14:31				
Sample: 2012 2022				
Periods included: 11				
Cross-sections included: 27				
Total panel (unbalanced) observations: 264				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.29885	2.019944	5.098582	0.0000
FEC_CAP	-0.005518	0.002528	-2.182714	0.0301
GHG_EMP	0.001024	0.000250	4.095299	0.0001
YNE	-0.133072	0.052446	-2.537325	0.0118
YE	0.248932	0.041236	6.036717	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.951851	Mean dependent var	14.28788	
Adjusted R-squared	0.945652	S.D. dependent var	5.671864	
S.E. of regression	1.322266	Akaike info criterion	3.506509	
Sum squared resid	407.3742	Schwarz criterion	3.926412	
Log likelihood	-431.8591	Hannan-Quinn criter.	3.675239	
F-statistic	153.5386	Durbin-Watson stat	0.953502	
Prob(F-statistic)	0.000000			

Figure 3.7. Model results: 4 KPI model

Source: prepared by author.

From the results it is clearly visible that all the variables are very significant as the probability is below 0.05.

- 1) $FE C_{CAP}$ – the model illustrates a negative impact, meaning that an increase of the unit in the energy consumption per capita results in a reduction of GVA from manufacturing by 0.005%. This highlights that the energy inefficiency correlates with lower industrial productivity & sustainability problems.
- 2) GHG_{EMP} – the model shows a positive and a very significant correlation. Each ton of GHG emissions per employee raises the gross value added in manufacturing sector, % of GDP by 0.001%. This shows that the industrial intensity drives value creation and together emissions. A industrial growth and environmental impact.
- 3) YNE – a strong negative coefficient, a 1.3% increase in young people neither in employment nor in education and training reduces the GVA output by 0.13%. This shows that social disengagement of youth negatively impacts manufacturing output.
- 4) YE – shows the strongest positive effect – a unit increase in STEM graduates raises $MGVA_{GDP}$ by 0.25%. This shows that education quality improves the innovation driven value creation in the manufacturing sector.

The R-squared explains the 95.2% of the variance, which confirms the excellent fit of the model. The adjusted R-squared, at 94.7% confirms the model's robustness and its adjustment for regressors. The F-static, being at 153.538 illustrates that the model is statistically meaningful. The Durbin-Watson statistic of 0.953502 – indicates a positive serial correlation. However, it is important to note that this is a common occurrence in panel datasets, as the country level indicators are historically following the same time trends. In addition, the ESG indicators are inherently correlated, seemingly feeding one another in terms of innovation and environmental impact. The limitation of the autocorrelation is acknowledged, and in the future will be explored more with more dynamic panel model application and lagged variables.

After generating the residual vs actual vs fitted graph, the illustration was analysed.

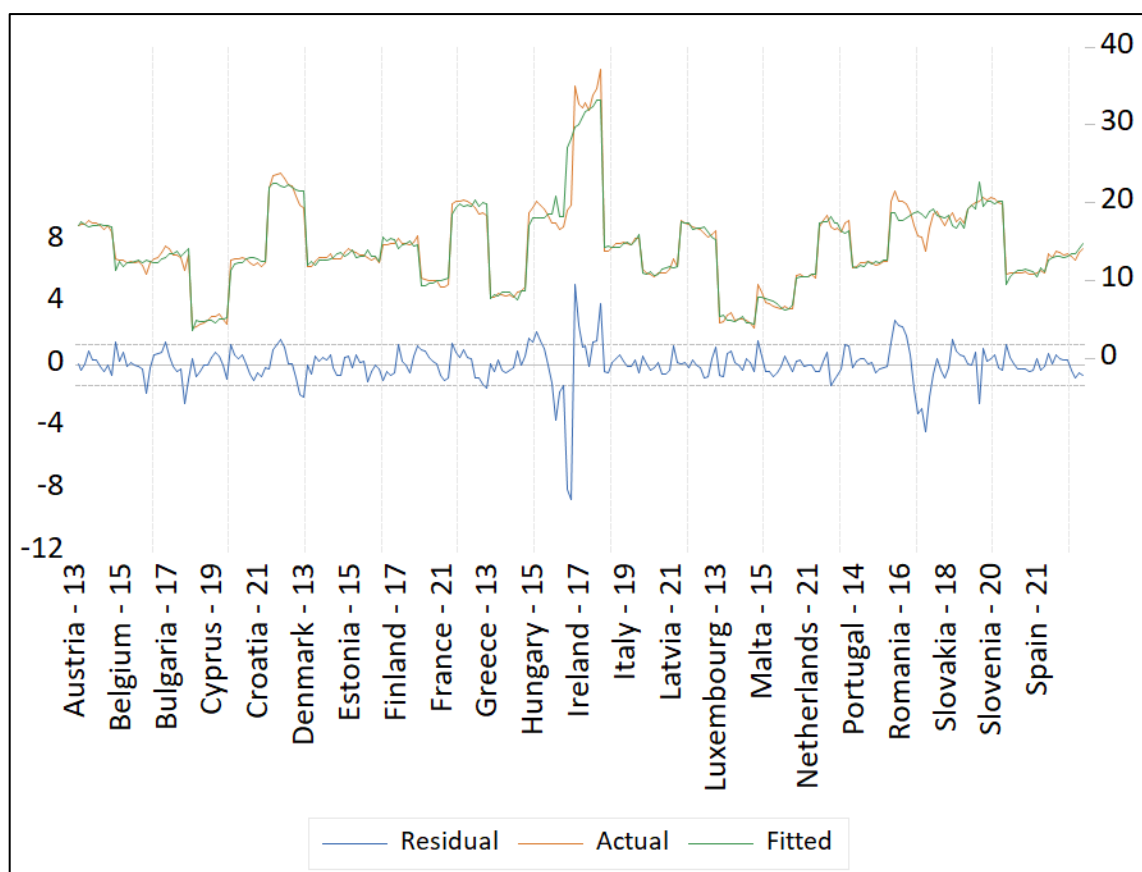


Figure 3.8. Model residual vs actual vs fitted graph

Source: prepared by author.

In the graph the actual line closely aligns with the fitted line, indicating that the predictive accuracy across all the countries and years is very high. The blue residual line is near 0 value, with exception - Ireland. This signals that the country specific factors are very important. Factors like export performance, economic volatility and other policy changes may have affected this residual line. This illustrates the need to consider unique national contexts, when analysing the model results.

All in all, the performed empirical analysis confirms the raised hypothesis – ESG-based indicators, particularly from the environmental, social, and governance pillars, have a statistically significant impact on innovation output in the manufacturing sector of EU-27 countries. Using the panel data from the year 2012 to 2022 and utilising the Eviews tool with Least Squares estimation method, the model indicates meaningful relationships between the variables and the innovation output, which is measured by the gross value added in the manufacturing sector as a percentage of GDP. The key observations are:

- GHG emissions per employee shows that the industrial intensity drives value creation and together emissions. A industrial growth and environmental impact.
- Graduates in STEM related education have a highly significant relationship with GVA, highlighting the importance of skilled workforce for the output growth in manufacturing.
- Final energy consumption per capita highlights that the energy inefficiency corelates with lower industrial productivity & sustainability problems.
- Youth disengagement show significant effects, signaling that labour market is shaping the manufacturing performance.
- The Durbin-Watson statistic of 0.953502 – shows autocorrlation, however, in the interpretable range. As the nature of the panel data & the ESG indicators are always interconnected.
- A noticable deviation in a residual graph for Ireland. This signals potential political and economical factors, that could have impacted national manufacturing performance.

The resulktis illustrate that ESG indicators influence the outupt in the manufacturing sector. The 4 KPI are clear and easily interpretable, also focusing on sustainability.

3.2. Limitations of the 4 KPI model

While the results of the model estimation have indicated some significant results and provided detailed insights on the relationships between different indicators and manufacturing sector performance, some limitations still emerged.

1. Inconsistency in units of measurement. One of the main issues with the generated model is its inconsistency with the units of the variables. In the model are included both nominal and percentage based idnicators. This makes their comparability and interpretability more complicated.
 - Nominal values – the final energy consumption per capita and the greenhouse gass emissions per employee bot were expressed in kilograms of oil equivalent per person and tons per person;
 - Percentage / ratio values – the *YNE* and *YE* variables were expressed as percentages or ratios of population groups.

Such mismatch of units can make the cross-variable analysis less robust, as the regression coefficients for nominal values and percentage based value do not carry the same proportional meaning.

2. Autocorelation. Even though the observed corelation is explainable, it is important to adress that the model does contain some variables that capture pretty much the same environmental impact: final energy consumption per capita and GHG emissions per employee. Such modeling can inflate the standard errors and reduce the robustness of the model.
3. ESG standartization. The created model does not capture a structured ESG framework. Only the environmental pillar was covered by the GHG_{EMP} and FEC_{CAP} indicators, and the social pillar with the YNE & YE indicators. This highlights that the governance pillar was not adressed.

Table 3.1. Initial ESG model illustration

ESG PILLARS	INDICATORS
ENVIRONMENTAL	- Final energy consumption per capita (kilograms of oil equivalent) - GHG emissions per employee (tons)
SOCIAL	- Young people neither in employment nor in education and training (%); - Graduates in tertiary education, in science, math, computing, engineering, manufacturing, construction (per 1000 of population aged 20-29);
GOVERNANCE	NO INDICATORS

Source: prepared by author.

To adress these limitations, the model will be reworked by the following actions:

- More indicators are going to be introduced in order to express the model in the same unit across all variables;
- More indicators are going to be implemented to adress the governance pillar.

- The introduced indicators will be less related to one another, with the idea of reducing the colinearity.

3.3. Final model development

In order to address the previously observed limitations, additional indicators are being introduced, where:

HTE – exports of high technology products as a share of total exports (%);

RE – share of renewable energy in gross final energy consumption (%);

EPE - national environmental protection investments of total economy, (% of GDP).

The added indicators are all expressed in percentages, in order to improve the interpretability of the results by making the model more harmonized. The introduction of the renewable energy indicator adds a percentage based item to the environmental pillar. In addition, the indicators such as the high-tech exports and the national environmental protection investments of total economy will cover the governance pillar of ESG, as it is linked to strategic economic planning and institutional support. The mentioned indicators are collected from Eurostat database to ensure reliability.

Table 3.2. A fragment of a 4 KPI model panel data set

TIME	COUNTRY	mGVA_GDP	HTE	RE	FEC_cap	GHG_emp	YE	YNE	EPE
2012	Austria	17,30	12,72	143,28	792	7022,88	:	6,80	:
2013	Austria	17,10	14,18	144,49	815	6946,67	22,20	7,30	:
2014	Austria	17,20	14,35	148,97	730	6824,36	23,00	7,70	:
2015	Austria	17,20	14,16	149,62	767	6881,83	21,90	7,50	:
2016	Austria	17,70	13,88	149,95	792	6676,2	22,10	7,70	:
2017	Austria	17,40	14,78	148,14	791	6798,58	22,00	6,50	:
2018	Austria	17,30	13,83	152,08	739	6325,17	22,80	6,80	3,10
2019	Austria	17,10	13,88	152,80	753	6485,87	23,40	7,10	3,10
2020	Austria	16,60	14,83	160,03	781	6341,62	24,40	8,00	3,00
2021	Austria	17,00	13,97	151,67	866	6712,15	25,00	8,50	3,40
2022	Austria	16,20	13,33	150,92	762	6089,05	24,30	8,10	3,20
2012	Belgium	12,60	8,56	30,45	762	8198,57	:	12,30	:
2013	Belgium	12,70	8,71	32,95	814	8227,31	13,00	12,70	:
2014	Belgium	12,60	9,70	35,05	664	8244,61	14,00	12,00	3,20
2015	Belgium	12,60	10,27	35,50	730	8206,53	13,30	12,20	3,10
2016	Belgium	12,20	10,00	38,85	729	8184,44	14,30	9,90	3,10
2017	Belgium	12,40	9,76	41,19	715	8146,61	13,60	9,30	3,30
2018	Belgium	12,30	10,21	43,36	704	8062,54	14,00	9,20	3,30
2019	Belgium	12,40	11,95	45,88	653	7897,44	14,20	9,30	3,30
2020	Belgium	12,00	13,83	57,60	657	7340,68	15,70	9,20	3,30
2021	Belgium	10,70	17,08	58,69	708	7419,76	16,40	7,40	3,30
2022	Belgium	12,20	15,05	63,91	604	6606,73	16,40	6,60	3,40
2012	Bulgaria	14,10	3,82	59,54	322	2637,04	:	21,50	:
2013	Bulgaria	12,80	3,97	72,70	313	2642,02	14,60	21,60	:
2014	Bulgaria	13,00	3,94	71,00	306	2658,1	14,20	20,20	3,30
2015	Bulgaria	13,60	4,42	72,63	314	2946,51	14,60	19,30	3,00
2016	Bulgaria	14,40	5,14	75,10	327	3184,58	13,90	18,20	2,20
2017	Bulgaria	14,00	5,37	74,84	341	3247,23	14,30	15,30	2,00
2018	Bulgaria	13,30	6,02	84,26	332	3304,29	13,60	15,00	1,80
2019	Bulgaria	13,30	6,32	88,37	327	3338,29	14,00	13,70	2,00
2020	Bulgaria	12,90	6,80	93,18	364	3284,49	13,10	14,40	2,00
2021	Bulgaria	11,20	6,41	78,49	369	3435,26	14,40	13,90	2,00
2022	Bulgaria	13,20	5,48	78,43	331	3431,23	14,60	12,30	1,80
2012	Cyprus	4,20	11,73	33,80	405	2935,4	:	16,00	:

Source: prepared by author based on Eurostat (2024a-o), OECD (2024), World Bank Group (2024a-b) and Transparency International (2024).

Once all data is collected & structured, it is uploaded into the Eviews software. The data is set up accordingly as per figures 3.1 – 3.4. Specification equation is formed:

$$MGVA_{GDP} = \beta_1 + \beta_2 HTE + \beta_3 RE + \beta_4 GHG_{EMP} + \beta_5 YNE + \beta_6 YE + \beta_7 EPE + \varepsilon \quad (3.4.)$$

As for the initial model, the fixed effects and Least Squares estimation method are being implemented. The equation estimation is activated.

Dependent Variable: MGVA_GDP				
Method: Panel Least Squares				
Date: 04/20/25 Time: 17:00				
Sample (adjusted): 2014 2022				
Periods included: 9				
Cross-sections included: 27				
Total panel (unbalanced) observations: 191				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	17.02134	3.157611	5.390574	0.0000
HTE	0.128617	0.040211	3.198593	0.0017
RE	-0.017366	0.013422	-1.293833	0.1976
FEC_CAP	-0.007063	0.003116	-2.266659	0.0248
GHG_EMP	0.000294	0.000420	0.699435	0.4853
YE	0.150883	0.048865	3.087766	0.0024
YNE	-0.034084	0.069690	-0.489081	0.6255
EPE	-1.231982	0.408495	-3.015901	0.0030
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.965372	Mean dependent var	14.18743	
Adjusted R-squared	0.958094	S.D. dependent var	5.885124	
S.E. of regression	1.204744	Akaike info criterion	3.370404	
Sum squared resid	227.8710	Schwarz criterion	3.949343	
Log likelihood	-287.8736	Hannan-Quinn criter.	3.604901	
F-statistic	132.6345	Durbin-Watson stat	1.552735	
Prob(F-statistic)	0.000000			

Figure 3.9. Updated 7 KPI model results

Source: prepared by author.

A Hausman test has been performed in order to compare the Fixed Effects against the Random effects. The results have confirmed the possibility of proceeding with the Fixed Effects.

Correlated Random Effects - Hausman Test				
Equation: Untitled				
Test cross-section random effects				
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	
Cross-section random	10.420075	7	0.1660	
Cross-section random effects test comparisons:				
Variable	Fixed	Random	Var(Diff.)	Prob.
HTE	0.128617	0.128693	0.000149	0.9950
RE	-0.017366	-0.011604	0.000047	0.4013
FEC_CAP	-0.007063	-0.004250	0.000002	0.0425
GHG_EMP	0.000294	0.000380	0.000000	0.7031
YE	0.150883	0.169439	0.000189	0.1766
YNE	-0.034084	-0.018534	0.000282	0.3540
EPE	-1.231982	-1.055164	0.011613	0.1008
Cross-section random effects test equation:				
Dependent Variable: MGVA_GDP				
Method: Panel Least Squares				
Date: 04/20/25 Time: 17:23				
Sample (adjusted): 2014 2022				
Periods included: 9				
Cross-sections included: 27				
Total panel (unbalanced) observations: 191				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	17.02134	3.157611	5.390574	0.0000
HTE	0.128617	0.040211	3.198593	0.0017
RE	-0.017366	0.013422	-1.293833	0.1976
FEC_CAP	-0.007063	0.003116	-2.266659	0.0248
GHG_EMP	0.000294	0.000420	0.699435	0.4853
YE	0.150883	0.048865	3.087766	0.0024
YNE	-0.034084	0.069690	-0.489081	0.6255
EPE	-1.231982	0.408495	-3.015901	0.0030
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.965372	Mean dependent var	14.18743	
Adjusted R-squared	0.958094	S.D. dependent var	5.885124	
S.E. of regression	1.204744	Akaike info criterion	3.370404	
Sum squared resid	227.8710	Schwarz criterion	3.949343	
Log likelihood	-287.8736	Hannan-Quinn criter.	3.604901	
F-statistic	132.6345	Durbin-Watson stat	1.552735	
Prob(F-statistic)	0.000000			

Figure 3.10. Updated 7 KPI model Hausman test results

Source: prepared by author.

After analysing the results, the model does show promising results with an increased Durbin-Watson statistics and the promising R-squared and Adjusted R-squared results. Considering this, the decision is being taken to proceed with further model development.

Variables with p-value of more than 0.05 are being removed. Furthermore, items with nominal units are being removed from the equation. Model equation specification is updated (see Formula 3.5.)

$$MGVA_{GDP} = \beta_1 + \beta_2 HTE + \beta_3 RE + \beta_4 YE + \beta_5 EPE + \varepsilon \quad (3.5.)$$

Dependent Variable: MGVA_GDP				
Method: Panel Least Squares				
Date: 04/20/25 Time: 17:14				
Sample (adjusted): 2014 2022				
Periods included: 9				
Cross-sections included: 27				
Total panel (unbalanced) observations: 191				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.00733	1.262433	11.09550	0.0000
HTE	0.131522	0.037327	3.523518	0.0006
RE	-0.020074	0.009650	-2.080076	0.0391
YE	0.150437	0.047877	3.142174	0.0020
EPE	-1.185219	0.400046	-2.962704	0.0035
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.964207	Mean dependent var	14.18743	
Adjusted R-squared	0.957495	S.D. dependent var	5.885124	
S.E. of regression	1.213315	Akaike info criterion	3.372097	
Sum squared resid	235.5413	Schwarz criterion	3.899953	
Log likelihood	-291.0353	Hannan-Quinn criter.	3.585904	
F-statistic	143.6701	Durbin-Watson stat	1.434960	
Prob(F-statistic)	0.000000			

Figure 3.11. Final 4 KPI model results

Source: prepared by author.

From the results it is clearly visible that all the variables are very significant at the 5% level, and the *HTE*, *YE* and *EPE* at the 1%.

- 1) *HTE* – the model shows that for every 1% increase in high-tech exports, there is a 0.13% increase in the manufacturing value added as % of GDP. This shows that the export competitiveness of the innovative technologies is a key driver for

manufacturing performance among the European Union countries. This can also indicate the industrial maturity and innovation capacity of the countries.

- 2) *RE* – an indication that for 1% increase in the share renewable energy in final energy consumption, there is a 0.02% decrease in manufacturing value added (% of GDP). Such result may indicate that there are complications amongst the manufacturing companies to introduce a transition to green energy, as well as probable higher costs and affect on the traditional, high-output energy sources. However, it is important to note that renewable energy is very important for sustainability, and such complications may be only short-term.
- 3) *YE* – a strong coefficient, showing that a unit increase of STEM graduates per 1000 young people increases the manufacturing gross value added by 0.15% - a very similar result to the previous model. This shows that education quality improves the innovation driven value creation in the manufacturing sector.
- 4) *EPE* – shows the strongest negative effect – a 1% increase in the environmental protection expenditure is associated with 1.18% decrease in manufacturing sector's GVA. This shows that due to regulatory compliance, increased costs, and disruptions, the performance in the manufacturing sector may be affected. However, it is important to highlight that environmental protection expenditure is key for sustainability, and this may only be a short-term trade-off.

The model also depicts better results than the initial model:

- The R-squared explains the 96.4% of the variance, which confirms the excellent fit of the model.
- The adjusted R-squared, at 95.8% confirms the model's robustness and its adjustment for regressors.
- Durbin-Watson statistic of 1.434960 - a mild positive autocorrelation, however it is not severe and is a big improvement from the previous model. The existing autocorrelation is explainable considering the nature of panel datasets, as the country level indicators are historically following the same time trends. In addition, the ESG indicators are inherently correlated, seemingly feeding one another in terms of innovation and environmental impact.
- The F-static, being at 143.6701 illustrates that the model is statistically meaningful.

After generating the residual vs actual vs fitted graph, the illustration was analysed.

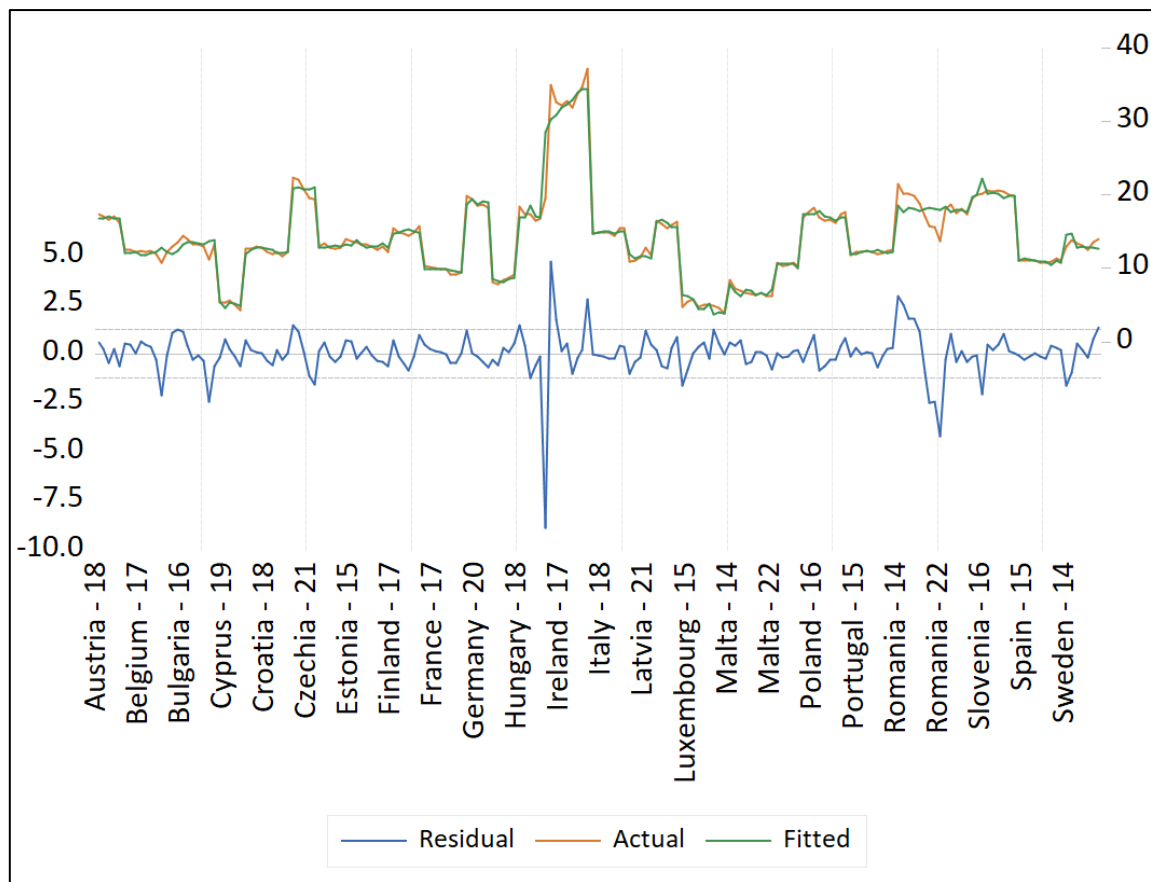


Figure 3.12. Final 4 KPI model residual vs actual vs fitted graph

Source: prepared by author.

The actual and fitted lines are closely aligned once again, indicating that the predictive accuracy across all the countries and years is very high. The residual line is near 0 value, with an exception –Ireland – a similar result to the previous model with different variables. This confirms that the country specific factors are very important. As with the previous model graph, the need to consider unique nationl contexts, is required when analysing the model results.

All in all, the developed model does confirm a strong relationship between ESG-based KPI and innovation performance in the manufacturing sector across 27 EU countries. By ensuring that all variable measurement units are synchronised and all of the ESG pillars are covered, the results are more robust and reliable. This model serves as an improvement to the previous one. The results confirm that the chosen indicators are all very significant to gross value added in the manufacturing sector. The high-tech exports indicate that competitiveness and technological intensity are very important for output in the manufacturing sector. In addition, the role of STEM graduates is key and reflects how important is the educated youth and human capital are for value creation. Indicators such as renewable energy share and

environmental protection expenditure reflect the complicated relationship between the environmental awareness and manufacturing. Both indicators showed a negative affect on the gross value added in the manufacturing sector. However, it highlights that this could be only a short term trade-off and that ways should be developed to reduce the negative short term effects of sustainable solutions.

Finally, the model does confirms that ESG based key performance indicators do have a significant impact on the output in the manufacturing sector. By implementing the environmental, social and governance indicators, manufacturing companies can create an environment for more sustainability focused innovative solutions.

3.4. Proposed model: innovation KPI with focus on sustainability for EU manufacturing companies

To finalise the study, the final framework of Key Performance Indicators of innovations with focus on sustainability is formed. This framework integrates environmental, social and governance related indicators to measure the output in the manufacturing sector. This framework may serve as a tool for companies and policymakers to assist them in staying competitive, assessing their impacts on innovation and sustainable development.

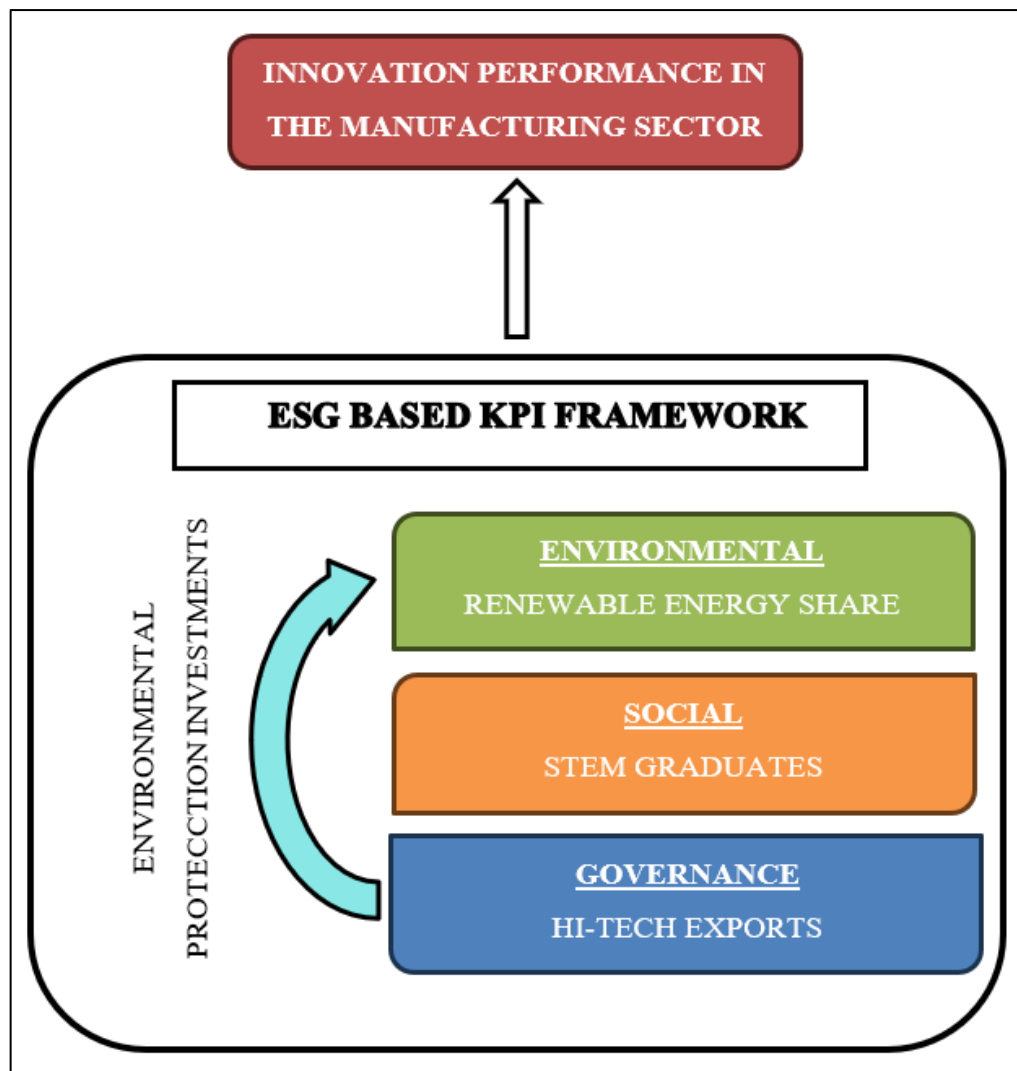


Figure 3.13. Final KPI Model

Source: prepared by author.

The presented framework draws inspiration from the reviewed literature, incorporating ESG based indicators due to their successful affect on the innovation output and sustainability. The framework robustness and effectivity has been confirmed by the performed panel data analysis, ranging from 2012 to 2022 for 27 European Union countries. The framework presents 4 key indicators, that represent environmental awareness, social education, government transparency. The indicators were chosen due to their significant impact on the gross value added in the manufacturing sector.

- 1) Exports of high technology products as a share of total exports (%) shows that the export competitiveness of the innovative technologies is a key driver for

manufacturing performance among the European Union countries. This can also indicate the industrial maturity and innovation capacity of the countries.

- 2) Share of renewable energy in gross final energy consumption (%) indicates that there are complications amongst the manufacturing companies to introduce a transition to green energy, as well as probable higher costs and affect on the traditional, high-output energy sources. However, it is important to note that renewable energy is very important for sustainability, and such complications may be only short-term.
- 3) Graduates in tertiary education, in science, math, computing, engineering, manufacturing, construction (per 1000 of population aged 20-29) shows that education quality improves the innovation driven value creation in the manufacturing sector.
- 4) National environmental protection investments of total economy, (% of GDP) shows that due to regulatory compliance, increased costs, and disruptions, the performance in the manufacturing sector may be affected. However, it is important to highlight that environmental protection expenditure is key for sustainability, and this may only be a short-term trade-off.

Integration of such framework assists companies in their longterm planning and performance monitoring, making them competitive and resilient for any changes in the global market.

CONCLUSIONS AND RECOMMENDATIONS

Key Performance Indicators framework has been established, meant to measure the sustainability effect of innovations. The framework can be used as a tool by companies to measure their innovation and sustainability impact, in order to stay competitive, attract stakeholder and labour attention, and reach their longterm goals.

1. Literature analysis has provided valuable insights into existing KPI frameworks used by manufacturing companies and confirmed them playing a role in company success. In addition, the reviewed literature has highlighted the ESG based factors, indicating the necessity of including environment, governance and social indicators to drive innovation and sustainability. Furthermore, literature has revealed that green patents and high-technology exports are a great representation of a countries innovation output, while the government transparency and corruption index are a representation of countries commitment to sustainability. A major finding was observed that STEM education is a key driver for innovation, as a well educated labour provides great literacy, creativity and long-term planning to their respective employers.
2. Methodologies used by researchers have been examined through literature review. It is noted that primary and secondary data researches are often used due to the insights that they both provide. A decision is made to implement an econometric panel data research on an macro-level. 27 European Union countries have been analysed from the year 2012-2022. The data for the conceptual framework has been collected from Eurostat, OECD and World bank databases and structured in a panel data. The following hypothesis has been raised: *„ESG-based indicators, particularly from the environmental, social, and governance pillars, have a statistically significant impact on output in the manufacturing sector of EU-27 countries.“*
3. With the use of Eviews the empirical analysis has been performed. Different combinations of indicators have been tested in order to find the most effective model. The following model of 4 indicators has been identified as the most robust and reliable. Empirical research has confirmed a strong relationship between ESG-based KPI and performance in the manufacturing sector across 27 EU countries. The actual vs residual graph has been generated. Actual and fitted lines are closely aligned indicating that the predictive accuracy across all the countries and years is very high. The residual line is near 0 value, with an exception – Ireland. This confirms that the

country specific factors are very important. Based on the empirical results, 4 key performance indicators have emerged as having an impact on the gross value added in the manufacturing sector:

- 1) Exports of high technology products as a share of total exports (%) for every 1% increase in high-tech exports, there is a 0.13% increase in the manufacturing value added as % of GDP.
- 2) Share of renewable energy in gross final energy consumption (%) –for 1% increase in the share renewable energy in final energy consumption, there is a 0.02% decrease in manufacturing value added (% of GDP).
- 3) Graduates in tertiary education, in science, math, computing, engineering, manufacturing, construction (per 1000 of population aged 20-29) –a unit increase of STEM graduates per 1000 young people increases the manufacturing gross value added by 0.15%.
- 4) National environmental protection investments of total economy, (% of GDP) – a 1% increase in the environmental protection expenditure is associated with 1.18% decrease in manufacturing gross value added.

4. Based on the empirical research results, several recommendations could be made for manufacturing industry leaders and stakeholders:

- 1) Prioritisation of High-Tech exports. As per empirical analysis results, it is clear that the high technology export indicator has shown to have the most significant relationship with the gross value added in the manufacturing sector. So in order to boost innovation performance and international competitiveness, companies should invest more into the production of high value technology, digitalisation & export diversity.
- 2) Improve STEM oriented education. As per results of the modelling, there is a significant impact of the share of STEM graduates. This highlights the importance of educated society and its ability to drive innovation. Considering this, European Union countries should continue improving the quality and accessibility of the tertiary education, specifically in science, engineering, maths and other related fields. In addition, collaboration between the companies and universities could ensure that the students will have the necessary skills required once they graduate.
- 3) Integration of renewable energy into manufacturing processes. Usage of renewable energy in manufacturing sector is key in ensuring a positive affect on

the environment. Companies should be investing more into renewable energy sources, making the energy intervention seem-less.

- 4) Investment into environmental protection. Even though the impact is negative, companies should look at it not as a costly endeavour, but an enabler of innovation. Investing into waste management, green production technologies and emission control will all contribute in ensuring companies longevity and competitiveness.
- 5) Align with ESG objectives. The research has shown that aligning with ESG objectives does have a valuable result. That is why companies should be incorporating ESG KPI for industrial performance monitoring and sustainability reporting. All these recommendations highlight the importance of environmental, social and governance indicators for manufacturing company success and competitiveness, while at the same time driving sustainable innovation.

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APPENDIXES

Appendix A. 28th Lithuanian Junior Researchers Conference “Science - Future of Lithuania” presentation

**VILNIUS
TECH**
Faculty of
Transport Engineering

Key Performance Indicators of innovations with focus on sustainability

Student – Irvin Koricki PIVfmu-23
Supervisor – Ruta Baneliene

25-04-2025

Research aim & objectives	
RESEARCH AIM	RESEARCH OBJECTIVES
Contribute to sustainability;	Existing KPI identification through Literature Analysis;
Development of a sustainability focused tool for companies to utilize;	Preparation of a conceptual KPI framework;
Define a KPI framework for sustainable innovation;	Data collection;
	Empirical testing;
	Final KPI framework establishment;

1

LITERATURE ANALYSIS

2

ESG

- Publication „What is ESG (environmental, social and governance)?“ by writer Alexander S. Gillis;
- Numerous regulations;
 - Reporting system;
 - Significant tool;
- Organizations sustainability, social affects;

3 pillars of ESG



3

ESG in Innovation & Sustainability

AFFECT ON INNOVATION & SUSTAINABILITY

Article „ESG and Innovation: Driving Sustainable Solutions“, published by a GENECAPSULE;	Publishing „Harnessing the Power of ESG Reporting to Foster Innovation and Growth: A Catalyst for a Sustainable Future“ by iRISCARBON;
Circular Economy	Market differentiation
Renewable Energy solutions	Cost reduction
Sustainable Supply Chains	Access to capital
Social Innovations	Attracting talent

4

KPI FRAMEWORK BASED ON ESG

ADEC KPI FRAMEWORK		
ENVIRONMENTAL	SOCIAL	GOVERNANCE
Energy consumption	Worker health and safety incidents	Board and management diversity metrics
Fuel consumption	Diversity and inclusion metrics	Executive compensation
Water consumption	Compensation equality metrics	Transparency of environmental, social and governance policies
Greenhouse gas emissions	Metrics related to human rights and labor policies	Disclosure and reporting programs
Resource efficiency metrics (energy, water, other materials)		

5

KPI FRAMEWORK BASED ON ESG

Non-financial Targets (ESG KPIs)		
Become a company which all our stakeholders feel an affinity and are able to say, "I like Toyota Boshoku"		
	Major KPIs	Targets for 2030
E Environment	Production GHG emissions reduction ratio (total volume) New	Down 50% (compared to FY2020)
	Scope 3 emissions reduction ratio (total volume) New	Down 30% (compared to FY2020)
	Number of products developed taking recyclability into consideration New	Under consideration
S Society	Number of AI/IoT-based "people-friendly" advanced technologies installed New	Under consideration
	Ratio of people who take regular exercise (aged 40 or more) New	30%
	Ratio of female managers New	5%
G Governance	Ratio of local employees in presidents of overseas entities New	80%
	Degree of implementation of the Toyota Boshoku Group Guiding Principles	90%
	Number of serious cyber security incidents	0

Realize
"I like Toyota
Boshoku"

QUALITY OF TIME AND SPACE

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TOYOTA BOSHOKU

6

ESG IN MANUFACTURING & INDUSTRIAL ENGINEERING

Key Points from AlphaSense Article

- **Why ESG Matters in Manufacturing**
 - Manufacturing impacts: air & water pollution, resource usage
 - Rising importance of worker safety & supply chain ethics
 - ESG adoption = increasing competitiveness and sustainability

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6 KEY ESG TRENDS IN MANUFACTURING

1. Smart Manufacturing
2. Supply Chain Transparency & Ethical Sourcing
3. Circular Economy
4. Innovation emphasis
5. Addressing Labor Shortages
6. Aligning with Customer ESG goals

8

ESG Success Stories:

Nike
Siemens
Unilever
L'Oreal
Nestle

9

METHODOLOGY

10

RESEARCH APPROACH & MODEL



- **Type of Analysis:**
 - Panel data regression analysis (2012–2022)
 - Covers 27 European Union countries
- **Research Goal:**
 - Analyze the relationship between ESG KPIs and innovation output in manufacturing

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SELECTED ESG-BASED INDICATORS



ENVIRONMENTAL	SOCIAL	GOVERNANCE
GHG emissions per employee (tons)	STEM graduates (per 1000 of pop. aged 20-29)	Environmental taxes per employee (mil. Eur)
Final energy consumption per capita (kg of oil equivalent)	Young people neither in employment nor education (%)	Corruption perception index (score)
Share of renewable energy in gross final energy consumption (%)		

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VARIABLE SELECTION STRATEGY



**Deductive approach → narrowing to
4 key indicators**

- Reasons for reduction:
 - **Degrees of freedom.**
 - **Multicollinearity.**

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INNOVATION OUTPUT



Gross Value Added of manufacturing sector (% of GDP)

*Reason – manufacturing GVA is strongly driven
by innovation and technology*

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RESEARCH HYPOTHESIS



*ESG-based indicators, particularly from the
environmental, social, and governance
pillars, have a statistically significant
impact on innovation output in the
manufacturing sector of EU-27 countries.*

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RESEARCH TOOL



EViews Software

- Complex panel data analysis
- Supports Fixed and Random effect models
 - Offers visual tools
 - User friendly interface



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DATA SOURCES



Eurostat, OECD,
Transparency
International

TIME	COUNTRY	MGVA_GDP	RE	FEC_cap	GHG_emp	YNE	YE	ET_emp	CI
2012	Austria	17,30	143,28	792	7022,88	6,80	:	0,66	69,00
2013	Austria	17,10	144,49	815	6945,67	7,30	22,20	0,65	75,00
2014	Austria	17,20	148,97	799	6834,36	7,70	21,00	0,65	41,00
2015	Austria	17,20	149,52	797	6681,83	7,50	21,50	0,65	46,00
2016	Austria	17,70	149,95	792	6676,2	7,70	22,10	0,63	66,00
2017	Austria	17,40	148,14	791	6795,58	6,50	22,00	0,66	49,00
2018	Austria	17,30	152,08	739	6325,17	6,80	22,80	0,73	90,00
2019	Austria	17,10	152,80	753	6435,87	7,10	23,40	0,75	64,00
2020	Austria	16,60	180,33	781	6341,82	8,00	24,40	0,65	90,00
2021	Austria	17,00	151,67	856	6712,15	8,50	25,00	0,77	71,00
2022	Austria	16,20	150,92	792	6085,05	8,10	24,30	0,7	79,00
2012	Belgium	12,60	30,45	762	8136,57	12,30	:	1,08	36,00
2013	Belgium	12,70	32,95	814	8227,31	12,70	13,00	1,07	55,00
2014	Belgium	12,60	35,05	664	8244,61	12,00	14,00	1,03	69,00
2015	Belgium	12,60	35,50	799	8296,53	12,20	13,30	1,05	42,00
2016	Belgium	12,20	38,95	729	8184,44	9,90	14,30	1,22	49,00
2017	Belgium	12,40	41,19	715	8146,61	9,30	13,60	1,34	54,00
2018	Belgium	12,30	43,38	704	8062,54	9,20	14,00	1,34	80,00
2019	Belgium	12,40	45,88	653	7897,44	9,30	14,20	1,39	57,00
2020	Belgium	12,00	57,60	637	7340,68	9,20	15,70	1,21	84,00
2021	Belgium	10,70	56,09	798	7415,76	7,40	16,40	1,3	56,00
2022	Belgium	12,20	63,91	804	6606,73	6,80	16,40	1,32	63,00
2012	Bulgaria	14,10	55,54	322	2637,04	21,50	:	0,34	44,00
2013	Bulgaria	12,80	72,70	313	2642,02	21,60	14,60	0,27	46,00
2014	Bulgaria	13,00	71,00	306	2658,1	20,20	14,20	0,27	61,00
2015	Bulgaria	13,60	72,63	314	2946,51	19,30	14,60	0,28	65,00
2016	Bulgaria	14,40	75,10	327	3184,56	18,20	13,90	0,3	68,00
2017	Bulgaria	14,00	74,84	341	3247,23	15,30	14,30	0,29	69,00
2018	Bulgaria	13,30	84,26	332	3304,29	15,00	13,60	0,31	75,00
2019	Bulgaria	13,30	88,37	327	3338,29	13,70	14,00	0,42	41,00
2020	Bulgaria	12,90	93,18	354	3284,49	14,40	13,10	0,45	48,00
2021	Bulgaria	11,20	76,49	389	3415,26	13,90	14,40	0,47	61,00
2022	Bulgaria	13,20	78,43	331	3411,23	12,30	14,40	1,21	48,00
2012	Cyprus	4,20	33,80	405	2933,4	15,00	:	0,44	80,00

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EMPIRICAL RESEARCH

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EXPERIMENTAL MODEL RESULTS

Dependent Variable: MGVA_GDP				
Method: Panel Least Squares				
Date: 04/20/25 Time: 14:30				
Sample: 2012 2022				
Periods included: 11				
Cross-sections included: 27				
Total panel (unbalanced) observations: 264				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.29184	2.847137	5.019724	0.0000
RE	-0.014007	0.010638	-1.318637	0.1893
FEC_CAP	-0.005348	0.002557	-2.091374	0.0376
GHG_EMP	0.000735	0.000316	2.325615	0.0209
YNE	-0.169092	0.057170	-2.957675	0.0034
YE	0.257199	0.042032	6.119100	0.0000
ET_EMP	-1.089372	0.782629	-1.391584	0.1654
CI	-0.008776	0.005777	-1.519044	0.1301
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.952944	Mean dependent var	14.28788	
Adjusted R-squared	0.946193	S.D. dependent var	5.671864	
S.E. of regression	1.315668	Akaike info criterion	3.506272	
Sum squared resid	398.1261	Schwarz criterion	3.965811	
Log likelihood	-428.8280	Hannan-Quinn criter.	3.691331	
F-statistic	141.1459	Durbin-Watson stat	1.004845	
Prob(F-statistic)	0.000000			

- **Fixed Effects Model**
 - o Prioritizes country-specific control
 - o Focus is on changes within countries over time, not across all countries
 - o Hausman test was conducted to confirm model selection
- **Least Squares Estimation**
 - o Addresses unobserved, time-invariant heterogeneity
 - o Introduces country dummies or demeanes the data
 - o Prevents biased coefficient estimation

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INITIAL MODEL RESULTS

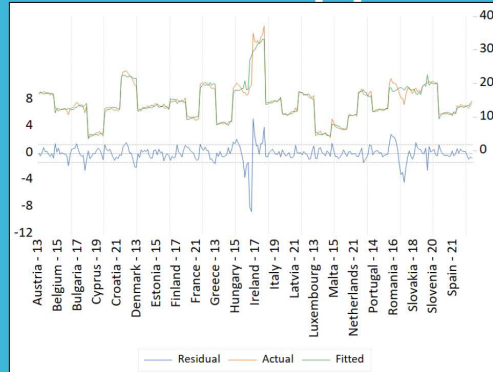
Dependent Variable: MGVA_GDP
Method: Panel Least Squares
Date: 04/20/25 Time: 14:31
Sample: 2012 2022
Periods included: 11
Cross-sections included: 27
Total panel (unbalanced) observations: 264

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.29885	2.019944	5.098582	0.0000
FEC_CAP	-0.005518	0.002528	-2.182714	0.0301
GHG_EMP	0.001024	0.000250	4.095299	0.0001
YNE	-0.133072	0.052446	-2.537325	0.0118
YE	0.248932	0.041236	6.036717	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.951851	Mean dependent var	14.28788
Adjusted R-squared	0.945652	S.D. dependent var	5.671864
S.E. of regression	1.322266	Akaike info criterion	3.506509
Sum squared resid	407.3742	Schwarz criterion	3.920412
Log likelihood	-431.8591	Hannan-Quinn criter.	3.675239
F-statistic	153.5386	Durbin-Watson stat	0.953502
Prob(F-statistic)	0.000000		



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INITIAL ESG BASED KPI MODEL

ESG PILLARS	INDICATORS
ENVIRONMENTAL	- Final energy consumption per capita (kilograms of oil equivalent) - GHG emissions per employee (tons)
SOCIAL	- Young people neither in employment nor in education and training (%). - Graduates in tertiary education, in science, math, computing, engineering, manufacturing, construction (per 1000 of population aged 20-29).
GOVERNANCE	

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INITIAL KPI MODEL LIMITATIONS

Model Limitations



Unit mismatch

Mixed use of nominal (e.g. kg, tons) and percentage values reduces interpretability.



Autocorrelation

Positive serial correlation observed; some indicators may overlap in impact.



Incomplete ESG coverage

Governance pillar not included, limiting full ESG assessment.

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EXPERIMENTAL MODEL RESULTS

Dependent Variable: MGVA_GDP
Method: Panel Least Squares
Date: 04/20/25 Time: 17:00
Sample (adjusted): 2014 2022
Periods included: 9
Cross-sections included: 27
Total panel (unbalanced) observations: 191

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	17.02134	3.157811	5.390574	0.0000
HTE	0.128617	0.040211	3.198593	0.0017
RE	-0.017366	0.013422	-1.293833	0.1976
FEC_CAP	-0.007063	0.003116	-2.286659	0.0249
GHS_EMP	0.000294	0.000420	0.699435	0.4853
YE	0.150883	0.048865	3.087766	0.0024
YNE	-0.034084	0.069690	-0.489081	0.6255
EPE	-1.231982	0.408495	-3.015901	0.0030

Effects Specification

Cross-section fixed (dummy variables)			
R-squared	0.965372	Mean dependent var	14.18743
Adjusted R-squared	0.958094	S.D. dependent var	5.885124
S.E. of regression	1.204744	Akaike info criterion	3.370404
Sum squared resid	227.8710	Schwarz criterion	3.949343
Log likelihood	-287.8736	Hannan-Quinn criter.	3.604901
F-statistic	132.0345	Durbin-Watson stat	1.552735
Prob(F-statistic)	0.000000		

- **Fixed Effects Model**
 - Prioritizes country-specific control
 - Focus is on changes within countries over time, not across all countries
 - Hausman test was conducted to confirm model selection
- **Least Squares Estimation**
 - Addresses unobserved, time-invariant heterogeneity
 - Introduces country dummies or demeanes the data
 - Prevents biased coefficient estimation

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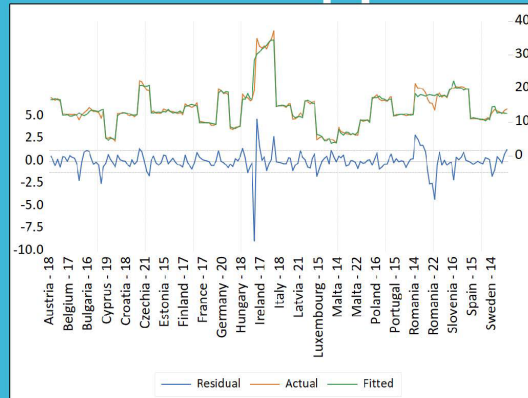
FINAL MODEL RESULTS

Dependent Variable: MGVA_GDP
Method: Panel Least Squares
Date: 04/20/25 Time: 17:14
Sample (adjusted): 2014 2022
Periods included: 9
Cross-sections included: 27
Total panel (unbalanced) observations: 191

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.00733	1.262433	11.09550	0.0000
HTE	0.131522	0.037327	3.523518	0.0006
RE	-0.020074	0.009650	-2.080076	0.0391
YE	0.150437	0.047877	3.142174	0.0020
EPE	-1.185219	0.400046	-2.962704	0.0035

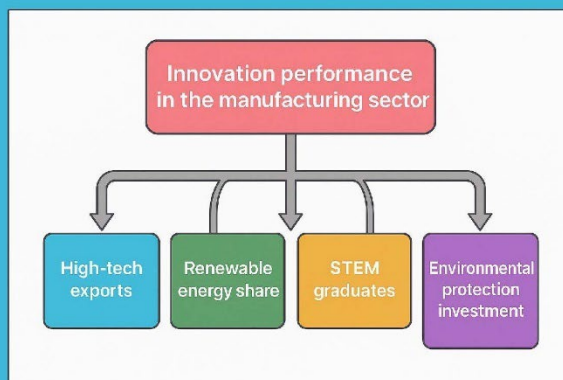
Effects Specification

Cross-section fixed (dummy variables)			
R-squared	0.964207	Mean dependent var	14.18743
Adjusted R-squared	0.957495	S.D. dependent var	5.885124
S.E. of regression	1.213315	Akaike info criterion	3.372097
Sum squared resid	235.5413	Schwarz criterion	3.899953
Log likelihood	-291.0353	Hannan-Quinn criter.	3.585904
F-statistic	143.6701	Durbin-Watson stat	1.434960
Prob(F-statistic)	0.000000		



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FINAL KPI MODEL



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CONCLUSION

- The model confirms a strong link between ESG indicators and innovation in EU manufacturing.
- Standardizing data and covering all ESG pillars improved reliability.
- High-tech exports have the biggest positive impact on innovation.
- STEM education is essential for driving innovation.
- Environmental efforts may reduce output short-term but are key for long-term sustainability.
- Overall, ESG-based KPIs significantly influence innovation performance.

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RECOMMENDATIONS

- Promote High-Tech Exports - Boost innovation & competitiveness through advanced technology production.
- Strengthen STEM Education - Invest in science & engineering education; link academia with industry.
- Adopt Renewable Energy - Integrate green energy in manufacturing to support sustainability.
 - Invest in Environmental Protection - Treat eco-investments as drivers of innovation, not just costs.
- Align with ESG Standards - Use ESG KPIs for better performance and sustainability tracking.

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Irvin Koricki
PIVfmu-23

Thank you 😊

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Appendix B. Statistics formed in a panel data set

Table 1. 16 KPI statistic panel data set

TIME	COUNTRY	MGVA_GDP gross value added of the manufacturing sector, as a percentage of gross domestic product (%)	RR recycling rate of municipal waste (%)	FEC_cap final energy consumption per capita (kg)	GGG_omp GHG emissions per employee in employment (ton (kg))	YNE young people neither in employment nor in education and training (%)	YE graduates in tertiary education, in science, maths, computing, engineering, manufacturing, construction per 1000 of population (aged 20-29)	ICT employed ICT specialists (% of total employment)	TE employment in technology and knowledge-intensive sectors (% of total employment)	RDP research and development personnel (% of population in the labour force)	ET_omp environmental taxes per employee (million euro)	CI corruption perception index (score)	GERD_GDP gross domestic expenditure on research and development in manufacturing sector (%)	BERD_GDP business enterprise expenditure on research and development in manufacturing sector (%)	DERT_cap development of environment technologies (innovations per person)	EE expenditure on education (% of GDP)	GEI government effectiveness indicator (score)	GRU government rule of law indicator (score)
2012	Austria	17.30	57.70	792.00	7027.88	6.80	-	3.60	3.50	1.54	0.66	69.00	2.93	-	48.79	5.48	1.56	1.86
2013	Austria	17.10	57.70	815.00	6946.67	7.30	22.20	3.70	3.80	1.55	0.65	75.00	2.98	1.31	39.37	5.55	1.67	1.45
2014	Austria	17.20	56.50	750.00	6824.16	7.70	23.00	3.60	4.10	1.65	0.65	41.00	3.11	-	43.18	5.45	-0.05	-0.12
2015	Austria	17.20	56.90	767.00	6881.83	7.50	21.90	4.00	4.00	1.65	0.65	46.00	3.07	1.35	45.07	5.46	0.68	0.15
2016	Austria	17.70	57.60	792.00	6676.70	7.70	22.10	4.10	4.10	1.7	0.65	66.00	3.13	-	39.05	5.48	1.18	1.09
2017	Austria	17.40	57.80	791.00	6798.58	6.50	22.00	4.40	4.40	1.71	0.66	49.00	3.07	1.41	42.24	5.37	0.92	1.02
2018	Austria	17.30	57.70	739.00	6325.17	6.80	22.80	4.50	4.20	1.79	0.73	90.00	3.11	-	43.62	5.23	1.99	1.88
2019	Austria	17.10	58.20	753.00	6485.87	7.10	23.40	4.30	4.00	1.86	0.75	64.00	3.14	1.46	48.80	5.22	0.95	1.15
2020	Austria	16.60	62.30	781.00	6341.62	8.00	24.40	4.50	4.10	1.84	0.63	90.00	3.21	-	46.51	5.57	2.21	1.94
2021	Austria	17.00	62.50	866.00	6717.15	8.50	25.00	4.50	4.50	1.94	0.77	71.00	3.26	1.61	33.06	5.49	1.17	1.44
2022	Austria	16.20	62.40	762.00	6089.05	9.10	24.30	5.00	5.00	2.02	0.70	79.00	3.18	-	21.95	4.77	1.53	1.67
2012	Belgium	12.60	53.40	762.00	8198.57	12.10	-	4.30	4.70	1.18	1.08	36.00	2.27	0.95	18.16	6.26	0.28	0.19
2013	Belgium	12.70	52.80	814.00	8227.31	12.70	13.00	4.20	4.40	1.18	1.07	35.00	2.32	0.95	19.65	6.63	0.61	0.61
2014	Belgium	12.60	53.80	664.00	8244.61	12.00	14.00	4.20	4.40	1.48	1.03	69.00	2.36	0.91	21.11	6.59	1.54	1.73
2015	Belgium	12.60	53.50	710.00	8206.53	12.20	13.10	4.20	4.40	1.57	1.05	42.00	2.43	0.93	20.50	6.45	0.45	0.43
2016	Belgium	12.20	53.50	729.00	8184.44	9.90	14.30	4.20	4.30	1.59	1.22	49.00	2.53	0.99	22.09	6.46	0.85	0.78
2017	Belgium	13.30	54.90	8146.61	8146.61	9.30	13.60	4.90	4.60	1.67	1.34	54.00	2.68	1.05	21.45	6.43	0.84	0.84
2018	Belgium	12.30	54.40	704.00	8062.54	9.20	14.00	5.20	4.90	1.77	1.14	80.00	2.86	1.12	24.34	6.38	1.66	1.79
2019	Belgium	12.40	54.70	653.00	7897.44	9.30	14.20	5.00	5.10	1.85	1.39	57.00	3.15	1.19	19.87	6.33	1.24	1.34
2020	Belgium	12.00	51.40	657.00	7340.68	9.20	15.70	5.00	5.10	1.92	1.21	84.00	3.37	1.27	21.90	6.80	1.84	1.85
2021	Belgium	10.70	55.50	708.00	7419.76	7.40	16.40	5.60	5.70	2.33	1.30	38.00	3.41	1.11	21.82	6.36	0.66	0.82
2022	Belgium	12.20	54.70	604.00	6606.73	6.60	16.40	5.60	5.80	2.41	1.32	63.00	3.29	-	13.84	-	1.00	1.04
2012	Bulgaria	14.10	25.00	322.00	2657.04	21.50	-	2.50	3.20	0.51	0.24	44.00	0.60	0.06	2.48	3.48	-0.17	0.09
2013	Bulgaria	12.80	28.50	313.00	2641.02	21.60	14.60	2.50	3.40	0.53	0.27	40.00	0.61	0.05	1.77	4.06	0.78	0.40
2014	Bulgaria	13.00	23.10	406.00	2658.10	20.20	14.20	2.50	3.30	0.59	0.27	61.00	0.79	0.09	2.27	4.07	1.02	1.01
2015	Bulgaria	13.60	29.40	314.00	2946.51	19.30	14.60	2.90	3.70	0.69	0.28	65.00	0.95	0.21	2.40	3.91	1.06	1.04
2016	Bulgaria	14.40	31.80	327.00	3184.58	18.20	13.90	3.00	3.90	0.78	0.30	88.00	0.77	0.19	1.94	3.39	1.91	1.93
2017	Bulgaria	14.00	34.60	341.00	3247.23	15.30	14.30	3.10	3.60	0.71	0.29	69.00	0.74	0.18	1.51	4.08	1.57	1.83
2018	Bulgaria	13.30	31.50	332.00	3304.29	15.00	13.60	3.30	3.90	0.8	0.31	75.00	0.76	0.18	1.83	4.05	1.70	1.46
2019	Bulgaria	13.30	34.60	322.00	3338.29	15.70	14.00	3.10	3.90	0.88	0.42	41.00	0.84	0.15	1.51	4.20	-0.01	-0.15
2020	Bulgaria	12.90	35.20	364.00	3384.49	14.40	13.40	3.30	3.80	0.87	0.45	43.00	0.85	0.16	2.14	4.51	0.68	0.11
2021	Bulgaria	11.20	28.20	369.00	3453.26	13.90	14.40	3.50	4.50	0.85	0.47	63.00	0.77	0.13	1.93	4.73	1.36	1.03
2022	Bulgaria	13.20	24.60	331.00	3431.23	12.30	14.60	3.80	4.80	0.91	1.21	48.00	0.75	0.13	1.10	-	0.92	1.02
2012	Cyprus	4.20	12.80	405.00	7955.40	16.00	-	2.60	2.90	0.57	0.44	80.00	0.44	0.02	2.31	5.90	1.62	1.81
2013	Cyprus	3.90	13.90	334.00	3944.12	18.70	15.50	2.70	2.60	0.58	0.41	36.00	0.48	0.03	1.88	6.47	1.25	1.33
2014	Cyprus	4.10	14.80	343.00	4974.56	17.00	15.70	2.80	2.90	0.54	0.43	83.00	0.51	0.03	0.79	6.42	1.81	1.83
2015	Cyprus	4.30	16.30	391.00	4522.57	17.30	16.80	2.70	3.00	0.57	0.47	60.00	0.48	0.04	1.47	6.30	0.66	0.84
2016	Cyprus	4.60	16.30	392.00	4484.69	16.00	17.10	2.70	3.00	0.64	0.47	62.00	0.52	0.06	0.77	6.12	1.91	1.04
2017	Cyprus	4.90	16.50	398.00	4460.69	16.10	18.50	2.90	3.10	0.65	0.54	43.00	0.54	0.06	1.43	5.70	0.13	0.19
2018	Cyprus	5.30	16.80	385.00	3901.76	13.20	18.60	3.20	3.20	0.73	0.56	47.00	0.61	0.09	0.77	5.03	0.73	0.46
2019	Cyprus	5.40	16.90	408.00	3588.97	13.70	19.80	2.70	2.90	0.87	0.55	57.00	0.70	0.09	0.77	5.21	1.00	0.99
2020	Cyprus	5.60	17.00	408.00	3838.23	13.90	20.60	3.10	3.30	0.93	0.52	39.00	0.83	0.12	2.35	5.64	1.17	1.03
2021	Cyprus	5.00	14.00	394.00	4653.53	12.50	20.50	3.90	3.90	0.98	0.53	89.00	0.78	0.09	2.72	5.24	1.79	1.95
2022	Cyprus	4.30	14.40	389.00	3480.98	12.50	21.90	4.60	4.70	1.01	0.60	47.00	0.70	0.09	1.80	-	0.98	0.80
2012	Croatia	13.50	14.70	600.00	4042.04	16.60	-	2.50	2.70	0.29	0.48	19.00	0.74	0.15	1.97	5.22	1.94	1.90
2013	Croatia	12.60	14.90	589.00	3694.89	19.60	6.60	2.60	2.90	0.29	0.54	68.00	0.79	0.19	0.23	4.52	0.97	1.19
2014	Croatia	12.70	16.40	531.00	3756.57	18.90	7.50	2.70	3.30	0.3	0.58	89.00	0.77	0.19	6.45	5.18	2.18	1.96
2015	Croatia	12.70	18.00	585.00	3606.94	18.00	10.00	2.70	3.30	0.3	0.64	71.00	0.82	0.30	0.59	4.97	1.48	1.40
2016	Croatia	12.90	21.00	587.00	3342.80	16.70	10.20	3.30	3.70	0.33	0.68	78.00	0.83	0.25	2.74	4.90	1.51	1.64
2017	Croatia	12.30	23.60	591.00	3606.23	15.50	10.10	3.30	3.50	0.57	0.72	40.00	0.84	0.27	1.45	3.86	0.36	0.47
2018	Croatia	12.20	25.30	576.00	3525.65	13.20	10.00	3.50	3.90	0.43	0.77	54.00	0.95	0.30	0.29	3.91	0.68	0.58
2019	Croatia	12.00	30.20	567.00	3325.69	12.00	10.20	3.20	4.20	0.49	0.79	72.00	1.08	0.36	4.72	3.92	1.50	1.71
2020	Croatia	12.20	29.50	582.00	3221.23	12.10	9.80	3.70	4.20	0.51	0.71	43.00	1.24	0.40	4.20	4.39	0.53	0.44
2021	Croatia	11.70	31.40	630.00	3122.27	12.50	10.30	3.60	3.60	0.49	0.77	53.00	1.24	0.25	4.26	4.06	0.88	0.76
2022	Croatia	12.30	34.20	593.00	2806.06	11.40	10.60	3.70	4.30	0.47	0.76	57.00	1.42	0.21	11.55	-	0.83	0.83
2012	Czechia	21.70	23.20	677.00	4145.73	8.90	-	3.40	4.40	1.17	0.60	76.00	1.76	0.47	4.35	4.22	1.52	1.55
2013	Czechia	21.30	24.20	691.00	4023.80	9.10	16.90	3.70	4.30	1.17	0.53	43.00	1.87	0.53	3.39	4.05	1.60	1.08
2014	Czechia	23.50	25.40	623.00	4063.79	8.10	16.60	3.70	4.80	1.24	0.55	48.00	1.94	0.55	5.18	3.97	0.68	0.22
2015	Czechia	23.70	29.70	642.00	3876.24	7.50	17.20	3.50	4.60	1.28	0.55	63.00	1.91	0.54	4.15	5.75	1.14	1.07
2016	Czechia	23.80	33.60	671.00	3781.09	7.00	17.00	3.70	4.70	1.28	0.58	51.00	1.63	0.54	6.24	5.53	1.03	1.14
2017	Czechia	23.20	32.10	680.00	3632.34	6.50	16.80	3.60	4.70	1.33	0.59	92.00	1.75	0.59	6.26	3.81	1.78	2.10
2018	Czechia	22.30	32.20	663.00	3714.77	5.60	16.50	4.00	5.00	1.42	0.62	89.00	1.88	0.63	6.39	4.27	1.01	1.37
2019	Czechia	22.10	33.30	652.00	3574.94	5.70	16.10	4.00	4.90	1.51	0.70	89.00	1.90	0.63	5.43	4.54	2.03	2.12
2020	Czechia	20.80	40.50	668.00	3448.79	6.40	16.00	4.20	5.10	1.55	0.65	69.00	1.95	0.60	7.75	4.72	1.41	1.45
2021	Czechia	19.90	43.30	749.00	3713.29	6.50	16.00	4.60	5.70	1.62	0.69	79.00	1.93	0.61	5.35	4.80	1.66	1.85
2022	Czechia	19.40	-	671.00														

Table 1. continuation

2019	Germany	19.40	66.70	695.00	2021.34	5.70	24.40	4.00	4.20	1.76	0.63	69.00	3.11	1.82	35.74	5.12	1.38	1.35
2020	Germany	18.60	70.30	697.00	1864.81	7.40	27.10	4.70	5.40	1.78	0.70	54.85	3.09	1.70	54.85	5.59	1.66	1.58
2021	Germany	18.70	69.30	693.00	5083.48	7.80	24.00	4.90	5.40	1.81	0.78	44.00	3.08	1.70	34.74	5.45	0.12	0.11
2022	Germany	18.30	69.70	691.00	4712.15	7.00	24.30	5.00	5.40	1.86	0.76	48.00	3.07	-	20.50	4.54	0.46	0.41
2012	Greece	8.10	17.00	461.00	5108.25	20.20	-	1.90	2.20	0.78	1.04	73.00	0.72	-	2.08	4.58	1.33	1.47
2013	Greece	7.80	15.80	348.00	5921.48	20.40	15.70	2.00	2.40	0.88	1.20	47.00	0.82	0.10	2.91	4.50	0.54	0.37
2014	Greece	7.80	15.40	353.00	6133.58	19.10	16.20	1.70	2.50	0.91	1.19	57.00	0.83	-	2.02	4.52	0.97	0.93
2015	Greece	8.50	15.80	412.00	5784.17	17.20	17.10	1.60	2.40	1.05	1.15	59.00	0.97	0.09	1.58	3.66	1.03	1.00
2016	Greece	8.10	17.20	403.00	5965.06	13.80	17.10	1.80	2.30	0.88	1.11	81.00	1.01	-	2.34	4.02	1.66	1.72
2017	Greece	8.00	18.90	409.00	5842.09	15.30	17.90	2.00	2.50	1.01	1.17	55.00	1.15	0.17	1.94	3.48	0.92	0.97
2018	Greece	8.20	20.10	364.00	5306.39	14.10	17.60	2.20	2.80	1.1	1.14	83.00	1.21	-	2.20	3.60	1.82	1.83
2019	Greece	7.80	21.00	382.00	5002.48	12.50	17.20	2.00	3.00	1.16	1.19	62.00	1.26	0.18	1.63	3.59	0.65	0.59
2020	Greece	8.40	18.10	400.00	4826.80	13.20	16.80	2.10	3.10	1.32	1.00	62.00	1.49	0.23	2.39	4.50	1.15	1.04
2021	Greece	8.70	17.50	401.00	4881.83	11.00	20.10	2.40	3.20	1.37	1.17	48.00	1.43	0.23	1.72	4.08	-0.07	0.45
2022	Greece	9.20	17.30	414.00	4389.50	10.70	21.30	2.50	3.40	1.5	2.01	51.00	1.48	0.26	1.55	-	0.79	0.60
2012	Hungary	18.50	25.50	643.00	2456.63	14.80	-	3.20	5.20	0.81	0.30	61.00	1.26	0.52	3.80	4.14	1.09	1.05
2013	Hungary	18.70	26.40	629.00	2410.51	15.50	11.20	3.30	5.30	0.86	0.37	38.00	1.38	0.33	2.77	4.19	1.09	0.97
2014	Hungary	19.40	30.50	558.00	2452.27	13.60	12.70	3.50	4.70	0.82	0.37	88.00	1.34	0.49	2.84	4.60	1.66	1.95
2015	Hungary	20.20	32.20	609.00	2578.79	11.60	12.20	3.60	4.70	0.8	0.39	75.00	1.34	0.40	4.07	4.50	1.47	1.80
2016	Hungary	19.60	34.70	651.00	2501.93	11.00	12.60	3.60	5.10	0.77	0.37	75.00	1.18	0.42	2.77	4.62	1.24	1.32
2017	Hungary	19.10	35.00	647.00	2721.34	11.00	12.10	3.60	4.80	0.86	0.64	43.00	1.31	0.43	3.11	4.65	0.30	0.42
2018	Hungary	18.40	37.40	599.00	2789.98	10.70	12.20	3.70	5.20	1.16	0.38	49.00	1.50	0.55	3.47	4.62	0.54	0.31
2019	Hungary	17.30	35.90	586.00	2726.31	11.00	12.30	3.40	5.70	1.21	0.41	57.00	1.46	0.50	2.97	4.22	0.89	0.83
2020	Hungary	17.30	32.00	618.00	2644.91	11.70	23.50	3.80	6.10	1.27	0.39	57.00	1.58	0.66	3.11	4.15	1.03	1.09
2021	Hungary	16.50	34.90	662.00	2606.52	10.60	13.50	3.90	6.40	1.3	0.40	88.00	1.63	0.70	1.84	4.68	1.75	1.80
2022	Hungary	16.80	32.80	606.00	2234.34	9.80	12.80	4.10	6.40	1.32	0.36	71.00	1.39	0.50	1.28	-	1.07	1.25
2013	Ireland	19.60	36.60	660.00	3360.03	19.20	-	4.80	8.20	1.35	0.79	85.00	1.55	-	10.97	5.76	1.20	2.02
2014	Ireland	19.00	37.40	640.00	3321.00	16.40	-	4.70	8.00	1.43	0.84	70.00	1.54	0.46	10.35	5.35	1.31	1.40
2015	Ireland	19.60	39.80	574.00	3531.96	15.30	23.90	4.80	8.10	1.52	0.91	81.00	1.48	-	10.23	4.87	1.61	1.57
2016	Ireland	34.90	-	605.00	3560.27	14.30	29.80	4.60	8.40	1.43	0.95	48.00	1.14	0.32	12.21	3.75	0.24	0.03
2017	Ireland	32.60	40.70	618.00	3546.96	12.60	30.60	4.90	8.50	1.52	1.01	45.00	1.15	-	9.27	3.75	0.48	0.54
2018	Ireland	32.10	40.40	592.00	3550.43	10.90	32.70	5.00	8.40	1.48	1.07	74.00	1.21	0.40	8.82	3.49	1.27	1.38
2019	Ireland	32.80	37.70	621.00	3587.82	10.10	35.20	4.80	8.10	1.35	1.03	50.00	1.08	-	11.47	3.38	0.49	0.32
2020	Ireland	31.90	37.40	595.00	3397.94	10.10	36.90	4.90	8.10	1.4	0.98	38.00	1.14	0.33	16.00	3.30	0.87	0.80
2021	Ireland	33.80	40.80	638.00	3476.16	12.00	39.90	5.70	9.20	1.5	0.89	59.00	1.12	-	13.89	3.25	0.93	0.96
2022	Ireland	34.60	-	604.00	3397.76	7.70	40.30	6.30	10.20	1.53	1.02	82.00	1.07	0.34	11.84	3.01	1.65	1.70
2012	Italy	37.10	-	520.00	2973.30	6.80	40.10	6.30	10.10	1.55	0.81	56.00	-	-	4.82	-	0.97	1.11
2013	Italy	33.80	38.40	571.00	5310.01	21.00	-	3.10	3.40	0.98	1.06	82.00	1.26	0.51	11.47	4.06	1.81	1.76
2014	Italy	33.80	39.40	568.00	4880.86	22.20	13.80	3.20	3.40	1.01	1.12	60.00	1.29	0.51	10.17	4.14	0.55	0.40
2015	Italy	33.80	41.60	490.00	4511.08	22.10	13.90	3.30	3.40	1.01	1.20	63.00	1.23	0.53	9.98	4.66	1.29	1.10
2016	Italy	34.30	44.50	540.00	4612.48	21.40	13.50	3.30	3.40	1.05	1.12	48.00	1.33	0.54	10.79	4.07	0.08	0.41
2017	Italy	34.70	45.90	535.00	4481.18	19.90	13.80	3.30	3.40	1.16	1.21	50.00	1.36	0.58	10.64	3.82	0.67	0.51
2018	Italy	34.80	47.80	548.00	4286.98	20.10	14.50	3.40	3.40	1.27	1.13	61.00	1.36	0.58	11.13	4.04	1.13	0.99
2019	Italy	34.90	49.80	530.00	4306.91	19.10	15.30	3.60	3.30	1.38	1.13	57.00	1.42	0.60	10.79	4.26	1.00	1.02
2020	Italy	34.80	51.40	521.00	4061.47	18.00	16.60	3.50	3.70	1.43	1.13	84.00	1.46	0.61	11.43	4.10	1.68	1.82
2021	Italy	34.50	51.40	516.00	3770.28	19.10	16.90	3.60	3.90	1.43	1.02	78.00	1.50	0.63	12.67	4.44	1.48	1.85
2022	Italy	35.40	51.90	565.00	4273.13	19.80	18.30	3.80	4.00	1.38	1.14	75.00	1.41	0.59	11.59	4.22	1.22	1.41
2013	Latvia	15.40	53.30	509.00	4198.64	15.90	18.50	3.90	4.00	1.38	0.93	42.00	1.37	0.56	6.04	0.11	-0.11	-
2014	Latvia	11.80	14.60	677.00	1953.14	14.90	-	2.20	2.50	0.56	0.49	48.00	0.69	0.08	2.80	6.58	0.51	0.30
2015	Latvia	11.30	25.90	630.00	1674.16	13.00	14.10	2.40	3.10	0.53	0.53	59.00	0.64	0.11	3.48	7.00	0.88	0.72
2016	Latvia	10.90	27.00	621.00	1653.18	12.00	13.10	2.50	3.40	0.6	0.58	59.00	0.71	0.13	1.50	5.28	0.95	1.02
2017	Latvia	10.80	28.70	559.00	1471.18	10.50	12.90	2.70	3.30	0.58	0.68	88.00	0.64	0.07	0.76	5.28	1.81	1.77
2018	Latvia	10.50	25.20	584.00	1294.75	11.20	12.70	2.70	3.10	0.54	0.71	73.00	0.45	0.07	1.19	4.66	1.15	1.20
2019	Latvia	10.90	24.80	616.00	1460.47	10.30	12.70	2.80	3.60	0.57	0.71	85.00	0.53	0.07	1.46	4.37	2.01	2.03
2020	Latvia	10.90	25.20	639.00	1685.82	7.80	13.80	2.50	3.50	0.62	0.72	72.00	0.66	0.08	0.78	4.24	1.42	1.40
2021	Latvia	11.00	41.00	621.00	1623.88	7.90	14.00	3.10	3.30	0.64	0.69	80.00	0.66	0.09	2.79	4.44	1.52	1.59
2022	Latvia	11.50	39.70	587.00	1558.74	7.10	14.10	3.60	4.00	0.71	0.65	45.00	0.76	0.11	5.13	4.85	0.26	0.11
2013	Lithuania	12.80	44.10	638.00	1389.63	8.60	15.10	3.80	4.50	0.79	0.76	46.00	0.77	0.13	4.78	4.62	0.44	0.56
2014	Lithuania	11.80	50.80	593.00	1200.79	8.60	14.70	3.80	4.60	0.76	0.73	73.00	0.81	0.16	4.23	5.30	0.81	0.41
2015	Lithuania	18.70	23.50	513.00	5178.79	11.20	-	1.90	2.40	0.72	0.24	52.00	0.90	0.08	2.18	4.76	0.41	0.21
2016	Lithuania	17.70	27.80	495.00	4687.44	11.10	22.50	1.80	2.20	0.77	0.25	38.00	0.95	0.09	2.73	4.60	1.00	0.92
2017	Lithuania	17.40	30.50	477.00	4848.31	9.90	19.30	1.70	2.10	0.82	0.25	59.00	1.03	0.14	2.25	4.49	1.03	0.92
2018	Lithuania	17.20	33.20	467.00	5026.04	9.20	18.50	2.10	2.30	0.74	0.28	81.00	1.04	0.10	2.75	4.23	1.74	1.77
2019	Lithuania	16.80	48.00	498.00	4428.65	9.40	18.00	2.50	2.50	0.76	0.28	54.00	0.84	0.10	2.02	4.00	0.93	1.02
2020	Lithuania	16.70	48.10	512.00	4453.03	9.10	18.90	2.70	2.50	0.82	0.31	82.00	0.99	0.11	1.65	5.81	1.81	1.74
2021	Lithuania	16.50	53.60	516.00	4462.69	8.90	19.90	2.70	2.90	0.85	0.35	60.00	0.93	0.15	2.60	3.89	0.55	0.38
2022	Lithuania	16.00	49.70	515.00	4352.59	8.60	19.80	3.10	3.20	0.92	0.41	64.00	0.99	0.14	1.61	3.96	1.18	1.11
2013	Lithuania	15.50	45.30	510.00	4290.93	10.80	18.70	3.30	3.30	1	0.48	47.00	1.12	0.14	2.00	4.		

Table 1. continuation

2014	Romania	21.50	13.10	372.00	3644.23	17.00	16.60	1.60	2.40	0.39	0.40	73.00	0.38	0.08	0.64	3.13	1.09	1.29
2015	Romania	20.20	13.30	372.00	3318.59	18.10	14.90	1.90	2.60	0.39	0.45	42.00	0.49	0.09	0.56	3.11	-0.17	-0.07
2016	Romania	20.10	13.40	376.00	3303.57	17.40	14.40	2.00	2.70	0.4	0.46	47.00	0.49	0.10	0.80	3.03	0.55	0.28
2017	Romania	19.80	14.00	395.00	3259.27	15.20	15.10	2.10	3.00	0.4	0.40	53.00	0.51	0.09	1.46	3.12	0.70	0.61
2018	Romania	18.90	11.10	399.00	3329.29	14.50	15.90	2.20	3.00	0.4	0.43	54.00	0.50	0.10	1.03	3.32	1.07	1.09
2019	Romania	17.10	11.50	400.00	3333.17	14.70	17.50	2.30	2.90	0.39	0.51	88.00	0.47	0.09	0.80	3.57	1.96	1.90
2020	Romania	15.80	11.90	416.00	3469.21	14.80	18.40	2.40	3.00	0.41	0.45	74.00	0.46	0.11	0.72	3.59	1.34	1.39
2021	Romania	15.60	11.30	456.00	3468.81	18.00	19.10	2.60	3.40	0.42	0.50	88.00	0.47	0.12	0.87	3.32	1.93	2.01
2022	Romania	13.70	12.30	414.00	2853.22	17.50	18.60	2.80	3.40	0.43	0.46	71.00	0.46	0.13	0.44	-	1.23	1.26
2012	Slovakia	17.30	13.40	522.00	7084.81	13.80	-	2.50	4.00	0.65	0.49	80.00	0.79	0.18	2.60	3.86	1.39	1.57
2013	Slovakia	16.70	10.80	525.00	6608.34	13.70	18.00	2.60	3.60	0.62	0.32	49.00	0.82	0.22	2.59	4.07	0.41	0.32
2014	Slovakia	18.50	10.40	429.00	6520.69	12.80	17.20	2.80	3.70	0.63	0.54	43.00	0.87	0.22	3.05	4.22	0.60	0.51
2015	Slovakia	18.80	14.90	474.00	6322.95	13.70	16.60	2.80	4.10	0.63	0.34	74.00	1.15	0.21	4.21	4.38	1.46	1.49
2016	Slovakia	17.80	23.90	495.00	6229.70	15.30	15.80	2.90	4.10	0.63	0.52	56.00	0.79	0.56	4.42	3.90	0.33	0.54
2017	Slovakia	17.10	29.90	505.00	6341.32	12.10	14.70	2.80	4.40	0.63	0.46	59.00	0.83	0.24	3.73	3.93	0.83	0.95
2018	Slovakia	18.10	36.30	467.00	6417.02	10.20	13.90	3.20	4.30	0.73	0.55	61.00	0.83	0.31	3.23	3.95	1.02	1.07
2019	Slovakia	18.70	38.30	484.00	5546.41	10.30	12.90	3.70	4.30	0.76	0.60	81.00	0.82	0.29	2.79	4.27	1.68	1.75
2020	Slovakia	17.50	45.30	503.00	5256.19	10.70	11.00	4.20	5.30	0.82	0.57	54.00	0.89	0.23	2.92	4.76	0.85	0.84
2021	Slovakia	18.10	48.90	545.00	6287.31	11.00	13.20	4.30	5.40	0.83	0.39	82.00	0.90	0.26	3.57	4.80	1.73	1.70
2022	Slovakia	17.30	49.50	495.00	5097.97	9.60	11.20	4.30	5.20	0.86	0.56	56.00	0.98	0.28	1.46	-	0.25	0.43
2012	Slovenia	18.70	42.10	608.00	2816.44	9.30	3.30	4.70	1.52	0.46	62.00	2.58	1.20	9.56	5.62	0.95	1.11	-
2013	Slovenia	19.20	34.80	601.00	2976.73	9.30	19.80	3.40	5.00	1.55	0.54	45.00	2.59	1.29	11.25	5.41	-0.16	0.38
2014	Slovenia	19.60	36.00	514.00	3027.35	9.40	19.80	3.50	5.20	1.31	0.54	52.00	2.39	1.22	10.06	5.29	0.49	0.68
2015	Slovenia	20.00	54.10	568.00	2892.66	9.50	19.90	3.60	5.90	1.45	0.60	57.00	2.22	1.19	9.29	4.91	1.14	1.00
2016	Slovenia	20.20	55.50	579.00	2894.23	8.00	33.30	3.50	5.50	1.48	0.61	61.00	2.03	1.13	10.48	4.79	0.91	0.84
2017	Slovenia	20.60	57.80	567.00	2968.25	6.50	19.40	3.80	5.70	1.47	0.56	85.00	1.88	1.04	8.95	4.78	1.61	1.70
2018	Slovenia	20.40	58.90	531.00	3056.34	6.60	20.70	4.00	5.50	1.56	0.56	71.00	1.96	1.07	7.81	4.93	1.46	1.70
2019	Slovenia	20.60	59.20	516.00	2997.54	7.00	20.80	3.90	5.70	1.69	0.78	73.00	2.06	1.12	9.21	4.89	1.23	1.35
2020	Slovenia	20.50	59.30	519.00	2874.22	7.70	20.50	4.40	7.00	1.67	0.68	43.00	2.16	1.15	5.95	5.38	-0.27	-0.11
2021	Slovenia	20.00	60.80	552.00	2950.22	6.60	21.60	4.80	6.80	1.74	0.73	50.00	2.14	1.15	7.83	5.37	0.38	0.37
2022	Slovenia	19.90	62.60	500.00	2738.76	8.30	22.40	4.50	6.40	1.72	0.74	52.00	2.10	1.12	4.94	-	0.73	0.57
2012	Spain	10.80	29.80	332.00	5011.42	18.60	13.60	3.20	3.70	0.9	0.39	56.00	1.29	0.31	8.16	4.48	1.09	1.10
2013	Spain	10.90	32.50	319.00	4933.37	18.60	19.40	3.30	3.70	0.88	0.53	90.00	1.27	0.30	7.38	4.35	1.99	1.90
2014	Spain	11.00	30.80	313.00	4798.45	17.10	21.10	3.20	3.60	0.83	0.21	74.00	1.23	0.30	6.52	4.30	1.34	1.43
2015	Spain	11.00	30.00	329.00	4670.70	15.60	22.40	3.20	3.70	0.88	0.54	87.00	1.21	0.29	6.58	4.28	1.75	1.96
2016	Spain	11.00	33.90	308.00	4614.71	14.60	21.60	3.40	3.60	0.91	0.54	72.00	1.18	0.29	5.91	4.23	1.17	1.18
2017	Spain	11.10	36.10	309.00	4507.10	13.30	21.90	3.50	3.80	0.96	0.53	79.00	1.20	0.30	6.95	4.21	1.29	1.53
2018	Spain	10.80	34.80	324.00	4439.92	12.40	21.50	3.60	3.60	1	0.56	52.00	1.23	0.32	6.63	4.18	0.45	0.33
2019	Spain	10.70	38.00	307.00	4228.59	12.10	20.90	3.70	3.70	1.01	0.55	42.00	1.24	0.31	5.84	4.23	0.53	0.42
2020	Spain	10.90	40.40	307.00	3933.91	13.90	20.90	3.90	3.90	1.03	0.22	77.00	1.40	-	6.27	4.90	1.55	1.53
2021	Spain	11.30	43.70	310.00	4073.96	11.00	23.40	4.10	4.10	1.08	0.58	56.00	1.40	0.35	6.43	4.87	0.45	0.30
2022	Spain	11.00	42.90	297.00	3350.11	10.50	23.00	4.30	4.40	1.13	0.51	59.00	1.41	0.35	4.32	4.32	0.69	0.92
2012	Sweden	14.10	46.90	846.00	3609.97	7.80	-	5.80	4.90	1.67	1.10	62.00	3.25	-	41.11	7.54	0.99	1.06
2013	Sweden	13.40	48.20	801.00	3356.73	7.50	14.70	5.70	4.90	1.64	1.08	77.00	3.28	1.39	42.24	7.61	1.77	1.77
2014	Sweden	13.00	49.50	746.00	3294.90	7.20	14.70	5.80	4.80	1.68	0.95	51.00	3.12	-	45.69	7.57	0.80	0.79
2015	Sweden	12.80	47.80	756.00	3313.38	6.70	15.30	6.10	4.90	1.67	1.01	80.00	3.24	1.36	43.37	7.44	1.38	1.66
2016	Sweden	13.50	48.40	772.00	3318.23	6.50	15.50	6.10	4.80	1.79	1.06	55.00	3.36	-	43.35	7.62	0.26	0.41
2017	Sweden	13.30	46.80	765.00	3217.22	6.20	15.00	6.60	5.00	1.73	1.00	62.00	3.39	-	48.64	7.57	1.00	1.11
2018	Sweden	13.40	45.80	736.00	3174.27	6.00	14.90	6.80	5.20	1.77	0.89	46.00	3.35	-	45.46	7.64	0.00	0.40
2019	Sweden	13.10	46.60	716.00	3164.62	5.30	15.80	7.00	5.40	1.75	0.91	53.00	3.40	1.25	44.64	7.64	0.38	0.62
2020	Sweden	12.60	38.50	694.00	2778.48	6.50	17.20	7.50	5.70	1.81	0.96	56.00	3.50	-	47.75	7.93	1.07	0.97
2021	Sweden	13.50	39.50	756.00	3012.37	5.10	19.20	8.00	6.20	2.18	0.84	60.00	3.42	1.26	44.08	7.57	0.92	0.80
2022	Sweden	14.00	39.70	673.00	2857.77	4.90	20.70	8.60	6.70	2.25	0.79	83.00	3.47	-	34.22	-	1.57	1.69

Source: prepared by author based on Eurostat (2024a-o), OECD (2024), World Bank Group (2024a-b) and Transparency International (2024).

Appendix C. 8 KPI model panel data set

Table 2. 8 KPI statistic panel data set

TIME	COUNTRY	<i>MGVA_GDP</i> gross value added of the manufacturing sector, as a percentage of gross domestic product (%)	<i>HTE</i> exports of high technology products as a share of total exports (%)	<i>RE</i> share of renewable energy in gross final energy consumption (%)	<i>FEC_cap</i> final energy consumption per capita (kg)	<i>GHG_emp</i> GHG emissions per employee in tons (kg)	<i>YE</i> graduates in tertiary education, in science, math, computing, engineering, manufacturing, construction per 1000 of population aged 20- 29 (graduates)	<i>YNE</i> young people neither in employment nor in education and training (%)	<i>EPE</i> national environmental protection investments of total economy, (% of GDP)
2012	Austria	17.30	12.72	143.28	792	7022.88	:	6.80	:
2013	Austria	17.10	14.18	144.49	815	6946.67	22.20	7.30	:
2014	Austria	17.20	14.35	148.97	730	6824.36	23.00	7.70	:
2015	Austria	17.20	14.16	149.62	767	6881.83	21.90	7.50	:
2016	Austria	17.70	13.88	149.95	792	6676.2	22.10	7.70	:
2017	Austria	17.40	14.78	148.14	791	6798.58	22.00	6.50	:
2018	Austria	17.30	13.83	152.08	739	6325.17	22.80	6.80	3.10
2019	Austria	17.10	13.88	152.80	753	6485.87	23.40	7.10	3.10
2020	Austria	16.60	14.83	160.03	781	6341.62	24.40	8.00	3.00
2021	Austria	17.00	13.97	151.67	866	6712.15	25.00	8.50	3.40
2022	Austria	16.20	13.33	150.92	762	6089.05	24.30	8.10	3.20
2012	Belgium	12.60	8.56	30.45	762	8198.57	:	12.30	:
2013	Belgium	12.70	8.71	32.95	814	8227.31	13.00	12.70	:
2014	Belgium	12.60	9.70	35.05	664	8244.61	14.00	12.00	3.20
2015	Belgium	12.60	10.27	35.50	730	8206.53	13.30	12.20	3.10
2016	Belgium	12.20	10.00	38.85	729	8184.44	14.30	9.90	3.10
2017	Belgium	12.40	9.76	41.19	715	8146.61	13.60	9.30	3.30
2018	Belgium	12.30	10.21	43.36	704	8062.54	14.00	9.20	3.30
2019	Belgium	12.40	11.95	45.88	653	7897.44	14.20	9.30	3.30
2020	Belgium	12.00	13.83	57.60	657	7340.68	15.70	9.20	3.30
2021	Belgium	10.70	17.08	58.69	708	7419.76	16.40	7.40	3.30
2022	Belgium	12.20	15.05	63.91	604	6606.73	16.40	6.60	3.40
2012	Bulgaria	14.10	3.82	59.54	322	2637.04	:	21.50	:
2013	Bulgaria	12.80	3.97	72.70	313	2642.02	14.60	21.60	:
2014	Bulgaria	13.00	3.94	71.00	306	2658.1	14.20	20.20	3.30
2015	Bulgaria	13.60	4.42	72.63	314	2946.51	14.60	19.30	3.00
2016	Bulgaria	14.40	5.14	75.10	327	3184.58	13.90	18.20	2.20
2017	Bulgaria	14.00	5.37	74.84	341	3247.23	14.30	15.30	2.00
2018	Bulgaria	13.30	6.02	84.26	332	3304.29	13.60	15.00	1.80
2019	Bulgaria	13.30	6.32	88.37	327	3338.29	14.00	13.70	2.00
2020	Bulgaria	12.90	6.80	93.18	364	3284.49	13.10	14.40	2.00
2021	Bulgaria	11.20	6.41	78.49	369	3435.26	14.40	13.90	2.00
2022	Bulgaria	13.20	5.48	78.43	331	3431.23	14.60	12.30	1.80
2012	Cyprus	4.20	11.73	33.80	405	2935.4	:	16.00	:
2013	Cyprus	3.90	18.12	38.75	354	3944.15	15.50	18.70	:
2014	Cyprus	4.10	5.21	41.41	343	4974.56	15.70	17.00	:
2015	Cyprus	4.30	10.90	44.94	382	4522.57	16.80	15.30	:
2016	Cyprus	4.60	6.85	45.78	392	4484.99	17.10	16.00	:
2017	Cyprus	4.90	10.15	48.37	398	4460.69	18.50	16.10	:
2018	Cyprus	5.30	9.70	63.06	385	3901.76	18.60	13.20	1.30
2019	Cyprus	5.40	4.60	61.90	408	3588.97	19.80	13.70	1.60
2020	Cyprus	5.60	4.99	73.44	408	3858.23	20.60	13.90	1.00
2021	Cyprus	5.00	5.33	83.69	394	3653.53	20.50	12.50	1.00
2022	Cyprus	4.30	5.02	85.18	389	3480.99	21.90	12.50	1.30
2012	Croatia	13.50	7.18	103.12	600	4042.04	:	16.60	:
2013	Croatia	12.60	7.87	110.14	589	3694.89	6.60	19.60	:
2014	Croatia	12.70	6.57	111.93	531	3756.57	7.50	18.90	1.80
2015	Croatia	12.70	7.08	115.36	585	3606.94	10.00	18.00	1.70
2016	Croatia	12.90	9.67	113.79	587	3342.8	10.20	16.70	1.80
2017	Croatia	12.80	9.20	111.52	591	3636.23	10.10	15.30	1.80
2018	Croatia	12.30	8.04	115.42	576	3525.65	10.00	13.30	1.70
2019	Croatia	12.00	8.11	120.90	567	3325.69	10.20	12.00	1.70
2020	Croatia	12.20	9.27	128.36	582	3221.23	9.80	12.10	2.10
2021	Croatia	11.70	7.77	129.75	630	3122.27	10.50	12.50	2.00
2022	Croatia	12.30	6.85	123.94	593	2806.06	10.60	11.40	1.80
2012	Czechia	21.70	16.09	46.98	677	4145.73	:	8.90	:
2013	Czechia	21.80	15.08	50.86	691	4024.8	16.90	9.10	:
2014	Czechia	23.50	15.30	55.49	623	4063.79	16.60	8.10	:
2015	Czechia	23.70	15.55	55.47	642	3876.24	17.20	7.50	:
2016	Czechia	23.80	15.05	54.92	671	3761.09	17.00	7.00	:
2017	Czechia	23.20	16.06	54.80	680	3632.34	16.80	6.30	:
2018	Czechia	22.30	17.85	56.05	663	3714.77	16.50	5.60	2.90
2019	Czechia	22.10	18.95	60.76	652	3574.94	16.10	5.70	2.80
2020	Czechia	20.80	20.64	65.03	668	3448.29	16.00	6.60	3.10
2021	Czechia	19.60	18.38	63.17	749	3711.29	16.00	6.50	2.90
2022	Czechia	19.40	19.19	65.68	671	3507.1	15.80	8.00	2.70
2012	Denmark	11.20	9.35	103.66	795	2432.58	:	7.30	:
2013	Denmark	11.80	9.30	111.39	799	2305.22	19.90	6.60	:
2014	Denmark	11.80	9.94	122.37	735	2269.68	20.80	6.40	:
2015	Denmark	12.50	10.82	127.73	782	2240.59	20.20	7.00	:
2016	Denmark	12.90	10.68	133.24	801	2274.91	23.30	6.70	:

Table 2. continuation

2017	Denmark	13.00	9.68	145.33	781	2361.44	22.60	7.60	:
2018	Denmark	13.00	9.47	149.44	769	2240.7	23.30	7.70	2.00
2019	Denmark	13.40	9.82	156.78	755	2157.25	23.70	7.70	2.00
2020	Denmark	12.80	11.45	157.78	733	2156.34	23.90	7.50	2.10
2021	Denmark	12.70	12.04	176.54	772	2192.21	26.10	7.10	2.00
2022	Denmark	12.80	11.44	182.28	685	1985.92	25.40	6.70	1.90
2012	Estonia	13.90	14.13	84.93	734	3039.53	:	12.20	:
2013	Estonia	13.60	14.94	81.86	708	3358.97	15.60	11.30	:
2014	Estonia	14.00	16.28	85.50	676	4068.69	13.50	11.70	2.60
2015	Estonia	13.70	15.52	95.58	652	3829.49	15.50	11.50	2.80
2016	Estonia	13.60	15.60	97.62	707	2804.24	16.20	9.60	2.20
2017	Estonia	13.30	12.01	99.76	714	2993.36	16.50	10.00	2.30
2018	Estonia	13.20	11.55	106.64	712	3089.37	15.70	10.30	2.40
2019	Estonia	12.90	11.08	112.16	717	3546.6	16.50	7.90	2.20
2020	Estonia	12.60	13.54	129.36	711	2591.53	17.30	9.20	2.30
2021	Estonia	13.00	12.81	139.07	725	2298.82	19.60	10.90	2.00
2022	Estonia	12.20	10.79	141.63	715	2015.2	18.10	10.70	2.00
2012	Finland	14.60	7.32	112.61	1,008	6182.98	:	8.60	:
2013	Finland	14.60	6.18	128.61	951	6176.98	22.00	9.30	:
2014	Finland	14.60	6.67	145.83	939	5596.55	22.30	10.20	:
2015	Finland	14.80	7.02	148.62	904	5530.48	23.70	10.60	:
2016	Finland	14.70	6.84	134.18	972	5404.35	24.30	9.90	:
2017	Finland	15.40	6.59	149.17	1,046	5165.99	22.40	9.40	1.80
2018	Finland	14.80	6.08	147.40	1,032	5044.1	23.80	8.50	1.80
2019	Finland	14.70	6.30	152.51	1,020	4830.36	24.80	8.20	1.60
2020	Finland	14.50	6.78	155.44	956	4558.77	26.50	9.30	1.70
2021	Finland	14.90	6.79	154.79	1,076	4543.73	25.60	7.70	1.90
2022	Finland	15.80	6.27	172.76	1,008	4212.41	26.50	7.80	1.80
2012	France	10.20	20.02	53.79	675	3871.12	:	12.50	:
2013	France	10.30	20.43	56.07	705	3938.19	:	11.20	:
2014	France	10.20	20.80	59.12	568	3833.23	:	11.20	2.00
2015	France	10.30	21.69	60.87	601	3709.4	24.70	12.00	1.90
2016	France	10.20	21.68	63.19	638	3681.46	25.50	11.90	1.90
2017	France	10.00	20.57	65.14	623	3624.7	26.20	11.40	1.90
2018	France	9.90	20.46	67.69	601	3520.27	26.50	11.10	1.90
2019	France	9.90	21.45	71.17	597	3399.79	27.40	10.60	2.00
2020	France	9.20	18.50	76.50	577	2996.23	29.20	11.40	2.00
2021	France	9.10	17.26	76.81	628	3200.01	29.70	10.60	2.00
2022	France	9.50	17.17	83.88	547	2920.85	29.90	10.10	2.00
2012	Germany	20.10	14.23	57.90	736	5359	:	7.10	:
2013	Germany	19.80	14.27	59.75	775	5356.04	17.80	6.30	:
2014	Germany	20.10	14.27	62.86	662	5242.64	19.30	6.40	:
2015	Germany	20.20	14.88	65.78	673	5410.08	20.50	6.20	:
2016	Germany	20.40	15.21	67.20	692	5355.84	20.10	6.70	:
2017	Germany	20.20	15.10	70.48	687	5461.09	20.40	6.30	:
2018	Germany	19.90	15.24	76.41	673	5225.02	20.10	5.90	2.20
2019	Germany	19.40	15.73	80.00	695	5021.54	24.40	5.70	2.20
2020	Germany	18.60	15.36	87.79	697	4944.83	22.30	7.40	2.30
2021	Germany	18.70	15.08	86.90	693	5088.48	24.00	7.80	2.20
2022	Germany	18.30	14.52	96.31	691	4712.15	24.30	7.00	2.10
2012	Greece	8.10	2.86	55.13	461	5108.25	:	20.20	:
2013	Greece	7.80	2.47	64.97	348	5924.48	15.70	20.40	:
2014	Greece	7.80	3.69	66.80	353	6133.58	16.20	19.10	:
2015	Greece	8.30	4.39	65.44	412	5794.12	17.10	17.20	:
2016	Greece	8.10	4.98	65.09	403	5965.06	17.10	15.80	:
2017	Greece	8.00	4.30	74.01	409	5842.09	17.90	15.30	:
2018	Greece	8.20	4.50	78.23	364	5506.39	17.60	14.10	1.40
2019	Greece	7.80	4.78	85.03	382	5002.48	17.20	12.50	1.40
2020	Greece	8.40	5.84	94.89	400	4826.8	16.80	13.20	1.50
2021	Greece	8.70	4.87	93.38	405	4881.83	20.10	11.00	1.40
2022	Greece	9.20	4.97	99.74	414	4589.5	21.30	10.70	1.40
2012	Hungary	18.50	17.27	50.90	643	2456.63	:	14.80	:
2013	Hungary	18.70	16.28	52.85	629	2410.51	11.20	15.50	:
2014	Hungary	19.40	14.48	50.21	558	2452.27	12.20	13.60	:
2015	Hungary	20.20	15.32	50.34	609	2578.79	12.20	11.60	:
2016	Hungary	19.60	15.90	50.46	631	2501.93	12.60	11.00	:
2017	Hungary	19.10	15.95	48.70	647	2731.34	12.10	11.00	:
2018	Hungary	18.40	15.52	46.80	599	2789.98	12.20	10.70	1.50
2019	Hungary	17.30	16.26	48.82	586	2726.31	12.30	11.00	1.60
2020	Hungary	17.30	16.82	55.05	618	2644.91	23.50	11.70	1.60
2021	Hungary	16.50	14.94	51.86	662	2606.52	13.50	10.60	1.40
2022	Hungary	16.80	14.77	58.46	606	2234.34	12.80	9.80	1.30
2012	Ireland	19.60	21.69	35.76	660	3300.03	:	19.20	:
2013	Ireland	19.00	20.89	38.56	640	3321	21.60	16.40	:
2014	Ireland	19.60	20.87	43.30	574	3531.96	23.90	15.30	1.40
2015	Ireland	34.90	24.44	46.93	605	3560.27	29.80	14.30	1.00
2016	Ireland	32.60	28.70	47.66	618	3546.96	30.60	12.60	1.00
2017	Ireland	32.10	34.49	54.90	592	3550.43	32.70	10.90	0.90
2018	Ireland	32.80	34.87	57.83	621	3587.82	35.20	10.10	0.90

Table 2. continuation

2019	Ireland	31.90	38.57	63.70	595	3397.04	36.90	10.10	0.90
2020	Ireland	33.80	42.49	71.67	638	3476.16	39.90	12.00	0.70
2021	Ireland	34.60	43.50	60.87	604	3397.76	40.30	7.70	0.70
2022	Ireland	37.10	42.46	61.80	520	2973.3	40.10	6.80	0.60
2012	Italy	13.80	6.36	66.00	571	5510.01	:	21.00	:
2013	Italy	13.80	6.64	71.55	568	4880.86	13.80	22.20	:
2014	Italy	13.80	6.71	74.44	490	4511.08	13.90	22.10	:
2015	Italy	14.30	6.96	76.74	540	4612.48	13.50	21.40	:
2016	Italy	14.70	7.13	77.73	535	4431.18	13.80	19.90	2.30
2017	Italy	14.80	7.56	78.94	548	4286.98	14.50	20.10	2.30
2018	Italy	14.90	7.68	78.66	530	4306.91	15.50	19.10	2.30
2019	Italy	14.80	7.92	81.90	521	4061.47	16.60	18.00	2.40
2020	Italy	14.50	8.31	89.13	516	3770.28	16.90	19.10	2.60
2021	Italy	15.40	7.77	84.08	565	4273.13	18.30	19.80	2.60
2022	Italy	15.40	8.00	86.85	509	4198.64	18.50	15.90	2.60
2012	Latvia	11.80	6.43	131.85	677	1958.14	:	14.90	:
2013	Latvia	11.50	8.05	139.40	630	1674.16	14.10	13.00	:
2014	Latvia	10.90	9.53	145.89	621	1653.18	13.10	12.00	:
2015	Latvia	10.80	10.84	145.12	559	1471.18	12.90	10.50	:
2016	Latvia	10.50	10.03	142.65	584	1294.73	12.70	11.20	:
2017	Latvia	10.90	10.47	150.21	616	1460.47	12.70	10.30	:
2018	Latvia	10.90	12.03	153.66	639	1685.82	13.80	7.80	1.10
2019	Latvia	11.00	9.94	156.66	621	1623.88	14.00	7.90	1.30
2020	Latvia	11.50	11.68	159.32	587	1558.74	14.10	7.10	1.20
2021	Latvia	12.80	9.72	157.29	638	1589.63	15.10	8.60	1.20
2022	Latvia	11.80	8.70	161.32	593	1510.79	14.70	8.60	1.20
2012	Lithuania	18.70	5.79	71.82	513	5178.79	:	11.20	:
2013	Lithuania	17.70	5.85	77.55	495	4637.44	22.50	11.10	:
2014	Lithuania	17.40	6.55	82.28	477	4848.31	19.30	9.90	:
2015	Lithuania	17.20	7.56	91.95	467	5026.04	18.50	9.20	:
2016	Lithuania	16.80	7.84	92.70	498	4428.65	18.00	9.40	:
2017	Lithuania	16.70	8.08	95.09	512	4453.03	18.90	9.10	:
2018	Lithuania	16.50	7.96	93.45	536	4162.69	19.90	8.00	1.70
2019	Lithuania	16.00	8.21	95.69	515	4332.59	19.80	8.60	1.40
2020	Lithuania	15.50	8.59	102.80	510	4290.93	18.70	10.80	1.50
2021	Lithuania	15.90	8.05	104.54	580	4154.6	18.20	11.30	1.90
2022	Lithuania	16.40	7.79	114.28	550	3626.93	17.90	9.70	1.70
2012	Luxembourg	4.60	26.70	15.53	923	6610.34	:	5.90	:
2013	Luxembourg	4.60	21.90	18.23	917	6234.79	3.60	5.00	:
2014	Luxembourg	4.70	19.61	23.05	841	6209.61	3.50	6.30	0.80
2015	Luxembourg	5.50	19.85	24.74	894	5811.98	3.40	6.20	0.80
2016	Luxembourg	5.80	15.34	25.06	902	5784.02	3.90	5.40	0.80
2017	Luxembourg	4.80	6.96	28.18	898	5549.78	3.80	5.90	0.90
2018	Luxembourg	5.00	7.11	33.02	823	5444.78	4.00	5.30	0.90
2019	Luxembourg	5.00	14.60	34.30	747	5386.92	3.90	5.60	1.00
2020	Luxembourg	4.90	4.94	50.78	790	4847.07	4.20	6.60	1.00
2021	Luxembourg	4.60	5.71	46.80	749	4676.39	4.90	8.70	0.90
2022	Luxembourg	3.90	5.50	54.14	696	3869.82	5.60	7.00	1.00
2012	Malta	10.80	29.62	20.59	172	383.29	:	10.80	:
2013	Malta	9.40	28.47	24.21	174	505.33	15.80	9.90	:
2014	Malta	8.40	28.68	27.77	170	522.34	15.70	10.30	2.20
2015	Malta	7.20	24.13	28.75	180	524.92	15.30	10.50	2.50
2016	Malta	7.00	18.27	34.05	171	472.7	13.70	8.80	2.00
2017	Malta	6.60	22.53	40.20	195	420.39	13.80	8.60	1.70
2018	Malta	6.50	24.05	46.46	192	369.93	12.00	7.40	1.70
2019	Malta	6.40	23.72	48.22	201	336.4	11.10	9.10	2.00
2020	Malta	6.70	29.81	53.82	205	333.94	10.10	9.60	2.20
2021	Malta	6.30	24.90	65.40	213	329.96	11.30	10.60	1.80
2022	Malta	6.30	31.10	74.51	217	323.08	11.60	7.20	1.80
2012	Netherlands	10.10	18.78	23.99	649	5922.16	:	4.90	:
2013	Netherlands	9.60	17.71	23.95	679	5887.55	:	5.60	:
2014	Netherlands	9.70	18.63	26.83	541	5851.85	:	5.50	:
2015	Netherlands	10.10	20.35	27.63	563	5873.71	:	4.70	:
2016	Netherlands	10.30	21.00	28.35	577	5950.03	:	4.60	:
2017	Netherlands	10.60	21.61	31.91	560	6004	12.00	4.00	:
2018	Netherlands	10.70	21.19	38.21	555	5863.84	12.80	4.20	1.80
2019	Netherlands	10.40	20.95	46.66	538	5705.03	13.60	4.30	1.80
2020	Netherlands	10.50	23.19	61.09	523	5574.11	13.80	4.50	1.80
2021	Netherlands	10.80	21.71	63.68	576	5568.45	15.50	2.60	1.80
2022	Netherlands	10.30	19.35	74.95	485	4980.66	15.40	2.80	1.80
2012	Poland	16.60	5.96	41.60	547	4394.72	:	11.80	:
2013	Poland	15.60	6.66	43.06	539	4292.68	:	12.20	:
2014	Poland	16.90	7.92	44.52	501	4232.43	20.50	12.00	1.80
2015	Poland	17.70	8.46	45.76	501	4080.62	21.40	11.00	1.90
2016	Poland	18.30	8.50	43.63	524	4073.57	21.50	10.50	2.00
2017	Poland	16.90	8.42	43.15	528	4214.46	23.60	9.50	1.90
2018	Poland	16.50	8.34	55.16	594	4301.84	20.90	8.70	1.90
2019	Poland	16.70	8.68	57.94	553	4153.68	20.10	7.90	1.90
2020	Poland	16.20	8.97	61.06	562	3935.9	17.70	8.40	2.00

Table 2. continuation

2021	Poland	17.30	8.77	59.43	598	3955.29	18.20	11.20	1.70
2022	Poland	17.70	9.14	65.51	556	3658.19	18.60	8.10	1.70
2012	Portugal	11.40	3.30	106.04	256	3518.39	:	13.90	:
2013	Portugal	11.60	3.40	110.35	252	3910.46	18.60	14.10	:
2014	Portugal	11.80	3.62	125.68	266	3744.1	17.80	12.20	1.50
2015	Portugal	12.30	3.81	130.66	265	3776.07	18.60	11.20	1.50
2016	Portugal	12.20	4.44	134.12	272	3438.69	19.20	10.50	1.40
2017	Portugal	12.40	4.54	133.72	271	3492.24	20.60	9.30	1.50
2018	Portugal	12.30	3.98	132.35	278	3247.84	20.50	8.30	1.50
2019	Portugal	11.90	5.38	135.14	279	3317.88	20.90	8.00	1.40
2020	Portugal	12.10	5.50	143.26	290	3282.95	21.70	9.10	1.70
2021	Portugal	12.40	4.74	143.71	290	3113.62	22.70	7.70	1.80
2022	Portugal	12.50	5.18	149.92	283	2918.42	22.70	6.70	1.70
2012	Romania	21.30	6.30	87.10	402	4222.93	:	16.80	:
2013	Romania	20.20	5.58	93.04	386	3590.36	17.60	17.00	:
2014	Romania	21.50	6.43	97.94	372	3644.23	16.60	17.00	1.70
2015	Romania	20.20	7.33	99.32	372	3318.59	14.90	18.10	2.30
2016	Romania	20.10	8.28	100.78	376	3303.57	14.40	17.40	1.80
2017	Romania	19.80	7.93	99.56	395	3259.27	15.10	15.20	2.10
2018	Romania	18.90	8.39	97.44	399	3329.29	15.90	14.50	2.50
2019	Romania	17.10	9.12	100.49	400	3323.17	17.50	14.70	2.50
2020	Romania	15.80	9.91	101.72	416	3469.21	18.40	14.80	2.50
2021	Romania	15.60	9.02	100.04	458	3468.81	19.10	18.00	2.70
2022	Romania	13.70	8.89	103.13	414	2855.22	18.60	17.50	2.70
2012	Slovakia	17.30	8.22	44.91	522	7084.81	:	13.80	:
2013	Slovakia	16.70	9.65	45.02	525	6658.34	18.00	13.70	:
2014	Slovakia	18.50	9.91	51.40	429	6520.69	17.20	12.80	:
2015	Slovakia	18.80	10.02	54.96	474	6322.95	16.60	13.70	:
2016	Slovakia	17.80	9.75	52.19	495	6229.2	15.80	12.30	:
2017	Slovakia	17.10	10.68	49.60	505	6341.32	14.70	12.10	:
2018	Slovakia	18.10	9.72	50.98	467	6417.02	13.90	10.20	2.10
2019	Slovakia	18.70	9.08	67.00	484	5546.41	12.90	10.30	2.20
2020	Slovakia	17.50	9.18	69.10	503	5256.19	13.00	10.70	2.00
2021	Slovakia	18.10	8.17	68.10	545	6287.31	13.20	11.00	1.90
2022	Slovakia	17.30	7.44	69.20	495	5097.97	13.20	9.60	2.00
2012	Slovenia	18.70	5.21	89.59	608	2816.44	:	9.30	:
2013	Slovenia	19.20	5.48	95.13	601	2976.73	19.80	9.20	:
2014	Slovenia	19.60	5.35	93.91	514	3027.35	19.80	9.40	2.30
2015	Slovenia	20.00	5.87	93.99	568	2892.66	19.90	9.50	2.10
2016	Slovenia	20.20	5.71	91.20	579	2894.23	33.30	8.00	2.00
2017	Slovenia	20.60	5.57	91.29	567	2968.25	19.40	6.50	2.00
2018	Slovenia	20.40	5.79	91.50	531	3056.34	20.70	6.60	2.10
2019	Slovenia	20.60	6.50	94.72	516	2997.84	20.80	7.00	2.20
2020	Slovenia	20.50	7.60	103.15	519	2874.22	20.50	7.70	2.70
2021	Slovenia	20.00	7.08	105.83	552	2950.22	21.60	6.60	2.40
2022	Slovenia	19.90	6.70	103.82	500	2738.76	22.40	8.20	2.50
2012	Spain	10.80	4.98	62.52	332	5011.42	15.60	18.60	:
2013	Spain	10.90	5.44	66.03	319	4933.37	19.40	18.60	:
2014	Spain	11.00	5.16	69.59	318	4798.45	21.10	17.10	1.50
2015	Spain	11.00	5.46	71.13	329	4670.2	22.40	15.60	1.50
2016	Spain	11.00	5.85	74.76	308	4614.71	21.60	14.60	1.50
2017	Spain	11.10	5.74	75.59	309	4507.1	21.90	13.30	1.60
2018	Spain	10.80	5.50	75.33	324	4439.92	21.50	12.40	1.60
2019	Spain	10.70	5.84	79.80	307	4228.59	20.90	12.10	1.50
2020	Spain	10.90	6.05	91.66	307	3935.91	20.90	13.90	1.70
2021	Spain	11.30	7.13	92.71	310	4073.96	23.40	11.00	1.70
2022	Spain	11.00	8.46	101.95	297	3550.11	23.00	10.50	1.80
2012	Sweden	14.10	12.85	183.59	846	3609.92	:	7.80	:
2013	Sweden	13.40	13.05	188.91	801	3356.73	14.70	7.50	:
2014	Sweden	13.00	12.91	195.76	746	3294.9	14.70	7.20	1.20
2015	Sweden	13.80	13.53	202.68	756	3315.38	15.30	6.70	1.10
2016	Sweden	13.50	13.38	207.44	772	3318.23	15.50	6.50	:
2017	Sweden	13.30	11.88	209.76	765	3217.22	15.00	6.20	:
2018	Sweden	13.40	11.28	213.14	736	3174.27	14.90	6.00	2.20
2019	Sweden	13.10	11.91	221.72	716	3164.62	15.80	5.50	2.20
2020	Sweden	12.60	12.85	232.85	694	2778.48	17.20	6.50	2.40
2021	Sweden	13.50	11.43	235.49	756	3012.37	19.20	5.10	2.50
2022	Sweden	14.00	11.96	248.31	673	2857.77	20.70	4.90	2.60

Source: prepared by author based on Eurostat (2024a-o), OECD (2024), World Bank Group (2024a-b) and Transparency International (2024).