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THE WORLD INDUSTRIAL PRODUCTION – STRUCTURAL DETERMINANTS

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Abstract: The annual pace of industrial production has shown a downward trend in the recent quarters, in the context of the fragmentation caused by the intensification of the geopolitical tensions following the outbreak of the crisis in Ukraine. Furthermore, the potential growth pace of this important coincident indicator for world economic activity is at very low level at present, at least compared to the developments in the cycle prior to the outbreak of the Great Financial Crisis (GFC). In this paper we apply standard econometric tools and use the databases of the Netherlands Bureau for Economic Policy Analysis (CPB), Federal Reserve (FED), and Bloomberg in order to assess the relation between the evolution of the world industrial production and several fundamental indicators, including the volume of world trade, the long-term real interest rate, and the volatility in the financial markets during the period January 2001 – January 2025. The econometric estimates confirm the direct relation between the evolution of industrial production and the dynamics of world trade. On the other hand, an inverse relationship is observed between the evolution of the industrial production and the dynamics of the long-term real interest rate and the volatility in the financial markets.

Keywords: world industry, world trade, real interest rates, volatility

JEL Classification : E44, F00, F13, F14

1 Introduction

From the historical perspective the industry has been the engine of the economy, either in advanced economies or in the emerging and developing countries.

Over the past years world industrial production has been confronted with the consequences of the coronavirus pandemic and the outbreak of the geopolitical crisis in Ukraine, including the fragmentation of international trade, and the increase of the real financing costs.

In this paper, we analyse the evolution of the volume of world industrial production and its dependence on several structural indicators, such as the volume of the international trade in goods, the long-term real interest rates, and the volatility in the financial markets.

In this respect, standard econometric tools are applied (Hodrick-Prescott filter, and the OLS regression) while using the databases of the Netherlands Bureau for Economic Policy Analysis, Federal Reserve and Bloomberg, monthly observations for the period January 2002 – January 2025.

According to the econometric estimates, the annual potential growth pace of the volume of the industrial production severely deteriorated after the outbreak of the crisis in Ukraine, given the geo-economic fragmentation, the upward trend of the real financing costs, and the high level of uncertainty.

The rest of the paper has the following structure: the literature review is briefly described in the next chapter; the methodology is presented in the third chapter; the fourth chapter is focused on the analysis of the recent developments of the volume of world industrial production; the analysis of the results of the econometric estimates follows in the fifth chapter; the conclusions are drawn in the last chapter.

2 Literature Review

The industrial production has always been an important component of economic activity, playing the role of an engine in the past centuries. Many experts analyzed the developments of industrial production and its

contributions to the growth and development of countries in the past decades. For instance, Szirmai (2012) emphasizes the contribution of industrialization to economic development across developing countries since 1950. The role of industry as the backbone of the economy was also underlined by Lichtblau et al. (2013), as the dynamics of the activity in this area have spillover impact for other sectors in the economy, given the strong interconnectedness. According to this paper, industry has a multiplier effect of 1.68 in EU economic activity. As regards macroeconomic analysis and forecasting, world industrial production represents a coincident indicator, as it is also considered a proxy for the dynamics of fixed investments in the real economy. Analysing the structural developments of world industrial production is very important nowadays, in the context of the implementation of technological progress and the persistence of unprecedented risks and challenges at a high level (including the trade war and geopolitical tensions).

On the one hand, the Digital Revolution and the Artificial Intelligence Revolution are transforming the real and financial sides of the economy with unprecedented speed. In fact, the current 4.0 Industrial Revolution is contributing to improving the performance of the economy through the optimization of the allocation of resources and the mitigation of risks, as emphasized by Malik et al. (2024). However, the recent exogenous shocks (coronavirus pandemic, the intensification of geopolitical tensions) and their consequences have had an important impact on the dynamics of industrial production.

Therefore, countries across the world have recently launched new industrial policies (NIP). In this respect, the study of Evenett et al. (2024) pointed out that industrial policy nowadays is also correlated with several factors, such as the electoral context, structural factors, and the current macroeconomic climate.

3 Methodology

In this paper standard econometric tools are applied in order to assess the structural developments of the volume of world industrial production, and its relation with fundamental indicators, such as the volume of the international trade in goods, the long-term real interest rate, and the volatility on the financial markets.

On the one hand, the Hodrick-Prescott filter is applied to distinguish between the structural and cyclical components of the macroeconomic indicators – the volume of the world industrial production, the volume of the international trade in goods, the long-term real interest rate, and the volatility on the financial markets.

This econometric filter is a well-known method implemented in the macroeconomic analysis, being based on the following relation:

$$\textbf{Min} \sum_{t=1}^{T} (\ln Y_t - \ln Y_t^*)^2 + \lambda \sum_{t=2}^{T-1} ((\ln Y_{t+1}^* - \ln Y_t^*) - (\ln Y_t^* - \ln Y_{t-1}^*))^2 \quad (1),$$

in which Y_t, Y_t^* and λ are the macroeconomic indicator, its trend (or the structural component), and the smoothness parameter. We used a level of 14400 for this parameter, the same as used by Hodrick-Prescott while working with monthly observations.

Afterwards, we estimated a standard OLS regression, with the trend component of the annual volume of the world industrial production being the dependent variable, while the trend component of the annual volume of the international trade, the trend component of the long-term real interest rate and the trend component of the volatility indicator as independent variables. This regression is expressed in the following line:

$$\text{Worldindtr} = c(1)+c(2)*\text{Inttradetr}+c(3)*\text{Longrealratetr}+c(4)*\text{Vixtr} \quad (2),$$

where Worldindtr is the trend component of the annual volume of the world industry, Inttradetr represents the trend component for the annual pace of the international trade in goods, Longrealratetr is the trend component of the long-term real interest rate, while Vixtr represents the trend component for the volatility index on the financial markets.

In this paper we used the 10YR real interest rate in the US as the proxy for the long-term real interest rate, and the VIX Index (which measures the volatility on the S&P 500 Index) as a proxy for the volatility on the financial markets.

We worked with monthly observations from January 2001 to January 2025, the data were collected from the Netherlands Bureau for Economic Policy Analysis (for international trade in goods, and world industrial

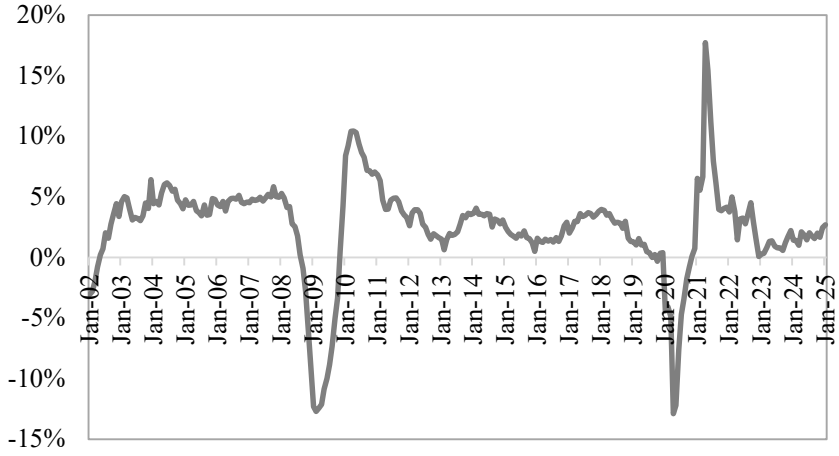
production), Federal Reserve (for the 10YR real interest rate in the US), and Bloomberg (for VIX indicator).

In this paper the econometric software E-Views was used.

4 The world industrial production – recent developments

The volume of the world industrial production has improved at the turn of the year 2025, before the implementation of the new trade tariffs by the largest economy in the world. According to the data released by the Netherlands Bureau for Economic Policy Analysis (CPB), the annual pace of the volume of world industrial production accelerated from 2.5% in December 2024 to 2.7% in January 2025. It is the best growth rate since October 2022, as can be noticed in the following chart. Overall, the volume of world industrial production climbed for the fourth year in a row in 2024, while the annual pace accelerated to 1.7%.

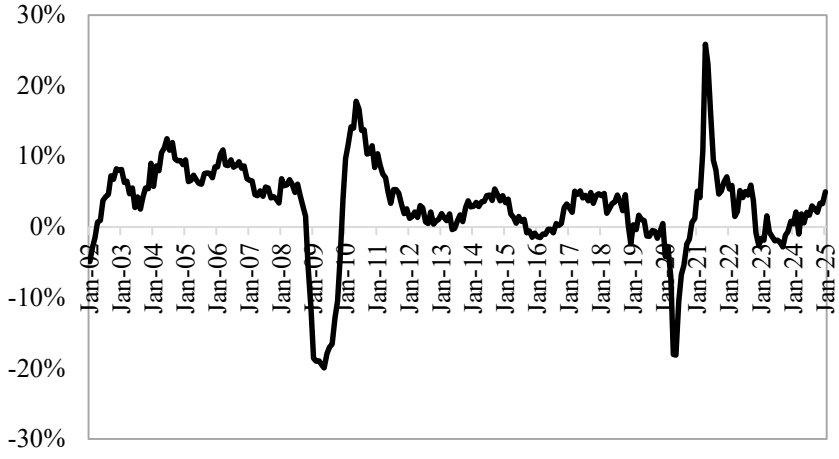
Figure 1. The annual pace of the volume of the world industrial production



Source: representation of the author based on the data of the Netherlands Bureau for Economic Policy Analysis (CPB), 2025

This evolution was mainly determined by the improvement in the volume of the world trade in goods. This indicator grew for the 10th month in a row in January 2025, while the annual pace accelerated to 5.0%, the highest level since September 2022, as reflected in the following chart. In 2024 the volume of the international trade in goods rebounded, climbing by an annual pace of 1.8%, following the contraction by an annual pace of 1.2% in 2023.

Figure 2. The annual pace of the volume of the world trade with goods



Source: representation of the author based on the data of the Netherlands Bureau for Economic Policy Analysis (CPB), 2025

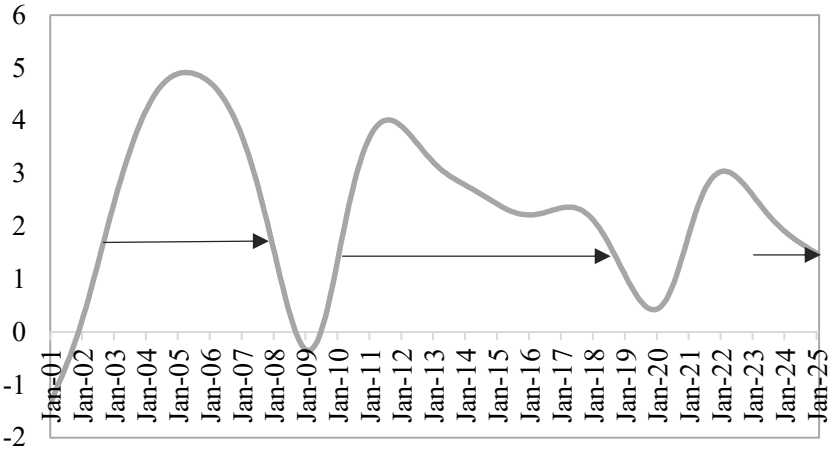
This, in turn, was determined by the measures implemented by the companies in anticipation of the increasing trade tariffs, one of the main topics on the Agenda of the New Administration in the USA, the largest economy in the world, with a nominal GDP of USD 29.2tn in 2024, according to the estimates of the Bureau for Economic Policy Analysis.

However, there can be noticed the divergence among the largest economies in the world in terms of the evolution of industrial production in January 2025. The US industrial production rose for the second month in a row in January, with the annual pace accelerating to 1.9%, the highest since October 2022. On the other hand, the annual pace of the volume of the industrial production in China (the second largest economy in the world, with a nominal GDP of over USD 18tn in 2024, according to the National Bureau of Statistics of China) decelerated to 5.7% in January 2025, the weakest since November 2024. Last, but not least, the volume of the industrial production in the Euroland (the main component of the European Union, with a nominal GDP of over EUR 15tn in 2024, according to Eurostat) continued to contract in January, but at a slower pace of 0.2%.

5 Interpretation of the results

According to the results of the econometric analysis, the annual potential pace of the volume of the world industrial production decelerated from around 3.0% in February 2022 (the month of the outbreak of the crisis in Ukraine) to 1.5% in January 2025. It is the lowest level since the month of October of the pandemic year 2020, as can be noticed in the following chart.

Figure 3. The annual potential pace of the volume of the world industrial production (%)



Source: representation of the author based on the results of the analysis using data of the Netherlands Bureau for Economic Policy Analysis (CPB)

Furthermore, the above chart allows us to notice the downward trend for the average annual potential pace of world industrial production over the past economic cycles.

According to the results of our econometric estimates, the annual potential growth pace for the volume of the world industrial production presented average levels of 3.5% during the pre-crisis economic cycle (2002-2007), 2.5% during the post-crisis cycle (2010-2019), and 2.2% after the outbreak of the crisis in Ukraine (period March 2022 – January 2025).

In other words, the potential growth pace of the volume of the world industrial production deteriorated significantly after the outbreak of the Great Financial Crisis, the worst financial crisis in the world since the Great Depression, as also underlined by the Kose et al. (2020). This evolution was determined by the negative impact of this crisis on the investment climate.

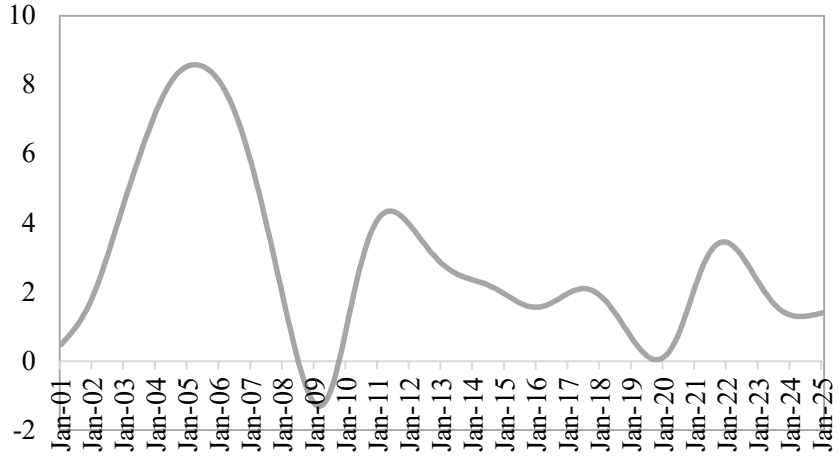
This downward trend of the annual potential growth pace of the world industrial production was mainly determined by the deterioration of the annual potential dynamic of the international trade in goods.

The results of the econometric estimates show that the annual potential pace of the volume of the international trade in goods registered an average of 6.1% during the pre-financial crisis economic cycle, the period 2002-2007.

During the post-crisis cycle the average level of the annual potential pace of the volume of the international trade in goods stood at only 2.2%, significantly lower compared to the previous cycle.

Furthermore, during the period March 2022 (the month after the outbreak of the crisis in Ukraine) – January 2025 the annual potential growth pace of the volume of international trade in goods presented an average of only 1.9%, as reflected in the following chart.

Figure 4. The annual potential pace of the volume of the international trade in goods (%)



Source: representation of the author based on the results of the analysis using data of the Netherlands Bureau for Economic Policy Analysis (CPB)

In fact, the econometric estimates confirm the direct relation between the evolution of the world industrial production and the dynamics of the international trade in goods, as can be noticed in the following table. According to our econometric analysis, the increase of the international trade in goods by 1% determined an advance of the world industrial production by 0.55% during January 2001 – January 2025, as can be noticed in the Table 1.

On the other hand, there can be noticed the negative relation between the evolution of the world industrial production and the dynamics of the long-term real interest rate in the US (a benchmark for the long-term interest rate in the world economy) and the volatility on the financial market in the US.

During January 2001 – January 2025 the increase in the long-term real interest rate in the US (the largest economy in the world) by 1% determined the contraction of the world industrial production by 0.69%. In fact, the increase of the real financing costs has a negative impact for the investments of the companies, with consequences for the production, as emphasized by Keynes (1978).

Last, but not least, the increase of the volatility on the US financial market by 1% had a negative impact of 0.05% for the evolution of the world industrial production in the interval January 2001 – January 2025, according to the results of our econometric analysis.

We point out that the level of the R-squared is above 91%, expressing that the dynamic of the world industrial production is explained to a large extent by the international trade in goods, long-term real interest rate in US, and the volatility of the S&P 500 index during the period January 2001 – January 2025.

Table 1. Results of the regression (2)

Dependent Variable: WORLDINDTR
Method: Least Squares
Date: 04/02/25 Time: 13:09
Sample(adjusted): 2001:01 2025:01
Included observations: 289 after adjusting endpoints
*WORLDINDTR = C(1)+C(2)*INTTRADETR+C(3)*LONGREALRATETR*
*+C(4)*VIXTR*

	Coefficient	*Std. Error*	*t-Statistic*	*Prob.*
C(1)	*2.447280*	*0.131535*	*18.60558*	*0.0000*
C(2)	*0.554869*	*0.012453*	*44.55825*	*0.0000*
C(3)	*-0.691761*	*0.040915*	*-16.90725*	*0.0000*
C(4)	*-0.047391*	*0.005965*	*-7.944193*	*0.0000*

R-squared	*0.912973*	*Mean dependent var*	*2.352093*
Adjusted R-squared	*0.912056*	*S.D. dependent var*	*1.423959*
S.E. of regression	*0.422279*	*Akaike info criterion*	*1.127443*
Sum squared resid	*50.82106*	*Schwarz criterion*	*1.178189*

Log likelihood	*-158.9155*	*Durbin-Watson stat*	*0.003668*

Source: representation of the author based on the results of the econometric analysis using data of the Netherlands Bureau for Economic Policy Analysis (CPB), Federal Reserve (FED), and Bloomberg

6 Conclusions

This article focused on the structural developments and determinants of world industrial production over the past decades.

The results of our econometric analysis emphasized the strong dependence of the world industrial production on the evolution of the international trade in goods. This result is very important, especially taking into account the present context, dominated by the change of the trade policy in the USA, as at the beginning of April the largest economy in the world decided to significantly increase trade tariffs with the rest of the world (by at least 10%).

These recent measures would have a negative impact on the international trade in goods in the short and mid-run.

Therefore, according to the results of our econometric estimates, the outlook for the world industrial production in the coming quarters is negative, with consequences for the evolution of the overall economic activity in the world. In fact, the probability of a global economic recession by the end of 2025 has significantly increased.

Another recession in the world economy following the multiple shocks in recent years (pandemic, geopolitical tensions, cost of living crisis) would have tremendous consequences for the development process and the transition to green economy, especially taking into account the very low manoeuvre room of the economic policy.

Against this background, we emphasize the importance of negotiations among the most important blocs in the world economy in order to avoid an escalation of the trade war and to adhere the WTO rules.

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THE ROLE OF INTERNATIONAL PARTNERSHIPS AND GLOBAL ALLIANCES FOR SECURING CRITICAL RAW MINERAL SUPPLY CHAINS

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Abstract: The global energy and digital transitions have significantly increased the demand for critical raw materials (CRMs) and exposed vulnerabilities in current supply chains. This paper investigates the geopolitical, economic, and environmental risks associated with the high concentration of CRM production and reserves in a limited number of countries and regions. The purpose of this study is to assess how international strategic partnerships can mitigate these systemic risks and ensure more secure, diversified, and sustainable access to key mineral resources. The objectives pursued include: mapping the global distribution of CRM reserves and production capacities; identifying key geopolitical and structural risks that threaten supply chain resilience; and analysing the most relevant international initiatives and bilateral or multilateral agreements aimed at cooperation on CRM. The study focuses in particular on the European Union's strategic partnerships with countries such as Canada, Namibia, Australia, and Japan, as well as transatlantic and Indo-Pacific alliances involving the United States, Canada, Japan, and Ukraine.

Keywords: critical raw materials, supply chain, international partnerships, geopolitical and structural risks.

1 Introduction

Critical minerals are essential resources for economic development and the global energy transition. They are indispensable for modern technologies, including batteries for electric vehicles, wind turbines, solar panels, and digital infrastructure (IEA, 2022). According to the European Commission (2023), dependence on a limited number of supplier countries leads to significant vulnerabilities both in developed and emerging economies. In this context, international partnerships have become a strategic component in securing supply chains.

This paper addresses the critical challenge of securing supply chains for CRMs by analysing the strategic role of international partnerships and global alliances. The issue is of paramount importance due to the concentration of CRM production and processing in a limited number of geopolitically sensitive regions such as China, the Democratic Republic of Congo, South America, and Indonesia. Such concentration exposes global supply chains to systemic vulnerabilities arising from geopolitical risks, export restrictions, resource nationalism, political instability, and various external shocks such as natural disasters and armed conflicts (IRENA, 2023). These factors threaten the stability and reliability of supply that are essential for the green and digital transitions.

To explore this issue comprehensively, the paper includes an analysis of quantitative data on global CRM reserves and production (USGS, 2024), which provides a detailed understanding of supply capacities and dependencies. The study investigates the responses of key actors, in particular the European Union, the United States (U.S.), Canada, Australia, Japan and Ukraine, through strategic partnerships and multilateral frameworks aimed at enhancing diversification, transparency and resilience of supply chains. These include policy instruments such as the European Raw Materials Alliance, and the Critical Raw Materials Act as well as bilateral and multilateral agreements to promote cooperation on sustainable mining practices, technology transfer, and capacity building.

By integrating recent empirical data and policy developments, this paper contributes to the existing literature by providing an updated assessment of risks in the CRM supply chain and mitigation strategies. It builds on previous research and reports from authoritative institutions such as the International Renewable Energy Agency (IRENA), the Organisation for Economic Co-operation and Development (OECD), the International Energy Agency (IEA), and the European Commission, while offering new insights into the evolving geopolitical dynamics and collaborative initiatives shaping the future of critical minerals supply security.

2 Literature review

The proliferation of emerging technologies – from renewable energy systems to electric vehicles – has led to a growing demand for critical mineral resources (CMRs). These materials are essential for the development and deployment of such technologies. However, their supply chains are often vulnerable to disruption, geopolitical tensions, and concerns over social and environmental sustainability (Althaf & Babbitt, 2020; Bhuwalka et al., 2021; Kramarz, Park & Johnson, 2021).

Addressing the challenges associated with critical mineral resources requires a collaborative approach involving governments, industry, and academia. Partnerships can play a pivotal role in developing comprehensive strategies to mitigate risks in the supply chain, diversify sources, and promote sustainable and ethical extraction and processing practices. A large number of researchers and practitioners are working to ensure a stable supply of these materials, which are critical to the transition to renewable energy technologies. The COVID-19 pandemic has further exacerbated the fragility of these supply chains, as disruptions in production and transport have contributed to increased uncertainty in the global economy (Giese, 2022). In this context, international actors have initiated partnerships aimed at mitigating the risks and addressing the challenges associated with critical mineral resources.

According to studies and policy reports (IRENA, 2023; Månberger & Johansson, 2019; OECD, 2016), CRMs' supply chains are exposed to a variety of geopolitical risks that jeopardise their stability and reliability. These risks include external shocks such as natural disasters, pandemics, armed conflicts, and mining accidents, which can significantly disrupt production and transport routes. In addition, the increasing trend towards export restrictions and resource nationalism, including the formation of mineral cartels that coordinate production volumes, pricing strategies, or market access, poses strategic challenges for consumer countries. Political instability and social unrest in resource-rich regions, manifested in strikes, violence, or corruption, further complicate the predictability of supply flows. Furthermore, market manipulation by dominant actors can distort global prices and restrict access for weak economies. In this context, international partnerships and global alliances are some of the most effective measures to mitigate these types of risks by promoting diversification, transparency, and collective resilience.

3 Research Methodology

The research methodology used in this paper is primarily qualitative and involves a comprehensive review and analysis of international literature, policy reports, and official documents published by key stakeholders, including international non-governmental organisations (NGOs) and European institutions. This analysis enabled a critical assessment of the current state of CRM supply chains, geopolitical risks, and policy responses.

In addition, the study examines and compares data on global CRM reserves and production in different regions and shows a significant concentration of these resources in a limited number of geographical areas. This geographical concentration emphasises the structural vulnerabilities of the global supply system, as dependence on a few key regions increases the risk of disruption. The analysis also included the mapping and assessment of existing strategic partnerships and international alliances to secure and diversify CRM supply. Particular attention was given to bilateral and multilateral agreements involving major actors such as the European Union, the United States, Canada, Australia, Japan, and Ukraine.

4 The Distribution of Reserves, Global Production, and Utilization of CRMs

Critical raw materials are naturally occurring elements and compounds that are economically important but whose supply is associated with a high risk due to geopolitical, geological, or market factors. These materials

are essential to the functioning of key industries such as renewable energy, digital infrastructure, aerospace, and defence. Their "criticality" arises from a combination of factors including their economic importance, the concentration of supply in a small number of countries, and the lack of viable substitutes or recycling technologies (European Commission, 2023).

The categorisation of a mineral as "critical" is not static, but evolves with technological advances and geopolitical dynamics. For example, the IEA points out that the energy transition will significantly increase demand for minerals such as nickel, copper, and manganese, creating new vulnerabilities in global supply chains (IEA, 2022). In addition, the concept of critical raw materials is increasingly linked to sustainability considerations, including the environmental and social costs of extraction, the carbon footprint of supply chains, and the ethical dimension of sourcing from conflict-affected regions (OECD, 2016). Effective governance frameworks and international partnerships are therefore crucial to ensure safe, responsible, and equitable access to these strategic resources.

CRM's classification reflects the strategic priorities of major global actors and their assessments of supply chain vulnerabilities. In 2024, the European Union (EU) enacted the Critical Raw Materials Act (CRMA) with Regulation (EU) 2024/1252, which identifies 34 CRMs, 17 of which are designated as strategic raw materials (SRMs). These SRMs are seen as critical to the EU's green and digital transitions and the regulation sets specific targets for extraction (10%), processing (40%), and recycling (25%) by 2030. The EU's SRM strategy emphasises resilience, sustainability, and reduced dependence on third-country suppliers, particularly in the context of increasing geopolitical tensions and supply disruptions (European Commission, 2024a).

In March 2025, the European Commission selected 47 Strategic Projects "to secure and diversify access to raw materials in the EU". All of them are located across 13 EU Member States: Belgium, France, Italy, Germany, Spain, Estonia, Czechia, Greece, Sweden, Finland, Portugal, Poland and Romania. The Strategic Projects cover 14 of the 17 SRMs listed in the CRMA (European Commission, 2025).

Also, in the United States, the USGS Mineral Commodity Summaries 2024 contain an updated list of 50 critical minerals considered essential to national economic security and defence. These include lithium, cobalt, rare earths, and other commodities needed for batteries, renewable energy infrastructure, and military technologies. The US strategy focuses on assessing supply chain risks and expanding domestic production and processing capabilities to reduce dependence on geopolitical rivals (USGS, 2024).

On the other hand, although China does not publish an official CRM list, it retains global dominance over the processing of 19 of the 20 most strategically important minerals, such as rare earths, graphite, and lithium. In 2024, the Chinese government revised its Mineral Resources Law to strengthen strategic reserves and incentivise increased production of key materials (Xinhua, 2024).

Meanwhile, the IEA warns of extreme market concentration in its Global Critical Minerals Outlook 2025: the three largest producing countries will control more than 75% of the supply for many key CRMs such as copper, nickel, and cobalt by 2035. The IEA calls for international cooperation and robust investment in diversified, resilient, and transparent value chains to support the global energy transition (IEA, 2025). These minerals are the foundation for strategic sectors of the global economy, from green energy and e-mobility to communications, robotics, and defence. Demand is continuously rising, increasing trade tensions and pressure on natural resources.

Table 1: Global Reserves and Production of Key Critical Raw Materials

Critical Raw Material	Global Reserves (metric tons)	Global Production (metric tons, 2023)	Used for
Lithium	28,000,000	180,000	EV batteries, energy storage
Cobalt	11,000,000	230,000	Batteries, super alloys
Nickel	>130,000,000	3,600,000	Stainless steel, batteries
Rare Earth Elements	110,000,000	350,000	Magnets, electronics, defence
Graphite (natural)	280,000,000	1,600,000	Batteries, lubricants
Copper	>1,000,000,000	22,000,000	Electrical wiring, electronics
Tantalum	>450,000	2,400	Capacitors, electronics
Niobium	>17,000,000	83,000	Steel alloys, superconductors
Tungsten	4,400,000	78,000	Metalworking, electronics

Source: USGS, 2024.

Table 1 provides a brief overview of global reserves, production volumes (estimated for 2023), and the main applications of the most important CRMs, which are essential for modern industrial and technological processes. The data illustrates the significant disparity in reserves and production volumes of the various minerals, reflecting their varying geological availability and market demand.

Lithium, with global reserves estimated at 28 million metric tons and production of 180,000 metric tons, is primarily used in batteries for electric vehicles and energy storage systems, underlining its central role in the ongoing energy transition. Cobalt, with reserves of around 11 million metric tons but a similar production level to lithium, is mainly used in the production of batteries and superalloys, which are essential for high-performance applications.

Nickel and copper are characterised by large reserves – more than 130 million and 1 billion metric tons respectively – and substantial production volumes. Their broad industrial use in stainless steel, batteries, electrical wiring, and electronics highlights their fundamental status in global manufacturing and infrastructure.

Although rare earths have smaller reserves, they occupy a crucial position due to their special applications in magnets, electronics, and defence technologies. Natural graphite, tantalum, niobium, and tungsten are less rich in reserves than copper and nickel, but play an indispensable role in niche applications such as battery anodes, capacitors, steel alloys, and metal processing. Although their production volumes are modest, they reflect targeted extraction to meet specific technological requirements.

Table 2: Countries with Largest Reserves and Production of CRMs

Critical Raw Material	Country with Largest Reserves	Share of Global Reserves	Country with Largest Production	Share of Global Production
Lithium	Chile	33.2%	Australia	47.8%
Cobalt	DR Congo	54.5%	DR Congo	73.9%
Nickel	Indonesia	42.3%	Indonesia	50.0%
Rare Earth Elements	China	40%	China	68.6%
Graphite (natural)	China	27.9%	China	76.9%
Copper	Chile	19.0%	Chile	22.7%
Tantalum	China	53.3%	DR Congo	40.9%
Niobium	Brazil	94.1%	Brazil	90.4%
Tungsten	China	52.3%	China	80.8%

Source: USGS, 2024.

The data in Table 2 illustrates the dominant role that certain countries play in both the reserves and production of key CRMs and shows a significant geographical concentration that has important geopolitical and economic implications. Chile emerges as a leading player in the lithium and copper sector and has around one third of the world's lithium reserves (33.2%) as well as substantial shares of copper reserves (19.0%) and production (22.7%). This underscores Chile's strategic importance for the global supply of these key materials, particularly lithium, which is crucial for the fast-growing electric vehicle and energy storage industries. The D.R. Congo has a marked dominance in cobalt, accounting for 54.5% of global reserves and an even more significant 73.9% of production. This concentration makes global cobalt supply chains very sensitive to the political and social conditions in this country and increases concerns about the security of supply and ethical sourcing.

China shows an overwhelming dominance in several CRMs, particularly rare earths, natural graphite, tantalum, and tungsten. With 40% of rare earth reserves and 68.6% of production, as well as dominant shares of natural graphite reserves (27.9%) and production (76.9%) and tungsten reserves (52.3%) and production (80.8%), China’s control over these minerals is a key factor in global supply chain stability and geopolitical dynamics. On the other hand, Indonesia is also an important supplier due to its significant share of nickel reserves (42.3%) and production (50.0%), reflecting its strategic role in the production of stainless steel and batteries. In the case of niobium, Brazil stands out with an extraordinary 94.1% share of global reserves and 90.4% of global production.

The country thus controls this niche but strategically important material, which is used in steel alloys and superconductors.

Overall, this data highlights the marked concentration of critical mineral resources in a limited number of countries, posing challenges in terms of supply chain diversification, geopolitical influence, and the need for international cooperation to ensure stable and ethical access to these vital materials. At the same time, the strategic importance of certain minerals is also determined by their substitutability, their recycling potential, and the environmental and social costs of their extraction. Criticality is therefore a dynamic concept that needs to be regularly reassessed due to technological development and geopolitical changes.

The concentration of production and processing in a few regions of the world (e.g. China, Democratic Republic of Congo, South America, or Indonesia) creates systemic vulnerabilities in supply chains. This fact justifies the urgency to develop international partnerships to minimise the risk of disruptions and ensure stable access to these key commodities.

5 Strategic Partnerships and Global Alliances for Critical Mineral Supply

5.1 European Union Initiatives

The European Union has increasingly recognised the strategic importance of securing access to critical raw materials. In response, the EU launched the European Raw Materials Alliance (ERMA) in 2020, which aims to promote partnerships throughout the supply chain and reduce dependence on external actors, particularly China (European Commission, 2020). The Critical Raw Materials Act proposed in 2023 further formalises these efforts by setting concrete benchmarks: For example, the EU must not depend on any one country for more than 65% of its annual consumption of strategic raw materials by 2030 (European Commission, 2023). These initiatives are part of a broader strategy for open strategic autonomy that aims to maintain integration into global markets while improving resilience.

Through bilateral and multilateral agreements, the EU has also begun to enter into strategic partnerships with resource-rich countries. In response to growing concerns about supply chain vulnerabilities and geopolitical dependencies, the European Union has actively pursued Strategic Partnerships (SPs) aimed at ensuring access to CRMs. These partnerships are formalised through Memoranda of Understanding (MoUs) and reflect a broader strategy of external engagement and diversification. So far, the EU has concluded such agreements with a number of countries, including Canada and Ukraine (2021), Kazakhstan, and Namibia (2022) as well as Argentina, Chile, Zambia, the Democratic Republic of Congo, and Greenland (all in 2023). These collaborations are intended not only to secure reliable sources of CRMs, but also to promote sustainable mining practises, technology transfer and capacity building, thereby aligning supply chain security with broader development and environmental goals (Müller, Ghiotto & Bárcena, 2024). These agreements are intended not only to secure the supply of raw materials, but also to promote responsible mining practises, technology transfer and local value creation. For example, the partnership signed between the EU and Namibia in 2022 includes provisions for joint investment in refinery infrastructure and skills development. This reflects the ambition to go beyond traditional commodity relations by integrating the principles of sustainability and development cooperation.

5.2. The European Union's Key Strategic Partnerships

The European Union's heavy dependence on CRM imports and the importance of CRM-based raw materials for industry have made the risks associated with these resources a major concern at the EU level (Løvik, Hagelüken & Wäger 2018). The essential role of CRMs in European industry has led to a variety of policy initiatives, stakeholder collaboration platforms, activities, and research projects aimed at addressing security of supply concerns. While these efforts focus primarily on critical metals, they also recognise that other raw materials may pose equally significant or even greater supply risks (Lewicka, Guzik & Galos, 2021).

The strategic importance that the EU attaches to access to critical raw materials is reflected in various policy initiatives such as the *European Green Deal*, the *Industrial Strategy for Europe,* and the *EU Regulation on Sustainable Investments* (Guzik et al., 2021). These strategies emphasise the need to improve access to existing primary resources and increase recycling activities. The EU has implemented numerous political initiatives, stakeholder collaboration platforms, industrial activities and research projects to improve access to and utilisation of existing primary resources and to intensify recycling efforts.

EU-U.S.: Strengthening Cooperation on Critical Minerals Security

In March 2023, the President of the European Commission, Ursula von der Leyen, and US President Joe Biden announced their intention to conclude an agreement on critical minerals, which could represent a strategic step towards strengthening the supply chains necessary for the green transition (European Parliament, 2023). Although the negotiations were authorized by the EU Council in July 2023, the talks are still ongoing and remain unpredictable, particularly given the changes in the US administration.

This initiative was expanded in April 2024 (European Commission, 2024b) when the EU, the US, and other members of the Minerals Security Partnership (MSP) announced the launch of the Minerals Security Partnership Forum - a significant step towards international cooperation on critical mineral resources (Lewicka, Guzik & Galos, 2021). The initiative aligns with the EU's broader strategy to diversify sources of supply and reduce dependence on single suppliers, as outlined in the discussions on "raw materials diplomacy" (Guzik et al., 2021; Løvik, Hagelüken & Wäger 2018) and aims to expand collaboration on essential resources required for the green and digital transitions in a broader and more ambitious framework (Løvik, Hagelüken & Wäger 2018). The Forum's dual approach demonstrates a commitment to responsible sourcing and development: on the one hand, it supports sustainable projects on the ground; on the other, it facilitates political dialogue on sustainable production, regulatory cooperation, and standards related to environmental, social and governance (ESG) policies. The policy of openness to new members - which requires adherence to the MSP principles - encourages global participation in building resilient and sustainable supply chains for key mineral commodities.

EU-Canada: Collaboration on Critical Minerals and Sustainability

The Strategic Partnership on Raw Materials, signed in June 2021, is an important mechanism to engage the European Commission and EU Member States in Canada's critical minerals and batteries value chains (European Commission, 2021). Its main objective is to improve the value, security, and sustainability of trade and investment in critical minerals and metals, which are essential for the transition to a green and digital economy. Agreed areas of collaboration under this partnership include the integration of commodity value chains, cooperation in science, technology, and innovation, and coordination within international forums to promote ESG criteria and standards.

EU-Australia: An Essential Partnership for a Sustainable Future

The partnership between Australia and the EU on critical minerals represents a significant opportunity to accelerate the transition to a net-zero emissions future (European Commission, 2024c). As a major producer and exporter of various mineral commodities, Australia is well positioned to meet the EU's growing demand for critical minerals needed for the energy transition. Australia's considerable mineral wealth and long experience in the mining sector can provide the EU with a sustainable and reliable source of critical minerals (Golev & Corder, 2015). At the same time, the EU's emphasis on resource security and its policies aimed at reducing import dependence, as well as increased recycling efforts, complement Australia's capabilities (Lewicka, Guzik & Galos, 2021). This partnership is particularly important given the complementary strengths and resources of the two parties. The EU, with its ambitious environmental and sustainability goals, has a vested interest in securing reliable and sustainable sources of critical minerals to support its green transition (Guzik et al., 2021). Cooperation could not only help to reduce vulnerabilities in global supply chains, but also promote sustainable practises in the extraction and use of raw materials.

EU-Japan: Agreements for Trade and Sustainability

The EU and Japan share a long history of economic and diplomatic cooperation, which has been extended in recent years to include the management of critical raw materials. The EU's strategic focus on Asia and Japan's growing economic presence in Europe have laid the foundation for closer collaboration in this area (Jańczak, 2021).

A milestone in EU-Japan relations is the Economic Partnership Agreement between the EU and Japan, which was signed in 2017. This agreement, which creates the largest free trade area in the world, sends a strong signal against protectionism and supports the modernisation of global trade rules (Hilpert, 2018). It is not just a trade deal, but also a strategic alliance between the EU and Japan that has the potential to help the EU take a leadership role in setting global trade standards (Frenkel & Walter, 2017). The expanded cooperation between the EU and Japan reflects a shared vision for open, sustainable, and rules-based global trade and provides a solid platform for collaboration on critical minerals and other strategic initiatives.

5.3. Global Alliances for Critical Mineral Supply

U.S.-Australia: A Strategic Partnership for Energy Transition Security

The United States and Australia have long maintained a strong strategic partnership, working together on a wide range of economic, political, and security issues. In recent years, this relationship has grown in importance as both countries seek to navigate the complex geopolitical landscape of the Asia-Pacific region. A key area of cooperation is the development and securing of critical mineral supplies in support of clean energy goals (White House, 2023).

With its abundant natural resources, Australia is well positioned to play an essential role in this partnership. As a major exporter of various mineral commodities, Australia's mining sector has been a crucial driver of economic growth for decades (Golev & Corder, 2015). Furthermore, Australia's proximity to the Asia-Pacific region and its economic ties with both the US and China give the country a strategic position with significant implications.

As the US and its allies seek to reduce their dependence on China for critical minerals, the partnership with Australia has become increasingly important. Australia's role as a stable and reliable supplier of these critical resources can help mitigate the risks associated with global supply chain disruptions and geopolitical tensions. In addition, the U.S.-Australia partnership on critical minerals can serve as a foundation for broader cooperation on new technology development, the transition to clean energy, and regional security and stability. By working together, the two countries can leverage their strengths and resources to address these complex and interrelated challenges.

U.S.-Canada: A Joint Strategic Commitment to Critical Minerals

Announced in January 2020, the Canada-US Joint Action Plan on Critical Minerals Collaboration is a strategic partnership to secure the supply chains of key critical minerals for various industry sectors. These include communications technologies, aerospace, defence and clean technologies (Giese, 2022).

The Action Plan promotes collaboration in several areas: (i) Industry engagement – developing partnerships with industry stakeholders to support supply chain capacity; (ii) Innovation – supporting research and development to find more efficient and sustainable solutions; (iii) Supply chains – securing resilient and diversified supply networks for critical minerals; (iv) Information exchange – sharing data on mineral resources and their potential; and (v) International collaboration – promoting joint efforts globally to improve access to critical resources (Government of Canada, 2020).

This initiative reflects a shared Canadian and U.S. commitment to reducing the risks associated with dependence on individual suppliers and supporting strategic economic sectors essential to the transition to cleaner and more sustainable technologies.

U.S.-Ukraine: A possible triumph for diplomacy

On 30 April 2025, the United States and Ukraine established a Reconstruction Investment Fund, opening the door for significant US investment in Ukraine's critical raw materials (CRM). The agreement ensures shared decision-making and revenues, with all profits reinvested in Ukraine for the first decade. Importantly, the agreement confirms Ukraine's sovereignty over its CRM resources under international law and includes key mineral-rich areas, some of which are near or within Russian-occupied territories. This complicates any potential U.S. recognition of Russian territorial claims and may deter further aggression due to the increased presence of US economic interests.

The agreement represents a strategic shift in US policy under the Trump administration - from transactional diplomacy to a long-term partnership - and at the same time strengthens Ukraine's international negotiating credibility. By linking cooperation in the field of mineral resources with defence and reconstruction, the agreement positions CRM as both an economic and security asset. At the transatlantic level, the agreement strengthens cohesion between the US and EU on sanctions and Ukraine integration and signals a broader consensus on the geopolitical value of securing CRM supply chains against authoritarian actors (Gould-Davies, 2025).

Canada-Japan: Dialogue and Shared Vision for Energy Resources

The growing global demand for critical minerals— essential to the manufacture of a wide range of high-tech products and the transition to a low-carbon economy has led to increased attention being paid to securing reliable and diversified sources of these resources. The cooperation between Canada and Japan in the field of

critical minerals reflects this general trend, as the countries seek to strengthen international cooperation and ensure resilient supply chains for critical minerals.

In May 2021, Canada and Japan agreed on six areas of bilateral cooperation on critical minerals, including the establishment of a Canada-Japan Critical Minerals Working Group under the broader framework of the Canada-Japan Energy Policy Dialogue. This working group will serve as a platform for both countries to facilitate trade, exchange information, and collaborate on standards related to critical minerals (Lewicka, Guzik & Galos, 2021).

6 Conclusions

The global transition to clean and green energy has reaffirmed the strategic importance of essential minerals. This paper has emphasised that the geographic concentration of CRM reserves and supply chains, combined with economic, geopolitical, ethical, and environmental challenges, poses significant risks and creates major vulnerabilities in global supply chains. Analysis of international literature, official reports, and strategic partnerships show that geopolitical risks, resource nationalism, and social challenges threaten the stability and predictability of access to CRMs. Nations are responding with a combination of trade policy, domestic investment, and international partnerships to ensure a sustainable and resilient supply of CRMs.

The path to reducing dependence on CRMs is fraught with challenges, and both the EU and the US must grapple with rising demand, geopolitical rivalries and the technical complexity of CRM extraction and processing. Therefore, this paper emphasises the increasing role of international alliances, such as those forged by the European Union, the United States, Canada, Australia, and Japan, in promoting diversification, sustainability, and resilience in critical mineral supply chains.

Recycling initiatives, advances in the circular economy, and strategic partnerships with resource-rich countries will play a crucial role in ensuring a stable CRM supply. Collaboration between governments, industry, and international organisations will be critical to creating resilient and sustainable supply chains that can support the transition. This holistic approach will be crucial to support the green transition while managing the complexity of the critical minerals landscape.

For further research, it is recommended to deepen the analysis of the effectiveness of existing partnerships in practice, explore emerging technologies that can change demand and supply dynamics, and investigate the socio-environmental impacts of expanding mining activities in resource-rich regions. Unilateral actions, such as recent initiatives of the Trump 2.0 Administration also deserve attention, including the executive order entitled *Unleashing America's Offshore Critical Minerals and Resources* (April 24, 2025) and the launch of an investigation on potential national security risks from imports of critical minerals and their derivative products (April 15, 2025). The criticality of raw materials will continue to be relevant in the years to come.

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RENEWABLE ENERGY INDUSTRY IN THE EU AS A KEY CLIMATE CHANGE DRIVER

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Abstract: The European Union aims to increase the share of energy from renewable sources (RES), mainly to combat climate change, but also to maintain its leading position in high-performance technologies. As a member of the European Union, Romania attaches great importance to the development of this type of energy, as can be easily observed from the ambitious targets set and the massive investments made in this field.
This article aims to analyse recent developments in the renewable energy sector in the European Union and in Romania in particular. In the first part of the paper, we conducted a quantitative analysis that included four indicators on renewable energy, and in the second part, we focused on the future development prospects of this sector in Romania. Our main findings show that even though Romania is well positioned in terms of the indicators analysed, the potential of RES is not yet fully exploited. To this extent, measures such as improving support schemes for RES, building and putting into operation new RES electricity generation capacities, in particular wind and solar, modernising existing cogeneration plants, or expanding nuclear generation capacities should be considered.

Keywords: renewable energy, Romania, climate change, European Union

JEL classification: Q42, Q48, Q49, Q54

1. Introduction

The transition to a low-carbon economy aims to create a sustainable energy sector that stimulates growth, innovation, and job creation, while improving quality of life, broadening the range of products and services available and, as a result, reducing electricity bills (Kurbatova et al., 2023; Haas et al., 2023; Saraji et al., 2023). A streamlined and coordinated approach at the EU level ensures a truly continental impact in the fight against climate change (Wang et al., 2024). Measures to promote renewable energy and improve energy efficiency are essential to reduce Europe's greenhouse gas emissions and meet the commitments made under the Paris Agreement (Karakosta et al., 2025; Gajdzik et al., 2024).

At the international level, the EU plays an important role, working with other countries, regions, and international organisations to find solutions to energy issues and ensure a reliable and competitive energy market in Europe (Kalantzakos et al., 2023). In line with the Paris Agreement, the Council of the European Union supports that the EU and its Member States will strengthen global action on climate change, demonstrating that a path to climate neutrality is not only essential but also feasible and desirable (Schwarte, 2021).

As mentioned above, renewable energy involves increasing the share of energy production from non-fossil fuels, such as solar, wind and hydro energy. Compared to their fossil fuel equivalents, such as coal, oil, and natural gas, renewable energy sources have a substantially lower impact on the environment (Chen et al., 2023). As a result, this proactive transition to renewable energy is emerging as a crucial and compelling strategy for ensuring the long-term sustainability of the planet, supporting the EU's objectives of reducing greenhouse gas emissions and stimulating sustainable economic growth (Gajdzik et al., 2024).

Romania, as a member state of the European Union, attaches great importance to the development of energy from renewable sources, as can be easily seen from the targets it has set and the legislation it has adopted (Ciot et al., 2025; Memo et al., 2023). The objective of this research is to analyse the latest developments in the renewable energy sector in the European Union and in Romania in particular. Therefore, a quantitative analysis of the energy sector in the European Union will be carried out, with a focus on Romania, from the perspective of

the most important indicators in the field, followed by an analysis of the development prospects for the renewable energy sector in Romania.

2. Literature review

The literature (Delbeke, 2024; Joița et al., 2023; Rimšaitė, L., 2024) shows that to become the first climate-neutral continent by 2050, European authorities must implement measures that enable European citizens to benefit from the green transition. The utilisation of energy from renewable sources has been demonstrated to engender a multitude of potential benefits (Algarni et al., 2023; Batra, 2023). These include the reduction of greenhouse gas emissions, the diversification of energy supplies, and the reduction of dependence on fossil fuel markets (especially oil and natural gas). Furthermore, the utilisation of renewable energy has been identified as a pivotal factor in fostering employment opportunities within the domain of green technologies (Ma et al., 2025; Chou et al., 2023). This aspect is poised to assume a significant role in the "Clean Industrial Deal".

On 11 December 2019, in view of the European Green Deal, the Union committed to finding solutions to the challenges related to energy, climate and the environment and to achieving climate neutrality by 2050, in line with the Paris Agreement. The literature (Nagaj et al., 2024; Battisti, 2023; Khaleel et al., 2024) also shows that the transformation of the Union's energy system plays a key role in this regard, as energy production and use account for more than 75% of greenhouse gas emissions.

The initial directive pertaining to renewable energy sources, which came into force on 23 April 2009, acknowledged that 20% of total final energy consumption across the European Union, and 10% of energy consumption within each EU Member State, should derive from renewable sources by the year 2020. The Directive further stipulates binding national targets in alignment with the EU's overarching objective. In accordance with the EU's policy directives, member states were obliged to devise indicative pathways to assist them in the achievement of their stated targets. They were further obliged to submit national action plans for the development of renewable energy, and to publish bi-annual national reports that would document the progress made in this field. As stated in the directive, a number of mechanisms are available to EU Member States for the purpose of stimulating investment in renewable energy sources. These comprise support programs, feed-in tariffs, joint projects, and cooperation with non-EU countries. Furthermore, environmental standards for biofuels are to be established.

The first revision of the Renewable Energy Directive was brought into force in 2018 as part of the "Clean Energy for All Europeans" package. The Directive, which was to be incorporated into national legislation by EU countries by June 2021, established a new mandatory EU target for 2030. This target stipulates that a minimum of 32% of gross final energy consumption must be derived from renewable energy sources. Additionally, it has set an augmented target of 14% for the share of renewable fuels in transport by 2030.

In accordance with Regulation (EU) 2018/1999, EU Member States were required to propose national energy targets and establish ten-year National Energy and Climate Plans (NECPs) for the 2021-2030 period by March 2023. The NECPs are subject to biennial monitoring through progress reports, and are subject to assessment by the Commission. The Commission is entitled to implement measures at EU level to ensure the NECPs comply with the EU's overall targets.

The second amendments to the Renewable Energy Directive were the result of three major changes in 2023. The "Fit for 55" package, implemented in July 2021, included the first amendment, the purpose of which was to align the EU's renewable energy targets with the new and ambitious climate goal.

In March and May 2022, as part of the REPowerEU package following Russia's aggression against Ukraine, the second bill aimed to accelerate the transition to clean energy, reflecting the decision to end dependence on Russian coal. This was to be achieved through the installation of heat pumps, increasing the capacity of solar photovoltaics and importing hydrogen from renewable sources and biomethane.

The third amendment of November 2022 aimed to accelerate the deployment of renewable energy, based on the principle that certain renewable energy installations are of high public interest. According to studies (Danilova, 2024; Gurreck, 2025), this allows for faster authorisation of renewable energy projects and specific derogations from EU environmental legislation.

The renewable energy guidelines that came into force in November 2023 increase the 2030 target for renewable energy sources to 42.5%, while European Union member states are aiming to reach 45%. In addition, the measures speed up the approval of new renewable energy installations, such as solar panels or wind turbines, and set a maximum approval period for new installations at 12 months in areas considered priority for renewable energy production and 24 months in other areas.

Regulation (EU) 2020/1294 establishes a mechanism for EU financing to help countries achieve their individual and collective renewable energy targets. This mechanism establishes links between countries that invest in projects (financing countries) and countries that agree to host new projects on their territory (hosting countries). The Commission sets out the operational framework and financing modalities, specifying that EU countries, funds or contributions from the private sector can finance activities under this mechanism. Energy produced through this mechanism counts towards the renewable energy targets of all participating countries.

The REPowerEU strategy was initiated with the objective of increasing solar photovoltaic capacity to 320 gigawatts by 2025, with a further ambition of reaching 600 gigawatts by 2030. The strategy encompassed a phased legal commitment to the installation of solar panels on new public, commercial and residential buildings, in addition to a strategy to double the pace of installing heat pumps in central and local heating systems. EU member states are obligated to pinpoint and implement strategies for the establishment of areas conducive to the development of renewable energy projects, accompanied by the acceleration and streamlining of permit processes. The revised Renewable Energy Directive establishes expedited procedures for the approval of permits for the installation of solar energy equipment.

Directive (EU) 2018/2001 on renewable energy sources includes targets for advanced biofuels, biogas and RFNBO (such as hydrogen) in the transport sector of 1% by 2025 and 5.5% by 2030. In July 2020, the Energy System Integration and Hydrogen Strategies set a target of at minimum 6 GW of renewable hydrogen electrolysers and the production of up to 1 million tonnes of renewable hydrogen in the EU by 2024. These strategies also set an ambitious target of 40 GW and 10 million tonnes by 2030, demonstrating a commitment to substantial growth. The REPowerEU plan, launched in 2022, established an ambitious target of producing and importing 10 million tonnes of hydrogen from renewable sources by 2030. In 2023, the Renewable Energy Directive set an indicative target of 42% renewable hydrogen in total hydrogen consumption by 2030 and 60% by 2035 for industry.

3. Methodology

The methodological design used in this article is a mixed one, based on an analysis of indicators on the progress of renewable energy in all Member States, with a focus on Romania (using the latest Eurostat data available), and a qualitative assessment of the future development prospects of the renewable energy sector in Romania, including the identification of possible measures for its sustainable development.

The quantitative analysis is based on Eurostat data and aims to highlight Romania's progress in the field of renewable energy compared to other EU Member States. To this end, we analysed the four most important indicators for renewable energy sources, namely: share of energy from renewable sources, share of energy from renewable sources in gross electricity consumption, share of energy from renewable sources for heating and cooling, and share of energy from renewable sources in transport.

The data used and background information were carefully selected from the relevant literature. The analysis focuses on the challenges and opportunities for developing renewable energy sources, while also looking at the current state of this sector in Romania and its prospects. The most important limitation of this research is related to the absence of data for the year 2024, and, bearing this in mind, the extension of the research as soon as this data becomes available is seriously taken into consideration.

4. Recent developments in the renewable energy sector in the European Union and Romania

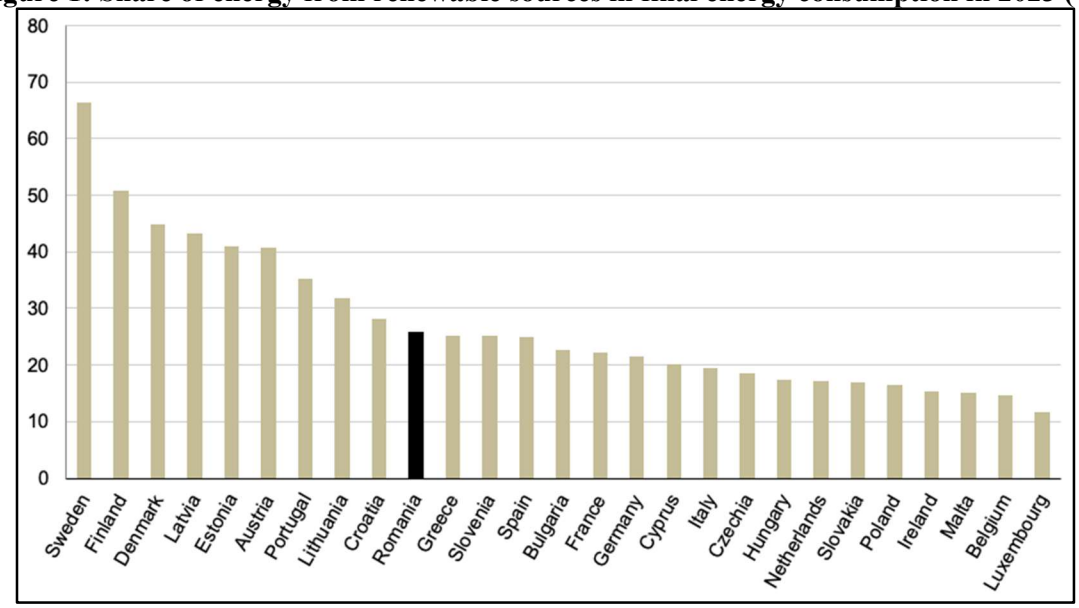
This section of the document presents statistical data on the share of energy from renewable sources in the total volume and in each of the three most important sectors for consumption (electricity, heating and cooling, and transport) in the European Union (based on the latest data from Eurostat), with a focus on Romania. Renewable energy sources include wind, solar (thermal and photovoltaic), hydropower, wave energy, geothermal energy, heat extracted by heat pumps, biofuels and the renewable fraction of waste.

4.1. Energy from renewable sources in gross final energy consumption

In 2023, the European Union's share of renewable energy was 24.5% of total energy use. This figure represents an increase of 1.5% compared to 2022, and is almost three times higher than in 2004 (9.6%). Directive 2023/2413 stipulates that the EU should endeavour to increase its reliance on renewable energy sources. In

accordance with this directive, the target for energy from renewable sources has been increased from 32% to 42.5%, with the aim of rising to 45%. This necessitates a collaborative effort among EU countries to ensure the attainment of the 2030 targets. In consideration of the newly established target, it is imperative to augment the proportion of energy derived from renewable sources within the EU's gross final energy consumption by approximately 20%. As demonstrated in Figure 1, the most recent data available concerning the proportion of renewable energy in final energy consumption is illustrated.

Figure 1: Share of energy from renewable sources in final energy consumption in 2023 (%)



Source: Author based on Eurostat data, 2024

In 2023, Sweden was ranked first in the world in terms of the proportion of its total energy consumption that came from renewable sources, with two-thirds of this total coming from such sources. Sweden has utilised solid biofuels, hydropower and wind energy. Finland attained second place with 50.8%, while Denmark secured third with 44.9%, employing biofuels and wind energy as primary sources of energy. The lowest shares of energy from renewable sources were recorded in Luxembourg (11.6%), Belgium (14.7%) and Malta (15.1%).

It is evident that certain nations have utilised statistical transfers to attain levels that surpass their 2020 targets, which in turn represent their commitment for the subsequent period extending from 2021 to 2030. Statistical transfers are defined as agreements between EU countries to transfer a quantity of energy from renewable sources from one country to another.

In Romania, the share of renewable energy in final energy consumption was 25.8% in 2023, the last year for which data are available, compared to 24.14% in 2022. Romania's strong performance in terms of this indicator is due to hydropower and investments in wind energy.

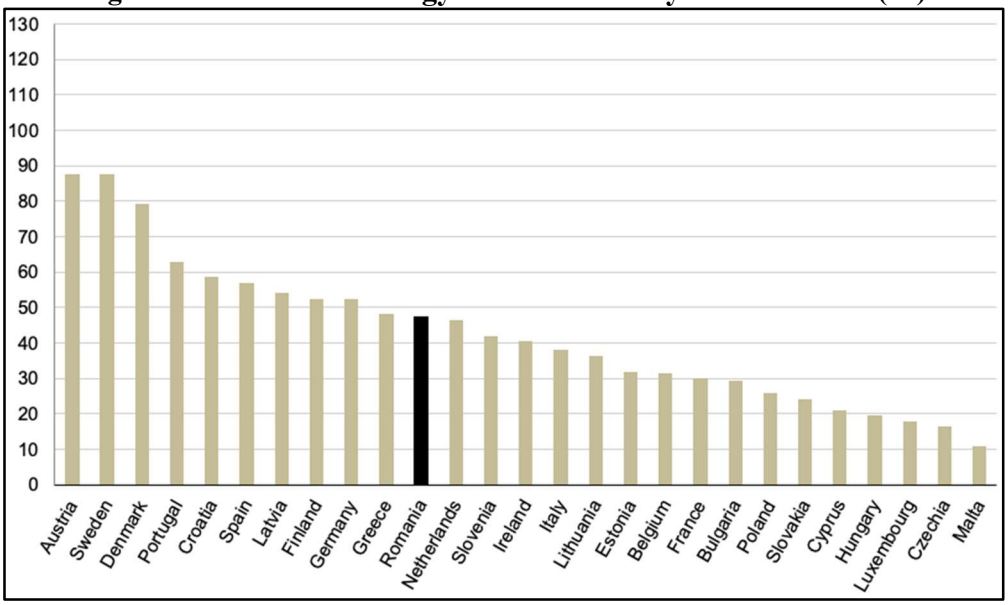
4.2. Renewable energy in the electricity sector

The criteria set out in Directive 2018/2001 stipulate that electricity produced from water and wind sources must be regulated to consider annual climate variations (hydropower has been regulated for the past 15 years, while wind energy has been regulated for the past five years, with separate regulation for onshore and offshore wind energy.)

The increase in electricity from renewable sources between 2013 and 2023 is due to the significant increase in electrical energy from wind and solar energy in the European Union. In 2023, renewable energy sources accounted for 45.3% of total electricity consumption in the European Union, an increase of 4% compared to the previous year (41.2% in 2022).

Electricity generated from wind and water sources accounts for more than two-thirds of total electricity generated from renewable sources (38.5% and 28.2%). The remaining electricity was produced from solar energy (20.5%), solid biofuels (6.2%) and other renewable sources (6.6%). Electricity produced from solar energy sources recorded the largest increase, from only 1% in 2008. This represents an increase of 7.4 terawatt hours in 2008 to 252.1 terawatt hours. The share of energy from renewable sources in electricity consumption is shown in Figure 2.

Figure 2: Renewable energy in the electricity sector in 2023 (%)



Source: Author based on Eurostat data, 2024

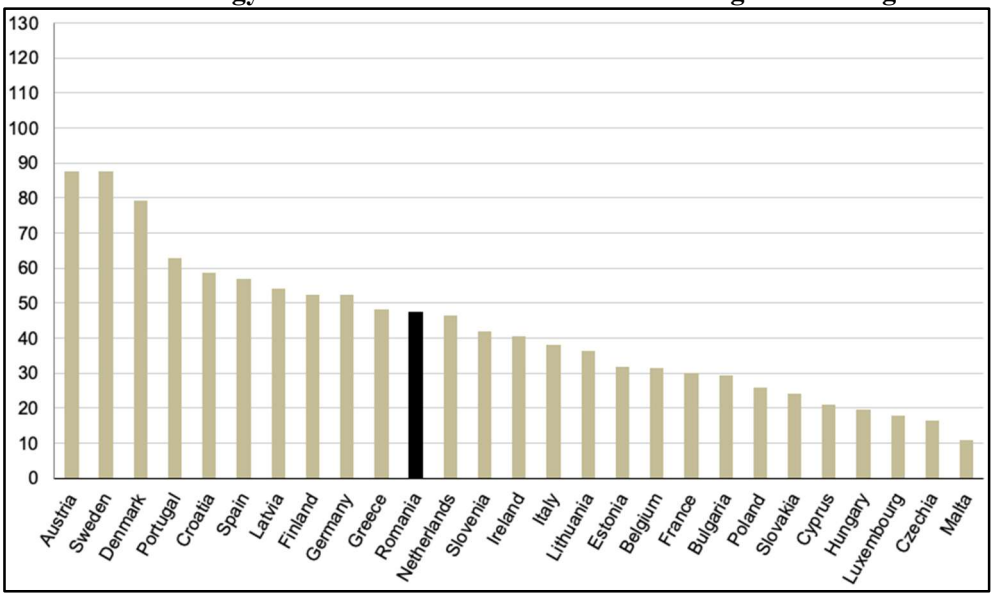
In 2023, more than 75% of the electricity used in the European Union came from renewable sources. The most significant proportions were in Austria, Sweden and Denmark, all of which had a share of around 80%. Portugal, Croatia, Spain, Latvia and Finland also used more than 50% of renewable sources for their electricity production. On the other hand, Malta, the Czech Republic, Luxembourg and Hungary had less than 20% of renewable sources in their electricity production.

In Romania, the share of renewable energy in electricity consumption in 2023 was almost 50%, more precisely 47.4%, compared to 43.7% in 2022. The reasons for Romania's very good performance in this regard were related to market liberalisation, European Union requirements, investments in infrastructure and favourable natural conditions.

4.3. Renewable energy in heating and cooling

In 2023, energy from renewable sources accounted for 26.2% of the total energy used for heating and cooling in the European Union. This is up from 11.7% in 2004. This increase was due to developments in industry, services and households. It includes energy from heat pumps for heating and cooling. Figure 3 shows the energy used for heating and cooling in the EU.

Figure 3: Share of energy from renewable sources in the heating and cooling in 2023 (%)



Source: Author based on Eurostat data, 2024

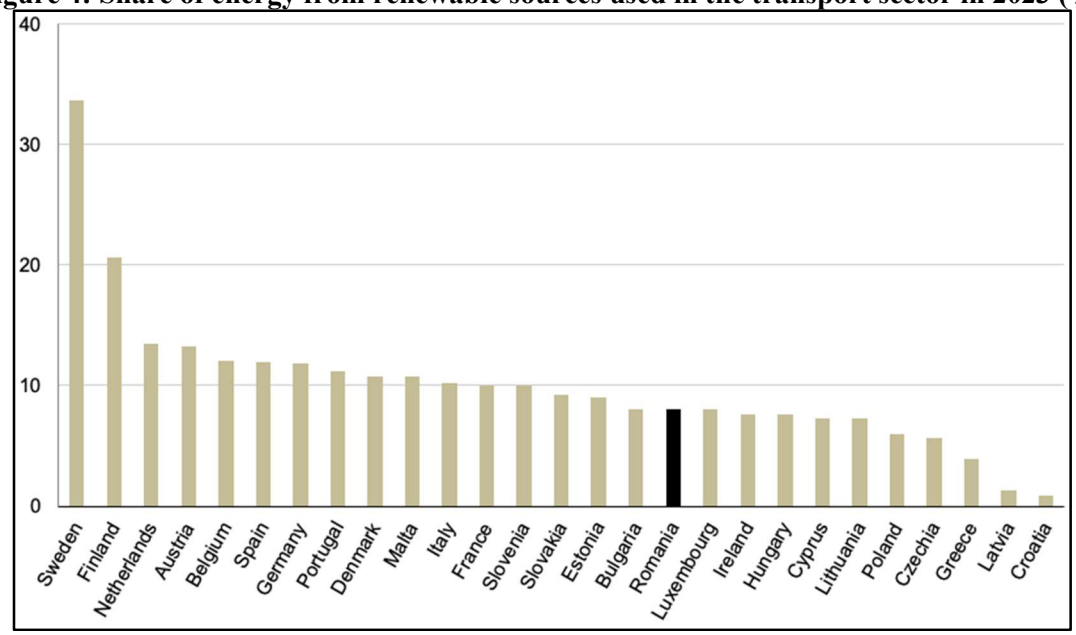
Sweden, Estonia, Latvia, Finland, Denmark and Lithuania were the countries with the highest percentages of renewable energy use in the heating and cooling sector, at over 50%. On the other hand, Ireland and the Netherlands were the only EU countries where less than 10% of the energy used for heating and cooling came from renewable sources.

Regarding Romania, in 2023 the share of energy from renewable sources in the heating and cooling sector was 29.1%, compared to 26.3% in 2022. The main renewable energy sources used by Romania for heating and cooling were biomass, geothermal and solar energy.

4.4. Renewable energy in the transport sector

The European Union has set a common target for 2030 of achieving a 29% share of energy from renewable sources (including biofuels, hydrogen, biogas, "green" electricity and others) in the transport sector. The proportion of energy from renewable sources utilised in the transport sector has increased from 1.6% in 2004 to 10.8% in 2023. Within the European Union, the proportion of renewable energy utilised for transport varied significantly, ranging from 33.6% in Sweden and 20.6% in Finland to less than 5% in Croatia, Latvia and Greece. Figure 4 illustrates the proportion of energy from renewable sources utilised in the transport sector.

Figure 4: Share of energy from renewable sources used in the transport sector in 2023 (%)



Source: Author based on Eurostat data, 2024

In Romania, the share of energy from renewable sources used in the transport sector was 8% in 2023, down by 8.2% compared to 2022. This decrease compared to 2022 was also recorded in other Member States, as a result of the decline in the level of electrification of the transport sector in the European Union.

5. Prospects for the development of the renewable energy sector in Romania

By 2035, Romania aims to make a significant contribution to achieving the EU's decarbonisation target and will follow best practices in environmental protection. Table 1 shows potential future measures for developing the renewable energy sector in Romania, together with the estimated results of their implementation.

Table 1: Future measures for the renewable energy sector in Romania

Measure	Estimated result
Improving support schemes for RES (combined with an increase in the performance of RES energy production technologies)	GHG emissions from the energy sector will reach 13.5 million tonnes of CO2 equivalent in 2030, a reduction of 87% compared to 1990
Implementing policies and measures for wind, solar, hydro and biomass energy	Increasement of the share of RES in gross final energy consumption to 44% in 2035 and 73% in 2050

Building and commissioning new electricity generation capacity from RES (mainly wind and solar).	Increasement of the share of RES in electricity (RES-E) to 73% in 2050.
Expanding clean generation capacity from nuclear and low-carbon gas sources	Diversified and balanced energy mix with low carbon emissions
Modernising existing cogeneration plants and building new units to replace existing polluting capacities	Increasement of the energy efficiency of power plant aggregates in operation and promotion of the production of electricity and heat in high-efficiency cogeneration plants
Developing high-capacity battery systems or geographically dispersed medium or low-capacity battery systems	Ensuring balancing for 15-20 GW installed in intermittent power plants at the national energy system level (2050)

Source: Author based on studied literature

The existence of support schemes for RES, coupled with the evolution of GHG emission costs in conjunction with an increase in the performance of RES energy production technologies relative to the decrease in investment and operating costs, will accelerate the energy transition in Romania. Consequently, it is anticipated that greenhouse gas emissions from the energy sector will attain 13.5 million tonnes of CO2 equivalent in 2030, representing a reduction of 87% in comparison with 1990 levels.

It is estimated that by 2050, renewable energy sources (RES) will account for 73% of the total electricity generation mix, a substantial increase that will be driven by the construction and commissioning of new RES electricity generation capacity, with wind and solar power projected to play a significant role in this transition. Furthermore, there are plans to replace several coal-fired units with natural gas-fired combined cycle units and RES-based units, to refurbish some existing nuclear units, and to build new large nuclear units and the first SMR plants by 2035.

In addition to RES (hydro, wind and solar), there will be an expansion of clean generation capacities from nuclear and low-emission gas sources for a diversified and balanced energy mix with low carbon emissions. The process of modernising existing cogeneration plants and constructing new units to substitute for current polluting capacities will lead to enhanced energy efficiency in operating power plants. Furthermore, it will foster the production of electricity and heat in high-efficiency cogeneration plants.

In 2050, total electricity production will exceed 100% of gross final consumption, as part of it will be used for green hydrogen production. In 2050, a new investment cycle will be necessary to replace the production capacities installed between 2020 and 2030, which will reach the end of their life cycle. This will also require finding solutions for the recycling or safe storage of the components used.

By 2050, it is estimated that 15-20 GW of intermittent power generation capacity will need to be balanced at the national energy system level. Thus, in addition to existing capacities, there is an opportunity to develop large-capacity battery systems or geographically dispersed medium-or small-capacity battery systems as a marginal solution in the balancing market. In this direction, technologies that are currently expensive but could become economically feasible and appropriate, depending on technological progress and the evolution of the energy sector, are fuel cells powered by hydrogen obtained through water electrolysis using energy from RES and other low-carbon energy production technologies.

6. Conclusion

Renewable energy is a fundamental part of the effort to combat climate change, and the European Union wants to become a world leader in the transition to a zero-emission economy. With this in mind, the EU has set ambitious targets for energy produced from renewable sources.

As a member state of the European Union, Romania must comply with European targets for renewable energy, while also aiming to contribute significantly to combating climate change by following best practices in environmental protection. The renewable energy landscape in Romania appears very positive, with the country ranking in the top half of European Union Member States for three of the four indicators analysed in this research. The main reason for this is the very good development of hydro energy and recent investments in wind and solar energy.

In terms of the steps that Romania needs to take in this field, it is necessary to improve support schemes for RES, build and commission new RES electricity generation capacity (mainly wind and solar), expand clean generation capacity from nuclear sources, modernise existing cogeneration plants and build new ones. It should

also be taken into account that a good understanding of the medium- and long-term objectives by all stakeholders in this field is imperative.

The limitations of this research are related to the unavailability of data for the year 2024. Taking this into account, an extension of this research will be considered when this data becomes available to the public.

Acknowledgement:

Scientific paper carried out during the sustainability period of the project entitled: "Support Center for IWE competitive research – innovation projects in Horizon 2020", ID 107540. The project was co-financed by the European Regional Development Fund through the Competitiveness Operational Program 2014-2020.

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RESHAPING EU STATE AID POLICY AMID GREEN TRANSFORMATION AND GEOPOLITICAL TENSIONS

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Abstract: State aid policy represents a cornerstone of the European Union's (EU) free and competitive internal market. While its traditional aim was to prevent unlawful competition and the unfair advantage of large companies, recent years—marked by successive crises beginning with the pandemic and followed by the disruptions caused by the war in Ukraine—have brought major transformations to this policy. The most significant shift is the emergence of state aid as a key instrument for mitigating the economic shocks experienced by Member States, allowing national authorities to provide targeted support across all economic sectors. Special legal derogations, such as the Temporary Framework and the Temporary Crisis Framework, have facilitated this change, enabling substantial volumes of aid to be granted across the EU.
Against this backdrop, our research pursues two objectives: first, to highlight the major regulatory transformations in state aid policy in response to recent economic and geopolitical challenges; and second, to assess—through a comparative analysis of aid granted by different Member States—whether the policy still upholds its central goals of fostering a competitive and green economy while preserving free competition within the EU internal market. Methodologically, we adopt a mixed approach, combining an in-depth literature review and a qualitative analysis of the most recent legal frameworks with a statistical examination of relevant state aid measures implemented during the post-pandemic period, using the latest available State Aid Scoreboard data. Our main finding underscores that, while facilitating economic recovery, state aid policy has also supported green development by promoting sustainable and clean growth across the EU.

Keywords: State Aid, European Union, economic recovery, sustainable development, free competition, pandemic crisis, pandemic crisis, Ukraine war

JEL Classification: *H23, H25, O38, Q57, Q58*

1 Introduction

State aid, as defined by Article 107 of the Treaty on the Functioning of the European Union (EU, 2012), refers to any selective advantage granted by national public authorities to undertakings, which may distort competition and affect trade within the internal market. While general measures such as broad tax policies or employment legislation fall outside this definition, targeted interventions—such as grants, tax relief, or preferential access to public resources—must be assessed under State aid rules. Though generally prohibited, State aid may be exceptionally justified when it serves legitimate policy objectives, such as economic development, innovation, or environmental protection. These exemptions are strictly regulated and form the basis of the EU's control framework.

According with EU's legislation, Member States must notify the European Commission before implementing new aid measures, unless exemptions apply (e.g. De minimis aid[1], Block Exemptions[2], or pre-approved schemes). The Commission conducts a preliminary review within 20 working days to determine whether a measure involves aid and if it is compatible with EU rules. In cases of serious doubt, an in-depth investigation is launched. The Commission also monitors compliance through transparency tools like the State aid Scoreboard and has powers to recover incompatible aid. Recent procedural reforms, including the introduction of sector inquiries and enhanced complaint mechanisms, aim to ensure greater accountability and reduce market asymmetries caused by unlawful aid.

The COVID-19 pandemic acted as a significant "black swan" event, triggering substantial derogations in State aid policy to support the most affected sectors. This unprecedented crisis was soon followed by the imbalances caused by the Ukraine war, further disrupting economies across the EU. These two major, unforeseen events have reshaped State aid policy, leading to the adoption of the Temporary Framework (European Commission, 2020) and the Temporary Crisis and Transition Framework (TCTF) (European Commission, 2022). While these measures proved vital in restarting economic growth and bolstering resilience in Member States' economies, this research argues that, amidst these sweeping changes, the core focus of State aid policy remained constant: safeguarding free competition and promoting sustainable development across the EU.

2 Literature review

In recent years, State aid policy has become a central topic in the literature, with numerous studies focusing on the reforms of this policy within the European Union and the various legal exemptions that grant Member States specific derogations (Knook, 2023; Werner &Verouden, 2025; Santa Maria, 2025). A significant body of academic literature has been dedicated to analysing the State Aid Modernisation (SAM) reform (López, 2023; Poulou, Polemis&Oikonomou, 2023; Andhov, Biondi &Rubini, 2023), launched by the European Commission in 2012.

Lopez (2023) analyses the goals of the 2012 State Aid Modernisation (SAM) reform through recent CJEU case law, showing a principled judicial approach to defining aid, assessing compatibility, and interpreting notification exceptions. Despite positive outcomes, some rulings may undermine the first two SAM objectives while reinforcing the third, underscoring that core features of the Treaty's State aid framework remain unchanged.

Poulou and others (2023) empirically assess State aid's impact on economic growth across 27 EU countries (2007–2019), finding a positive effect and supporting the need for a pan-European industrial policy. They offer policy recommendations on the SAM reform's effectiveness and its post-pandemic relevance. Andhov, Biondi, and Rubini (2023) argue that the single market remains central to EU integration, proving resilient through multiple crises—from recessions to Brexit and the Ukraine war. Their analysis highlights incremental reforms that enhance the single market's ecological, social, and industrial sustainability, while balancing social goals with competitiveness under the Treaty's vision of a "highly competitive social market economy". Some studies show that the SAM reforms marked a shift in State aid governance, which has been further shaped by the Ukraine war (Drăgoi, 2024). The Russian Federation's 2022 invasion triggered economic disruption across the EU, especially due to sanctions. In this context, the mentioned study shows that the State aid became a key tool to mitigate these effects, with a focus on how Romania used these instruments to cushion the economic fallout.

Researchers have explored in detail how SAM reform marked a turning point in EU State aid policy, shifting the focus toward more effective, transparent, and strategically aligned interventions. Studies have examined how SAM streamlined procedures, expanded the scope of the General Block Exemption Regulation (GBER), and introduced a more principle-based approach to enforcement (Merola&Cogoni, 2024). Scholars have

[1] ***De minimis aid*** refers to State aid that is considered too small to distort competition or trade within the EU. Under EU rules, aid of this type is exempt from prior notification to the European Commission if it does not exceed €200,000 per undertaking over a three-year period. The aim is to reduce the administrative burden for small amounts of aid that are unlikely to have a significant impact on the market.

[2] ***Block Exemptions*** refer to specific categories of State aid that are deemed compatible with the EU internal market without the need for prior notification to the European Commission. These exemptions apply to aid measures that fall within defined criteria, such as support for small businesses, research and development, or environmental protection. The goal is to streamline the process for aid that has clear, positive economic or social impacts, reducing the administrative burden for both Member States and the Commission.

also emphasized the reform's role in prioritizing aid measures with the greatest potential impact on the internal market, enhancing legal certainty for Member States, and aligning aid policy with broader EU goals such as competitiveness, innovation, and sustainable development. These exemptions have played a pivotal role in addressing the diverse challenges faced by Member States, allowing for more flexible approaches to economic support during crises.

While a substantial body of research has examined the policy's contribution to the EU's green transition (Hildebrandt, 2022; Gràcia, Lunneryd & Papaefthymiou, 2023; Verschuur & Sbrolli, 2021; Piechucka, Saurí-Romero & Smulders, 2023), particularly its alignment with the European Green Deal objectives (Gupta, 2023), there has been insufficient focus on the systemic changes to State aid policy during the pandemic and the post-pandemic period.

The "black swan" crises and their impact on State aid policy — particularly the pandemic and the war in Ukraine — have been analysed more often separately than in conjunction in recent literature. Łopatka, &Fedorowicz (2021) points out that the COVID-19 pandemic led the Polish government to impose restrictions on business activity to limit citizens' mobility and contain the virus. In response to the resulting economic disruptions, the government implemented the "Anti-Crisis Shield" to support employment, business continuity, and liquidity. Kubera (2021) states that the COVID-19 outbreak struck the global economy—including the EU—suddenly and severely, pushing many previously stable businesses toward liquidity crises. To safeguard economic continuity, public authorities introduced support measures that raised significant questions under EU State aid rules. The mentioned study examines the EU's revised State aid response to the pandemic, analysing which public instruments qualify as aid, the types of measures used by Member States, and the principles guiding their approval by the European Commission, based on legal texts, literature, and selected COVID-19-related cases. A series of research are presenting the impact of the Ukraine war on State Aid policy (Drăgoi, 2024; Bomprezzi et al., 2025; Glanville & Pattison, 2024; Pellicciari, 2023; Kolliopoulos, 2025). It is worth mentioning that some of these studies are even critical regarding the State aid success in an era of crisis. Kolliopoulos (2025) states that State aid control has been a supranational policy area since the inception of the European Economic Community, with the European Commission playing a central role in safeguarding the internal market—especially during the major crises of the past fifteen years. Yet, in the absence of a permanent EU-level fiscal capacity, state aid remains the primary tool for Member States to support their national economies. This is particularly evident in the banking sector, where the Commission has shown leniency toward government interventions, in contrast to the more supranational approach of the European Banking Union. This tension creates challenges for the EU's rescue and resolution framework and the integrity of the banking market. As a result, while the Commission retains a formal centralized role, Member States effectively shape domestic aid strategies—leading to a form of "shallow supranationalism."

Our in-depth review of the existing literature reveals that although significant attention has been paid to the immediate impacts of some game-shifting events (the pandemic and the Russian – Ukrainian war), few studies have investigated the comparative allocation of State aid across different Member States in recent years, particularly in the context of special derogations related to the pandemic and the Ukraine war. This gap is especially pronounced when it comes to exploring how green objectives were prioritized during the approval of such derogations, despite the fact that both the pandemic and the Ukraine war have dramatically reshaped the economic and political landscape of the EU. In this regard, our research aims to address this gap by providing a comparative analysis of State aid allocation, with a particular focus on the integration of green objectives into aid measures approved during these crises. However, our analysis is currently constrained by the lack of published data for 2024, which limits the scope of our findings. To overcome this limitation, we propose to continue our research once the necessary data becomes available, allowing for a more comprehensive understanding of the evolving role of State aid in fostering both economic recovery and sustainable development.

3 Methodology

This study relies on a comparative quantitative and qualitative analysis of State aid expenditure data as reported in the *2024 edition of the EU State Aid Scoreboard*. The Scoreboard provides detailed annual data submitted by Member States under Article 6(1) of Commission Regulation (EC) 794/2004, covering the period from 2000 to 2023. Only finalized and verified aid measures are included, with cases under examination or not qualifying as State aid (e.g. general measures, de minimis aid, or certain railway and crisis-related financial sector interventions) being excluded.

The analysis is structured around three categories of interest:

1. *Pandemic-related State aid* under the COVID-19 Temporary Framework (which expired in most respects on 30 June 2022, with exceptions for investment and solvency support until 31 December 2023),
2. *Crisis aid in response to the war in Ukraine* under the Temporary Crisis and Transition Framework (TCTF), which includes a limited prolongation until 31 December 2024 for the agriculture, fisheries and aquaculture sectors,
3. *Green transition aid*, with special focus on measures aimed at energy efficiency, renewables, and clean tech, under sections of the TCTF that remain active until 31 December 2025.

Expenditures are considered both in nominal terms and as aid elements[3] (the actual economic advantage conferred to recipients), following Scoreboard methodology. Special attention is given to the comparative structure of **i**nstruments—such as grants, loans, guarantees, and tax exemptions—across the EU[4].

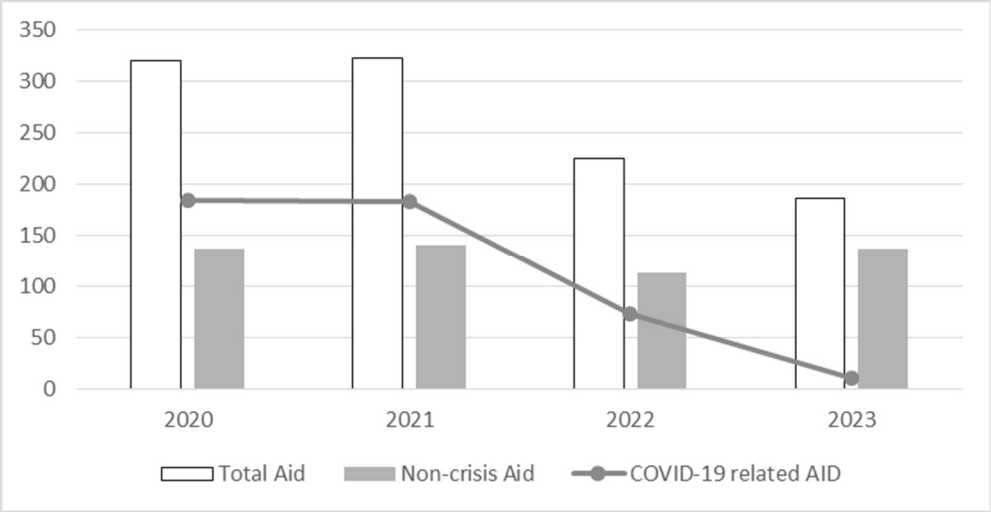
The study also includes a focused case study on Romania, evaluating its use of State aid instruments under the three categories in comparison to the EU average, with particular emphasis on policy priorities and economic resilience.

By combining Scoreboard data with a contextual review of EU legal frameworks and recent reforms, this methodology enables an assessment of the evolving role of State aid policy in managing economic shocks and driving structural transitions.

4 The State aids granted in EU to boost economic recovery during the post-pandemic era

Based on the legal framework (The Temporary State aid Framework and The Temporary Crisis and Transition Framework) one may see a robust surge of the pandemic related State Aid at EU's level, both in 2020 and in 2021, followed by a sharp decline of such aids in 2022 and in 2023(Figure 1).

Figure 1: Evolution of crisis and non-crisis State Aid in EU between 2020 and 2023 (EUR billion)



Source: Author based on State Aid Scoreboard data (https://competition-policy.ec.europa.eu/state-aid/scoreboard/scoreboard-state-aid-data_en).

[3]One must note that Member States report State aid expenditure based on the aid element, which reflects the economic advantage given to beneficiaries. If actual expenditure data is unavailable by the reporting deadline (June 30), Member States may provide estimates or commitment information. The aid element is calculated differently depending on the instrument: for grants, it typically matches the budgetary expenditure, while for guarantees, the benefit comes from the risk carried by the State, potentially without any payment being made. State aid is granted when the guarantee is issued, not when payments are made.

[4] State aid represents a cost to public authorities and a benefit to recipients, with the aid element depending on the form of aid provided. Common instruments include grants and tax exemptions, which are fully transferred to recipients and may be granted through the budget or tax/social security systems. Equity participation constitutes aid when a private investor, under normal market conditions, would not have made the investment.

As illustrated in Graph 1, the total volume of state aid granted across the European Union exhibited a clear deceleration between 2020 and 2023, declining from a peak of EUR 323.28 billion in 2021 to a significantly lower EUR 186.78 billion in 2023. This downward trajectory reflects a broader shift in the fiscal stance of Member States following the height of the COVID-19 pandemic. During the crisis, the expansion of state aid was imperative to stabilize national economies and facilitate a coordinated EU-wide recovery. The subsequent reduction in aid levels suggests that these policy instruments were effective in achieving their primary objectives, thereby allowing national governments to scale back exceptional support measures financed exclusively from their own budgets.

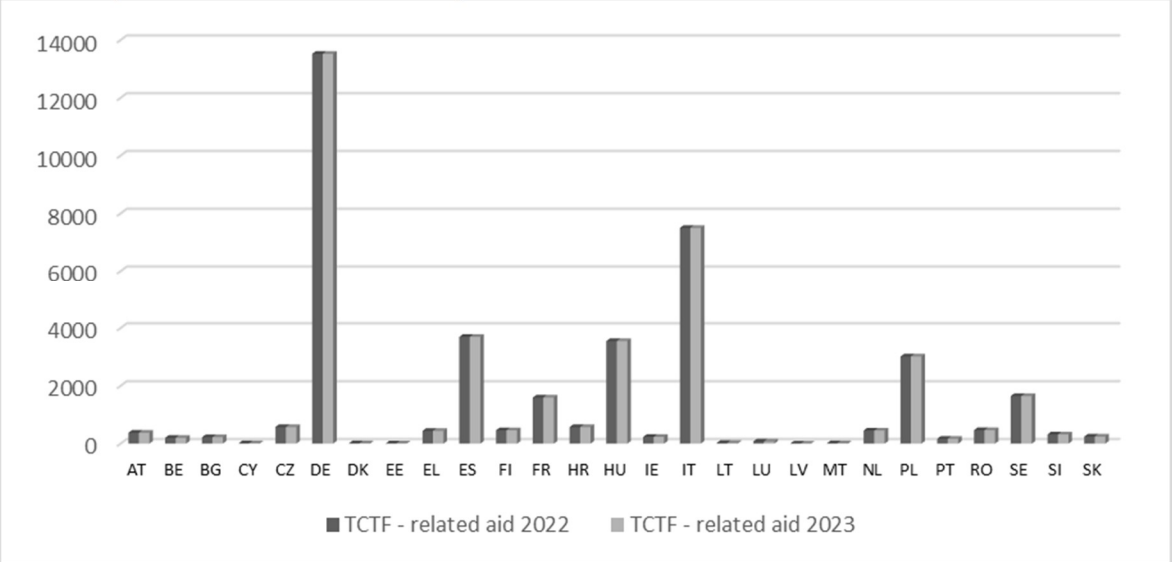
It is important to underscore that, unlike other forms of financial support—such as EU-funded subsidies—state aid is fully financed from national budgets, making it both a potent and fiscally constrained policy tool. Consequently, the withdrawal of such measures in the post-pandemic context aligns with the principle of proportionality, whereby public interventions are phased out once the exceptional conditions that justified them subside.

From 2022 onward, a different form of state aid began to emerge in response to the economic repercussions of the Russian invasion of Ukraine. Specifically, war-related aid rose to EUR 42.83 billion (equivalent to 0.27% of EU GDP) in 2022 and marginally decreased to EUR 39.43 billion (0.25% of EU GDP) in 2023. This evolution demonstrates the adaptability and responsiveness of the EU state aid policy framework, which has proven capable of accommodating emerging external shocks without reverting to a generalized interventionist paradigm.

Both the Temporary Framework for State Aid in the context of the COVID-19 pandemic and the subsequent framework addressing the Ukrainian crisis were strictly time-bound and applied under exceptional derogation clauses. Crucially, access to such aid was contingent upon clear and demonstrable evidence that the beneficiaries were directly impacted by the specific crisis in question. This approach has ensured the targeted application of state aid while preserving the integrity of the internal market.

As previously mentioned, the Member States have been affected by the crisis triggered by the war in Ukraine. Consequently, substantial amounts of aid were granted to mitigate the negative economic impacts of this geopolitical shock across EU countries. As illustrated in Figure 2, Germany and Italy were the countries that allocated the largest amounts of aid related to the war in Ukraine, both in 2022 and 2023.

Figure 2: TCTF – related aid per Member State in 2022 and 2023 (EUR million)



Source: Author based on State Aid Scoreboard data (https://competition-policy.ec.europa.eu/state-aid/scoreboard/scoreboard-state-aid-data_en).

Note: TCTF-related aid refers to **public financial support** that EU Member States have granted to companies under a **temporary and flexible legal framework** established by the European Commission. It targets **crisis relief** and **economic resilience**, while also supporting the **EU's long-term goals for clean energy and industrial transformation.**

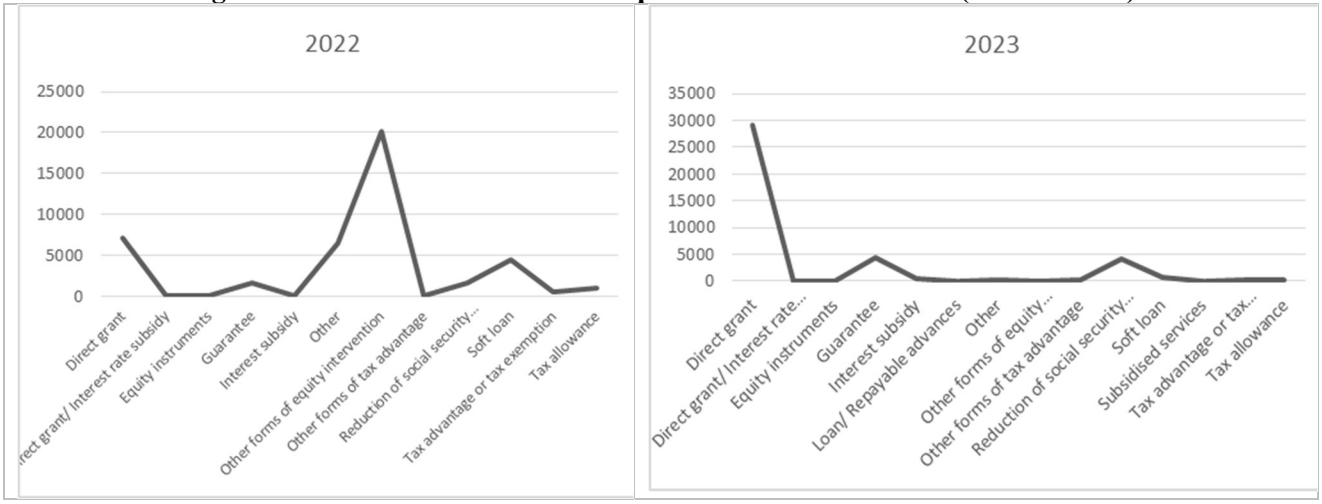
Amidst the multifaceted economic repercussions of Russian Federation's aggression in Ukraine, the EU has strategically deployed the Temporary Crisis and Transition Framework (TCTF) to empower Member States to implement a diverse array of aid measures designed to both mitigate immediate economic shocks and catalyse the transition to a net-zero economy. Under this framework, initially introduced as the Temporary Crisis Framework on 23 March 2022, Member States were authorized to provide limited support to companies adversely affected by the crisis—support that directly addressed liquidity shortages, high energy prices, and supply chain disruptions. In response to feedback from Member States, subsequent amendments, such as those adopted on 20 November 2023, adjusted aid ceilings and extended the duration of critical support measures (for instance, until 30 June 2024), ensuring that companies received adequate relief during periods of heightened energy demand in the winter months. In parallel, the Commission further refined the framework on 2 May 2024 by specifically extending the provisions under Section 2.1 for sectors like primary agricultural production, fisheries, and aquaculture until 31 December 2024, thereby acknowledging the unique challenges faced by these industries in the current geopolitical climate. Beyond these immediate relief mechanisms, the TCTF encompasses a suite of measures under Sections 2.5 to 2.8 that are aimed at accelerating the EU's green transition; these provisions are designed to stimulate investments in renewable energy, energy storage, and decarbonisation of industrial processes, thereby aligning crisis management with long-term strategic objectives such as the roll-out of renewable technologies, the manufacturing of strategic equipment like batteries and solar panels, and the overall pursuit of a sustainable energy future. By integrating both crisis alleviation and forward-looking environmental initiatives, these aid measures collectively fortify the EU's resilience against geopolitical shocks while simultaneously paving the way for a robust, green, and competitive economic landscape.

5 The focus on green development: How the State Aid shaped the sustainable growth in the Member States

As mentioned before, Temporary Crisis and Transition Framework (TCTF) aimed to: cushion the economic impact of the war; to support sectors affected by high energy prices and supply chain disruptions, to ensure liquidity and prevent bankruptcies and to compensate for direct damages caused by the war. The tools for granting such aids allowed limited amounts of aid to companies hit by the crisis, were directed to offset high energy prices, permitted liquidity support through guarantees and subsidised loans and allowed support for renewable energy, storage, and decarbonisation.

According to the latest statistics, the most commonly used tools for TCTF-related aid at EU level were direct grants and other equity interventions in 2022, while in 2023, direct grants combined with interest rate subsidies became the preferred forms of support (Figure 3).

Figure 3: TCTF – related aid in EU per tool in 2022 and 2023 (EUR million)



Source: Author based on State Aid Scoreboard data (https://competition-policy.ec.europa.eu/state-aid/scoreboard/scoreboard-state-aid-data_en).

The aid measures implemented under the Temporary Crisis and Transition Framework (TCTF) have not only provided an essential buffer against the economic consequences of Russia's aggression in Ukraine, but have

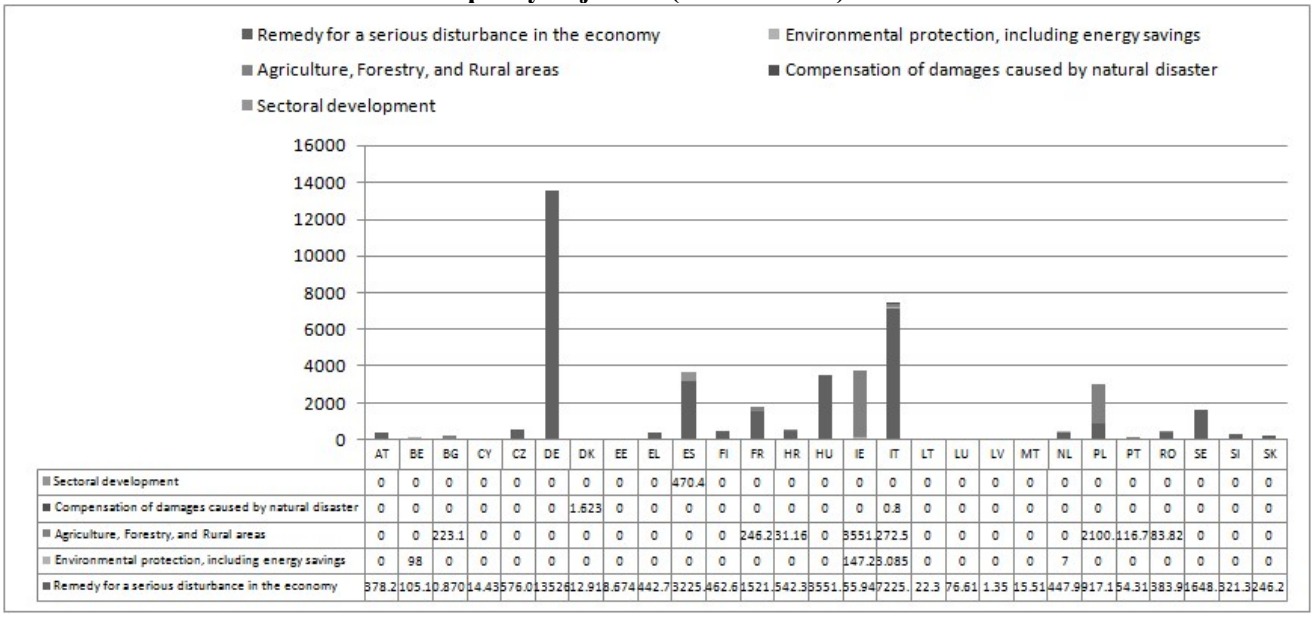
also played a critical role in accelerating the EU's green transition by targeting investments with long-term strategic value; specifically, under point (85) of the TCTF, Member States have been empowered to establish support schemes aimed at fostering the development and production of technologies essential for achieving climate neutrality, including batteries, solar panels, wind turbines, heat pumps, electrolysers, and equipment for carbon capture usage and storage (CCUS), as well as the key components and critical raw materials necessary for their manufacture or recovery, thus ensuring the EU's technological and industrial self-sufficiency in vital green sectors, while simultaneously strengthening supply chains and reducing external dependencies that are particularly risky in times of geopolitical instability; in order to safeguard the strategic purpose of these investments and prevent distortive effects within the internal market, strict conditions were attached to the aid, such as mandatory commitments from beneficiaries to maintain the investment in the target region for a minimum of five years (or three for SMEs), prohibitions against relocation of production within the Union in the two years preceding and following the aid, and exclusions for undertakings in financial difficulty, while Member States were also encouraged to embed environmental, social protection, and employment-related requirements into their schemes in a non-discriminatory manner; altogether, these aid instruments have served a dual purpose—on one hand, enhancing the EU's economic and industrial resilience in the face of acute geopolitical tensions, and on the other, reinforcing the foundations of the continent's sustainable transformation by mobilising public resources to strategically guide private investment toward green and future-proof technologies.

Under the latest Scoreboard published in 2024, all Member States primarily supported undertakings through non-repayable instruments in 2023. Direct grants and combined direct grants/interest rate subsidies accounted for over 90% of aid in Austria and over 50% in 19 other Member States, including Romania, Germany, and France. Italy (30%), Malta (37%), and Denmark (40%) allocated the smallest shares to these tools. Instead, Denmark and Italy relied heavily on tax advantages, representing 58% and 48% of their total aid, followed by Sweden (37%) and France (34%). Credit-based instruments like loan guarantees were most used in Croatia (27%), with notable shares also in Italy (13%), Romania (7%), and Cyprus (6%). In Malta, Slovakia, Lithuania, Czech Republic, and Germany, over a quarter of total aid was classified under 'other' instruments.

In 2023, approximately 91% of total expenditure related to crisis objectives under the TCTF or inspired by its principles—amounting to EUR 35.79 billion—was directed toward remedying serious disturbances in the economy, while the remaining 9% (EUR 3.67 billion) supported other objectives, including EUR 2.94 billion for agriculture, forestry, and rural areas, EUR 2.43 million for fisheries and aquaculture, EUR 470.45 million for sectoral development, EUR 248.30 million for environmental protection and energy savings, and EUR 9.42 million for compensation of damages caused by natural disasters.

Moreover, the latest available date are showing that in 2023, environmental protection was the main State aid objective in twelve Member States, including Denmark, Germany, and Romania, and the second most used in nine others (Figure 4); it represented 30% of total EU aid. Addressing serious economic disturbances was the top objective in nine Member States such as Hungary and Italy, and ranked second in countries like Germany and Romania, accounting for 25% of EU-wide aid. Research and innovation ranked second in Belgium and the Netherlands and exceeded 10% of aid in 7 other Member States, contributing 9% at EU level. Regional development was the main focus in Portugal and ranked second in Latvia, Croatia, and Italy, representing 8% of total expenditure.

Figure 4: State aid expenditure under the TCTF or based on its principles by Member State in 2023 by policy objective (EUR million)



	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
Sectoral development	0	0	0	0	0	0	0	0	0	470.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Compensation of damages caused by natural disaster	0	0	0	0	0	0	1.623	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
Agriculture, Forestry, and Rural areas	0	0	223.1	0	0	0	0	0	0	0	0	246.2	31.16	0	3551	272.5	0	0	0	0	0	2100	116.7	83.82	0	0	0
Environmental protection, including energy savings	0	98	0	0	0	0	0	0	0	0	0	0	0	0	147.2	3.085	0	0	0	0	7	0	0	0	0	0	0
Remedy for a serious disturbance in the economy	378.2	105.1	0.870	14.43	576.0	13526	12.91	8.674	442.7	3225.	462.6	1521.	542.3	3551.	55.94	7225.	22.3	76.61	1.35	15.51	447.9	917.1	54.31	383.9	1648.	321.3	246.2

Source: Author based on State Aid Scoreboard data (https://competition-policy.ec.europa.eu/state-aid/scoreboard/scoreboard-state-aid-data_en).

Between March 2022 and the end of 2023, EU Member States granted a total of EUR 164.08 billion in TCTF-related aid, with Germany, Italy, and Spain providing the largest nominal amounts, while Hungary, Italy, and Poland allocated the highest shares relative to their GDP; overall, such aid accounted for 0.50% of the EU27 GDP in 2023.

During the same time framework, only 21% of the nearly EUR 762.40 billion in approved TCTF aid was actually spent, with most Member States using less than half of their budgets; only Spain, Latvia, Cyprus, Italy, and Sweden spent more than 50% of the approved amounts.

6 Conclusion

Our first finding shows that environmental protection became the main objective of State aid in 2023, highlighting the EU's growing focus on accelerating the green transition across many Member States. The next finding reveals that tackling economic disturbances linked to the war in Ukraine remained a central goal, with substantial aid directed at ensuring resilience through liquidity, compensation, and price mitigation. A further finding confirms that TCTF enabled Member States to respond flexibly to both urgent economic shocks and long-term decarbonisation goals.

An additional finding highlights that since the majority of Member States have spent less than half of their approved TCTF budgets, there remains significant room for further support under the existing framework, enabling governments to mobilise unused resources to address ongoing economic and green transition challenges. *Our last finding indicates that the aid tools used under the TCTF successfully balanced crisis response with strategic investment, helping to stabilise affected sectors while fostering the shift to a net-zero economy.*

Acknowledgement:
This scientific paper was published during the sustainability period of the project with the title: "Support Center for IEM research projects - competitive innovation in Horizon 2020", ID 107540. The project was co-financed from the European Regional Development Fund through the Competitiveness Operational Program 2014 - 2020.

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AN ECONOMETRIC PERSPECTIVE ON PUBLIC ENVIRONMENTAL CAPITAL FORMATION AND INDUSTRIAL EMISSIONS: EVIDENCE FROM SEVEN EU COUNTRIES

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Abstract: This paper investigates the dynamics and relationship between greenhouse gas emissions from industrial processes and product use (GHG), and general government expenditures on environmental protection in gross fixed capital formation (GFCF). Based on data extracted from Eurostat covering the period from 2005 to 2022, we employed ordinary least squares regression models to assess the degree to which general government expenditures in environmental protection in gross fixed capital formation impact greenhouse gas emissions from industrial processes, and product use. The results show a negative and statistically significant relationship between GFCF and GHG in France, Germany and Romania and the assumptions of linear regression were met, or corrections were employed using the Prais-Winsten procedure.
In contrast, there is no clear linear relationship between the indicators analysed in Bulgaria, the EU, Hungary and Poland.
The results show that public expenditures on gross fixed capital formation in environmental protection have a heterogeneous effect on greenhouse gas emissions across the selected countries. Therefore, each country should tailor its strategies to mitigate emissions.

Keywords: emissions, public investments, industry, environment, econometrics

JEL Classification: C33, C51, H54, Q53

1 Introduction

One of the EU's priorities is to achieve climate neutrality by 2050. To this end, greenhouse gas emissions should be reduced in stages, by 55% in 2030 and by 90% in 2040. These ambitious targets entail significant changes in industrial production, specifically its transformation from a linear, extract-produce-waste model to the circular one, based on a reuse, repair and recycle model. How to achieve these targets is a topic of discussion among scholars and decision-makers across the EU. This paper aims to provide an assessment tool that demonstrates how public investments in gross fixed capital formation in environmental protection could impact industrial greenhouse gas emissions across the analysed countries of the EU.

According to Statista (2025a), in 2023, the power sector was the largest generator of GHG emissions, accounting for 15 gigatonnes of carbon dioxide equivalent, of which coal-fired power plants produced 70%. The transportation sector ranks second, accounting for up to 16% of global emissions, mainly from road vehicles, particularly passenger cars. In this context, mitigating the emissions from industrial processes and product use becomes relevant for scholars and decision-makers who shape environmental policies.

From 2000, when the USA was the largest emitter of GHGS, to 2023, the EU decreased GHG emissions by 28%, and the United States by 17%. By contrast, China boosted GHG emissions by 163% (Statista, 2025b).

According to Eurostat (2025a), general government expenditures in environmental protection in gross fixed capital formation (GFCF) include public investment in long-term, physical assets intended to prevent, reduce, or eliminate pollution and other environmental degradation(Eurostat, 2025a) and greenhouse gas emissions from industrial processes, and product use (GHG) include data on carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3).

2 Literature review

Zioło et al. (2019) found that energy productivity substantially impacts greenhouse gas emissions and emphasised that environmental taxes help mitigate emissions, particularly in developed countries.
Kaur et al. (2022) discovered a positive relationship between greenhouse gas emissions and expenditures for implementing mitigation strategies to address climate change.

Tang et al. (2024) show that environmental public spending reduces regional carbon emissions. Spada et al. (2019) showed that agricultural research and development investments decrease the livestock sector's impact on GHG emissions and the environment. Mohamued et al. (2021) found a positive effect of innovation on GHG emissions reduction initiatives in oil-importing countries.

In Spain, Retegi et al. (2014) identify sectors responsible for 71% of all industrial greenhouse gas emissions, namely the manufacture of other non-metallic mineral products, the manufacture of chemicals and chemical products, the manufacture of food products and the manufacture of basic metals.

Beke-Trivunac et al. (2014) demonstrate that only a small portion of environmental spending is allocated to long-term investments, most of it being diverted to pollution abatement, waste and wastewater management and biodiversity protection for operating expenses.

Dincă et al. (2023) emphasise that public spending in the southern EU region is influenced by greenhouse gas emissions from the agricultural sector, temperature and GDP.
Lim and Moon (2020) argue that increased awareness of environmental threats positively leads to greater support for growing public spending and lower living standards. In addition, Kulin and Sevä (2019) suggest that people support increasing government spending on the environment if they believe public institutions are fair, effective and incorruptible.

Azaki and Lutfi (2022) underline that "a green infrastructure investment policy framework can be developed through five main approaches: alignment of policy goals and targets, policies that enable investment to grow through incentives, development of investment schemes/financial instruments, strengthening of alternative resources and institutional capacities, and promoting the importance of green investment."

This paper examines the previously unexplored impact of general government expenditures on environmental protection in gross fixed capital formation on greenhouse gas emissions from industrial processes and product use, emphasising immediate and delayed effects of this relationship through robust economic models across seven EU countries.

3 Methodology

The data on greenhouse gas emissions from industrial processes, product use (GHG), and general government expenditures in environmental protection in gross fixed capital formation (GFCF) were extracted from the Eurostat database (Annexes 1 and 2). We selected Romania's neighbouring countries, Bulgaria and Hungary, as well as France, Germany, Italy, and Poland, countries that rank high in the EU's rankings regarding the selected indicators.

First, we analysed the percentage change of the selected indicators from 2005 to 2022, to ascertain their trends and compare them, thereby adding a better understanding of the results of the second step, namely the econometric analysis. We used ordinary least squares regression in Gretl based on the log-transformed GHG as the dependent variable and the log or log-lag GFCF as the predictor to reveal how a 1% increase in GFCF in the same or previous year impacts GHG as a percentage. The identified statistically significant relationships were tested to determine if they met the linear regression assumptions of linearity, homoskedasticity, normality, and lack of autocorrelation. Autocorrelation was corrected with the Cochrane-Orcutt or Prais-Winsten procedures.

4 Quantitative analyses

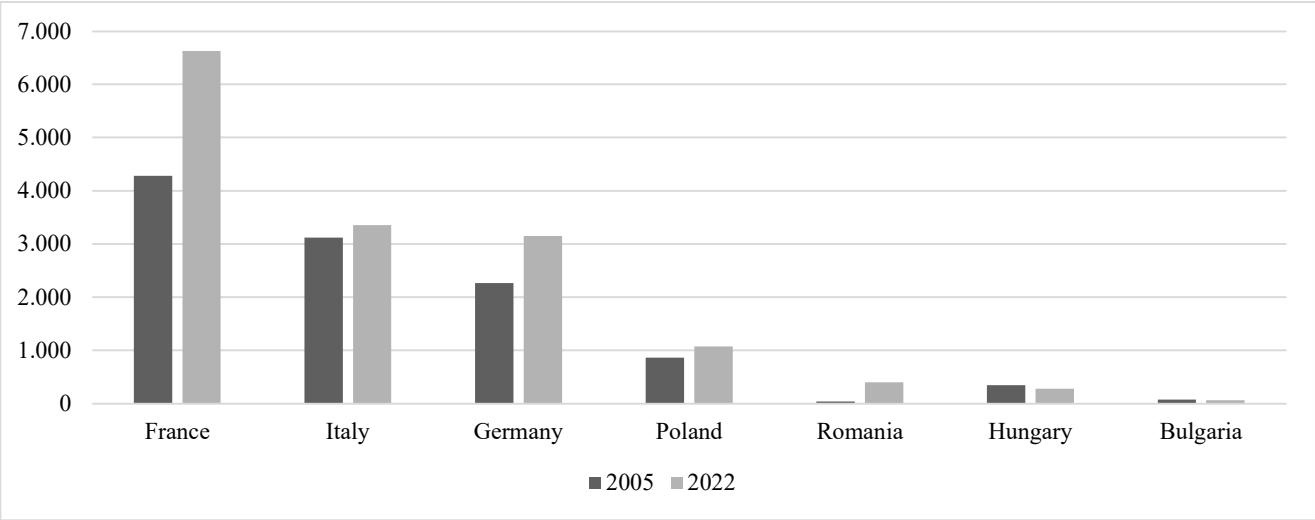
Between 2005 and 2022, in the EU, general government expenditures on environmental protection in gross fixed capital formation increased by 34.5%, from 18.2 billion euros to 24.5 billion euros.

In 2022, France ranked first in the EU with 6.6 billion euros, representing a 54.73% increase from 2005 (Figure 1). It was followed by Italy (3.4 billion euros with a 7.4% increase) and Germany (3.1 billion euros with a 39.1% increase in the analysed interval). From the former Eastern Bloc, Poland spent the most on environmental protection, namely 1.1 billion euros, a 24.2% increase from 2005, seconded by Romania (400 million euros and

a boost of 994% in the same interval, the highest among the EU countries), Hungary (277 million euros and a decrease of 19%), and Bulgaria (63.5 million euros and a drop of 13.7%).

It is worth mentioning that during the first year of COVID-19 pandemic, some countries increased government expenditures on environmental protection in gross fixed capital formation: Italy (by 7.72%), Germany (by 3.65%), Poland (by 1.79%) and Romania (by 1.68%), while the rest of the analysed countries decreased it: France by 10.61%, Hungary by 1.06%, Bulgaria by 0.98%. Overall, the EU decreased GFCF by 0.44% between 2019 and 2020.

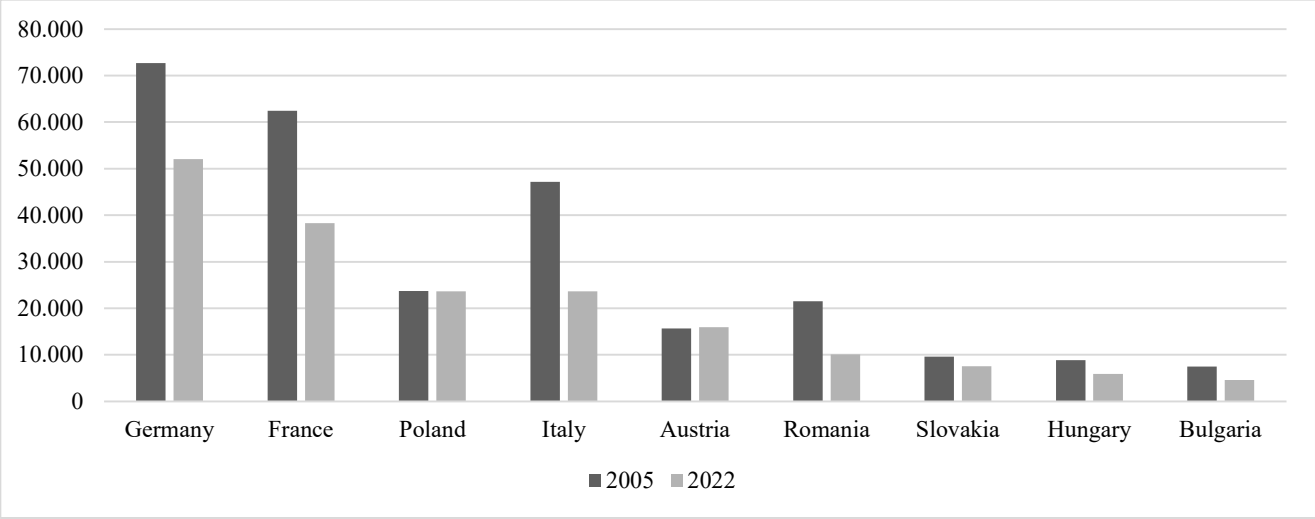
Figure 1. General government expenditures in environmental protection in gross fixed capital formation - million euro -



Source: Eurostat (2025a).

In the same time interval, greenhouse gas emissions from industrial processes and product use (GHG) in the EU decreased by 32.12%, from 430 million tonnes in 2005 to 292 million tonnes in 2022.

Figure 2. Greenhouse gas emissions from industrial processes, and product use - Thousand tonnes

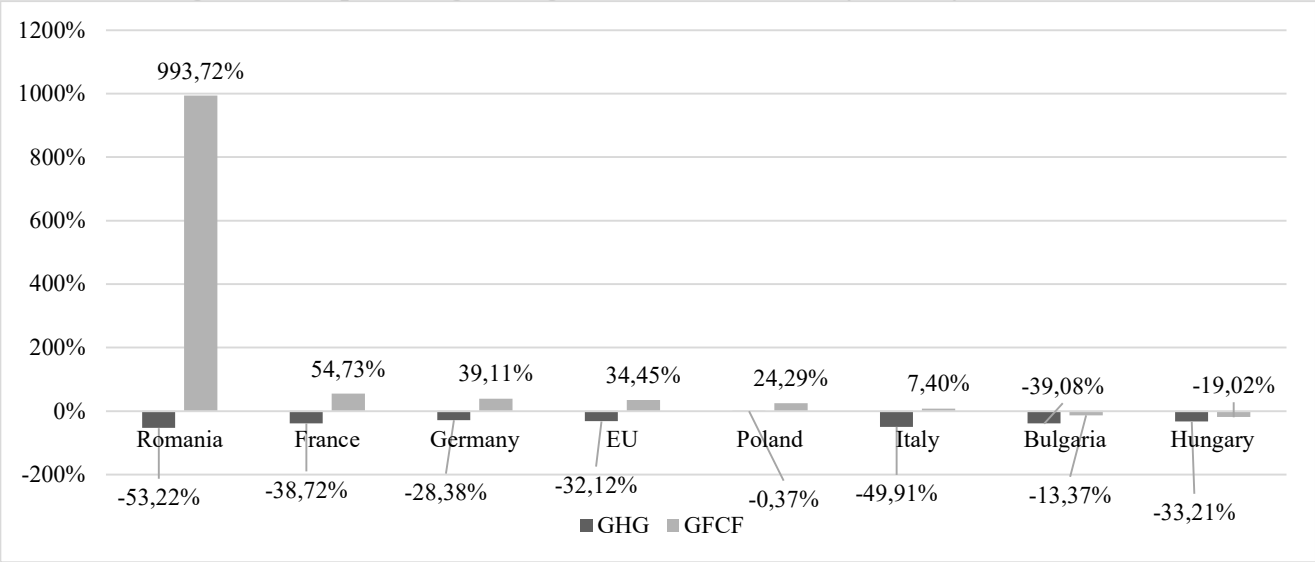


Source: Eurostat (2025b).

Regarding GHG emissions, in 2022, Germany was the largest polluter in the EU, with 52 million tonnes, a 28.4% decrease from 2005, followed by France (38.3 million tonnes, and a drop of 38.7%) and Poland (23.6 million tonnes and a slight decline of 0.37% from 2005). Romania registered the highest reduction in GHG emissions, by 53.2%, from 21.5 million tonnes in 2005 to 10 million tonnes in 2022. It was followed by Italy (-50%) and Bulgaria (-39%).

Between 2019 and 2020, the first year of the COVID-19 pandemic, the highest reductions in GHG emissions were recorded in France (-13%), Italy (-11%) and Germany (-7%). Increases were registered in Romania (0.92%) and Hungary (0.22%).

Figure 3. The percentage change in GHG and GFCF by country, 2005-2022, %



Source: Author's based on data from Eurostat (2025a and b).

Regarding the percentage change over the analysed time frame, the highest increase in GFCF was recorded in Romania (993.72%), accompanied by a reduction in GHG of 53.22%, followed by France, which experienced a 54.73% increase in GFCF and a decrease in GHG of 38.72% and by Germany that recorded a 39.11% growth in GFCF associated with a decline of 23.38% in GHG.

Despite a 24.29% increase in GFCF, Poland recorded virtually no reduction in emissions. By contrast, Italy achieved a significant reduction in GHG with minimal expenditures.

Bulgaria and Hungary represent a special category of countries in which the emissions decreased against the background of reduced expenditures.

5 Econometric analysis

The econometric analysis was based on the data from Annexes 1 and 2. We used a log-log Ordinary Least Squares model (OLS) in which both dependent and independent variables are log-transformed using Gretl, Add, and Logs of selected variables. The models allowed us to estimate elasticity directly: a 1% change in X, the independent variable (GFCF), results in a ß% change in Y, the dependent variable (GHG).

Model log-log lag (OLS regression) for Romania

For Romania, we used the log GFCF and the log GHG. Under Gretl, we used the following steps: Model and Ordinary Least Squares. In the window (gretl: specify model), we selected l_GFCF as regressor and under (lags…) we selected lag order 1 to 1. The dependent variable was l_GHG. The results of the regression model are displayed in Table 1. For Romania, we used log-transformed data on general government expenditures in environmental protection in gross fixed capital formation (GFCF) lagged by one year to achieve better results, and log-transformed data on greenhouse gas emissions from industrial processes, and product use (GHG).

Table 1: OLS, using observations 2006-2022 (T = 17). Dependent variable: l_GHG

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	10.8290	0.240617	45.01	<0.0001	***
l_GFCF_1	−0.227843	0.0413905	−5.505	<0.0001	***

Mean dependent var	9.514634	S.D. dependent var	0.206086
Sum squared resid	0.225004	S.E. of regression	0.122476
R-squared	0.668888	Adjusted R-squared	0.646814
F(1, 15)	30.30189	P-value(F)	0.000061
Log-likelihood	12.63928	Akaike criterion	−21.27856
Schwarz criterion	−19.61214	Hannan-Quinn	−21.11292
rho	0.094300	Durbin-Watson	1.621227

The linear relationship was tested at a 95% confidence level to see if it was statistically significant.

The null hypothesis (H_0) implied that there was no statistically significant linear relationship between l_GFCF_1 and l_GHG in Romania.

The alternate hypothesis (H_a) supported a statistically significant linear relationship between the two variables.

H_0: $\rho = 0$. H_a: $\rho \neq 0$.

The regression statistics are displayed in Table 1.

Since the P-value = 0.0001, smaller than the significance level: $\alpha = 0.05$, the null hypothesis (H_0) is rejected (Table 1).

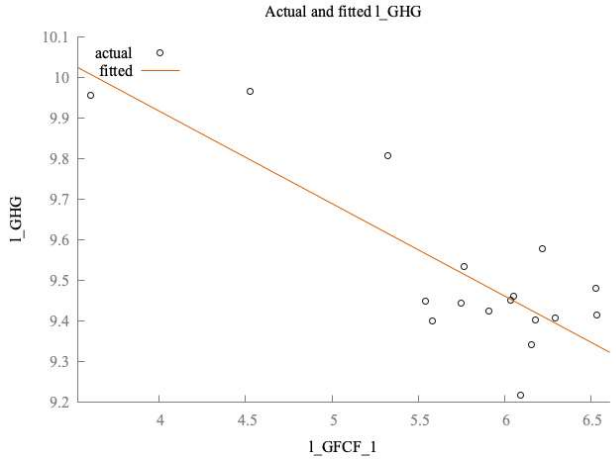
Therefore, we are 95% confident that a statistically significant linear relationship exists between l_GFCF_1 and l_GHG in Romania.

Table 2: The results of tests to verify the assumptions

Lagrange Multiplier (LM) test for non-Linearity (squared terms), Null hypothesis: relationship is linear, $\alpha = 0.05$	Test statistic: LM = 0.28034 with p-value = P(Chi-square(1) > 0.28034) = 0.596478 P-value> α, we fail to reject the null hypothesis Relationship is linear
White's test for heteroskedasticity, Null hypothesis: heteroskedasticity not present, $\alpha = 0.05$	Test statistic: LM = 1.22527 with p-value = P(Chi-square(2) > 1.22527) = 0.541922 P-value> α, we fail to reject the null hypothesis Homoskedasticity
Test for normality of residuals, Null hypothesis: error is normally distributed, $\alpha = 0.05$	Test statistic: Chi-square(2) = 0.024551 with p-value = 0.9878, P-value> α, we fail to reject the null hypothesis Error is normally distributed
Breusch-Godfrey test for autocorrelation up to order 3, Null hypothesis: no autocorrelation, $\alpha = 0.05$	Test statistic: LMF = 1.2428 with p-value = P(F(3, 12) > 1.2428) = 0.33741, P-value> α, we fail to reject the null hypothesis No autocorrelation
Estimated Equation of the regression line	*Log(GHGt)=10.83-0.23log(GFCFt-1) (Figure 4)*

According to the model, in Romania, a 1% increase in GFCF in the previous year is associated with a 0.23% decrease in GHG in the current year.

Figure 4: Actual and Predicted Log(GHG) in Romania Based on Lagged GFCF (2006–2022)



The model is statistically significant at a 95% confidence level ($\alpha = 0.0001 < 0.05$). R-squared = 0.6689, suggesting that 67% of the variation in GHG is explained by the relationship between the two selected variables.

The same methodology, with various procedures, was applied to the EU, as well as to Bulgaria, France, Germany, Hungary, and Poland, as shown in Table 3.

Table 3: Summary table of linear regression statistical data and associated tests

Country/ Indicators	EU	Bulgaria	France	Germany	Italy	Hungary	Poland	Romania
r	-0.043	0.156	0.779	0.648	0.655	0.174	0.236	0.818
R^2	0.001	0.024	0.607	0.419	0.429	0.030	0.056	0.669
P-value	P-value, 0.871>α	P-value, 0.548>α	P-value, 0.0002<α	P-value, 0.0004<α	P-value, 0.004<α	P-value, 0.505>α	P-value 0.362>α	P-value. 0.0001<α
Intercept	14.189	8.198	22.959	14.937	5.931	9.059	10.465	10.829
Slope	−0.157	0.071	−1.424	−0.485	0.566	−0.038	−0.049	−0.228
Statistical significance at a 95% confidence level	No	No	Yes	Yes	Yes	No	No	Yes
Lagrange Multiplier (LM) test for non-Linearity (squared terms) Null hypothesis: relationship is linear, α=0,05			Test statistic: LM = 0.400558 with p-value = P(Chi-square(1) > 0.400558) = 0.526801 p-value >α Relationship is linear	Test statistic: LM = 0.570652 with p-value = P(Chi-square(1) > 0.570652) = 0.45 p-value >α Relationship is linear	Test statistic: LM = 1.86598 with p-value = P(Chi-square(1) > 1.86598) = 0.171936 p-value >α Relationship is linear			Test statistic: LM = 0.28034 with p-value = P(Chi-square(1) > 0.28034) = 0.596478 p-value >α Relationship is linear
White's test for heteroskedasticity, Null hypothesis: heteroskedasticity not present, α=0,05			Test statistic: LM = 0.779211 with p-value = P(Chi-square(2) > 0.779211) = 0.677324 p-value >α Homoskedasticity	Test statistic: LM = 4.75071 with p-value = P(Chi-square(2) > 4.75071) = 0.0929817 p-value >α Homoskedasticity	Test statistic: LM = 2.28152 with p-value = P(Chi-square(2) > 2.28152) = 0.319576 p-value >α Homoskedasticity			Test statistic: LM = 1.22527 with p-value = P(Chi-square(2) > 1.22527) = 0.541922 p-value >α Homoskedasticity
Test for normality of residuals, Null hypothesis: error is normally distributed, α=0,05			Test statistic: Chi-square(2) = 3.45389 with p-value = 0.177827 p-value >α Error is normally distributed	Test statistic: Chi-square(2) = 1.39718 with p-value = 0.497287 p-value >α Error is normally distributed	Test statistic: Chi-square(2) = 3.51922 with p-value = 0.172112 p-value >α Error is normally distributed			Test statistic: Chi-square(2) = 0.024551 with p-value = 0.9878 p-value >α Error is normally distributed
Breusch-Godfrey test for autocorrelation up to order 3, Null hypothesis: no autocorrelation, α=0,05			Test statistic: LMF = 6.70819 with p-value = P(F(3, 12) > 6.70819) = 0.0065656 p-value <α **Autocorrelation**	Test statistic: LMF = 2.5853 with p-value = P(F(3, 13) > 2.5853) = 0.0978873 p-value >α No autocorrelation	Test statistic: LMF = 3.6965 with p-value = P(F(3, 12) > 3.6965) = 0.0429664 p-value <α **Autocorrelation**			Test statistic: LMF = 1.2428 with p-value = P(F(3, 12) > 1.2428) = 0.33741 p-value >α No autocorrelation
Equation of the linear regression line			$Log(GHG_t)$= 18.75-0.93log($GFCF_{t-1}$) From Prais-Winsten procedure (Table 4)	$Log(GHG_t)$= 14.94-0.49log($GFCF_t$)	$Log(GHG_t)$= 11.2754-0.1906log($GFCF_{t-1}$)+ε_t			$Log(GHG_t)$= 10.83-0.23log($GFCF_{t-1}$)

The models for France and Germany indicate a statistically significant relationship between the log-transformed data on greenhouse gas emissions from industrial processes, and product use (GHG), and the log-transformed data on general government expenditures in environmental protection in gross fixed capital formation (GFCF), lagged one year in the case of France.

France: As with Romania, we used log-transformed data on general government expenditures in environmental protection in gross fixed capital formation (GFCF) lagged one year and log-transformed data on greenhouse gas emissions from industrial processes and product use (GHG) to achieve better results. Therefore, a 1% increase in government expenditure in year (t-1) is associated with a 0.93% decrease in greenhouse gas emissions from industry in year t. Autocorrelation was corrected using the Prais-Winsten procedure, resulting in a more accurate model.

Table 4: France: Prais-Winsten, using observations 2006-2022 (T = 17)
Dependent variable: l_GHG
rho = 0.908516

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	18.7492	1.66015	11.29	<0.0001	***
l_Generalgovernmentexpenditure_1	−0.932045	0.194903	−4.782	0.0002	***

Statistics based on the rho-differenced data:

Sum squared resid	0.036454	S.E. of regression	0.049298
R-squared	0.901623	Adjusted R-squared	0.895065
F(1, 15)	5209.610	P-value(F)	1.75e-20
rho	−0.027889	Durbin-Watson	1.986368

Statistics based on the original data:

Mean dependent var	10.83607	S.D. dependent var	0.144972

Germany: To get a better model that meets the regression assumptions, we used the log-transformed data on GHG and GFCFA. The results demonstrate that a 1% increase in GFCF is associated with a 0.49% decrease in GHG in the same year.

Italy: Autocorrelation was corrected with the Cochrane-Orcutt procedure (Table 5), but the resulting model was not statistically significant (p-value =0.08>α).

Tabel 5: Italy - Cochrane-Orcutt, using observations 2007-2022 (T = 16)
Dependent variable: l_GHG
rho = 0.93366

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	11.2754	0.823785	13.69	<0.0001	***
l_GFCF_1	−0.190592	0.104186	−1.829	0.0887	*

Statistics based on the rho-differenced data:

Sum squared resid	0.029952	S.E. of regression	0.046254
R-squared	0.939457	Adjusted R-squared	0.935132
F(1, 14)	3.346504	P-value(F)	0.088723
rho	−0.315429	Durbin-Watson	2.506563

For Bulgaria, Hungary and Poland, the relationship has a very low correlation coefficient and is not statistically significant.

6 Interpretation of the results of quantitative and econometric analyses

In Table 6, we presented the centralised results of the quantitative and qualitative analyses. In the quantitative analysis section, we identified three groups of countries based on the dynamics of GFCF and GHG. France, Germany, Italy, and Romania, in which the increase in GFCF is accompanied by a decline in GHG. Poland, the outlier, where the rise in GFCF was associated with almost no decrease in GHG. And Bulgaria and Hungary, where both indicators declined.

Table 6: Quantitative and econometric indicators of the relationship between GHG and GFCF

Country	GHG Change	GFCF Change	Statistical Significance	Relationship Type	Elasticity (approx.)
Romania	-53.22%	993.72%	Yes	Lagged	-0.23
France	-38.72%	54.73%	Yes	Lagged	-0.93
Germany	-28.38%	39.11%	Yes	Current	-0.49
Italy	-49.91%	7.40%	No	Lagged	-0.19 (not statistically significant)
Poland	-0.37%	24.29%	No	None	No clear pattern
Bulgaria	-39.08%	-13.37%	No	None	No clear pattern
Hungary	-33.21%	-19.02%	No	None	No clear pattern

Examining Table 6, we identified two additional groups: (1) the effective expenditure countries (France, Germany, and Romania) and (2) the paradoxical countries (Bulgaria, Hungary, Italy, and Poland).

Group 1: In these countries, there is a negative, statistically significant relationship between GFCF and GHG. The impact of investments is lagged in France and Romania, meaning that spending in year t leads to a reduction in emissions in year t+1.

In Germany, this effect is immediate, within the same year, indicating an even more efficient allocation of funds to mitigating emissions.

Group 2: Italy experienced a substantial drop in emissions, accompanied by a minimal increase in expenditures, which could be attributed to other factors that require further investigation, as in the cases of Bulgaria and Hungary, where emissions dropped despite a decline in expenditures or Poland, where the increase in GFCF did not translate in a decrease in GHG.

7 Conclusion

In this paper, we investigated the impact of general government expenditures in environmental protection in gross fixed capital formation on greenhouse gas emissions from industrial processes and product use in the EU and six member states between 2005 and 2022. Using econometric models (log-log and log-log lag), we found negative and statistically significant relationships between the selected indicators in France, Germany and Romania. For France and Romania, the use of log-log lag data on GFCF generated better models, demonstrating that a 1% increase in GFCF in the previous year is associated with a 0.93% and a 0.23% decrease in GHG, respectively. The best result for Germany involved using the log-log econometric model, without the lag of GFCF, which revealed a decline of 0.49% of GHG for a 1% increase in GFCF in the same year.

In Italy, the relationship became negative after addressing autocorrelation with the Cochrane-Orcutt procedure, but it lost its statistical significance at a 95% confidence level.

In the EU, Bulgaria, Hungary and Poland, we did not identify a statistically significant relationship regardless of the data transformation employed.

The results emphasised heterogeneities among the analysed countries regarding the analysed relationship, suggesting different effects of public environmental expenditures on mitigating greenhouse gas emissions. The significant cross-country differences indicate that a single EU policy may not be effective for all the member states.

Future research should focus on identifying the causes of these heterogeneities, particularly for the member states in which the relationship proved to be statistically insignificant, to provide decision-makers with additional practical tools for shaping customised policies and institutions that mitigate greenhouse gas emissions and achieve climate neutrality by 2050.

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Annexe 1: General government expenditures in environmental protection in gross fixed capital formation- million euro

Year	EU	Bulgaria	France	Germany	Hungary	Italy	Poland	Romania
2005	18,201.4	73.3	4,283.0	2,263.0	341.8	3,121.0	864.3	36.6
2006	21,180.2	164.5	4,351.0	2,986.0	450.6	3,030.0	966.1	92.4
2007	22,084.1	119.4	4,754.0	2,523.0	386.3	3,180.0	992.7	204.7
2008	22,675.6	88.0	4,994.0	2,489.0	375.4	3,433.0	1,106.7	265.5
2009	22,790.4	220.0	5,074.0	2,618.0	212.3	3,404.0	1,085.4	318.8
2010	22,090.1	55.9	5,133.0	2,647.0	369.5	2,814.0	1,328.0	500.8
2011	22,039.4	56.1	5,361.0	3,429.0	399.1	2,629.0	1,541.5	683.0
2012	20,897.3	63.9	5,214.0	3,210.0	374.2	2,653.0	1,213.5	470.3
2013	20,729.0	169.4	5,112.0	3,402.0	625.1	2,234.0	1,261.0	480.7
2014	20,060.2	69.6	5,079.0	3,332.0	739.4	1,896.0	1,354.7	540.0
2015	20,698.9	111.6	4,811.0	3,248.0	952.8	2,064.0	1,416.0	688.6
2016	17,243.1	54.0	4,486.0	3,500.0	119.1	1,955.0	537.0	369.1
2017	17,216.1	48.4	4,771.0	3,124.0	159.0	1,774.0	540.4	255.6
2018	18,870.0	72.0	5,053.0	3,326.0	249.6	1,785.0	1,058.5	313.6
2019	20,946.7	71.2	5,692.0	3,372.0	396.9	2,240.0	1,032.6	416.8

Year	EU	Bulgaria	France	Germany	Hungary	Italy	Poland	Romania
2020	20,853.7	70.5	5,088.0	3,495.0	392.7	2,413.0	1,051.1	423.8
2021	21,845.4	128.6	5,633.0	2,890.0	352.9	2,845.0	1,011.2	443.5
2022	24,471.3	63.5	6,627.0	3,148.0	276.8	3,352.0	1,074.2	400.3

Source: Eurostat (2025a).

Annexe 2: Greenhouse gas emissions from industrial processes, and product use - Thousand tonnes

Year	EU	Bulgaria	France	Germany	Italy	Hungary	Poland	Romania
2005	429,934.6	7,509.51	62,438.15	72,688.4	47,132.13	8,873.8	23,732.01	21,542.78
2006	433,497.4	7,325.19	63,964.76	73,025.88	43,607.01	8,509.39	26,007.17	21,098.28
2007	445,324.19	7,775.21	64,995.49	76,125.84	43,661.65	8,348.01	28,402.24	21,297.07
2008	420,550.31	6,854.38	60,715.42	71,967.46	41,095.54	7,251.44	27,121.82	18,190.75
2009	347,914.74	3,829.88	50,614.99	64,002.71	35,735.18	6,252.28	21,736.51	12,106.43
2010	364,531.89	4,087.85	53,743.64	61,782.62	36,590.78	6,435.29	22,882.28	13,845.19
2011	364,191.16	4,631.54	53,282.44	63,192.75	36,346.48	6,594.06	25,638.89	14,444.51
2012	348,869.02	4,351.29	51,152.96	60,409.07	33,226.21	6,291.51	24,635.59	13,121.85
2013	345,396.29	4,237.03	52,889.53	60,269.99	31,758.76	5,674.5	23,627.67	11,411.74
2014	351,993.52	4,528.69	52,328.8	60,544.87	30,995.96	6,426.67	25,107.47	12,140.63
2015	342,573.38	5,162.41	50,802.88	59,778.25	29,093.66	7,007.67	24,356.91	12,183.45
2016	344,828.89	5,366.52	50,557.7	61,485.48	28,470.01	6,545.85	24,557.56	12,271.79
2017	351,267.33	5,245.92	51,774.28	65,346.74	28,005.55	7,230.19	25,068.7	12,402.01
2018	344,206.57	4,921.23	49,114.92	62,437.21	28,608.26	7,466.07	25,563.33	12,694.56
2019	331,028.81	4,591.88	45,951.67	59,352.38	27,329.77	7,353.36	25,081.12	12,629.4
2020	307,232.58	4,321.05	39,977.19	55,254.65	24,289.62	7,369.28	24,526.59	12,745.97
2021	317,997.1	4,582.44	42,322.67	57,046.25	25,300.24	7,144.36	24,588.76	12,843.27
2022	291,844.53	4,574.92	38,262.97	52,061.33	23,608.99	5,927.06	23,645.03	10,077.72

Source: Eurostat (2025b).

SHIFTING PATTERNS IN GLOBAL FLOWS OF TRADE, CAPITAL, MIGRATION AND INFORMATION

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Abstract: Since the beginning of time, the world's economies have been interconnected. These connections have ranged from simple partnerships to complex exchanges of resources. Throughout human history, no country has ever possessed all the resources it needed, making international connections essential. People, trade, capital, and information have always been the key flows driving global interaction, although their evolution varies depending on the global context. In an ever-changing international system shaped by economic, political, and social factors, these flows shift in scale and direction but consistently remain the forces that keep states connected.
Economic flows are reflected in the export and import of goods and services, migration (i.e., the movement of people), technology transfer, information exchange, innovation, foreign direct investment, and the operations of transnational corporations. Without these components, the global economy cannot function effectively, increasing the risk of widening gaps between countries or even their isolation. Therefore, international economic flows are essential for global growth, the development of partnerships, diversification of supply sources, market expansion, and job creation. They are the engine of growth and development.
This article aims to identify the defining features of each type of flow and to demonstrate the importance of the global economic circuit they create. By analysing trade, migration, capital, and technology flows, the paper will justify their critical role in the economies of all countries, regardless of their level of development.

Keywords: global economic flows, trade and investment, international migration, technology transfer, economic interdependence, globalization dynamics, FDI

JEL Classification: F02, F, F2

1. Introduction

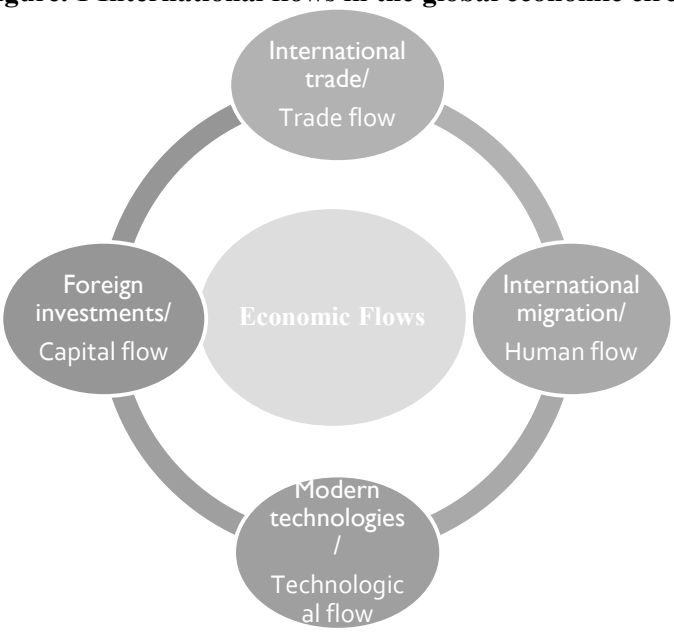
People, values, goods, services, and financial resources play a central role in connecting countries, shaping geopolitical dynamics, and fostering economic development. Despite ongoing military conflicts, economic shocks, and health crises, international economic flows have continued to sustain interdependence among nations. So, International economic flows play a crucial role in connecting the countries of the world, facilitating commercial, financial, human and technological exchanges between national economies. These flows include commercial transactions of goods and services, foreign direct investment, technology transfers, innovations and information. Thanks to these flows, the states cooperate, thus generating an economic growth at the national level, but also globally. Each flow has its own contribution in determining the interdependence between states. For example, international trade, as the first economic flow in establishing relations between states, connects producers and consumers on the same market. Foreign direct investments, generated by transnational corporations, represent another important pillar of international economic flows. They bring capital, innovations, talent, creativity, technological and managerial know-how, contributing to increasing the efficiency and competitiveness of national economies. And the migration flow contributes to increasing the incomes of underdeveloped countries through remittances, exchange of mentality, economic and social policies, this being one of the saving flows in some countries of the world.

In the context of the reformation of the current global conjuncture, international economic flows are becoming increasingly complex and interconnected, reflecting even more their impact on the development of the countries of the world, by creating prosperity and sustainability.

2. Literature review and analysis of key concepts in defining international economic flows and its related elements

To study the impact of economic flows in the world economy, it is necessary to define the theoretical concepts. The methodological and theoretical-scientific support of the article relies on several specific notions, which aim to determine the basic actors in the global circuit, such as international trade, capital flows, international migration, or innovative technologies, researched by a number of authors such as A. Bulatov, G. Ohlin, M. Thorton, S. Clerck, and others. Even if in recent years we have seen a trend towards deglobalization, it is a short-term trend, because no state has the capacity to develop independently, with its own resources alone (Popa, 2023). At the same time, global economic flows are essential for the functioning of economies at the macro and micro scales, for large and small companies. This happens through the activity of transnational corporations, which are catalysts for investment, capital and account for about two-thirds of global exports (McKensey, 2023). Similarly, labor migration continues to be a key issue in the global economy, and information technologies are the path to a new era of development. Hence, the importance of not only monitoring the connection between the flows and their vital contribution to maintaining global prosperity despite all the turbulence. Researchers' interest in the movement of flows dates back to the 16th century, when Richard Cantillon first established the concept of the economic circuit (Thorton, 2004). He saw the economy as an interconnected system of flows between producers, traders, consumers, and landowners (Maldini, 2025). Initially referring only to micro-level relationships, the concept later evolved to include the exchange of goods between countries, and then other economic flows. Years later, the notion of international movement of economic resources has been developed and researched by the Swedish economist Eli Heckscher together with Nobel laureate Bertil Ohlin and others. The essence of the concept is that the different endowment of countries with resources leads not only to their specialization and the resulting international trade in goods and services, but also to the movement of resources between countries (Bulatov, 2023). Given the fact that during the development of the world economy, international flows have intensified, especially under the process of globalization, the world economic circuit is defined as the totality of international flows in the form of goods and services, capital, human and technological flows (Fig. 1.).

Figure. 1 International flows in the global economic circuit



Source: Adapted by the author from researched literature.

The international economic flow is a specific form of manifestation of interdependencies between economic units in different countries, states, and international organizations within the global economic circuit. Alternatively, flows are monetary expressions of economic actions and the effects of events resulting in changes in economic value within a reporting period (Clerck, 2015). Flows can provide complex and multidimensional, tangible and intangible, and providing services such as transportation or technologies. Looking at the four dimensions separately, trade is the first flow of the global circuit, and it comprises the movement of goods and

services from one country to another, by crossing the customs borders of that country. Or international trade is defined as the exchange of goods or services between two or more countries, regulated by international institutions, notably the World Trade Organization (Isachenko, 2023). International capital flows are the transfer of financial assets, such as cash, stocks, or bonds, across international borders. They have become an increasingly important part of the global economy in recent decades and are an important source of growth for national economies (OECD, 2025). Another international flow is migration or human flow, which is the movement of a person or a group of people, either crossing an international border or within the same state. Thus, the concepts of international migration and internal migration emerge (IOM, 2025). In recent years, especially as a consequence of the COVID-19 pandemic, technological flows have been bursting in all areas. Technological transfer is the introduction into the economic circuit of specific technologies and machinery, equipment and facilities, hybrids, varieties, breeds, preparations, resulting from research or purchased, in order to increase the efficiency and quality of products, services, processes or to obtain new ones, which are required on the market or by adopting an innovative behavior, including the activity of disseminating information, explaining, transmitting knowledge, consulting (Popa, 2023). On the other hand, economist Arjun Appadurai (Powell, 2011) proposed a framework for understanding global flows based on five dimensions:

- Ethnoscapes – is about the movement of people, including migrants, tourists, and refugees;
- Technoscapes – refers to the global configuration of technology and the flow of technology across borders;
- Financescapes – describe the global flow of capital and money;
- Mediascapes – refers to the distribution of information through various media (i.e., television, internet);
- Ideoscapes – are associated with the spread of ideas and ideologies (democracy, human rights).

3. Methodology

To understand the evolution of flows in the world economy, the author uses several research methods, such as analytical, qualitative, and quantitative, based on data provided by international economic institutions, particularly UNCTAD and the World Bank. Analysis and synthesis allow us to identify the factors that stimulate the development of international flows, as well as their movement caused by various factors arising from changes in the global economy. The author separates the information on each flow, analyzing and studying the causes and effects of each flow. So, our research employs an evolving analysis of the economic flows investigated over the period 2011-2022, using a quantitative assessment based on data from statistics presented by UNCTAD or the World Bank, using indicators specific to these flows. In order to identify the importance of global economic flows, the author analyzes how the global volume of exports, imports, FDI inflows, FDI outflows and other specific indicators have expanded over the period 2011-2022, by investigating the databases provided by international financial institutions.

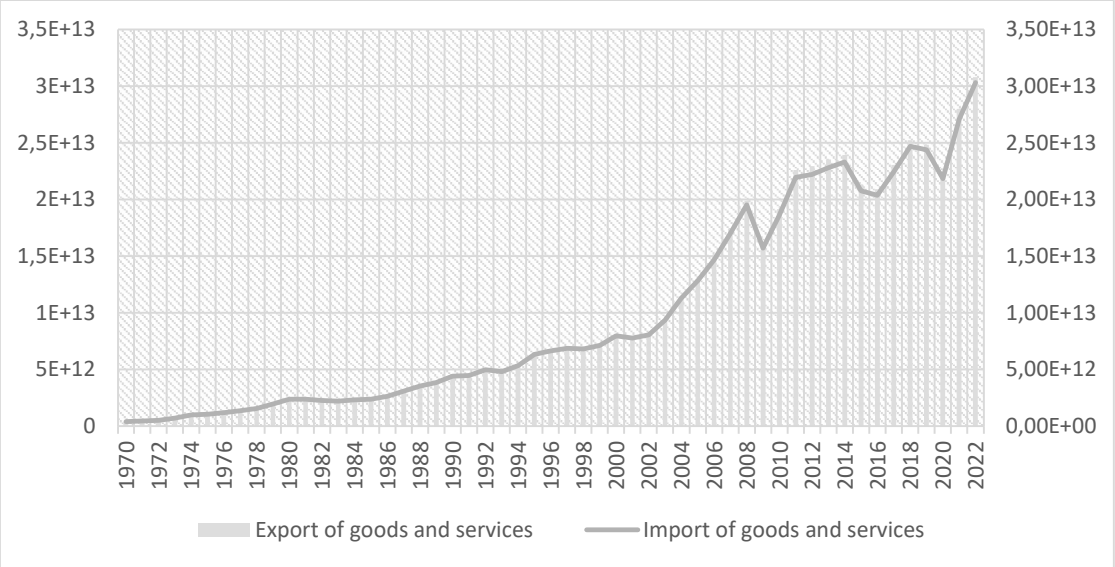
4. Trade flow research as the primary tool of interaction between states

Throughout history, trade has largely defined the evolution of the world economy. The analysis of international trade is primarily concerned with the trajectory and content of trade: who and what imports and exports. Moreover, trade is subject to various cyclical factors that influence the price and quality of products, the quantity traded or the location of production.

International trade has two components: exports and imports, and the difference between them is the trade balance (Hurduzeu, 2017). This is worth mentioning in order to be able to understand what contribution each of them have in the economic development, and it is through them that interdependence between states is created.Considering that trade is the first flow which determined the connection between countries, it is very important to observe how it has evolved in order to understand how trade relations between the countries of the world have changed. At the beginning of the 20th century, agricultural products represented the main product category in international trade, gradually decreasing from 37% to 12% of total world trade in terms of value. In the post-war period, the share of manufactured goods increases from 47% to about 71% of world trade. In the same period, as a result of the Scientific and Technical Revolution, the share of chemicals and textiles in global

trade increases. Between 1980 and 2000, trade in services expanded. The share of world services exports rose from 17% to 30%. Until the financial crisis of 2009, developed countries maintained a high share of world trade, and appears the polarization of trade flows around US, EU, Japan, and China. Transnational corporations become the main participants in promoting trade flows. Then, as a consequence of the development of the circular economy, creative, bio-based goods enter global trade. After 2020, under the influence of Covid 19, military conflicts in various places, serious shifts in global trade flows are happening, and Trump is the president who comes to accentuate these changes even more by changing the US trade policy towards the countries of the world.Since 1970, international trade has shown an upward trend with significant growth rates in volume and value of exported and imported goods. Over the last decade, trade reached an unprecedented level in terms of volume and absolute value, and relative to world output. Thus, from a starting value of trade in goods and services in the 1970s of 2.1 trillion USD, values have grown exponentially, peaking in 2008 at 21.3 trillion USD. The international trade dynamics experienced a substantial impact due to the financial and economic crisis, which started in 2008, and whose consequences were reflected in the value and volume of international transactions in goods and services in 2009. As a result, the value of global trade dropped to 17.2 trillion USD in 2009, reporting a sharp decline. Thereafter, between 2010 and 2014, moderate but steady increases in the value of trade in goods and services were recorded until 2015, when the value of transactions declined by 13% to 23 trillion USD. Over time, trade volumes increased until 2019. And in 2020, the pandemic crisis disrupted international trade flows, leading to an unprecedented increase of up to 31 trillion USD in the value of both exports and imports in 2022 (WB, 2025).

Figure 2. Developments in global exports and imports of goods and services between 1970 and 2022



Source: adapted by the author from World Bank data https://data.worldbank.org/indicator/NE.IMP.GNFS.CD

The main countries participating in international trade are China, the USA, the European Union, and Japan(Table 1).

Table 1. Leading participants in world trade of goods and services in 2022 (million USD)

2022	EXPORT	IMPORT
Total	24 904 375	25 640 775
USA	2 064 758	3 320 880
Japan	746 612	897 803
EU	7 493 996	7 462 675
China	3 584 284	2 747 312

Source: compiled by the author based on UNCTAD data.

So, from this table we deduce who are the main players in world trade. It also clearly shows the global trade competition and the struggle to dominate the world market.

In this context, the tariffs imposed by Trump in 2025 created panic, imbalances and trade wars on the global arena.

The role of trade policies in the development of world trade

Trade policy is fundamental for a country's economic development, influencing the nature, dynamics, structure, and geographical pattern of trade.

Trade policy *means the totality of regulations adopted and applied by a State (of a legal, administrative, fiscal, budgetary, financial, banking, or foreign exchange nature) aiming to restrict or promote its trade with foreign countries and exposing the national economy to the most acceptable degree of external competition.* (Chistruga, 2016).

Trade policy is also a term that describes the regulations and policies that dictate how economic agents in different countries can trade with each other. Trade policy includes tariffs, import quotas, export constraints, and restrictions against foreign-owned companies operating domestically, etc. Thus, through its trade policy, any government/state aims to achieve the following objectives: to improve its exports and imports commodity structure; to strategically reorient and select its trading partners; and to ensure a dynamic and beneficial balance of trade.

There are three types of trade policy:

1. *Autarchic trade policy* represents a state of economic isolation from other states, inward-oriented to satisfy consumer needs at any price, ignoring the advantage involved in trade with other states. The consumer does not have access to a broad range of foreign products;

2. *Liberal trade policy* is a favorable and open policy towards imports and exports. States can trade freely, and consumers have access to a wide range of foreign products;

3. *Protectionist trade policy* lies between the two extremes and aims to protect certain socially sensitive sectors of the economy from foreign competition. In this policy, the state seeks initially to protect domestic producers, while the access of some foreign products to the local market should be determined by the circumstances of each country and the current international economic situation.

In trade policy, several types of instruments exist to *regulate imports*, both tariff (duties, tariffs) and non-tariff (quotas, certificates, minimum/maximum prices) measures, as well as measures to promote and *stimulate exports* (tax incentives, credit, foreign exchange, fairs, exhibitions). These policies or techniques determine the type of economy and the measures the state struggles with to ensure the prosperity of consumers and producers. Trade is the flow that not only generates international visibility, economic growth, and the creation of jobs. It is the first economic flow that has promoted collaboration between states. Global competition, the battle for markets and power, is initially achieved through trade and then extends to other flows.

5. International Financial Flows, Foreign Direct Investment, and Transnational Corporations

International financial flows assume different forms, such as international loans, remittances, technical assistance, financial assistance, etc. One of the most important categories is Foreign Direct Investment (FDI). When investment involves foreign capital, it is a complex approach.

Foreign (international) investment is the total expenditure made outside the country in industry, agriculture, transport, technology, and different organizations, directly or indirectly, through banks or other financial means.

Portfolio investment (PI) always refers to a purely financial investment by purchasing shares on the financial market. It also include bonds, which are debt securities. These investments are also referred to as passive investments, as the investor does not exercise control over the enterprise and may have only limited influence within the enterprise (Bonciu, 2009).

The largest and most substantial investment flows are foreign direct investment (FDI).

Foreign direct investment (FDI) is a foreign investment by an entity resident in one country made in an enterprise resident in another economy aimed at obtaining a lasting interest;

The United Nations Conference on Trade and Development (UNCTAD) also defines FDI as an investment that involves a long-term relationship and reflects an entity's interest in a foreign economy. The FDI flows have three components:

- Participation in the share capital of a company;

- Reinvested profits;

- Intra-company loans.

Therefore, FDI represents all the financial, material, technological, and managerial flows that a natural or legal person conducts in an economy other than the one in which it is resident for the realization of a lasting and productive activity through the control of that economy.

Foreign direct investment flows can be:

- *Inflow – the total investments made in a country by non-resident firms, states, or investors during a year;*

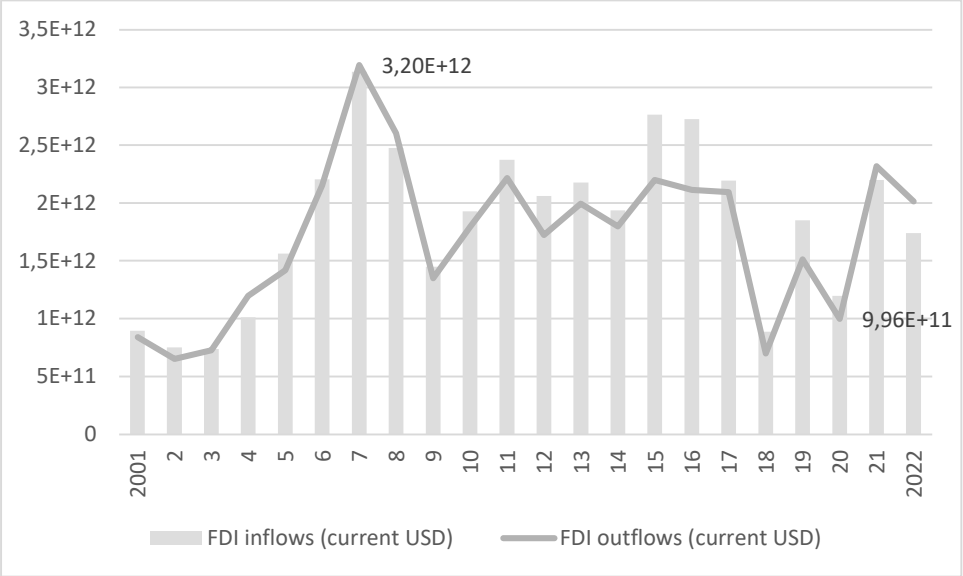
- *Outflow – the total investments made by residents into a foreign country during one year.*

Foreign direct investment stocks represent the value of shareholders' equity and reserves belonging to the investing firm plus the value of subsidiaries' net debts to the investing company.

The evolution of foreign direct investment between 2001 and 2022

Changes in the global economic and political environment have driven the evolution of FDI inflows and outflows. Significant declines were recorded between 2001 and 2003, mainly due to a fall in flows to developed countries (Figure 3).

Figure 3. Evolution of global FDI inflows and outflows over the period 2001-2022



Source: adapted by author based on World Bank data https://data.worldbank.org/indicator/BM.KLT.DINV.CD.WD

In terms of volume, direct investment inflows reached a record level of over 3 trillion dollars in 2007. Foreign direct investment outflows grew along with inflows, rising steadily from 2003 to 2008 until the financial crisis from 2009 severely affected international flows. Between 2010 and 2019, a slight stabilization of FDI inflows and outflows worldwide was recorded, but in 2020, the COVID-19 pandemic strongly affected them with an unprecedented drop. Thus, the volume of FDI inflows decreased from 1.9 trillion dollars to 1.2 trillion dollars. In addition to the 2020 pandemic, during this period, global investment flows were constantly affected by various factors, notably regional military, conflicts, and movements of refugees or illegal migrants.

Regarding the geographical distribution of FDI flows, according to UNCTAD reports, in the period 2021-2022, the largest share of FDI flows was oriented towards Asian countries (662 billion USD), being the most dynamic and attractive region, followed by North America (338 billion USD), and South America (208 billion USD). A catastrophic drop is recorded in Europe (51 billion dollars), the reason being the pressure of conflicts in the region, BREXIT, the difficult recovery from the COVID-19 pandemic, and finally, with the same unstable situation for decades, the African countries (48 billion USD) (UNCTAD, 2024).

The countries with the largest inflows and outflows of FDI are the U.S.A, China, Japan, Germany, Australia, and Canada. The highest investment areas are technology, telecommunications and digital infrastructure, the automotive industry, energy, transportation, and medicine.

Among the most powerful and dynamic participants in the global economy are transnational corporations. Their strength comes from the massive volume of goods and services they handle. In the specialized

literature, they are referred to as transnational corporations, multinational companies, or international firms. In the broadest sense, they define those firms that operate outside the borders of their home country through 'production' units controlled to a greater or lesser extent by the 'parent company.' They are the prime promoters of capital flows. The best-known definition of a transnational corporation comes from John Dunning, considered by many experts to be the "father of transnationals," who defines a transnational as "a firm that engages in foreign direct investment and owns and controls value-creating activities in more than one country" (Dunning, 2009).

The United Nations considers that a company qualifies as transnational if it meets the following criteria (Chistruga, 2016):

- turnover volume must be more than 2 billion dollars;
- presence of subsidiaries in at least 6 countries;
- the share of overseas assets should constitute 25% - 30% of the company's total assets;
- 20% - 30% of the turnover volume should come from foreign sales.

According to UNCTAD, today, an estimated 82,000 transnational corporations operate through 840,000 subsidiaries around the globe. They account for a huge share of world exports and GDP and provide hundreds of millions of jobs worldwide.

Every year, changes appear in the number of transnational corporations due to capital concentration. Changes in annual capital flows occur in several ways:

Merger – a concentration technique whereby two or more firms merge into one;

Acquisition by absorption –a technique through which one company fully buys another company;

Acquisition by participation – refers to the acquisition by a company of only a part of the capital of another company.

There are two types of relationships in the activity of a TNC :

1. The transnational company's relationship with the country of origin – is a partnership relationship aimed at promoting the country's brand and increasing revenues for the national budget;

2. The transnational company's relationship with the host country (the country where the parent company's subsidiaries operate) is complex, with a set of advantages and challenges for both the company and the host country (Table 2).

Table 2. The implications of TNCs on host countries

Positive effects	Negative effects
TNCs contributed to the transfer of new technologies in these countries;	Repression of local companies by the TNC 's use of force;
TNCs can provide financial and production means to modernize local industry;	Setting monopoly prices;
TNCs provide jobs for the native population;	Non-compliance (e.g. tax evasion);
TNCs contributed to the qualification of certain socio-professional categories and to the better use of local production capacities;	Pollution of the environment;
TNCs contribute to the attraction of local producers in the process of international specialization;	Destabilization of the situation on the labor market by attracting labor force from local firms to TNC branches through high wages;
TNCs' investments in the economies of these countries have reduced the demand for external loans.	The possibility of TNCs to influence host country government policy.

Source: adapted by the author based of own research

Thus, the flow of capital, together with transnational corporations is essential in the development of the world's economies. They lead to the improvement of production relations, the expansion of the geography of production, the strengthening of economic globalization, and competitive relations at the world level.

6. Human flows, international labor migration and its impact on economic growth

Migration involves the movement of people across national borders. It takes many forms, depending on the factors that motivate people to leave their country of origin. The process of going abroad originated the concept of diaspora, which is the catalyst for human flows by maintaining cultural, economic, and political links with their countries of origin. Diasporas may be a significant factor in shaping cultural identities and transnational bonds. At the same time, remittances are another economic flow in migration, an indispensable source of economic growth for countries dependent on this phenomenon.

Several migration-specific notions are identified.

Emigration is the action or phenomenon of an individual or group of individuals leaving their country or region of birth to settle in another country.

Immigration is the movement of people to another country where they are not natives to settle there to live for an indefinite period.

Brain drain, or brain exodus, is when many highly educated and skilled people leave their country to live and work in another country with better wages and conditions.

Remittances are funds transfered between parties in the form of a voucher, invoice, or even a gift. However, 'remittance' refers more broadly to funds sent by migrants to their relatives in their home country while working and living abroad. These are also known as financial transfers by migrant workers. Remittance means "send back". Most families living in slow-growing economies and developing countries rely heavily on remittances as their main source of income. Today, most money transfers are done electronically, through banks or other financial services.

The human flow is not limited to simple migration. However, international labor migration refers to the movement of the employable population across the borders of one's own country to enter into employment relationships with employers in other countries.

The causes of international migration also determine the influence of the phenomenon on the global economy, expressing its direct impact on the connection between states:

- intensifying the internationalization of economic life;
- uneven development of national economies;
- the integrationist processes in the world economy that stimulate the movement of workforce between associated countries;
- the broadening of the international economic system through the interaction between the two antagonistic blocs until the 1990s: capitalist and socialist;
- the improvement of the global transportation system, which allows information, goods, services, and people to move quickly and freely anywhere in the world;
- social relations, expressed through the internationalization of marriages and cultures;
- the demographic factor, in terms of unequal population growth in the world countries and, correspondingly, the uneven filling of labor markets.

Therefore, the migration process is quite broad and complex, determined by a number of objective and subjective factors that change from one period to another, from one country to another, and even from one social group or individual to another.

Discussing general trends in the movement of people, more people than ever are now living in a country other than their birth country. According to the IOM's World Migration Report 2022, as of December 2020, the number of international migrants was estimated to be around 281 million globally, 60 million more than in 2010. International migrants accounted for 3.6% of the global population in 2020, up from 2.8% in 2000 and 2.3% in 1980 (Table 3).

Table 3. Evolution of the number of migrants by categories in 2019-2020

Indicators	2020	2019
Total number of migrants	281 million – 3.6% of the population	272 million – 3.5% of the population

Women	135 million – 3.5% of the world's female population	130 million – 3.4% of the world's female population
Men	146 million – 3.7% of the world's male population	141 million – 3.6% of the world's male population
Labour force	169 million	164 million
Missing migrants	3900 missing	5400 missing
Remittances	702 billion dollars	719 billion dollars

Source: Adapted by author from data provided by IOM, https://publications.iom.int/system/files/pdf/WMR-2022_0.pdf

While a growing number of individuals migrate out of their initiative, out of a desire to make a difference in their lives, a substantial percentage of them migrate forcibly. The UNHCR (United Nations Refugee Committee) reports that the number of forcibly displaced people globally was 79.5 million at the end of 2019. About 26 million of these were refugees (20.4 million refugees under UNHCR mandate and 5.6 million Palestinian refugees under UNRWA mandate). 45.7 million people were internally displaced, 4.2 million were asylum seekers, and 3.6 million were Venezuelans displaced abroad. It should also specify the sharp increase in the number of Ukrainian and Afghan migrants as a consequence of the military conflicts between 2021 and 2022, with over 6.3 million Ukrainians and 2.3 million Afghans (Hachi M., Popa M., 2022).

We are now in an unprecedented era of mobility, and the need to facilitate orderly, safe, regulated, and responsible migration and mobility is becoming increasingly relevant and mandatory. The need to address the challenges and maximize the opportunities that this mobility brings was acknowledged through the inclusion of migration in the 2030 Agenda for Sustainable Development, which highlights the positive contribution of migrants to inclusive growth and development. Migration features in a number of Sustainable Development Goal (SDG) targets, such as ending modern slavery and addressing the vulnerability of migrant workers. However, the central reference to migration in the SDGs is target 10.7 on facilitating "orderly, safe, secure, regulated and responsible migration and mobility of people, including the implementation of planned and well-managed migration policies" (Vidal, 2022). Hence, current trends in international migration are caused by:

- Migration policy making;
- Developing partnerships between countries and governments;
- Ensuring migrants' welfare and respecting their rights;
- Supporting safe and orderly mobility during crises;
- Promoting regulated migration.

Looking at the current global juncture, international migration trends are shaped by several changes and influenced by:

1. The Russian – Ukrainian military conflict and tensions in the region;
2. The impact of COVID-19 on the global economy and the evolution of its mutations;
3. The active process of economic integration in South America adjusted by the structural and political crisis in Venezuela;
4. The new global economic crisis, triggered by pandemics and the Russian-Ukrainian war, has changed mikgration corridors and asylum policy conditions;
5. Changing the migration order in the USA, with the US administration attempting to change previous migration policies;
6. The fall of the Afghan government and the Taliban's rise to power have triggered massive population movements out of the country;
7. Geopolitical shifts in South-East Europe, etc.

In conclusion, we can state that the process of labor migration will never be static and predictable. Any local, regional, or global change generates strategic alterations in the movement of individuals, which are the consequence of cyclical changes.

7. Innovation and technological flow in the global economic circuit

Today, humanity is developing faster than ever, relying on innovation. Scientists and engineers constantly seek new systems and software to create innovative products. In this continuous development process, technology transfer plays a pivotal role. The whole process of technology transfer comprises scientific, technological, organizational, financial, and commercial steps through which new ideas, products, and operations must pass in any field of the economy. Therefore, the technology transfer flow is largely based on innovations and know-how. Thus, the process of technology transfer is a complex process, which requires in-depth analysis at all stages, starting from the emergence of the innovative idea, including legal protection of intellectual property, the manufacturing of the breakthrough product, to the final stage – obtaining profit from commercialization.

The role of innovation in the world economy

Innovation originates from the concept of novelty and creativity. It is a continuous process resulting from the development and application of new ideas and technologies. It is the engine of economic growth. A growing number of economists are assessing how technology and innovation greatly impact economic growth, directly reflecting on welfare. In these contexts, the potential of an economy to innovate depends on the level of research and development stock, human capital, involvement in international trade, market regulation, and technology transfer. Currently, innovation is supported by access to the internet, investment in research and development, intellectual capital, and the globalization process. At the same time, it is a preoccupation for governments, companies, universities, and civil society.

Innovation has several dimensions. That combines not just economic but also social and cultural aspects, some of which are abstract and not subject to economic evaluation. Indicators commonly used in the empirical analysis of innovation are the tendency towards research and development, the adoption of technologies, patents per worker, and human factor skill intensity.

From the perspective of the G20 (the world's major economies), in collaboration with the Organization for Economic Cooperation and Development, countries with high innovation potential support economic growth and innovative business through the following strategies and objectives: (Popa, 2023)

- Monitoring ICT performance and progress;
- Long-term funding in research and science;
- Boosting innovation to overcome global challenges;
- Stimulating the real potential to step into the Fourth Industrial Revolution;
- Addressing common challenges through international cooperation in science and innovation;
- Increasing the quality of science in academia;
- Nurturing human talent and skills;
- Investing more in scientists and the creative class;
- Promoting national and international student mobility;
- Facilitating mobility of researchers;
- Promoting innovation collaboration between companies;
- Supporting business innovation and stimulating entrepreneurship.

Annually, the World Intellectual Property Organization (WIPO) drafts the Global Innovation Report, ranking 133 countries according to their innovation capabilities. For example, in 2024, new aspects of digital innovation based on artificial intelligence (AI), supercomputing, and automation are identified, as well as deep innovation trends in science driven by biotechnology and nanotechnology (WIPO, 2024).

According to these indicators, Switzerland is for the 13th year the most innovative country in the world. Sweden is in second place and the United States third, followed by the United Kingdom (4th) and Singapore (5th), entering the top 5. Finland (6th) is close to the top 5, and every other Nordic (Denmark 9th and Sweden) and Baltic (Estonia 16th, Lithuania 34th, and Latvia 37th) economy is also on an upward trend, except Iceland, which remains stable at 20th. China ranks 12th, while Japan is in 13th place. Israel (14th) is in the top 15. Saudi Arabia (48th), Brazil (49th) and Qatar (50th) are in the top 50, while South Africa (59th) and the Republic of Moldova (60th) are in the top 60.

8. Conclusions

Following our extensive analysis of global economic flows, we have identified several conclusions:

- ✓ The evolution of international trade has followed an upward trend, with exponential growth rates since the 1970s, in terms of total volume and value of goods and services traded globally;
- ✓ The rise of China, and consequently of Asia, in the world rankings is by far the most notable change in the international trade picture since the 1980s;
- ✓ Technology transfer and innovation are the driving forces in today's global economy. They manifest themselves in human resources with completed tertiary education, exports of IT products, intellectual assets, particularly patent applications, scientific articles of international value, research and development expenditure, and rapid growth in the number of employees in creative-innovative companies;
- ✓ The migration process is quite broad and complex, determined by a series of objective and subjective factors that change from one period to another, one country to another, and even from one social group to another or individuals , with positive and negative effects on both the country of emigration and that of immigration;
- ✓ Foreign direct investment alongside transnational corporations brings economic growth, creates jobs, and diversifies the global product assortment.

These summaries show us that the world is undergoing a profound reshaping, complex and complicated but fully involving international flows. They remain the driving force in the development of states now and in the future. All the connections are reconfiguring, but they remain as strong as ever.

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Acknowledgement: The work of Popa Marina was conducted in the Project " Exploring Return Migration Dynamics in the Republic of Moldova: a Qualitative Analysis". *Project code*: PN-IV-P8-8.3-ROMD-2023-0173, BABEȘ BOLYAI UNIVERSITY, Cluj Napoca and, ASEM, Chișinău, 2024-2026.

TRADE IN SERVICES AND EMPLOYMENT: HARNESSING OPPORTUNITIES AND ADDRESSING CHALLENGES

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Abstract: Considering the recent trends in international business, influenced by the new opportunities offered by increasing digitalization, as well as challenges generated by the post-pandemic economic and geopolitical pressures, this paper investigates the impact of recent developments in services and trade in services on employment. The starting point of this research is the statistical evidence highlighting the contribution of service activities to economic development and, implicitly, employment, as revealed by their high share in GDP and the labour market, globally. The paper is focused on the analysis of trade in services, with its particularities in terms of modes of supply and increased ability to use digital technologies, from the perspective of its capacity to create opportunities and also challenges on employment, depending on service industries as well as the level of development and market openness of countries. The research methodology combines a qualitative analysis of studies and empirical evidence in the field of services, trade in services and employment, accompanied by statistical data, covering the last three decades, available in the databases of international organizations. The main conclusion is that, despite the economic, geopolitical, technological or regulatory challenges, the strength of the services sector, due to the diversity of services, the dependence on services of all economic activities, the favourable service regulations, as well as the resilience of service industries in recent years, will continue to sustain the growth of trade in services and, implicitly, employment, thereby ensuring improvements in quality of life and economic development in all countries.

Key-Words: trade in services, employment, modes of supply, digital services, artificial intelligence.

JEL Classification: F13, F23, J24, L8, O11, O24.

1Introduction

Over the last decades, the developments in service business models have generated significant economic effects, mainly highlighted by the increasing share of services in gross domestic product, employment and international trade and investments (WBG, 2025). Given the growing role of services in economy, the concept of servicification[1] has emerged, services having an essential contribution in all economic activities (June Dong, 2019), and thus being able to indirectly support jobs in other sectors as well. Therefore, nowadays, service activities employ the most jobs at global level (WBG, 2025), generating an increase in productivity in all industries, as well as significant improvements of the quality of life in all countries (Hofmeister et al., 2023). The high number of jobs in services has been sustained by the rapid expansion of trade in services, due to many determining factors, among which the implementation of favourable regulatory measures in many countries and the extensive processes of liberalization of trade in services, supporting the international business opportunities, over the last three decades (UNCTAD, 2020). The recent service developments have been also related to technological advances (WEF, 2025) and the increase in digital service business models, all conducting to positive effects on the economy, in general, and on employment, in particular.

Despite all these positive developments, employment remains a major challenge in many economies, from the perspective of insuring well-being and social inclusion (WTO, 2024a), jobs created in the service sector failing to solve the major social and economic problems in some countries and regions. A recent challenge is related to the intensive implementation of new technologies, especially artificial intelligence in service industries

[1] **Servicification** refers to the growing role and integration of **services in manufacturing and other traditionally non-service sectors.** It captures how firms increasingly **buy, produce, use, and sell services** as part of their overall production process—even when their final output is a good, not a service.

(WTO, 2024b). At the same time, the persistence of uncertainty regarding the future economic developments - fuelled by increasingly global challenges - is likely to remain a major concern. Geopolitical tensions driving economic fragmentation, alongside the urgency of measures to address climate change are expected to reshape the global labour market in the coming years (WEF, 2025). In the context of a fractured multilateral trade system with increasing market instability and asymmetries in trade benefits (UNCTAD, 2025a), the prospects of service industries and trade in services can offer an encouraging employment perspective, due to the wide variety of domains covered by this sector and the crucial role of some services in economic and social areas (e.g. medical, educational or environmental), although some of them could be partially affected by other trade restrictive measures (as is the case of transport and logistics services affected by the import tariffs imposed by the United States in 2025).

2 Literature review

The effects of service developments, including trade in services, on employment have been extensively analysed in reports and studies conducted by international organizations and academic researchers, highlighting the relevant trends in this area. Besides the main trends in trade in services, World Trade Organization also examined the impact of the trade openness and technological progress on employment and economic well-being (WTO, 2017), underlying also even the role of trade in services in sustaining the inclusiveness (WTO, 2024a) and reducing the gender inequality (WTO, 2019). The International Labour Organization's experts analysed the multiple effects of international trade and trade policies on labour market and the specific characteristics of employment related to trade activities, in this regard identifying the role of trade in facilitating the diffusion of new technologies, underling the increasing need for superior professional skills (ILO & WTO, 2017), as well as the relationship between trade and decent work (Corley-Coulibaly et al. (eds.), 2023).

The economic benefits of trade in services have been also highlighted by the Organization for Economic Cooperation and Development, in this regard being underlined the role of further liberalization of services trade policies in creating new employment opportunities. However, the persistence of trade barriers and inequalities hinder the positive effects of trade in service on job market (OECD, 2025a). At the same time, World Economic Forum's experts investigated the current world trends in jobs and skills amid increasing geoeconomic fragmentation landscape and the widespread of smart technologies, where service industries are affected especially by artificial intelligence tools (WEF, 2025).

All the international organizations' reports have gone together with the academic researches revealing particular evidences related to the impact of the increasing of services and trade in service on the labour market. In this context, Schwarzer (2015) made a comprehensive investigation related to the service sector as the largest employer worldwide, including the specific analyses related to the job quality and gender equality, the services trade having direct and indirect effects on employment. Baldwin & Forslid (2020) identified a major trend of developing countries in global service exports, given their comparative advantage of low-cost labour in services. Recently, as the use of artificial intelligence has intensified, the research on labour market in the service sector underlined the way this sector is facing new challenges (Georgieva, 2024), with smart technologies having a great potential to substitute professionals in many service industries, from IT to legal or cultural services (Dell'Acqua et al., 2023; WTO, 2024b). Given the fastest growth in trade in services and particularly in digital services, experts underline that the good jobs in the future economy are going to be in highly specialised services, with the deepening wage gaps between different skilled service workers in different countries (Wolf, 2025).

A significant and positive impact of trade in services on employment across various economies, industries and social categories has been demonstrated in many previous researches. In this respect, Maliszewska & Winkler (2024) confirmed that international trade is associated with higher employment levels, increased labour earnings, higher labour productivity and better job quality, but with differences across countries depending on their level of development. Based on some empirical analyses, Lassmann (2020) concluded that foreign trade activities are positively associated with employment in advanced economies, but with differences in the emerging economies, in terms of job quality, wage levels, skills and gender. An Organization for Economic Cooperation and Development's study found that growth in service exports is linked with increased employment, particularly in business-to-business services sectors (OECD, 2025a). Summarising, these studies collectively have highlighted the beneficial role that trade in services plays in fostering employment growth, enhancing earnings, and improving job quality, emphasising also the differences between sectors, regions and countries.

3. Methodology of research

This study aims to explore the effects of trade in services expansion on employment, underlying also their recent opportunities and current challenges, depending on the service industries, modes of supply on international markets and technological influence. The starting point of this paper is the analysis of the specific developments in the service sector over the past few years. The research is conducted on three major directions, in this regard three hypotheses are formulated and tested assumptions, as follows: (i) trends in services developments emphasised by the contribution of services to GDP and employment, as well as the evolution of trade in services in order to demonstrate the hypothesis that trade in services have the potential to create economic benefits and jobs, in number, quality and inclusiveness (H1); (ii) the positive influence of trade in services on employment based on detailed analysis of the four modes of services supply, in order to demonstrate the hypothesis according to which service business openness favours job creation in service industries, especially those intensive in technology and knowledge with influence on economic development (H2); (iii) the potential of new technologies to create jobs in innovation-intensive services in order to demonstrate the hypothesis according to which employment in service businesses are not at risk considering the recent progress in implementation of artificial intelligence that facilitate trade in services (H3).

The research methodology is designed to evaluate the capacity of the service sector, and particularly of trade in services, to sustain the labour market, in the context of opportunities but also challenges related to market access and the implementation of digital technologies. In this regard, a mixed approach is envisaged that combines qualitative analysis of existing studies in the field of services, trade in services and employment, with quantitative analyses based on statistical data, covering the last three decades, published by international organizations, such as the World Bank, the World Trade Organization, Organization for Economic Cooperation and Development, as well as International Labour Organization.

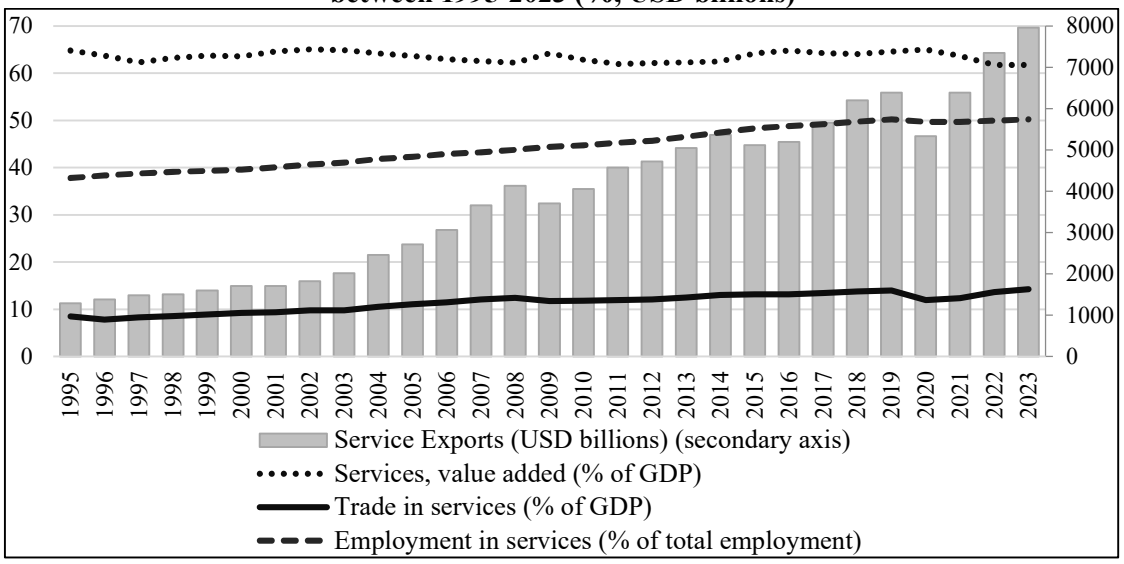
This allows us to make some relevant correlations between trade in services and employment, not only in numbers, but also by categories and quality of jobs, emphasising the differences by countries according to their level of development. The main limitation of this study is related to the lack of aggregate statistical data, so it fails to carry out a more detailed specific analysis to provide a global picture of how trade in services has supported employment, this being partially covered depending on the data available in certain fields and countries.

4. Research results

4.1. Trends in services developments: value added of GDP, trade and employment

In recent decades, the service sector has experienced notable developments, its expansion generating major economic and social benefits, in the overall context of the dynamic forces reshaping global economy (e.g. globalization, climate change, and digitalization). As revealed in Chart 1, the key trends in services are demonstrated by the evolution of the main indicators over the last three decades. Accordingly, services have contributed two-thirds of the value added of global GDP and have provided half of global employment, reflecting the dominance of the service sector over other economic sectors, and for some categories of services even their resilience in times of crisis (such as financial crisis in 2008 and pandemic crisis in 2020). Also, for three decades, service exports have continued to reach records year after year, culminating in 2024, at USD 8,687 billion, according to WTO (2025a), their overall growth rate managing not to be affected by unfavourable global economic conditions during the post-pandemic years. At the same time, all economies have confirmed a high level of openness to trade in services, emphasised by the share of services trade of GDP reaching 14.24% in 2023. The development of service sector has created new job opportunities, generating a positive trend of labour market, nowadays this sector providing more than 50% of total employment at the global level (WBG, 2025).

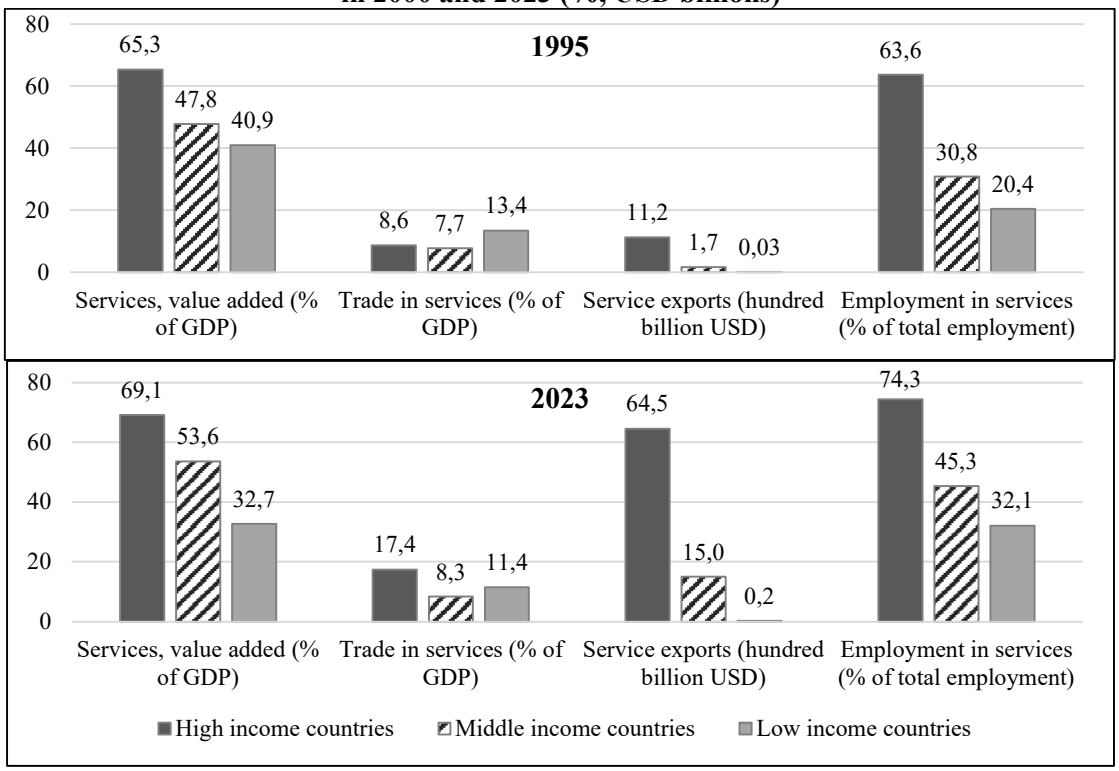
Chart 1: Global trends in services: value added of GDP, employment, and trade, between 1995-2023 (%, USD billions)



Source: Author's representation based on WBG (2025).

The contribution of different categories of countries to the global service positive trends is, however, uneven, the data in Chart 2 highlighting the differences between countries depending on their level of development, data comparing 2023 and 1995 reflecting the maintenance of the gap between countries. Therefore, the high-income countries perform best on all indicators of service developments, due to their specialization in high-performance international services, while low-income countries achieve modest results, according to their limited economic capacities, these latter countries being specialized in services such as tourism or transport that capitalize on their geographical advantages. The differences between countries are also justified by numerous factors, mainly those related to the different capacity of countries to ensure adequate infrastructure, skilled labour and human capital, appropriate regulations and institutions, access to financing and technology, and ensuring market and structural conditions (UNCTAD, 2020; WTO, 2017; WTO, 2019). Considering that high-performance services are associated with a high level of economic development, over 70% of multinational companies that provide international services are headquartered in developed countries, compared to 30% in developing ones, of which China takes 20% (UNCTAD, 2024b), this particular situation explaining also the differences in Chart 2.

Chart 2: Service developments indicators by categories of countries, in 2000 and 2023 (%, USD billions)



Note: The countries classification is based on WBG (2024).
Source: Author's representation based on WBG (2025).

The recent performance of service sector is sustained by the high-performance service sectors, experiencing a rapid growth, strong productivity, high value-added output, and significant contributions to exports and employment. These sectors are often supported by technology, innovation, digital infrastructure and skilled labour, generating high value-added per employee, being intensive in innovation and knowledge and predominantly oriented to export. Consequently, the key service sectors that correspond to these characteristics are: information and communication technology (ICT) services, financial services, professional and business services, transport and logistics, health and education services, tourism as well as environmental services (WTO, 2025; UNCTAD, 2025b; UNCTAD, 2024a; OECD, 2025b; ITC, 2025).

ICT services are the leading high-performance segment, including software development, cloud services, data processing and telecommunications, their latest advances being driven by the digital transformation, cloud computing, remote work and lately artificial intelligence. The main performers in this field are Ireland (with 22.1% of global ICT service exports, in 2023), followed by India (15.58%) and the United States (6.35%) (ReportLinker, 2023).Financial services, with their large variety of domains covering banking, insurance, investment and fintech services, have been sustained by global capital flows supported by favourable regulations and the general international expansion of businesses for which financial services are indispensable, as well as the recent digital banking and blockchain. The top countries in this field are the United Kingdom (withUSD98.1 billion financial service exports, in 2023), followed by the United States (USD 73.1 billion), Singapore, Switzerland and Luxembourg (The Global City, 2024). Professional and business services, represented by legal, consulting, engineering, accounting and marketing services, have been facilitated by business globalization, outsourcing and the complexity of business environment (as in the case of legal services). The international market in these areas is dominated by the United States (with USD189 billion, professional service exports in 2019), the United Kingdom, Germany and Netherlands (ITA, 2025a). Transport and logistics, covering mainly freight, warehousing and supply chain management services, have been considerably sustained by global trade, investment in infrastructure and recently e-commerce, the major hubs being located in China, Singapore, the United Arab Emirates, and Netherlands. In 2023, the leading exporters of transportation services were Germany (with USD 334 billion), China (USD 219 billion) and the United States (USD 218 billion) (OEC, 2025). Another services segment is represented by health and life sciences services, with medical diagnostics, biotechnology and

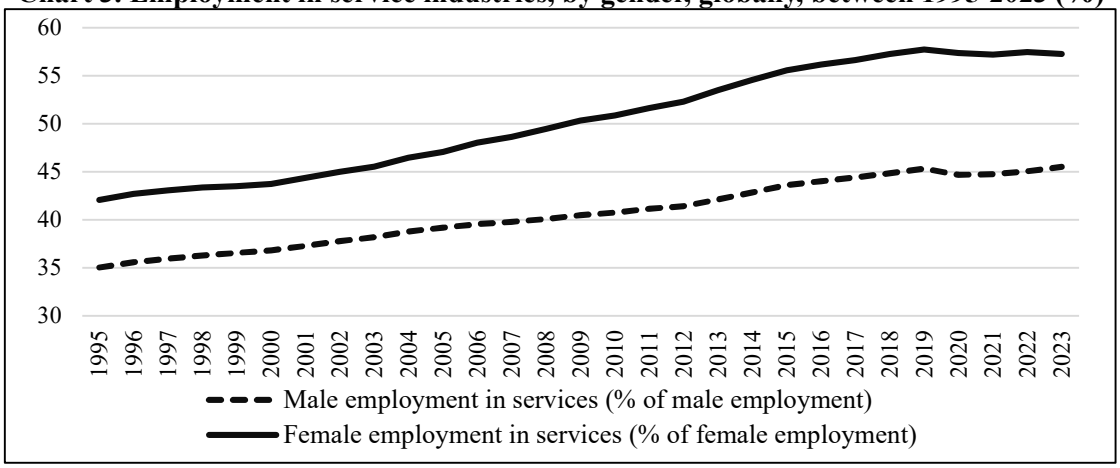
telemedicine services, driven by research and development as well as technological innovations, the top countries in this area being the United States, Germany, Japan and South Korea. The upskilling needs, global student mobility and lately e-learning are the major drivers of the latest developments in education services, with their main segments of online learning platforms and international education services. The main providers are the United States (with 33.7% of global exports of educational services), the United Kingdom (22.6%), Australia (16.9%) and Canada (12.3%) (ITC, 2025; SEPC, 2024). In recent years, the high-performance service sectors have been added with tourism and creative services, where cultural, digital content, gaming and design services stand out, driven by the global digital distribution, worldwide audiences and streaming platforms, the key players being South Korea, the United States, France and Japan. Environmental, social and governance regulations, climate transition and sustainability goals have generated a new category of services, namely environmental and green services, including renewable energy consulting, environmental impact analysis and waste management services. The main exporters of environmental technologies are Canada, Germany, France, the United Kingdom and Japan (ITA, 2025b).

The determinant factors influencing the latest developments of the best performing services, which as presented are mainly concentrated in high-income and emerging countries, provide arguments that support the data presented in Chart 2. In recent years, in addition to traditional service sectors, namely tourism and transport, many middle-and even low-income countries have increasingly capitalized on their comparative advantages to export high-performance services. This trend creates significant employment opportunities, generating higher-quality jobs in developing countries as well. A relevant example is India, which, in the last decade, due to its integration into global service value chains, IT service exports have contributed to economic growth and numerous and well-paid jobs (in 2024, India's technology sector contributed 7.3% to GDP, with 5.8 million jobs, and USD224.4 billion exports) (Times of India, 2025).Similarly, the IT and business process management sector is the largest employment source in the Philippines, the “Industry Roadmap 2028”projecting to reach 2.5 million employees and USD59 billion in annual revenues by 2028) (Business World, 2025).The development of the service industries in India and the Philippines in strongly related to their participation in the global services value chains, with the strategies of delocalization and outsourcing of business processes of many multinational companies, attracted by low costs, the availability of human capital and the attractive business environment for the service sector in these countries. The experience of these countries shows that participation in the global services value chains stimulates economic growth and generates a considerable number of well-paid jobs, data revealing that employment in the service sector has increased more than tenfold over the last 15 years, as well as significant increases in income, no other sector having the capacity to generate comparable results in recent years (Nano & Stolzenburg, 2022).

Although the growth of service exports presents vast opportunities for job creation and economic diversification in developing and emerging countries, challenges remain in ensuring equitable access to these jobs, continuously improving skills to maintain competitiveness in the global market, and managing the impact of automation and smart technologies (UNCTAD, 2024a).

The recent trends have also demonstrated that the service sector can have a contribution to solving gender inequalities, the large variety of activities of services and export openings providing significant employment opportunities for women. Consequently, the growth in services trade can contribute to enlarged female workforce participation (WB & WTO, 2020; Sauvé, 2024; APEC, 2023). Data in Chart 3 emphasises that the share of women employed in the services sector has increased since 1995, in 2023 services accounting for 57% of total female employment globally, with major differences between countries according to their level of development (82% for high-income countries, 51% for middle-income countries and 32% for low-income countries, in 2023 (WGB, 2025).

Chart 3. Employment in service industries, by gender, globally, between 1995-2023 (%)



Source: Author's representation based on WBG (2025).

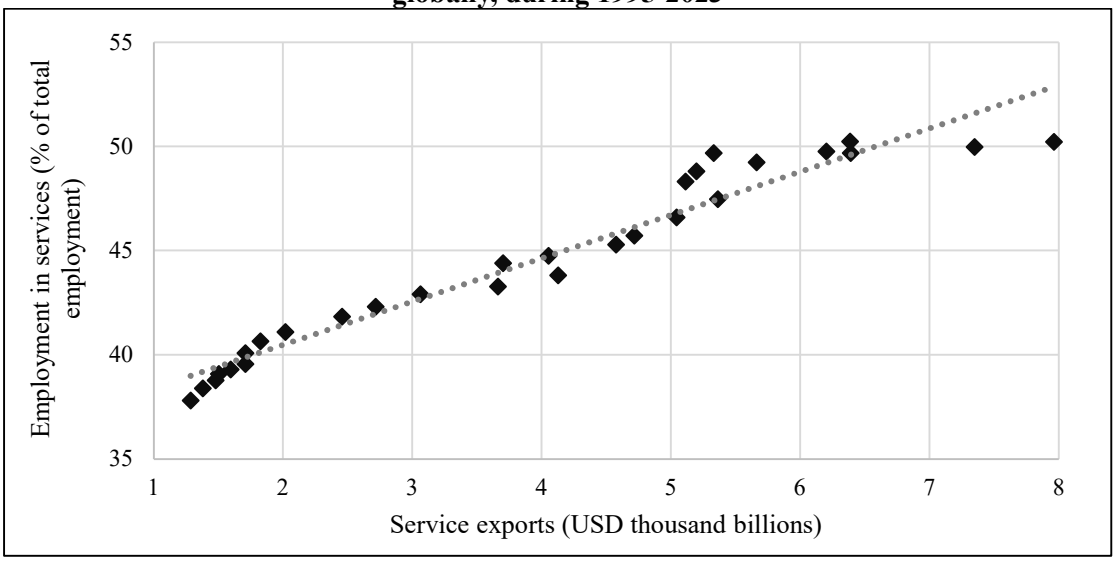
Considering the positive trends in services developments emphasised by the major contribution of services to GDP and employment, as well as the expansion of trade in services and its contribution to GDP, the detailed analysis of the job categories created by the best performing service industries, the first hypothesis (H1), according to which trade in services has the capacity to create numerous and good quality jobs and sustain inclusiveness all generating positive influence on economic development, is demonstrated.

4.2. Service exports and employment, supporting economic development

Among the positive effects of service sector and trade in services expansions, those on employment are considered the most significant, due to the capacity of service industries not only to create jobs and consequently improve living standards, but also to provide good quality jobs, generating a better quality of life. However, the relationship between trade in services and employment is complex and varies across industries and economies, depending especially on their level of development associated to the physical infrastructure, telecommunications and digital infrastructure, technological equipment, education, national regulations, financial resources and market conditions. Beside the favourable conditions of national economies sustaining the expansion of service exports, their contribution to increased employment depend on the international economic conditions, mainly at the level of partner countries.

The positive correlation between service exports and employment in the service sector is confirmed by data represented in Chart 4, where it can be observed that an increase in service exports often leads to job creation and enhanced economic activities. In this regard, three particular examples can be relevant: (i) The United Kingdom is highly specialised in professional business services, where consulting services account for a significant share of service exports. Between 2016 and 2024, the total service exports grew of 74%, with management consulting service exports increasing by 114%, this international success contributing to the expansion of the consulting sector, and supporting employment and UK's economic growth (Middlehurst, 2025). (ii) For many years, the services sector in Spain has recorded robust growth driven by growing external demand, mainly for tourism services, but also for other services with a positive impact on employment and the national economy. In 2024, the Spanish tourism sector generated the most dynamic job growth rate in the economy, with 3.6% (Álvarez Ondina, 2025), this sector continuing to be the major driving force behind Spain's economy, contributing significantly to GDP and regional development, fuelling small businesses, promoting cultural exchange and enhancing Spain's global reputation. The Spain's non-tourism service exports are primarily driven by business services (36%), transportation (24%), and telecommunications, IT, and information services (17%), the firms exporting non-travel services tending to be larger, invest more in research and development, have more qualified employees and be more productive in terms of workforce (Martín Machuca, C. & García Esteban, 2023). (iii)The services sector is a major source of jobs in Romania, with 54.9% of employees working in service industries in 2023 (NISR, 2024). The increase in external demand and exports of services have contributed to job creation, especially in IT (this sector is in the top employers at national level), finance and accounting, as well as business services, these demonstrating Romania's level of specialization in these fields in recent years and its role as an important destination for outsourcing services, mainly from Western Europe (RAIFT, 2023).

Chart 4: Correlation between service exports and employment in services, globally, during 1995-2023



Source: Author's representation based on WBG (2025).

The relationship between trade in services and employment is better highlighted from the perspective of the four modes of service supply, as defined by the General Agreement on Trade in Services (GATS) (WTO, 1995). Each mode of supply creates specific jobs, with different opportunities and challenges, in the broader context of globalization, in which trade in services has evolved over the recent years (Mann, 2019). Therefore, the analysis of the four modes of supply of services reveals the following particular developments of trade in services and employment.

(i) The cross-border supply of services (mode 1 of GATS) has been supported by technological advancements, nowadays being intensively used in the context of the digital services and artificial intelligence expansion. The recent growth of mode 1 services (Chart 4) has stimulated the direct job creation in sectors such as telecommunications and IT infrastructure, the increased cross-border data flows sustaining new jobs in building and maintenance of internet infrastructure, data centres and telecommunications networks. As well as, the demand for efficient and secure digital platforms for service delivery drives innovation and job creation in software development and cybersecurity. As industries expand and new technologies emerge, more specialized training programs and educational institutions are needed to equip the workforce with the necessary skills for cross-border delivery of services. At the same time, mode 1 has an important impact on smaller businesses, the digital tools allowing them to reach international clients without a physical presence abroad (implying high investments and complex management capacities), the lower barriers to entry foreign markets and sustain trade in services, enabling more businesses to grow and eventually create jobs. Nowadays, there are well-known examples of countries and companies where mode 1 has created numerous jobs such as call centre operations, back-office functions and a large variety of IT services within the business process operations sector offering services to worldwide clients, individuals or companies (Rippling, 2023).The online platforms connecting freelancers (such as programmers, graphic designers or content creators) from different countries with global clients demonstrate that the mode 1 has an important potential for creating jobs for individuals. Companies providing cloud infrastructure and software services to businesses globally, enabling client companies to operate more efficiently, are able to create more jobs. In essence, by removing geographical barriers and leveraging technology, mode 1 facilitates a significant expansion of service markets, which in turn leads to increased investment and innovation, creating jobs in export and import economies.

(ii) The movement of people as services consumer (mode 2 of GATS, known as consumption abroad) is predominantly related to the exports of services such as tourism and hospitality, education, health and maintenance services, generating jobs in the countries where the services are consumed. Tourism and hospitality stand out as the most significant sector, sustaining employment in accommodation, food and beverage, transportation, recreation, entertainment and retail. This is mainly the case for low-income countries that have natural and geographical advantages, where tourism services play an important role in their economies and support jobs. It is well recognized that the tourism sector is a major job generator globally, supporting

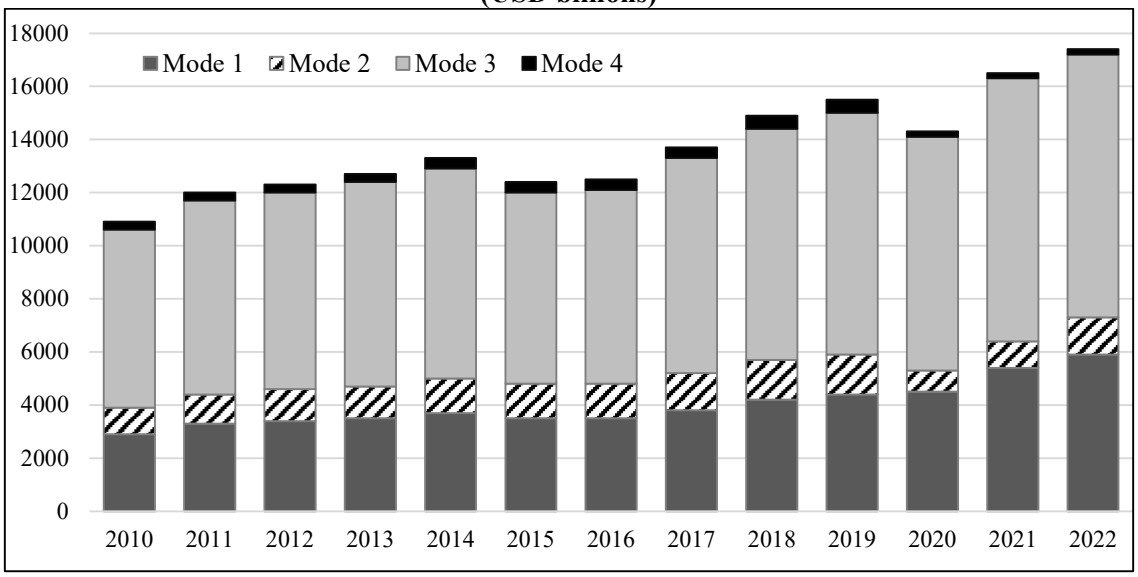
approximately 1 in 10 jobs worldwide, not only within the sector itself but also in related industries (WTTC, 2024). Travel abroad for educational, healthcare or professional purposes offers the possibility of creating a considerable number of highly skilled jobs, such as teachers, doctors or engineers, as well as supporting staff. However, job creation in services provided through mode 2 faces challenges related to employment instability caused by seasonal services (the case of tourism) and missing employment opportunities caused by regulatory barriers (such as visa restrictions limiting the access of foreign consumers) or economic vulnerabilities (such as the sensitivity to global economic instabilities).

(iii) The commercial presence (mode 3 of GATS, known as foreign direct investment/ FDI), where a service provider establishes a business in another country to offer services, significantly contributes to job creation, as foreign companies set up offices, factories, or subsidiaries, leading to employment opportunities in the host countries. Developing countries often benefit from FDI, which brings in capital, technology and expertise, fostering economic growth and job creation especially in services industries due to the fact that investment into services accounts for 72% of the total FDI stock in the world (Zhan, 2024). In developed countries, mode 3 enhances competition and innovation, leading to more specialized job opportunities, their activities creating a need for local expertise and people who can work in multinational environments. The challenges associated with mode 3 of GATS, such as regulatory barriers, high entry costs, and market competition, gave significant effects on global job markets: related to uneven job distribution, skill gaps, market disruptions and economic dependence on foreign companies.

(iv) The movement of natural persons as services providers (mode 4 of GATS) is associated mainly to the very specific skill sets and high level of expertise. This mode supports in job creation, particularly in sectors such as IT, consulting, healthcare and construction. As revealed in Chart 4, in recent years, trade in services by mode 4 has been shrinking, partly due to the expansion of digital methods of delivering services abroad. However, mode 4 employment opportunities are associated to access to global talent (by hiring skilled professionals from other countries and filling gaps in specialized industries), knowledge transfer (foreign professionals bring expertise that can enhance local workforce skills), boost to service sectors (industries such as finance, engineering and education benefiting from temporary foreign workers) and increased economic activity (temporary workers contributing to local economies through accommodation, transport and other services expenses). The challenges in job creation by mode 4 are related to strict regulations on temporary workers, limiting job opportunities (in the case of visa, strict rules on work permits and immigration restrictions), employment instability (mode 4 jobs are often short-term), local workforce competition (foreign professionals may compete with domestic workers, sometimes causing tensions) (OECD, 2025c).

Summarising, the recent positive developments of trade in services are able to generate a large variety of jobs as identified within the analysis on modes of supply, sustained by the favourable regulations and trade policies as well as the capacity of services to use new technologies in trading them on foreign markets (OECD, 2022).The diversity of service fields and types of providers, from individual professionals or online providers to companies, their complexity and the interrelationship of service areas, rise some statistical challenges in collecting data on jobs created by each mode of service provision in foreign markets. However, the commercial presence (mode 3) could be considered the most rigorously monitored segment from the perspective of jobs created in the service sector through foreign direct investment (FDI) and associated with trade in services. For example, in 2022, at the global level, FDI in software and IT services created 556,183 jobs (the highest of any industry and 5.7 times more than in 2010), in business services 243,647, in transportation and warehousing 119,503, in financial services 57,243, and in hotels and tourism 25,077 (Irwin-Hunt, 2023). The data presented in Chart 5 highlights that mode 3 has continued to hold the largest share among the modes of supply of services for many years, while mode 1 has grown in recent years due to the increase of trade in digitally delivered services. This representation can provide an insight into the jobs created by each mode of supply, considering that a higher volume of trade in services is associated with a greater number of jobs created.

Chart 5: The evolution of trade in services by modes of supply, worldwide, between 2013-2022 (USD billions)



Source: Author's representation based on WTO (2025a).

The positive developments of trade in services have been sustained by the favourable regulations and trade policies under the trade agreements. Trade in services regulations play a crucial role in shaping employment opportunities across different sectors. Although these regulations are often governed by international agreements (as GATS), the recent regional partnerships such as Regional Comprehensive Economic Partnership (RCEP) (Crivelli et al., 2022) or the European Union and United Kingdom trade and cooperation agreement (EC, 2021) have proved a greater influence on the businesses operating on international markets and consequently on employment. At the beginning of 2025, WTO's members with different levels of development from all regions were signatories to 201 regional trade agreements with preferential status that jointly regulate trade in goods and services and 3 exclusively for trade in services, all being engaged in processes of opening up their national regulatory framework for trade in services (WTO, 2024b). The main aspects of trade in services regulations with impact on employment in services are related to market access rules, national conditions related to the establishment of foreign service providers, all impacting job availability for local and international workers. In terms of trade in services regulatory framework, the most relevant aspects are related to services domestic regulations (WTO, 2024c), affecting job accessibility and employment opportunities for foreign workers by licensing, certification and professional standards (especially in sectors like healthcare, finance and education), as well as labour mobility policies with regulations on the movement of professionals (in the case of mode 4 of GATS). FDI policies affect job creation and the provision of fair employment opportunities through a wide variety of regulations such as those regarding the establishment and operation of foreign companies, as well as competition in domestic markets.

Despite the positive developments, trade in services has encountered a number of obstacles, the global barriers to services trade remaining high in 2024, generating significant fragmentation across countries and sectors, leading to an uneven playing field (OECD, 2025c). Even the recent developments of services have been sustained by the rise of digital technologies, mainly in information and communication technology (ICT), financial and professional services, contributing significantly to the growth in service exports (WTO, 2025; García Guzmán et al., 2024), trade in services faces specific barriers, mainly related to cross-border data transfers. The persistence of specific obstacles, mainly derived from national regulations, can also hinder opportunities in service labour markets.

The importance of external economic policies in creating employment related to service exports can be exemplified by the recent tariff measures adopted by the United States (US) administration affecting trade in goods. These measures could affect trade in services (Ossa, 2025), given that many service segments are dependent on trade in goods, or if the trade in services is used as part of retaliatory measures against the US, both situations affecting economic growth and employment. In this case, a relevant example is Ireland, an economy heavily relied on US multinational companies in the technology sectors, facing some vulnerabilities due to

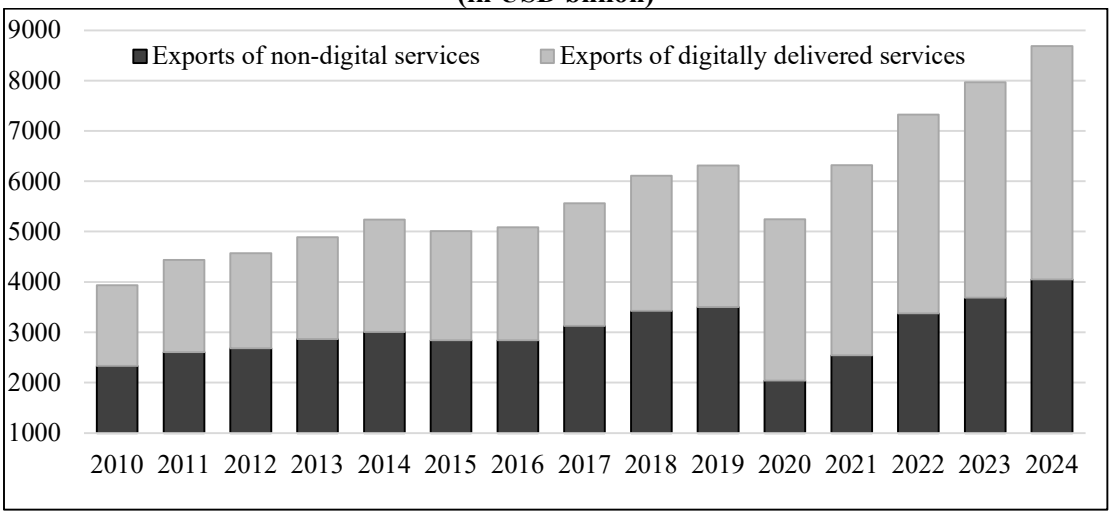
potential changes in US economic policies, with the potential to influence both service exports and employment in this country (Reuters, 2025).

Summarising, the impact of service exports on employment is influenced by international demand and the specific services characteristics of economies, as well as the external economic environment. Considering the direct correlation between service exports and employment, given the specificity of the four modes of service supply, where the role of trade in services favourable regulations on employment is critical, the second hypothesis (H2), according to which services businesses openness favours job creation, is demonstrated.

4.3. The effects of new technologies on employment related to trade in services

During the recent years, trade in services has been favoured by the implementation of technologies, generating a large variety of services, and an easiness in their international tradability and creating new categories of jobs, but also replacing others, especially considering the latest developments in smart technologies. Data represented in Chart 6demonstrates the new development of trade in digitally delivered services, where the latest statistics are sustained by the intensification of services based on digital and smart technologies. At the same time, the data reveals that this category of services proved resilience against global shocks, as pandemic crisis, especially due to sectors such as software, consulting and online education.

Chart 6. The exports of digitally and non-digitally services, globally, during 2010-2024 (in USD billion)



Source: Author's representation based on WTO (2025)

The digital services are associated to increased productivity, trade in services driving efficiency growth by fostering competition and innovation, facilitating the access to services as intermediate inputs enhancing the efficiency in other sectors and leading to job creation. At the same time, the increased trade in services can lead to a shift towards higher value-added activities and better-paid jobs, especially in emerging and developing economies, their participation in global value chains contributing also to their employment and in this way supporting economic and social national policies. Despite these, the growth in trade in digitally delivered services is accompanied by some challenges, mainly related to job displacement, caused by the competition from foreign service providers, as well as the automation and technological advancements facilitated by international trade, contributing to job losses and exacerbating wage inequality, with differences across skill levels and services sectors (OECD, 2024).Researchers underline the disruptive potential and also the need for adaption of industries and jobs according to the expanding use of artificial intelligence (Klein & Gattegno, 2025). As artificial intelligence is expected to affect nearly 40% of jobs around the world, some of them being replaced and others requiring skills improvement, a careful balance of policies is needed (Georgieva, 2024).

To the point, the rise of digital trade is transforming the services sector, creating new job opportunities while also posing challenges related to automation and skill requirements. Therefore, national authorities play a crucial role in mitigating the negative impacts of services trade and maximizing its benefits, an important role here being attributed to promoting education, training, and labour market flexibility.

Considering that the developments in trade in digital services have the potential to create significant employment opportunities and enhance job quality, but also posing challenges that require careful policy

attention, the third hypothesis (H3) is demonstrated according to which technological innovations in services businesses favour the creation of new categories of jobs and enhance the efficiency in all economic sectors, given their intensive use in all industries. At the same time, fears regarding the loss of traditional jobs in some service industries due to the rapid pace of evolution and their replacement by technologies (with artificial intelligence being considered the main disruptive factor for the labour market) can be balanced by new, higher quality and better paid jobs, this type of effect being specific to all previous technological revolutions.

5. Concluding remarks

The analysis of the relationship between trade in services and employment emphasises the direct correlation between them, the globalization of service industries generating significant opportunities in creating jobs, improving the quality of life and sustaining economic development. The investigation of any type of trade in services effect imposes taking into account the specific characteristics of each service industry strongly related to the four modes of service supply, in the particular case of employment, each mode fuelling specific categories of jobs with specific abilities and skills. Nowadays, the employment associated to trade in services is increasingly related to the international demand for services, the more or less favourable service policies of some countries and the increasing implementation of digital technologies in service industries, all of them generating new opportunities and facing various challenges for job markets. The impact of trade in services on employment is influenced by a variety of determinant factors, creating also many vulnerabilities, as demonstrated during the pandemic crisis (for services involving personal contact, such as tourism) or geopolitical tensions (as the maritime transport services disruptions caused by the Russian - Ukrainian conflict, since 2022, or Red Sea instability, since 2023). The recent developments in smart technologies are going to reconsider the job market perspective in many service businesses, with creating new types of jobs, but replacing other, in order to sustain their economic efficiency, as it has happened in all previous technological revolutions. In view of all the analyses carried out in this paper, the three main hypotheses were demonstrated through statistical evidence, detailed descriptions and examples of service industries and countries involved in the service export, to highlight the relationship between trade in services and employment.

Summarising, the impact of trade in services on employment is a multifaceted issue with significant implications for economies worldwide. The positive impact of trade in services on employment is mainly supported by its capacity to create jobs, with exports of services growth leading to increased employment, particularly in sectors such as information technology, finance and professional services, but also tourism and transport. At the same time, the expansion of global value chains in services is creating new employment opportunities for various skill levels in many emerging economies. However, the trade in services does not automatically create jobs, a series of challenges being generated by the particularities of service industries (such as shortages in qualified labour, due the rapidly evolving service sectors, or displacement of lower-skilled workers, caused by automation or outsourcing), and the differences between countries (with the dominance of high-income countries in exports of high value-added services, while developing economies may struggle to compete on traditional services, such as tourism and transport). Despite all the current challenges, the diversity of services, the dependence of all economic and social activities on services, as well as the resilience due to the innovative capacity of some service industries in recent years, will support the further growth of trade in services and, implicitly, employment, in number and quality, capable of sustaining the well-being and economic development.

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THE ECONOMIC IMPACT OF EDUCATION AND VOCATIONAL TRAINING IN THE CURRENT GLOBAL CONTEXT: A COMPARATIVE ANALYSIS – EUROPE VS. USA

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Abstract: In the current global context, marked by accelerated digitalization, ecological transition, and structural labor market shifts, vocational education and training (VET) systems have become strategic levers for increasing economic competitiveness and workforce adaptability. This article provides a comparative analysis of the economic impact of VET systems in the European Union (EU) and the United States of America (USA), focusing on institutional frameworks, funding structures, labor market integration, and responses to recent crises such as the COVID-19 pandemic and the war in Ukraine. Using operational and financial indicators—such as participation rates across age groups, employment outcomes, investment volumes, and employer engagement—the study identifies significant differences: the EU emphasizes structural coherence, dual training systems, and public financing, while the USA model favors decentralization, flexibility, and strong private-sector involvement. The analysis reveals that VET contributes to increased productivity, higher employment rates, and reduced social inequalities, especially when aligned with digital and green skills development. Furthermore, the article highlights the need for adaptive policies that combine the EU's focus on equity and institutional integration with the USA's agility and innovation capacity. The conclusions suggest that transatlantic convergence could foster a resilient and inclusive global VET ecosystem, capable of responding to rapid economic and technological changes. Strategic investments, coordinated public–private partnerships, and digital infrastructure development emerge as key pillars for future-proof VET systems.

Keywords: vocational education and training, economic impact, European Union, United States, productivity, labor market, digital skills, comparative policy;

JEL Classification - A20

1. Introduction

In the current global context, shaped by the acceleration of digital transformation, the emergence of smart technologies, and ongoing demographic and climate challenges, vocational education and training (VET) have gained unprecedented economic and social importance. The capacity of countries to respond to labor market shifts, foster innovation, and reduce inequalities is largely dependent on the effectiveness of VET systems and the quality of human capital developed through them (Hanushek & Woessmann, 2015; Becker, 1993).

Vocational training is no longer perceived merely as an alternative to academic education, but rather as a strategic lever for economic development, contributing to increased productivity, reduced unemployment, and smoother transitions to green and digital economies (CEDEFOP, 2023; OECD, 2023). It also supports social inclusion and upskilling, offering adult learners pathways to professional reintegration and lifelong learning (Illeris, 2011; Gudănescu, 2008).

Both the European Union and the United States of America have recognized the strategic value of VET, yet their institutional models differ substantially. The EU promotes a dual system model, combining theoretical learning and in-company practice—especially effective in countries like Germany and Austria—while also emphasizing transnational cooperation via programs like Erasmus+ and the Pact for Skills (European Commission, 2021; CEDEFOP, 2022). In contrast, the U.S. approach is decentralized and market-driven, relying on regional community colleges, private certification providers, and corporate training initiatives (Symonds et al., 2011; LinkedIn Learning, 2023).

This paper aims to conduct a comparative analysis of the economic impact of VET systems in Europe and the USA, identifying their strengths and limitations, and evaluating how recent crises—such as the COVID-

19 pandemic and the war in Ukraine—have affected public investments, participation rates, and policy orientations. By correlating recent statistical indicators with key policy frameworks, the study seeks to identify best practices and formulate strategic recommendations that support a resilient and future-oriented VET ecosystem (World Economic Forum, 2023; Zamfir & Stoica, 2006).

2. Education and Vocational Training Europe vs SUA – comparative analysis

The initial education systems in Europe and the United States face a range of structural and functional challenges that impact the quality, equity, and relevance of education. In Europe, the main identified issues include inequalities in access to education, especially between urban and rural areas or among different social groups; a high early school dropout rate in certain member states; a weak correlation between the skills acquired in school and the demands of the labor market; chronic underfunding of the education system especially in emerging countries and difficulties related to digitalization, particularly in training teachers and equipping schools with adequate technology. In the United States, the education system is affected by significant disparities in funding and quality between school districts; the persistence of de facto educational segregation along racial and economic lines; an excessive focus on standardized testing, which limits the development of critical and creative skills; the high cost of higher education, which negatively impacts student motivation in earlier stages of education; and serious issues related to school safety. These common and specific challenges underline the need for deep and coherent reforms to ensure an inclusive, equitable, and future-oriented education system.

Vocational education and training (VET) stand at the core of economic and social adaptation strategies in response to structural transformations driven by digitalization, globalization, and ecological transition. However, the formulation of an effective VET policy requires a deep understanding of how this system influences human capital and the real economy. The differences between the European Union and the United States in terms of VET system architecture are relevant for comparative policy analysis, as they affect employment rates, productivity, and workforce adaptability.

In the European Union, in 2022, approximately 48.7% of upper secondary students were enrolled in vocational education programs (VET), according to CEDEFOP. However, this rate varies significantly across countries: Germany, Austria, the Czech Republic, and Finland exceed 65%, while other member states such as Spain and Ireland report participation below 30%. In parallel, in the United States, Career and Technical Education (CTE) programs serve around 12 million students annually, across high schools and community colleges, though participation is more fragmented and dependent on local initiatives and public–private partnerships.

In terms of adult education and continuous training, only 10.8% of European adults participated in such programs in 2022 (Eurostat), with significant disparities: over 20% in Nordic countries (Denmark, Sweden), compared to under 3% in Eastern Europe (Romania, Bulgaria). In the U.S., approximately 22% of adults are enrolled in non-university postsecondary education, yet the lack of a unified structure for providers and certifications reduces the long-term impact. The budgets allocated to VET differ considerably between the two regions.

In the EU, public spending on vocational education ranges between 0.4% and 0.8% of GDP, depending on the country (CEDEFOP, 2023). In the U.S., federal funding for CTE was only $1.4 billion in 2022 (under the Perkins Act), supplemented by state and local funds—still modest relative to the size of the system. Regarding private sector involvement, European companies contribute significantly to VET through dual systems. For example, in Germany, companies invest over €9 billion annually in apprenticeship training. In the U.S., large corporations often offer in-house training programs; according to a 2023 LinkedIn Learning report, 77% of American companies increased their training budgets, and Fortune 500 companies spend on average $1,300 per employee per year on training and development.

The essential research question formulated in this study is: To what extent do different levels of public funding and private engagement in VET generate comparable economic outcomes in terms of employability, productivity, and adaptability to technological change? This question is addressed through a multi-dimensional analysis:

- Operational dimension: number of participants and the characteristics of VET delivery systems.
- Economic dimension: government expenditures and private investments, impact on GDP and employment.
- Structural dimension: governance, institutional partnerships, and integration with labor markets.

Formulating the problem in this way allows not only for an evaluation of impact but also for an understanding of the underlying logic behind each system's efficiency. This approach serves as a foundation for identifying good practices and potential convergence areas between European and American VET models.

2.1. Operational and Financial Indicators of education and training systems in the EU and the USA

In the context of global economic transformations, vocational education and training (VET) play a crucial role in adapting the workforce to labor market demands. Discrepancies between VET systems in the European Union (EU) and the United States of America (USA) generate significant differences in terms of participation, funding, and private sector involvement. This section analyzes these aspects using recent statistical data about various aspects related to education and training systems. The rate of participation in educational system for Europe and USA are presented in the Table 1, below.

Participation Rates in VET – EU vs USA

Table 1: Participation in education – Age group 6–24 years (2022/2023)

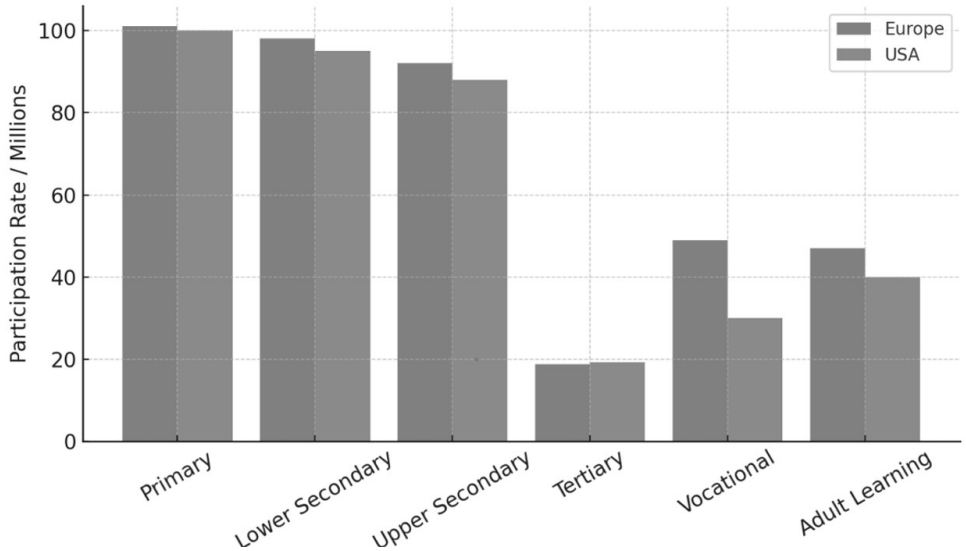
Indicator	Europe (EU-27)	USA
Primary education participation (ages 6–11)	98.5%	99.0%
Secondary education participation (ages 12–17)	95.2%	93.8%
Post-secondary/tertiary/postgraduate (ages 18–24)	34–38%	52–56%

***Source**: EUROSTAT, OECD, and U.S. NCES (National Center for Education Statistics), 2022, 2023*

The data in the table reflect an almost universal participation rate for children aged 6 to 17 in primary and secondary education in both the European Union (EU-27) and the United States of America (USA), indicating effective coverage of compulsory education. Relevant differences appear in the 18–24 age group, where participation in post-secondary education is significantly higher in the USA (52–56%) compared to the EU (34–38%).

This discrepancy can be explained by the extended accessibility of community colleges in the USA, the diversity of post-secondary training options, and the prevailing educational culture that encourages continued studies. In contrast, in Europe, early transition to the labor market and the indirect costs of tertiary education reduce participation in this age group, especially among youth from disadvantaged backgrounds. The gap points to a reform opportunity for European states to enhance flexibility and diversification in post-secondary educational pathways. As we can observe in the Figure 1, in both areas the first three levels of education are followed by the great majority of children, but the tertiary level is followed only by 20-30 percents of young people, increasing the percent of participants later during the career.

Figure 1: Comparative participation in different education levels (Europe vs USA 2020-2023)



Source: Eurostat, OECD, EducationData.org

Adult Participation and Institutional Structure in VET Systems – EU vs USA

Adult participation in CVET reveals a structural difference: while in Europe, participation is modest and directly correlated with education level, in the USA, even individuals with low levels of education take part in training programs in significant proportions, mainly training on the job. This reflects both the active training policies implemented by employers and the career culture oriented toward reskilling and adaptability. The data are presented in the Table 2.

Table 2. Adult Participation in Continuing Vocational Education and Training -2023

Indicator	Europe (EU-27)	USA
General participation (ages 25–64)	11%	28%
Participation of low-educated adults	4%	17%
Participation of highly educated adults	18%	38%

Source: Eurostat, OECD, and U.S. NCES (National Center for Education Statistics), 2023

The institutional structure shows (Table 3) that Europe prioritizes coherence between formal education and vocational training, through certificate recognition and integration into the ECTS credit system. In the USA, the focus is on quick outcomes, accessible formats, and diverse providers—without systemic integration, but with high adaptability.

Table 3. Institutional Structure and Types of Education Providers

Indicator	Europe (EU)	USA
Main providers	CVET centers, universities, NGOs	Community colleges, universities, companies
Link to higher education	Strong	Limited
Preferred formats	Face-to-face & blended	Online & community-based

Source: Eurostat, OECD, and U.S. NCES (National Center for Education Statistics), 2023

VET Financing and Economic Impact – EU vs USA

Public funding for VET varies significantly between the two regions. In the EU, public expenditure on education accounted for 4.7% of GDP in 2023. In the USA, public spending on education reached 5.44% of GDP in 2023. By category public or private expenditures, the share is presented in the Table 4., and the taxes for participation are

Table 4. Public and Private Funding for CVET

Indicator	Europe (EU)	USA
Public funding share	60–70%	30%
Private funding share	30–40%	70%
CVET tax credit	Present in some countries	Extensive (federal and state level)

Source: European Commission, Trading Economics, 2023

Funding systems reflect a different philosophy: in Europe, continuing training is seen as a public responsibility, supported by national and European funds. In contrast, the USA emphasizes individual responsibility and private sector involvement. This approach enhances efficiency, but may lead to exclusion for disadvantaged groups.

European Union and other countries: In 2023, public spending on education in the EU represented 4.7% of GDP. The pandemic and the military crisis caused a temporary reallocation of funds toward healthcare and economic support, impacting education investments. However, through the Next Generation EU program, the EU allocated over €800 billion for recovery, including for the modernization of education and training systems.

United States of America: In 2023, public education spending reached 5.44% of GDP. The federal government allocated additional resources to support schools in adapting to online learning and to mitigate learning loss due to the pandemic.

The Table 5 presents the level of employability in both studied areas, as opportunities after participation in VET.

Table 5. Impact of VET on Public and Private Economic Activity – Employability

Indicator	Europe (EU)	USA
Increase in employment opportunities after CVET participation	+9%	+15–20%
Internal career mobility	Medium	High

Source: Eurostat, OECD, and U.S. NCES (National Center for Education Statistics), 2023

The impact on employability is evident in both regions, but the USA offers greater career mobility, due to the rapid recognition of acquired competencies and opportunities for professional reskilling. Europe ensures stability, but sometimes struggles with flexibility and responsiveness to economic changes.

The Table 6 presents the level of implementation of digitalization and circular economy/green skills and so called green jobs on the labor market in both studied ares.

Table 6. Focus on Digital and Green Skills

Indicator	Europe (EU)	USA
Programs for digital skills	65%	75%
Green skills initiatives	Recently growing	Emerging

Source: Eurostat, OECD, and U.S. NCES (National Center for Education Statistics), 2023

Both regions prioritize digital skills, though the USA leads in program digitalization and implementation speed. Meanwhile, Europe is making significant progress in integrating green objectives into CVET, aligning with climate strategies, the circular economy, and the European Green Deal.

Table 7. Below, reveals a higher level of employer commitment in the United States toward professional training and employee skill development, both through CVET and direct on-the-job training. Europe faces challenges in standardizing these practices across member states, which affects the competitiveness and adaptability of the European labor market compared to the American one.

Table 7. Employers Involvement

Indicator	Europe (EU)	USA
Employers offering CVET	70%	94%
On-the-job training	45–55%	80%

Source: Eurostat, OECD, and U.S. NCES (National Center for Education Statistics), 2023

Employers' involvement is more extensive in the USA, where companies see continuing training as part of business and competitiveness strategies. In Europe, involvement is less uniform and often dependent on national policies and public funding support. This can affect the efficiency and adaptability of the labor force to market changes.

This analysis highlights the structural and financial differences between the EU and U.S. VET systems, emphasizing the need for tailored policies to maximize the efficiency and impact of these programs on the economy and society.

2.2. SWOT Analysis – VET in the European Union and the United States of America

Category	European Union (EU)	United States of America (USA)
Strengths	- Consolidated dual system with efficient school–company integration - High participation in some countries (>60%)	- Decentralized, flexible, and adaptable system - Strong private sector participation (77%) - High corporate training

	- Graduate employment rate: 76% - Support via EU funds (ESF+, Erasmus+) - CEDEFOP networks and the Pact for Skills	budgets: $1,300/year/employee - Industry-aligned vocational programs
Weaknesses	- Disparities among member states (<30% participation in some) - Underfunding in Eastern Europe (<0.4% of GDP) - Low public perception of academic education - Slow adaptation to digitalization	- Lack of a national certification framework - Low high school participation in CTE: 17% - Low federal funding ($1.4 billion) - Unequal access in rural areas
Opportunities	- Increased demand for digital/green skills - Expansion of partnerships with SMEs - Reforms via the EU Skills Agenda - Cross-border qualification recognition	- High demand for skilled workers - Expansion of re-skilling/up-skilling post-COVID - Regional public–private collaborations - Micro-certifications from Big Tech companies
Threats	- Ageing active population - Risk of institutional stagnation - Migration of skilled youth - Slow pace of digital adaptation	- Political gridlock on funding expansion - Lack of national certification recognition - High education costs - Global technological competition

Source: Author's own conception

3. Problem Solution

To address systemic differences and the impact of recent crises on vocational education and training (VET) in the European Union and the United States of America, an integrated approach is required—one that combines public policy interventions, institutional innovation, and strategic partnerships with the private sector. The proposed solutions must aim both at strengthening the components of initial education and expanding access to adult continuing training.

• Increasing public investment in VET

A first solution involves increasing national budgets dedicated to technical and vocational education. In the EU, countries with the best graduate employment outcomes (e.g., Germany, Austria) allocate over 0.7% of GDP exclusively to VET, while the EU average is 0.6% (CEDEFOP, 2023). In the USA, federal contribution remains modest ($1.4 billion in 2022), being unevenly complemented at the state level (BLS, 2023). There is a need to increase predictable funding for educational infrastructure and to support the digital and green transition in vocational curricula.

• Strengthening public–private partnerships

The second intervention line proposes expanding partnerships between training institutions and companies. In Germany, the dual system supports the training of over 1.3 million apprentices annually (CEDEFOP, 2022), 75% of which is funded by the private sector. In the USA, Fortune 500 companies invest on average $1,300 per employee per year in training (LinkedIn, 2023). These models should be replicated through tax incentives and clear regulations regarding apprenticeships and certifications.

• Digitalizing access to education and lifelong learning

The COVID-19 crisis accelerated the shift to digital education. Viable solutions include the development of integrated platforms for micro-certifications and modular learning. In the USA, Google and IBM already offer such programs free or at low cost. In the EU, the Digital Education Action Plan (2021–2027) aims to increase digital literacy across all forms of education (European Commission, 2021). This solution helps reduce geographical barriers and costs for participants.

• Aligning VET more closely with labor market demand

In both analyzed regions, there is a mismatch between the qualifications offered and the skills demanded by employers. CEDEFOP studies show that 45% of European employers have difficulty recruiting qualified workers (CEDEFOP, 2023). It is recommended to develop regional labor market observatories and to annually update VET programs based on predictive analysis of sectoral trends. The Table no.8 presents the financial solutions and resources for the funding of education and training systems in the studied global areas.

Table 8. Comparison of structural solutions applicable to VET in the EU and USA

Solution	European Union	United States of America
Public funding	0.6% of GDP on average; varies by country	$1.4 billion federal + state funds
Private sector involvement	Over €9 billion/year in Germany alone	$1,300/employee in large corporations
Digitalization	Digital Education Plan, Erasmus+, eTwinning	Online certifications by BigTech (Google, IBM)
Crisis response	Next Generation EU – €800 billion	Emergency Relief Funds (COVID)

Source: Data processed by the author

Recent crises—namely the COVID-19 pandemic and the war in Ukraine—have tested the resilience of both educational and vocational training systems. These events highlighted the urgent need for adaptability, digital transformation, and strategic investments in human capital development. In the European Union, programs such as *Next Generation EU* and the *Digital Education Action Plan* served as robust responses aimed at modernizing educational infrastructure and supporting continuous learning. In the United States, solutions emerged primarily from the private sector and regional initiatives, with an emphasis on micro-certifications and fast-track practical training.

The data presented in this research support the hypothesis that the success of a VET (Vocational Education and Training) system depends on four essential factors:

1. Predictable and sustainable public funding, aligned with the needs of the real economy.
2. Functional partnerships with the private sector, ensuring curriculum relevance and job market integration.
3. Accessible digital infrastructure, enabling flexible and lifelong learning.
4. Dynamic mechanisms for adapting to changing skill demands, including during times of crisis.

Therefore, a convergence of the two models, within a framework of transatlantic cooperation, could be envisaged—one that combines the rigor of European standards with American agility and pragmatism. Such an approach could foster the development of a global vocational training ecosystem, capable of coherently responding to the economic, technological, and social challenges of the 21st century.

In the medium and long term, investments in technical and vocational education should no longer be seen as costs, but rather as accelerators of sustainable economic growth, social inclusion, and strategic resilience. In this sense, the formulation and implementation of evidence-based educational policies, with the support of all relevant stakeholders, becomes a shared priority for both regions.

Conclusions

The present article, entitled *"The Economic Impact of Education and Vocational Training in the Current Global Context: A Comparative Analysis – Europe vs USA,"* demonstrates, through a well-documented and multidimensional approach, the strategic role of education and vocational training (VET) in enhancing economic competitiveness, promoting social inclusion, and facilitating the transition to a green and digital economy.

The comparison of institutional models, financing levels, and VET policy efficiency in the European Union and the United States has revealed both points of convergence and relevant contrasts:

- The European model is based on structural coherence, stable public–private partnerships, and integration within the formal education system, especially through dual systems. While it offers balanced outcomes in terms of equity and stability, it can be hindered by slow adaptability and inter-state disparities.

- The American model promotes flexibility, decentralization, and rapid innovation, often driven by private initiatives and a strong culture of lifelong learning. However, it suffers from a lack of unified frameworks and unequal access based on region and socioeconomic status.

As a synthesis, the United States shows significantly higher adult participation in continuing vocational education and training (CVET) than the European Union, with 28% vs. 11% overall participation, and a stronger inclusion of low-educated adults (17% vs. 4%). This reflects a more dynamic reskilling culture in the US, supported by employer-led initiatives and flexible learning formats.

Funding models differ fundamentally: the EU relies on public financing (60–70%), while the US is primarily privately funded (70%), with extensive tax incentives available.

In terms of institutional structure, the EU uses a more integrated approach (CVET centers, universities), while the US benefits from decentralized, flexible systems (community colleges, online platforms). Employers in the US are more engaged, with 94% offering CVET compared to ~70% in the EU, and on-the-job training is more prevalent.

While both regions prioritize digital skills, the US leads in implementation (75% vs. 65% of programs). The EU is advancing more rapidly in green skills integration, aligned with its climate strategies.

In conclusion, the EU emphasizes equity and systemic cohesion, while the US model is more market-driven and ROI-focused, offering faster adaptation to labor market changes.

Taking into consideration recent global crises—the COVID-19 pandemic and the conflict in Ukraine—both systems have come under pressure but responded in different ways. Europe mobilized massive public resources (*Next Generation EU*), whereas the USA saw a faster private-sector response, emphasizing digital learning and micro-certifications.

The analysis highlighted that the economic impact of VET manifests across three key dimensions:

- Increased productivity, by aligning workforce skills with the real needs of the economy.

- Reduced unemployment and higher employability, especially among youth and adults undergoing professional retraining.

- Lower social inequality, by facilitating access to lifelong learning and developing alternative qualification pathways.

Strengthening the role of VET as a driver of economic transformation requires an integrated vision and inter-institutional coordination. It is essential to develop a hybrid model that combines Europe's quality and equity standards with the pragmatism and dynamism of the United States.

In conclusion, education and vocational training are no longer just sectoral policies, but strategic investments in a nation's economic and social future. Both the EU and the USA must reinforce their commitment to VET through sustainable funding, strategic partnerships, and the integration of new technologies into education systems to build a resilient, competitive, and equitable workforce.

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IMPACT AND INVESTMENT PERFORMANCE AMONG ROMANIAN STARTUPS

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Abstract: Impact-driven startups blend profit and purpose, raising the question of whether their dual orientation influences funding success. This paper investigates 182 Romanian startups (with investment rounds raised between 2021 and 2023) to analyze whether impact startups, defined here as ventures in health, education, sustainability, wellbeing, or food sectors, exhibit different investment performance compared to traditional startups. We employ an econometric model with a binary impact field as the key independent variable, controlling for funding stage (pre-seed, seed, Series A) and year. Our dataset, drawn from the How to Web 2024 report, allows a national-level analysis of impact orientation in Romania's nascent startup ecosystem. The results indicate that factors beyond impact status and stage largely determine funding outcomes. We discuss potential reasons, including the underdevelopment of Romania's venture market and high variance in deal sizes, and draw implications for entrepreneurs and policymakers. The paper concludes with recommendations for the development of policy instruments (Environmental, Social and Governance incentives, co-investment schemes, targeted grants) to foster impact-driven entrepreneurship in Romania.

Keywords: impact startups; venture capital; emerging markets; Romania; social entrepreneurship; startup funding

JEL Classification: L26; G24; O52

1 Introduction

Impact startups, defined as innovative startups with an explicit social or environmental mission, have gained global prominence by tackling societal challenges through business solutions. These ventures operate in sectors such as healthtech, edtech, sustainable products, wellbeing services, and food/agritech, aiming for measurable positive impact alongside financial returns. Internationally, impact-oriented entrepreneurship has expanded as investors increasingly seek "profit with purpose" opportunities (Y-Labs B. , 2024). However, it remains unclear whether an orientation towards helps or hinders startups' ability to attract venture investment, especially in emerging markets. This paper focuses on Romania, an upper-middle-income EU economy with a developing startup ecosystem, to examine the relationship between impact orientation and investment performance. Romania's tech entrepreneurship landscape has historically lagged behind Western Europe. Entrepreneurial activity rates are below global averages, only about 10% of Romanian adults are early-stage entrepreneurs, one of the lowest rates in the region (Lehel-Zoltán, 2022). Venture funding in Romania has likewise been modest. In 2024, Romanian startups raised roughly €128-130M in venture capital, a record high yet a fraction of funding in neighbouring ecosystems (e.g., Poland, Turkey, Greece each drew over €500M) (Djurickovic, 2025). This underdevelopment is attributed to a historically small pool of local investors and limited exposure to global Venture Capital (VC) networks (Lehel-Zoltán, 2022). Nevertheless, recent years have seen

growing momentum. Romania has exceeded €100M in startup investments for four consecutive years (TUPIKOV, 2025), and boasts strengths like a large IT talent pool and support from European programs (Djurickovic, 2025). Within this evolving ecosystem, impact-oriented startups form a notable segment. According to How to Web Report from 2024, education (14.3%) and health (12.7%) are among the top three industries for Romanian early-stage startups. This suggests that a substantial share of new ventures align with impact domains, echoing global trends of rising sustainability and health innovation. In Romania's context, no prior research has quantitatively examined this issue. Given the country's nascent impact investing scene (the first local impact-dedicated funds in Central and Eastern Europe only appeared in recent years), understanding whether impact status of a startup affects funding is both novel and policy-relevant.

This paper aims to fill that gap by analysing a unique dataset of 182 Romanian startups from 2021-2023. Using an econometric approach, we test whether being an "impact startup" (in defined sectors) correlates with the investment amount raised, controlling for the startup's funding stage and year. We find that, within this national sample, impact orientation has no significant effect on funding amounts. The explanatory power of our model shows however that other factors predominantly drive investment size. We discuss possible interpretations, for example, that Romania's venture market does not markedly differentiate between impact vs. non-impact ventures in early-stage funding, perhaps because all startups face similar capital constraints. We also outlined policy recommendations to strengthen impact entrepreneurship in Romania, and suggested avenues for future research. By combining the growing discourse on impact investment with new evidence from Romania, this study provides a timely contribution on the intersection of impact and startup financing in an emerging European ecosystem.

2 Literature Review

The rise of impact-oriented entrepreneurship and investing has spurred a body of research on how social missions interact with financial performance. Impact investing, broadly defined as investing with the intention to generate social/environmental impact alongside financial return, has expanded rapidly, reaching an estimated $1.57 trillion globally in 2023 (GIIN, 2024). As the field grows, a central debate is whether pursuing impact entails a sacrifice in financial outcomes or whether impact ventures can perform on par with traditional ventures.

Several studies and market analyses suggest that impact-driven ventures need not underperform. Jeffers, Lyu & Posenau examined 94 impact investing funds (with active investment between the years 1999-2021) and find their returns comparable to non-impact funds after adjusting for risk (Jeffers, 2024) Similarly, a Morgan Stanley analysis of thousands of investment funds found no financial trade-off between sustainable (ESG-focused) funds and traditional funds, with sustainable funds even exhibiting lower volatility. These findings challenge the notion that pursuing social objectives inherently dampens financial success. They align with reports that private impact-focused VC funds can achieve competitive returns while advancing mission objectives.

On the other hand, scholars have noted structural hurdles for impact startups in raising capital. Traditional venture investors often exhibit a bias toward opportunities with perceived "unicorn" scale and quick exits, which can disadvantage startups prioritizing social impact or longer-term gains. In emerging markets especially, impact ventures historically relied on grants or philanthropy due to a scarcity of impact-focused investors. This bias may lead to a funding gap, where impactful startups struggle to attract the venture funding and guidance needed for scale. However, the same commentary points out this mindset is increasingly outdated given the empirical evidence that many impact businesses are profitable and investment-worthy (Y-Labs V. B., 2020). The context of Central and Eastern Europe (CEE) and other emerging markets adds further nuance. Impact investing in CEE is a relatively recent phenomenon, with pioneering funds only launched in the past few years (Ionita, 2022).

3. Data and Methodology

This study utilizes a dataset of 182 Romanian startups derived from the How to Web, Venture in Eastern Europe 2024 - a report published by the How to Web conference (and its underlying data for Romania's deals). How to Web is a leading Romanian startup conference and research initiative that annually documents venture investments in Eastern Europe. The 2024 report provides detailed information on venture deals in Romania for the years 2021, 2022, and 2023, which we extracted and compiled for analysis. Each observation in our dataset corresponds to a funding round raised by a Romanian startup during 2021-2023. By focusing exclusively on

Romanian startups, the dataset offers a targeted view of the national startup ecosystem. Table 1 presents the first lines and the header of the processed dataset.

Table 1 – The Dataset

Company	industry	round	round	Total round amount (€)	year	Impact
Rongo Design	Agriculture	Pre-seed	1	15,000	2023	1
Vatis Tech	AI	Pre-seed	1	200,000	2021	0
SmartHuts	AI	Pre-seed	1	190,500	2021	0
Meetgeek.ai	AI	Pre-seed	1	150,000	2021	0
Kubeark	Big Data	Pre-seed	1	2,800,000	2023	0
Data Against Data	Cybersecurity	pre-seed	1	75,000	2022	0
AMSIMCEL	DeepTech	pre-seed	1	500,000	2022	0
AiVA	Deeptech	Pre-seed	1	70,000	2023	0
Streams Live	E-commerce	pre-seed	1	70,000	2022	0

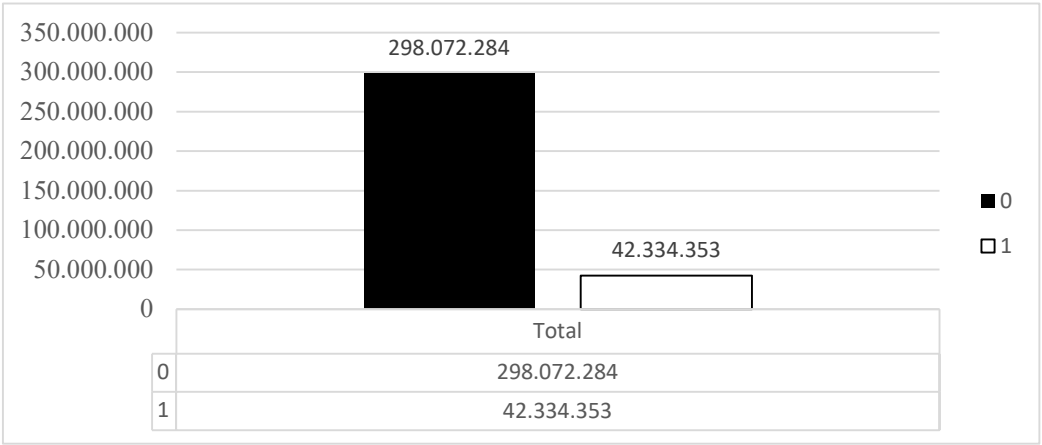
Source: Author-processed data, from the dataset.

For each startup funding round, we have the following key variables:

- **Investment Amount (EUR)**, the dependent variable, measured as the total amount of funding raised in the round. This includes equity investments and, where applicable, convertible notes if they were part of a bridge round.
- **Impact Startup** is the main independent variable of interest. We coded each startup as an impact startup (Impact = 1, 0 if not) if its business operates in any of the following domains: health, education, sustainability/environment, wellbeing (including fitness or mental health), or food/agriculture.
- **Funding Stage**, included as a control variable because the stage of a startup (and its round) is a well-known determinant of investment size. We use three broad stage categories: pre-seed (code 1), seed (code 2), and Series A (code 3).
- **Year**, included as a control for time effects (coded as 2021, 2022, 2023). The venture funding climate can vary year-to-year might affect investment amounts.

Figure 1 presents the total amount of invested capital in impact startups versus non-impact startups in the studied years. Data, from 2021 to 2023, in Euro, shows €298M total investments in non-impact startups, versus a small €42M for the impact ones (white, code 1, being the impact startups, while black, code 0, non-impact ones).

Figure 1. Amount invested in non-impact startups VS impact startups



Source: Author processed data, from the dataset.

4. Econometric Model

To assess the effect of impact orientation on investment performance, we estimate a multiple linear regression model of the form:

$$\textbf{InvestmentAmount} = \beta_0 + \beta_1 \cdot \textbf{ImpactDummy}_i + \beta_2 \cdot \textbf{Stage} + \beta_3 \cdot \textbf{Year2022} + \beta_4 \cdot \textbf{Year2023} + \varepsilon$$

Where:

- **InvestmentAmount** is the total amount raised in the investment round
- **ImpactDummy** is a binary variable equal to 1 if the startup operates in an impact sector and 0 otherwise.
- **Stage** is a numeric variable indicating the stage of the funding round (1 = pre-seed, 2 = seed, 3 = Series A or later).
- **Year2022** and **Year2023** are dummy variables indicating the year in which the funding round took place. The base year is 2021.
- **ε** is the error term, capturing unobserved influences on the investment amount.

In this model:

- β_1 is the coefficient of primary interest; it represents the average difference in investment amount between impact and non-impact startups, holding constant the stage and year of investment.
- β_2 captures the incremental change in funding associated with more advanced funding stages. Since later-stage rounds tend to be larger, we expect β_2 to be positive.
- β_3 and β_4 measure any average change in funding amounts in 2022 and 2023, respectively, compared to the reference year 2021.
- β_0 is the intercept term.

One consideration is multicollinearity between stage and year: later years might have more later-stage rounds. In our sample, 2021 had mostly early rounds whereas by 2023 there were a few more Series A; however, seed deals exist in all years, and correlation checks did not show severe collinearity.

5. Empirical Results

Table 2 presents the regression results for the investment amount model. The table reports OLS coefficients, robust standard errors, and significance levels for the impact dummy, round stage, and year dummies. We summarize the key findings here:

Table 2

Regression Statistics	
Multiple R	0.192305885
R Square	0.036981553
Adjusted R Square	0.020750905
Standard Error	0.442938648
Observations	182

Source: Author-processed data.

- **Impact Dummy** The coefficient on the Impact startup dummy is statistically insignificant and near zero in magnitude. This indicates that, after controlling for stage and year, being an impact-oriented startup had no significant effect (either positive or negative) on the amount of funding raised. In practical terms, an impact startup in Romania does not appear to raise significantly more or less money than a similar-stage non-impact startup in the same year

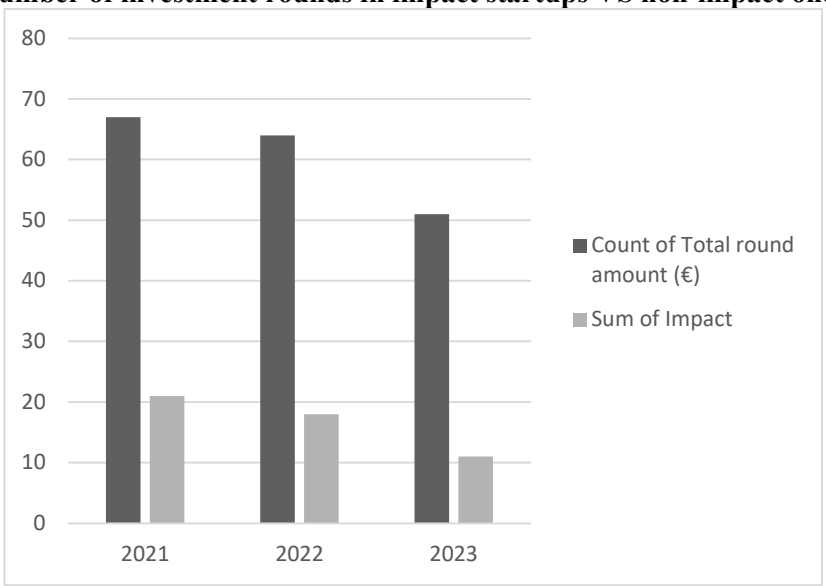
- **Round Stage**: The coefficient on Stage is positive and highly significant, as expected. Moving to a higher funding stage is associated with a large increase in investment amount. In the regression, each unit increase in stage code (e.g., from 1 to 2, or pre-seed to seed) is associated with an increase of several million euros in funding, holding other factors constant.
- **Year Dummies:** The year controls show that 2022 had a statistically higher average investment amount than 2021, while 2023's coefficient is positive but not significant. By 2023, average deal sizes slightly receded (the global venture slowdown likely affected Romania as well) hence 2023 is not significantly different from 2021 in the model.
- **Overall Fit**: The regression's overall explanatory power is extremely low. The R square of our model is only 0.036, meaning just about 3.6% of the variance in investment amounts is explained by the included variables. This is an unusually low R square for a model that includes an obvious factor like stage.

These results point to a key conclusion: Impact orientation had no notable predictive power for investment size in Romanian startups, whereas funding stage was the dominant factor, and year effects were modest. The insignificance of the impact dummy is central to our research question, it suggests that, in this context, investors did not systematically favour nor disfavour impact start-ups in terms of how much capital they provided, once stage is taken into account, so methods to incentivise investors into investing are needed.

It is also informative to compare descriptive statistics between impact vs. non-impact groups. In our sample, the mean investment amount for impact startups was approximately on par with (or slightly lower than) that of traditional startups, but differences were not statistically meaningful given the variance. Impact startups had some large rounds (the largest being a healthtech seed round of about €10-11M in 2022) as well as many small pre-seed rounds; non-impact startups included the absolute largest rounds (e.g., a fintech's €60M Series B in 2021) along with numerous modest seed raises. The median funding of impact startups was actually very similar to the median for non-impacts (both around mid-six figures, reflecting that most deals are early-stage across the board). These comparisons reinforce that there is no clear funding advantage for impact ventures, they populate both the lower and middle ranges of deal sizes much like other startups. What drives a given deal's size seems related to factors like the startup's growth metrics, team, or investor negotiations, rather than simply whether the startup is in, say, the health sector or the fintech sector.

Figure 2 illustrates the trend in count of impact startup deals by year, showing an 19 average in 2021-2022 but a dip in 2023. This reflects that impact-oriented ventures became more prominent in deal flow in the middle of the examined period, possibly due to heightened interest in health and education solutions during the pandemic's peak.

Figure 2. Number of investment rounds in impact startups VS non-impact ones (M Euro)



Source: Author processed data, from the dataset.

However, as Table 1's results demonstrate, even during that surge, the average funding per deal for impact ventures did not diverge notably from others. It is worth noting that impact startups in 2022 contributed strongly to the overall funding volume: for instance, the health and education sectors accounted for a combined ~27% of startups that year (How to Web, 2024), and one of the top rounds was in healthtech (Ionita, 2022). Yet, statistically, once stage is controlled, those contributions don't translate into a distinct "impact effect".

In summary, the regression analysis finds no evidence that impact orientation is associated with higher or lower investment amounts in this sample. The model's low fit underscores that investment size is influenced by many other factors beyond the scope of our three predictors.

Table 3. Anova table

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1.3410893	0.44702977	2.27850136	0.08115394
Residual	178	34.922647	0.19619465		
Total	181	36.2637363			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	98.85581333	83.1015005	1.18957916	0.23579617	-65.1351	262.846726	-65.1351	262.846726
round	-0.125485245	0.06809552	-1.84278	0.06702396	-0.2598636	0.00889314	-0.2598636	0.00889314
Total round amount	-3.01318E-09	6.3682E-09	-0.47316	0.63667741	-1.558E-08	9.5537E-09	-1.558E-08	9.5537E-09
year	-0.048642754	0.04109821	-1.18357	0.23816	-0.1297452	0.03245968	-0.1297452	0.032459

The ANOVA table shows that the overall regression model has weak statistical significance. The Significance F value is 0.081, which is just above the conventional threshold of 0.05. This means there's an 8% probability that the observed relationships happened by chance, so the model is only marginally significant and not very reliable.

Looking at the individual variables:

- "Round" (investment stage) comes close to being statistically significant (p = 0.067), suggesting there may be a relationship between funding stage and investment amount, but it's not strong enough to draw firm conclusions.
- "Total round amount" has an extremely small coefficient and a very high p-value (p = 0.637), indicating it contributes no meaningful explanation in the model—possibly due to redundancy or model mis-specification.
- "Year" also shows no statistically significant effect (p = 0.238), suggesting the year of the investment doesn't strongly influence the funding amount in this specification.

The intercept (constant) is also statistically insignificant (p = 0.236), further confirming that the model overall lacks stability or predictive strength. In summary, none of the included variables show a clear, statistically significant impact on investment amounts, and the regression explains only a very small portion of the variation. This implies that key explanatory factors may be missing or that the model structure needs refinement. Although the regression results are not statistically significant, the analysis remains highly relevant for two key reasons. First, the lack of strong explanatory power is itself a finding: it reveals that Romania's early-stage investment ecosystem does not yet distinguish clearly between impact and non-impact ventures in terms of funding levels. This neutrality suggests that market forces alone are not systematically rewarding social or environmental value, which opens space for targeted public interventions. Second, the data confirms that impact startups exist in meaningful numbers and compete for funding on the same terms as purely commercial ones. The fact that their funding levels are not significantly different highlights a missed opportunity: with more supportive policies (like

tax incentives or co-investment schemes), these ventures could scale faster and deliver greater social returns. Therefore, rather than seeing the lack of correlation as a failure, it should be understood as a signal that the market alone is not enough, and that public policy can play a catalytic role in nurturing high-impact innovation where private capital is still neutral or cautious.

6 Discussion

Our model captures only a minor portion of what drives investment sizes. This is not entirely surprising in the context of startup investments

The lack of a significant impact dummy effect suggests that, in Romania's recent startup market, impact startups did not receive systematically different funding amounts than non-impact startups. This may be due to no discernible funding bias against impact ventures or no special premium or extra support either

Reasons for Low Impact Differentiation may be that the investor ecosystem in Romania is small, with local venture investors (funds and angels) comprising of only a few dozen active players, many of whom are generalists who invest across sectors and, on the other hand, many of the largest rounds in 2021–2023 were in fintech or enterprise software (non-impact sectors). Impact startups in Romania have tended to be earlier-stage

Implications of the Results: For entrepreneurs, the result is somewhat encouraging: if you are building an impact startup in Romania, you can aim to raise competitive round sizes akin to any other startup. The market, though small, does not appear to systematically undervalue impact-focused businesses in terms of capital provided. For investors and policy-makers, the absence of an impact effect may highlight that impact investing is still in an early stage locally. There may be room to introduce more dedicated impact capital that could selectively push high-impact ventures further.

Limitations and Further Research: We acknowledge the limitations influencing these findings. Our impact classification is broad and might group together diverse sectors, the investment dynamics could differ between, say, healthtech vs. clean energy startups, but we lacked granularity to separate them. Future research could extend this by analysing a longer period (as data become available for 2024-2025) and by making cross-country comparisons.

7 Policy Recommendations

The impact ecosystem's underdevelopment means that proactive policies could be beneficial to nurture impact-driven entrepreneurship. Below we list several recommendations that might strengthen support for impact startups:

A. Introduce ESG-Linked Incentives for Investors: The government can encourage more capital to flow into impact startups by offering incentives tied to Environmental, Social, and Governance (ESG) outcomes. For example, Romania could implement a tax credit or deduction for angel investors and venture funds that invest in certified impact startups (similar to schemes used to stimulate R&D investment).

B. Establish a Public Co-Investment Fund for Impact Ventures: A proven way to catalyse venture investment in under-served areas is through co-investment programs where the state participates alongside private investors. We suggest as a potential beneficial action, the creation a Romanian Impact Co-Investment Fund (possibly via an existing entity like the Romanian Innovation Fund or in partnership with European Investment Fund). This fund would match private VC or angel investments into qualifying impact startups. Such schemes have been used in other countries to stimulate investment in regions or sectors perceived as risky.

C. Expand Grant Programs and Blended Finance for Early Stages: Over 62% of Romanian startups reported not seeking external funding, and many rely on personal funds or grants at the earliest stages. For impact-focused founders, grant programs can be a lifeline to develop prototypes and gain traction. Expanding targeted startup grants for impact innovation might be potentially beneficial.

D. Develop Impact Measurement and Recognition Frameworks: One subtle barrier is that investors may not fully understand or trust the "impact" claims of startups. Introducing standard impact measurement frameworks (aligned with global norms like IRIS+ metrics[1]) could boost credibility.

[1] *IRIS+ (Impact Reporting and Investment Standards Plus) is a global standard for measuring, managing, and optimizing impact in impact investing. It is developed by the Global Impact Investing Network (GIIN) and is widely used by impact investors, development finance institutions, and mission-driven organizations.*

E. Foster Impact-Focused Networks and Mentorship: While not a direct financial policy, creating networks can indirectly improve funding outcomes. The government and ecosystem partners should foster mentorship or acceleration programs linking successful entrepreneurs and investors with impact founders.

8 Conclusion

This study presented a quantitative analysis at how impact orientation relates to startup investment outcomes in Romania. Using a dataset of 182 startup funding rounds from 2021 to 2023, we examined whether startups in impact sectors raised significantly different amounts of capital compared to their non-impact counterparts. Our econometric analysis, controlling for round stage and year, found no statistically significant effect of being an impact startup on the investment amount. In other words, within this national sample, impact-driven ventures raised funds on par with other start-ups at similar stage. These findings contribute to the broader conversation on impact investing in emerging markets by providing concrete evidence from Romania. The result indicates that impact ventures did not receive additional capital beyond prevailing norms, pointing to an opportunity for targeted interventions to further amplify their growth.

For future research, one fruitful avenue would be comparative studies across CEE. Do other CEE countries exhibit similar patterns, or are there cases where impact start-ups perform markedly better or worse? Cross-country regressions could incorporate ecosystem variables (like availability of impact funds or public support) to see if those influence the impact–funding relationship. Another avenue is longitudinal: tracking this cohort of startups forward to see if impact-oriented ones differ in growth, revenue, or survival. Qualitative research could complement our quantitative approach by interviewing entrepreneurs and investors to understand perceptions, do impact founders feel disadvantaged or do investors claim to value impact?

In conclusion, pursuing a social mission has been compatible with raising capital in Romania's venture scene, neither a handicap nor a golden ticket. This neutrality is a foundation upon which stakeholders can build. By implementing thoughtful policies and leveraging the enthusiasm of a new generation of founders, Romania can ensure that impact-driven startups not only raise capital, but also scale up and deliver both financial returns and social benefits. In doing so, it stands to transform its underdeveloped startup landscape into a vibrant engine of inclusive and sustainable innovation.

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ARTIFICIAL INTELLIGENCE AND ITS ECONOMIC CHALLENGES IN EU COUNTRIES: IMPLICATION FOR THE REPUBLIC OF MOLDOVA

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Abstract: This article aims to determine the future influence of AI on the Moldovan economy. The relevance of this research topic derives from the European Commission's decision to launch the European AI Strategy as early as 2018, with fundamental objectives related to the adoption of AI throughout the economy, in both the public and private sectors. The strategy also aims to prepare society for the transformations brought about by AI, and to oversee the functioning of an appropriate ethical and legal framework that responds to the EU's vision regarding technological values.
Global projections also estimate that, by 2030, around 70% of businesses will use at least one artificial intelligence technology, such as computer vision, natural language processing, virtual assistants, automation/robotics and machine learning. It is estimated that this technology will generate an additional annual increase in global GDP of around 1.2%, with disruptive effects on countries, businesses and the labour market. This makes the topic of this research a global issue of high timelines.
The research method is a comparative approach to the benefits of AI and the risks it may generate. Synthesis and inference, as well as scenario building based on factual data and a pragmatic approach that respects realism and the possibility of anticipating disruptive actions.
The research will quantify the impact of AI on the structure of the Moldovan economy and the new business models it will generate, as well as the problems that may arise in connection with it. The research will also identify how the labour market of the Republic of Moldova will change in the context of EU integration and assess the current preparedness for the implementation of EU strategies in the field of AI.

*Keywords***:** *Development economy, technology change, innovative development, labor market*

JEL Classification: O1, O2, O31

1. Introduction

Artificial intelligence (AI) is becoming increasingly prevalent in the world around us. It is not only the key technology of the digitisation process, but also the main disruptive factor in our world. Intelligent machines now operate using high-level cognitive processes such as thinking, perception, learning, problem solving and decision making. There have also been advances in data collection and aggregation, computational processing and analysis power, sensor technology and robotics. AI also presents opportunities to augment human intelligence, significantly improving the way we live and work.

AI has become a strategically important area with the potential to drive economic development. It also has a wide range of social implications. At EU level, the European Commission presented a European AI strategy in April 2018 in its Communication 'Artificial Intelligence for Europe (COM.2018).

The objectives of the European AI strategy announced in this communication are:
- strengthen the EU's technological and industrial capacity and the adoption of AI across the economy by both the private and public sectors
- prepare for the socio-economic changes brought about by AI
- ensure an appropriate ethical and legal framework.

Subsequently, in December 2018, the European Commission and Member States published a 'Coordinated Plan on Artificial Intelligence', COM (2018), on the development of AI in the EU.

Taking this into account, the article aims to conduct a pre-emptive analysis of the economy's readiness, as well as assessing the future influence of AI.

2. Literature review

AI is an increasingly debated topic (Kaplan and Haenlein, 2020). One of the main topics of debate related to AI concerns the extent to which users trust and accept AI (Hengstler et al., 2016). While several authors emphasise the importance of initial trust in these new technologies (McKnight et al., 2002; Lee and See, 2004), others focus on how to integrate them into individuals' everyday work (MacVaugh and Schiavone, 2010). For example, consumers are much more willing to accept banking robots than smart cooking or legal advice devices. One of the main topics of debate related to AI is the degree to which users trust and accept AI (Hengstler et al., 2016). Several authors emphasise the importance of initial trust in these new technologies (McKnight et al., 2002; Lee & See, 2004), as well as how to integrate them into individuals' everyday work (MacVaugh & Schiavone, 2010).

The impact of these advancements is evident in various domains, including medicine (Holzinger et al., 2019), finance (Bahrammirzaee, 2010; Königstorfer & Thalmann, 2020), agriculture (Bannerjee et al., 2018), self-driving vehicles (Tong et al., 2019), robotics (Vrontis et al., 2022) and social media (Ozbay & Alatas, 2020). In a matter of months, companies have shifted their corporate approach towards AI-related projects. This shift is highlighted by the increasing number of references to AI in earnings reports, which often come at the expense of Environmental, Social and Governance (ESG) considerations (Patnaik & Vlastelica, 2023; Goodkind, 2023b). Google, Microsoft and Meta have accelerated the development of their AI products, Bard, Bing and LLaMA respectively (Wangsa, Shakir et. all, 2024), and the increased demand for AI chips has seen Nvidia reach a significant market capitalisation milestone of $1 trillion on Wall Street (Goodkind, 2023a).

The 'Dutch AI Manifesto' (2018) outlines the significant impact of AI on key business areas and recognises the need for substantial investment in the development of robust AI systems. It also places a strong emphasis on research, innovation and education. From this literature, we can deduce that the impact of AI has been researched in various areas and on the effect of these technologies on some economic sectors in developed countries. However, there has been no research into the effect of AI on less developed economies or their readiness. Currently, however, there is a significant disparity between developed and less developed economies. If this situation does not change, there is a risk that we will remain a less developed economy for the foreseeable future.

3. Research metodology

The research methodology employed in this study integrates a comparative analysis within the European Union framework, focusing on both the potential benefits and inherent risks associated with artificial intelligence, as well as the broader economic disparities. We applied techniques of synthesis and logical inference, alongside the formulation of strategic directions grounded in empirical evidence and guided by a pragmatic lens. This approach remained anchored in a realist perspective, incorporating the capacity to anticipate possible disruptive developments. Through this analytical framework, we assessed the prospective impact of artificial intelligence on specific sectors of the Moldovan economy. In particular, we examined anticipated transformations in the labour market structure of the Republic of Moldova in the context of EU integration and evaluated the country’s current level of institutional and policy preparedness for the implementation of relevant EU strategies in the field of AI.

4. Research area

Based on the existing statistical data we made an analysis of the possible effect that AI could have on the Moldovan economy. Taking as a benchmark the findings of a McKinsey study that estimates AI has the potential to provide additional global economic activity of about $13 trillion by 2030, or about 1.2 percent additional growth per year. However, a 2019 McKinsey study warned that "Europe is adding an AI gap to its digital divide"; European companies lag behind their US counterparts in adopting big data architecture and advanced machine learning techniques that underpin AI. If we consider the trends in the EU market, by 2030 at least 75% of EU businesses will use cloud technology, AI and big data, and at least 90% of SMEs will have a basic level of 'digital intensity'. Taking this into consideration, we can also note legally that the economy is not oriented towards the implementation of AI, nor is there any strategy regarding its use, despite such a strategy existing not only at the EU level, but also in neighbouring countries such as Romania, which has already made a much more significant leap in this direction.

It is also worth noting that the current focus is on the ICT sector, which has become the main driver of digitalisation and innovation in Moldova and is growing rapidly. In 2021, the IT industry accounted for over 4.2% of gross domestic product (GDP), with sales exceeding 10 billion lei. The ICT sector accounted for over 7.6% of GDP, with sales of over 18 billion lei in 2021, generated by around 2,000 companies employing over 30,000 people. According to the NBM report for 2022, the export of ICT services reached USD 501.85 million. IT exports have grown by more than 30 percent annually over the last five years, reaching a record level of 468.67 million USD in 2022.

Based on existing statistical data, we analysed the potential impact of AI on the Moldovan economy. We took the findings of a McKinsey study as a benchmark, which estimates that AI could provide an additional $13 trillion of global economic activity by 2030 — equivalent to an additional 1.2 percent growth per year. However, a 2019 McKinsey study warned that 'Europe is adding an AI gap to its digital divide'; European companies are lagging behind their US counterparts in adopting the big data architecture and advanced machine learning techniques that underpin AI.

In fact, general presentations on the state of AI often don't present Europe as a player, nor do they consider some European countries. This could be due to language barriers and the large number of European states, but it also indicates a lack of interest in this subject from the EU and its Member States, as well as a lack of funding for such studies. When assessing a country's AI capabilities, both the 'outputs/outcomes' and the 'inputs' should be analysed. Outputs are the actual AI capabilities and can be measured in terms of, for example, the number of AI firms or the level of AI usage by businesses. However, as important advances are made in machine learning and other AI techniques, it is equally important to study the key factors influencing AI development, as this may provide insight into future trends.

A 2020 survey found that only one to three percent of EU businesses with ten or more employees use AI, such as machine learning, natural language processing or speech recognition (excluding the financial sector). Considerable differences exist between European countries: 20% of Irish companies and 12% of Maltese firms report analysing large volumes of data internally using machine learning, compared to 5% in Denmark, 2% in Germany, France and Italy, and 1% in Greece, Latvia and Poland. However, the divergence is not as pronounced for techniques such as language processing.

5. Results and Discussions

Taking these factors into account, we have created a forecast based primarily on the total number of employees, broken down by sector. AI will also be implemented by companies because it has a positive impact on labour productivity and the potential replacement of some workers. This will affect some sectors more than others, but it will certainly impact the entire economy.

Table 1. Number of employees in the Republic of Moldova in 2023

Average number of employees (full-time equivalent), persons	623 600
Share service sector, %	57.6
Share in manufacturing, %, in	12.2
Share in industry, %, %, in manufacturing	14.4
Share of employees in construction, %, %, in industry	7.1
Share of agricultural sector in average number of employees, %	20.8

Source: Elabored by the author based on data from the National Bureau of Statistics of the Republic of Moldova.

Other criteria that we considered when drawing conclusions were the recorded economic situation, including the fact that the number of employees has decreased, although the largest decrease was in construction, which may be related to the season. However, there has been a downward trend in the number of employees in both manufacturing and trade.

Table 2. Trends in economic activity by type of activity in Q1 2024

	Manufacturing	Construction	Retail trade and services
Economic situation	-8.8↘	-5.4 →	+0.8 →
Sales revenue	-13.7 ↘	-13.6 ↘	-4.3 →
Number of employees	-1.6 →	-2.9 →	-1.2→

Source: Elabored by the author based on data from the National Bureau of Statistics of the Republic of Moldova.

We have observed a decline in the number of enterprises in the Republic of Moldova. The main causes are a lack of market demand (low market capacity), which accounts for about 30% of cases, a lack of skilled labour (23%), and a lack of financing sources (21%). Considering that AI could replace at least part of the labour force, we are already witnessing this phenomenon, where some jobs are being replaced. This would increase labour productivity and reduce costs in the coming years. While all these factors would certainly lead to increased economic competitiveness, they would also raise significant social issues, particularly for older and less qualified people. Another critical challenge identified concerning the prospective implementation of artificial intelligence is the shortage of qualified personnel and researchers capable of laying the foundational groundwork. The statistical data unequivocally illustrate this deficit.

Table 3. Number of research/innovation employees

	Persons			
	2021		2022	
	Total	including women	Total	including women
Total	**4 157**	**2 150**	**3 889**	**2 023**
researchers	2 920	1 459	2 809	1 429
technicians	245	172	173	125
auxiliary staff	561	291	430	248
other categories of employees	431	228	477	221

Source: Elabored by the author based on data from the National Bureau of Statistics of the Republic of Moldova.

We estimate that, in the near future, the distribution of PhD students by scientific field will reveal a slight increase in the share of social and economic sciences (50.7% in 2022 compared to 50.3% in 2021). The fields of medical and legal sciences attract the highest number of students (21.4% and 17.6%, respectively), followed by economic sciences (12.4%) and humanities (11.9%). Other scientific fields are less represented among doctoral students, particularly agricultural sciences (2.7%) and military sciences and intelligence (0.8%).

Another hypothesis we discussed was investigating the perception among employees in various sectors of the need for innovation. To this end, we developed a survey involving employees from 27 companies and 4 banks in the Republic of Moldova. We would like to draw the following conclusions from the results:Out of the total number of those interviewed, approx.31.5% had worked in their current role for more than five years, 28.8% for one to three years, and 26% for three to five years.13.7% with up to 1 year's experience. Of those surveyed, 47.9% belong to enterprises with up to 30 employees, 27.4% to enterprises with more than 500 employees and 9.6% to enterprises with 51–100 employees. Of those surveyed, 61.6% work in the service sector, 28.8% in financial banking and manufacturing and 9.6% in agriculture. When asked how motivated employees are to contribute new ideas, 77% of respondents indicated that they are motivated and 23.3% indicated that they are not. When asked how often the management team communicates innovation needs or what innovations they have introduced, over 77% of respondents gave a positive answer and 17.8% gave a negative answer. When asked how much their organisation collaborates with others in the same value chain, 70% said yes and 20.5% disagreed. The key finding is that employees have a higher level of awareness of the need for innovation than government decision-makers do. This indicates a discrepancy between what we want and what society wants.

So, we are also in a difficult situation. We can see that there are many obstacles to overcome. For now, we need to identify these obstacles and develop a strategy to address them. The areas that will develop successfully in the coming years will certainly be technology-based. They will transform the economic landscape of the world and its countries.

We also believe that it is worth paying attention to some philosophical approaches to technology in general. Technology 'just opens a door; it doesn't force someone in'. This is a compelling metaphor. It

encapsulates the viewpoint known as 'technological voluntarism', which is the opposite of technological determinism. Technology only presents an opportunity; the choice of what to do with it remains ours. However, while this view contains an element of truth, it ultimately seems incomplete.

Following the metaphor of open doors, Kranzberg also highlights the inadequacy of a view that focuses narrowly on the initial decision to use or not use a technology. Many of our problems with technology arise from the unintended consequences of seemingly benign technologies being widely used.

Tortoise Media's global AI rankings rank countries based on implementation, innovation, and investment, providing an aggregate score that may combine output and input measures. Three EU countries are in the top ten (Germany, the Netherlands and France), 15 are in the top 30 and 22 are in the global top 50. Some countries are leaders in various areas — for example, in terms of operating environment, EU countries top the list, with Poland, Slovenia, Lithuania and Slovakia in the top five. Notably, the UK has the highest score of any European country in this ranking, placing third after the US and China.

In order to prepare for these AI challenges, three elements are crucial: the so-called 'AI Triad' of talent, data and computing power. Talent is clearly the most important factor. In fact, economic power will be dictated by a 'battle for talent'; whoever 'wins' will have world supremacy in AI. There are also a number of pillars underpinning these ecosystems that need to be identified, activated and leveraged in an interconnected way.

6. Conclusions

Technology today is inherently geopolitical, with artificial intelligence emerging as a critical factor in the strategic competition among major global powers. This reality poses significant challenges that the European Union and its Member States must urgently address. AI is poised to reshape the global balance of power, redefine interstate relations, and impact geopolitics at large. Consequently, the EU must respond proactively by implementing necessary reforms, taking into account not only its internal policies but also the external implications of its actions, including its relationships with allies, partners, supportive states, and rivals.

While there are avenues for the EU and its Member Sates to confront these challenges, many European countries have yet to initiate substantial efforts in this direction. It is imperative that Europe commits greater time, resources, and financial investment to harness the opportunities presented by AI on the international stage while effectively managing its risks.

This transition demands that numerous European countries, particularly economies such as the Republic of Moldova, reevaluate their business models, restructure workflows, and rethink educational frameworks to capitalize on technological advancements. Such a transformation requires significant investments in research, education, and IT infrastructure, supported jointly by public funding and private enterprises. Furthermore, a comprehensive overhaul of education is essential, including the development of lifelong learning programs for adults. Instead of narrowly focusing on applied technical skills prone to rapid obsolescence, educational strategies should emphasize cultivating young people’s capacity for adaptive learning.

Building upon these foundations, AI systems must adhere to seven fundamental principles: human involvement and oversight; technical robustness and safety; privacy and data governance; transparency; diversity, non-discrimination, and fairness; social and environmental well-being; and accountability. Compliance with these principles necessitates both technical and non-technical approaches, with developers bearing primary responsibility for their assessment and implementation. Moreover, addressing these principles presents ongoing challenges for research and innovation, underscoring the urgent need to train a new generation of experts in AI and AI ethics.

Acknowledgments: The article was developed within the framework of Subprogram 030101 „Strengthening the resilience, competitiveness, and sustainability of the economy of the Republic of Moldova in the context of the accession process to the European Union”.

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GERMANY'S LABOUR SHORTAGE: BETWEEN STRUCTURAL PRESSURE AND UNCERTAIN HORIZONS

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Abstract: Germany is currently facing a profound labour shortage that transcends sectoral boundaries and reflects deeper demographic and structural transformations. Following a brief post-pandemic rebound, the German economy has entered a phase of stagnation and mild contraction, further intensifying labour market pressures. Persistent shortages, particularly in skilled occupations, point to long-standing imbalances and systemic constraints. This article examines the structural drivers of these imbalances, focusing on demographic ageing, sectoral disparities, and the enduring weaknesses of Germany's education, vocational training, and labour migration systems. Drawing on recent statistical and institutional data and policy developments, the analysis shows that, despite being targeted, existing measures remain insufficient in both scope and coherence. Structural rigidities and demographic inertia continue to hinder the country's ability to adjust to long-term labour market shifts. These findings suggest that a more integrated and forward-looking reconfiguration of Germany's labour model is needed to ensure long-term economic resilience and demographic sustainability.

Keywords: German labour market, workforce shortages, demographic change, skills mismatches, vocational training, structural constraints, policy responses

JEL Classification: J11, J21, J23, J24

1. Introduction

For sometime now, Germany's labour market is experiencing a period of significant imbalance, influenced by the convergence of long-term demographic shifts and ongoing structural rigidities. While labour shortages are not a new phenomenon, their recent intensification in terms of both scope and persistence has brought the issue to the forefront of economic, academic and policy debates. What was once considered a cyclical or sector-specific concern has evolved into a challenge that cuts across sectors and has systemic implications.

Over the years, the German economy has been experiencing a slow and uneven recovery following the combined impact of the pandemic, geopolitical disruptions and macroeconomic volatility. Against this backdrop, labour market pressures have intensified, revealing a significant mismatch between labour supply and the evolving demands of employers. These tensions are particularly evident in skilled occupations, where recruitment difficulties persist despite sustained job vacancies and increasing wage incentives.

While numerous studies have explored individual aspects of this phenomenon, such as demographic ageing, vocational training bottlenecks, and integration barriers, the overall picture remains fragmented. This paper aims to provide a more comprehensive analysis by examining how demographic inertia, sectoral asymmetries, and institutional dynamics interact to create sustained labour market tension.

The paper is structured as follows: Section 2 provides an overview of the literature on labour shortages; Section 3 outlines the methodology; Section 4 analyses the demographic and structural

drivers of labour market pressure; Section 5 evaluates recent policy responses; and Section 6 concludes with a summary of the main findings.

2. Literature review

A growing body of research has examined the complex interplay between demographic change, labour market dynamics and institutional responses in Germany. Robust longitudinal data from the Federal Statistical Office (Destatis[1]) and Eurostat reveal persistent trends in population ageing, declining fertility and rising old-age dependency ratios, which constrain the labour supply in the long term. Gans (2018) and Nowossadeck et al. (2019) delve deeper into these structural pressures, highlighting their cumulative demographic impact on the working-age population and its implications for welfare sustainability.

In terms of the labour market, the Institute for Employment Research (IAB[2]) has developed nuanced indicators to monitor recruitment bottlenecks, sectoral disparities and the evolving mismatch between supply and demand. The concept of "labour market tightness", analysed by Bossler and Popp (2023a), provides a valuable means of capturing the uneven regional and occupational distribution of these shortages. Their research suggests that structural constraints, rather than cyclical fluctuations, are driving the observed imbalances.

Vocational education and training (VET) have been identified as vital tools for enhancing workforce adaptability. However, studies by Cedefop[3] (2020, 2023) and the Federal Institute for Vocational Education and Training (BIBB[4], 2023)) reveal ongoing discrepancies between training provision, labour market requirements, and the aspirations of younger cohorts. Langen and Dörsam (2025) echo these findings in their examination of the correlation between remuneration patterns and unfilled apprenticeships, highlighting structural disincentives in the system.

Policy responses have tended to alternate between activation strategies and support mechanisms. While federal initiatives such as WeGebAU and the Social Labour Market aim to promote inclusive employment, several evaluations, including those by Bernhard and Senghaas (2021) and the IAB-FORUM (2025d), highlight the limited coherence, scalability and foresight of these measures. The OECD (2024, 2025) provides a broader macroeconomic perspective by contextualising Germany's labour shortages within global megatrends and productivity shifts.

Taken together, these contributions offer a comprehensive and multi-layered picture of the structural vulnerabilities shaping Germany's labour market. This study builds on this body of work by combining statistical evidence with institutional insights to explore how demographic rigidity, sectoral imbalances, and vocational system inertia jointly influence labour shortages in the German context.

3. Methodology

This paper employs a mixed-methods approach, integrating quantitative demographic and labour market data with a structurally informed analysis of institutional dynamics and policy responses. By combining statistical evidence with interpretative depth, the research aims to diagnose not only observable labour market trends and their underlying demographic and structural foundations.

[1] For reasons of clarity and consistency, the Federal Statistical Office of Germany will hereinafter be referred to as "Destatis".
[2]Similarly, the Institute for Employment Research (*Institut für Arbeitsmarkt- und Berufsforschung*) will often be referred to as IAB in what follows.
[3]The acronymstands for the full name of the institution:European Centre for Development of Vocational Training.
[4]The acronym BIBB derives from the German title *Bundesinstitut für Berufsbildung*, which is a central body responsible for research, policy development, and monitoring in the field of vocational education in Germany.

The quantitative dimension is based on official data from the German Federal Statistical Office (Destatis), Eurostat, the OECD, the Federal Employment Agency (BA[5]), and the Institute for Employment Research (IAB). Key indicators include the total fertility rate, life expectancy for the 65+ age group, old-age dependency ratios (OADRs), unfilled job vacancies, as well as sectoral disparities in employment.

Two complementary indicators of labour market tightness are used to assess the evolving relationship between labour supply and demand: *Tightness A*, based on registered jobseekers and reported vacancies, and *Tightness B*, which focuses on officially unemployed individuals and the same demand-side measure. Both indicators are constructed using data from June each year, in line with statistical conventions established by the BA and IAB. This mid-year reference point provides a consistent, seasonally neutral overview and ensures comparability over time.

While demographic series are presented over extended timeframes to highlight long-term structural pressures, the core analysis of labour market indicators focuses on the periodfrom 2011 to 2024. This choice reflects both data availability and the need for internal consistency across sources, particularly for indicators such as the IAB Labour Market Barometer, which was introduced in 2011.

Together, these methodological choices enable a longitudinal and multi-scalar analysis of Germany's labour shortage challenge, accounting for national dynamics as well as territorial and sectoral asymmetries that shape recruitment conditions across the country.

The analysis of these trends serves more than a descriptive purpose. It offers insight into the structural causes of Germany's current labour shortage – observed particularly in the domain of skilled work – and brings into focus the demographic imbalances that have progressively reshaped the country's workforce. This diagnostic perspective also supports the qualitative analysis of federal policy responses undertaken in the second part of the paper. Rather than evaluating isolated outcomes, the focus lies on the coherence, scope and structural alignment of recent measures, assessed considering the systemic imbalances identified in the first part.

4. Mapping the German labour shortage: from demographic shifts to sectoral and skillsmismatches

4.1 Demographic pressures and structural change in the German workforce

To fully understand Germany's current labour shortages, it is first necessary to examine the demographic forces that have reshaped the country's population structure in recent decades.

Since the beginning of the current millennium, Germany has been undergoing a deep demographic transformation, driven by a persistent decline in fertility and rising life expectancy. This dual shift has accelerated the ageing process and widened the generational gap, pushing the country into a demographic trap that exerts growing pressure on the labour market and, more broadly, on its economic and social systems.

To understand the roots of this transformation, it is necessary to trace back its historical origins. The demographic imbalances observed in recent decades are not the result of sudden shocks, but rather the consequence of long-term trends that began unfolding more than half a century ago.

By the late 1960s, the post-war period of economic expansion (known as "the German economic miracle"), which had supported relatively elevated birth rates during the 1950s and early 1960s, came to an end. At the same time, a gradual shift in collective mentality began, characterised by growing individualism, emancipation and increased personal autonomy (Gans, 2018). Life priorities were increasingly shifting away from traditional values centred on family and reproduction. Germany's birth rate subsequently entered a period of marked decline, particularly during the 1970s and 1980s. Since

[5] To ensure readability, the German Federal Employment Agency will henceforth be abbreviated as BA, the established acronym derived from its original German name (*Bundesagentur für Arbeit)*.

the early 2000s, fertility rates have stabilised at a low level, with minor fluctuations, including a modest rise between 2010 and 2016, a slight decline thereafter, and a brief uptick during the COVID-19 pandemic. Despite these oscillations, the total fertility rate (TFR) has consistently remained below replacement level[6], contributing significantly to the country's long-term demographic imbalance (Box 1, Figure 1).

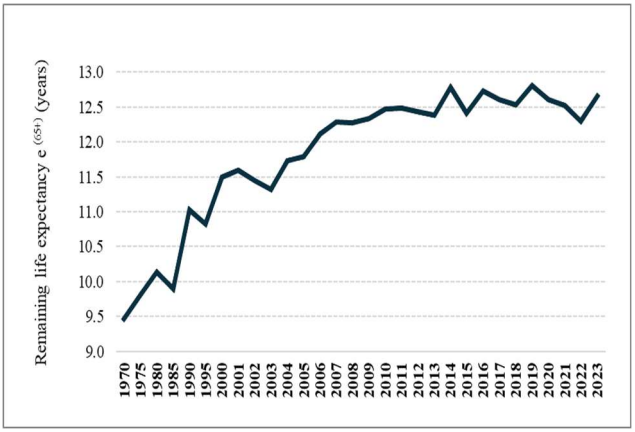
This persistent demographic asymmetry, however, is not solely the result of declining fertility. It has been compounded by steady gains in life expectancy among the 65+ individuals, a trend that has reinforced population ageing, increased the old-age dependency ratio, and added mounting pressure on the structure and sustainability of the labour market. These dynamics are illustrated in greater detail in Figure 2 (Box 1).

Reflecting improvements in health, medical care, living standards, and preventive medicine, as well as growing public awareness regarding healthy ageing (Nowossadeck, von der Lippe, & Lampert, 2019), life expectancy for the 65+ age group has steadily increased in Germany over the past four decades, slowing temporarily during the COVID-19 pandemic before rising again in 2023 (Box 1, Figure 2). Evolving alongside persistently low fertility rates, this upward trend has accelerated population ageing, increased the old-age dependency ratio and reshaped the demographic composition of the workforce.

Box 1: Germany's demographic transition: shifting patterns of fertility and longevity, 1970-2023[1]

Figure 1: Trends in the total fertility rate[2], 1970-2023

Figure 2: Average life expectancy at ages 65 and over[3], 1970-2023



Notes: [1]2023 is the latest year for which statistical data are available in the Destatis and Eurostat databases; [2]TFR represents the average number of children a woman would have over her lifetime, based on current age-specific fertility rates (according to UN/Eurostat/WB definitions); [3]Life expectancy at age 65+ ($e^{(65+)}$) represents the average number of additional years individuals in this age group are statistically projected to live, based on current mortality rates. Calculated specifically for this analysis, in line with international standards, this indicator highlights population ageing and rising old-age dependency. Source: The author's calculations and graphical representations based on data provided by Destatis (2025) [*code:12612-0009*] and Eurostat (2025) [*https://doi.org/10.2908/DEMO_MLEXPEC*].

As younger age groups become progressively less represented in the overall population, the proportion of older individuals continues to rise, a structural change that is increasingly placing visible strain on labour supply, social protection systems, and long-term care services. While these gains in longevity represent a major societal achievement, they have also triggered a profound transformation in

[6] Replacement-level fertility is defined as the average number of children a woman would need to have for a population to replace itself from one generation to the next in the absence of migration. In developed countries, this level is usually around 2.1 children per woman, accounting for child mortality and other demographic factors(Galan, 2025).

the country's demographic profile, gradually inverting the base-to-peak proportions of the age pyramid and exacerbating the intergenerational imbalance.

The following box illustrates these shifts, presenting both the evolving age structure of the German population (Figure 3) and the long-term trajectory of the old-age dependency ratio (Figure 4).

Box 2: Changing age structures and the rise of intergenerational pressure in Germany

Figure 3: Demographic profile: age and gender distribution in 2024 vs. the 2000s average

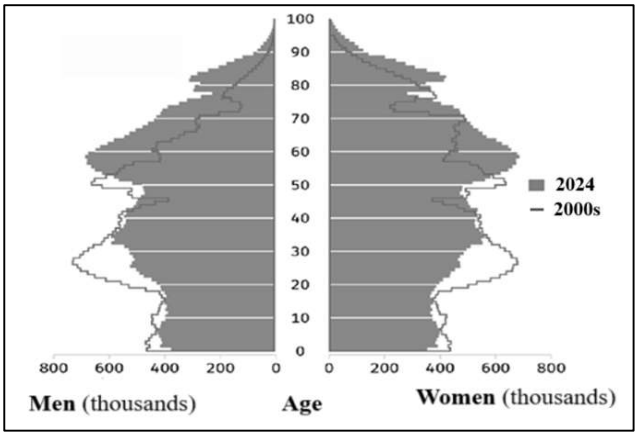
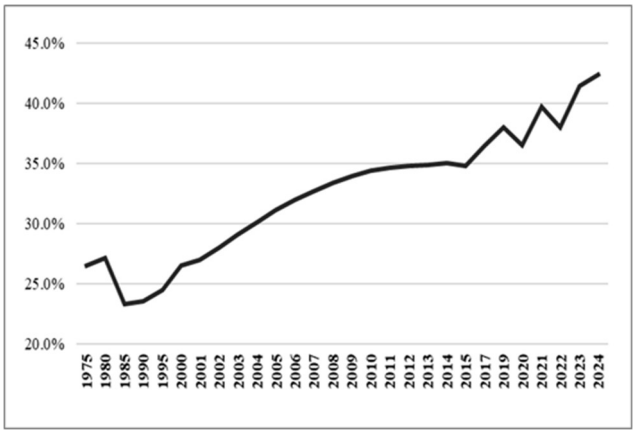


Figure 4: Structural dynamics of the old-age dependency ratio*, 1970-2023



Note: *OADR refers to the number of people aged 65 and over for every 100 individuals of working age (defined by the OECD as those between 20 and 64 years old) (OECD, 2025).
Source: The author's graphical representation based on data provided by Destatis (2025) [*Age structure of the population in Germany*] and OECD Data Archive (2025) [*Old-age dependency ratio*].

The OADR in Germany has followed a markedly upward trajectory since the mid-1980s, with a notable acceleration beginning in the early 2000s. In 2024, it reached an all-time high, emphasising the growing demographic burden on the working-age population. At present, this burden translates into a dependency ratio of 42.2%, meaning that for every 100 individuals of working age, there are over 42 persons aged 65 and above, a demographic configuration that implies just over two active contributors for each retiree (Destatis, 2025a).This structural change is quietly transforming the intergenerational dynamic, with a shrinking pool of contributors expected to meet the rising demand for pensions, healthcare, and long-term care services.

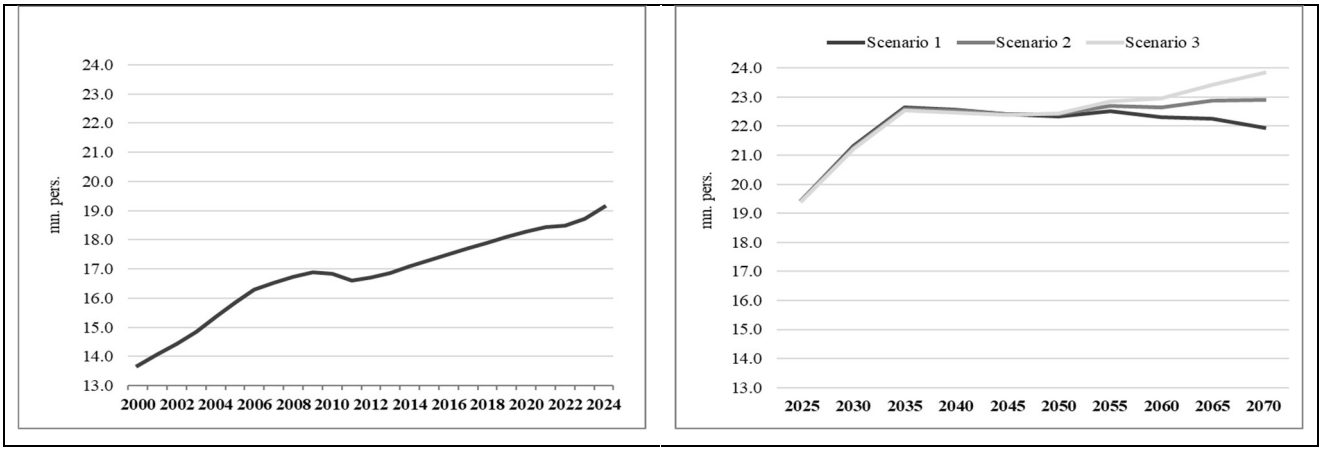
While the evolving shape of Germany's age pyramid reveals the increasing weight of older cohorts within the population, the numerical growth of the 65+ age group provides further evidence of the scale and persistence of this demographic shift. At the same time, the narrowing base of the pyramid reflects a steady decline in the size of younger cohorts, a trend which exacerbates the demographic imbalance by weakening the potential for future labour force replacement.

Furthermore, Box 3 presents both historical trends and long-term projections for this age group, emphasising the extent to which ageing has become an integral structural feature of Germany's demographic outlook.

Box 3: Germany's 65+ population: trends and projections, 2000-2070

Figure 5: Population aged 65 and over: historical trend, 2000-2024

Figure 6: Projected population aged 65 and over: comparative scenarios, 2025-2070



Note: The three alternative scenarios illustrated in Fig. 3 are based on different assumptions regarding fertility, life expectancy, and net migration. These are: Scenario 1 – moderate birth rate and life expectancy, with low net migration; Scenario 2 – moderate birth rate, life expectancy and net migration; Scenario 3 – moderate birth rate and life expectancy, with high migration.
Source: The author's calculations and graphical representations based on data provided by Destatis (2025) [*code:12411-0005; code: 12421-0002*].

As Figure 5 shows (Box 3), the number of individuals aged 65 and over has increased steadily over the past two and a half decades, with only minor fluctuations following the global financial crisis. Currently, the median age exceeds 45, with over 20% of the national population aged above 65. Nevertheless, the overall age structure has undergone a modest rejuvenation in recent years, driven by sustained positive net migration[7] and an upward – albeit irregular – rise in birth rates. However, these trends have not been sufficient to counteract the broader ageing dynamic. Despite this partial demographic offset, a birth deficit persists, and the combined effect of these positive impulses has yet to produce a tangible recalibration of Germany's population structure.

According to the latest projections by Destatis, the size of this age group is expected to remain significant throughout the coming decades, albeit with slight variations depending on assumptions about fertility rates, life expectancy, and net migration (Figure 6).

All three official projection scenarios indicate that the 65+ population will remain high in the long term. The low-migration scenario – generally considered the most conservative[8] – forecasts a gradual decline after 2040, while the medium- and high-migration scenarios suggest either stabilisation or continued growth until 2070. Taken together, these trajectories reinforce the notion that population ageing in Germany is not a transient phenomenon, but a deeply rooted structural transformation. This long-term demographic pressure will be further intensified by the gradual retirement of Germany's post-war baby boom generation, born between 1955 and 1969(Quitzau, 2023). Their withdrawal from the labour market is expected to be completed by 2036, resulting in the simultaneous loss of a large cohort of experienced workers and a significant shift in the country's fiscal balance, as many former taxpayers become recipients of state benefits.

4.2 Tracing labour market imbalances: from general tensions to sectoral gaps

To capture the structural challenges currently facing the German labour market more precisely, Box 4 juxtaposes two complementary indicators: the quantitative evolution of labour demand, as

[7] Since 2010, immigration has consistently exceeded emigration, with the demographic surplus concentrated among younger, economically active individuals.

[8] The low migration scenario is considered the most pessimistic because of its underlying assumptions, which imply a broader demographic contraction, including low inward migration, persistently low fertility and a shrinking working-age population. Although it projects a slight reduction in the elderly population after 2055, it simultaneously suggests an increase in dependency ratios and heightened pressure on social systems.

reflected in the number of job vacancies (presented in registered and estimated forms[9]), and the qualitative expectations surrounding its fulfilment, as captured by the IAB Labour Market Barometer[10]. While vacancy figures illustrate the upward trajectory of demand, the barometer conveys the degree of institutional confidence in the labour market's ability to respond to it. Taken together, these indicators provide a clearer understanding of the growing discrepancy between rising labour needs and the perceived capacity to meet them, a pattern that is becoming increasingly indicative of structural imbalance.

Figure 7 therefore presents both officially registered vacancies (as reported by the Federal Employment Agency/BA) and total open positions, including those not reported to public employment services. The latter are estimated by the IAB Job Vacancy Survey, a quarterly, establishment-level instrument that provides a broader perspective on labour demand than administrative data(Institute for Employment Research/IAB, 2025b,c). This methodology enables a more accurate assessment of unmet labour demand across sectors and firm sizes.

As shown in Box 4, the total number of job vacancies in Germany almost doubled between 2011 and 2024, reaching an all-time high in 2022. In contrast, the IAB Labour Market Barometer – which reflects employment agencies' expectations regarding the likelihood of filling these positions – followed a downward trajectory over the same period, with only short-lived recoveries followed by renewed declines. This growing discrepancy between the volume of vacancies and the perceived ability to fill them suggests that labour demand has increasingly outpaced supply, both in terms of quantitative availability and qualitative alignment (i.e., including skills, experience, and sectoral readiness), even as filling prospects have failed to improve and have, in fact, steadily worsened over time.

Box 4: Job vacancy trends and labour market confidence in Germany, 2011-2024[1]

Figure 7: Reported and total job vacancies (BA vs. IAB[2],*), 2011-2024**

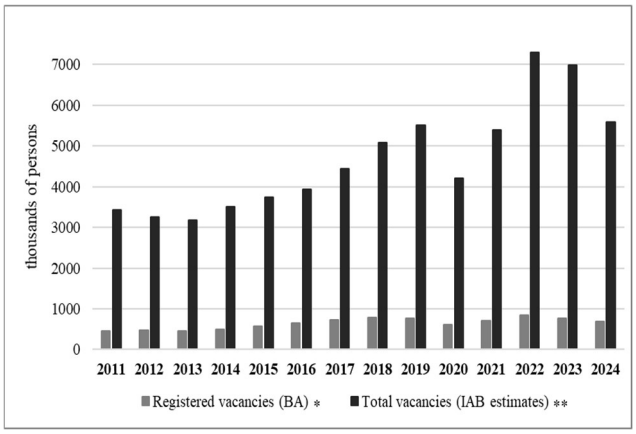
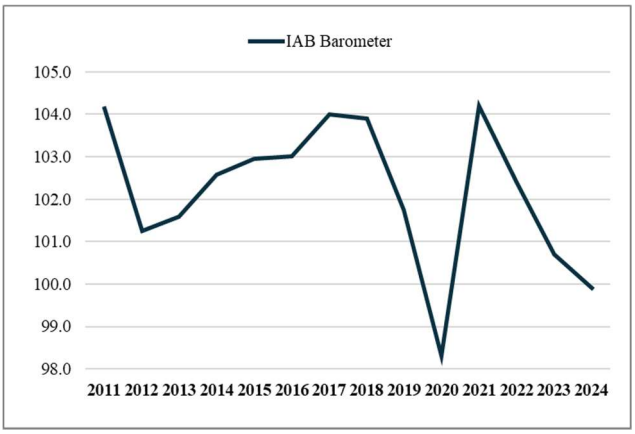


Figure 8: IAB Labour Market Barometer:annual average[3], 2011-2024



Notes:[1]The time frame 2011-2024 was selected to ensure consistency between the two indicators used in Box 4, as the IAB Labour Market Barometer is only available from 2011 onwards.[2]Although the IAB vacancy data are collected and published on a quarterly basis, we use annual aggregates here to support a consistent interpretation of long-term trends; ***The substantial discrepancy between the number of vacancies officially registered with the BA and the IAB's estimate of total vacancies is not a statistical anomaly, but a structural feature of the German labour market. This gap reflects the fact that a

[9]The deliberate inclusion of both BA figures and IAB estimates allows us to contrast formal reporting behaviour with wider labour market dynamics, offering a more nuanced understanding of the structural pressures shaping Germany's labour market.

[10]The IAB Labour Market Barometer is a confidence index based on the monthly evaluations of local employment agencies across Germany. Set against a neutral benchmark of 100, it anticipates short-term developments in employment and unemployment over a three-month period. Values above 100 reflect optimistic expectations, while those below the threshold indicate growing concerns about labour market conditions(Institute for Employment Research/IAB, 2025a). As a non-dimensional index, it operates on a scale without physical units, serving as a qualitative gauge of institutional outlook.

considerable share of employers – especially those in smaller firms or high-skilled sectors less reliant on public placement services – do not report their job openings to the Federal Employment Agency. In contrast, the IAB Job Vacancy Survey captures this unreported demand through direct employer responses at the establishment level, offering a more complete and accurate picture of labour market pressure that would otherwise remain institutionally invisible.; [3]Similarly, while the IAB Labour Market Barometer is released monthly, annual averages have been calculated by the author to ensure coherence with the vacancy data presented in Figure 7 and to enable a harmonised, year-based comparison across all indicators examined in this paper.
Source: The author's calculations and graphical representations based on data provided byFederal Employment Agency/BA (2025a,b) and Institute for Employment Research/IAB (2025a,c).

While the early post-pandemic years appeared to signal a potential rebalancing between labour supply and demand, developments in 2023 and 2024 instead point to the consolidation of structural strain. The persistence of elevated vacancy levels alongside stagnant or shrinking labour pools indicates a chronic imbalance, with no signs of meaningful correction in the short term.

To better understand the depth and persistence of these imbalances, the next section will examine their underlying structural causes in more detail, focusing on the sectoral and regional disparities that are increasingly fragmenting the German labour market and limiting its capacity to allocate human resources efficiently.

Although labour markets in many advanced economies, including Germany, have been described as "tight" since the pandemic, this phenomenon cannot be attributed solely to a numerical shortage of workers. While the number of vacancies increased significantly as labour demand surged, the issue was not simply that there were too few people available; rather, the match between jobs and job seekers became increasingly strained. In other words, Germany's labour market has been experiencing structural tensions, as opposed to a classic labour shortage (Van Doornik, Igan, & Kharroubi, 2023).As argued by Doornik, Igan and Kharroubi (2023),this imbalance is rooted in a growing disconnect between the nature of available jobs and the profiles, preferences or locations of potential candidates.

Accordingly, despite the increase in job openings since 2020 (Figure 7, Box 4), the pool of job seekers has remained relatively unchanged (Figure 9, Box 5). This pattern suggests that the observed tightening of the labour market may be less a result of a shrinking labour supply, and more a reflection of persistent mismatches[11] – e.g., in skills, geography, and occupational expectations –as highlighted in recent studies. International analyses have confirmed this tendency, emphasising that labour market tightness is often fuelled by supply-side constraints (e.g. demographic shifts, participation trends and changing worker preferences) and demand-side behaviours (e.g. labour hoarding and shifts in sectoral demand)(Bossler & Popp, 2023a).

To further clarify this evolving disparity, we examine two complementary annual indicators of labour market tightness, covering the period from 2011 to 2024 (Figure 10, Box 5). These metrics offer broad and narrow perspectives on the pressure exerted on the German labour market. The first, *Tightness A*, measures the ratio of job vacancies to the total number of job seekers, providing an overview of the balance between labour demand and potential labour supply. The second, *Tightness B*, relates job vacancies solely to the number of registered unemployed individuals, offering a more specific, institutionalised view that aligns with conventional unemployment statistics. While *Tightness A* captures the full spectrum of individuals actively seeking employment, including those already employed but looking to change jobs, *Tightness B* isolates the strain on the pool of officially unemployed jobseekers. When analysed together, these two indicators enable a more nuanced understanding of labour market tension, helping to distinguish between visible and latent mismatches in the German context.

[11]As will be shown in the relevant part of this section, the author's own calculations are limited to volume-based indicators of labour market tightness (A and B), which quantify the relationship between job vacancies and labour supply. References to skill, occupational or regional mismatches are offered as interpretative hypotheses, supported by existing empirical research rather than derived from matching-pattern data.

Box 5: Structural tensions in the German labour market: job seeker trends and tightness indicators, 2011-2024

Figure 9: Number of total job seekers and registered unemployed in June 2011-2024*

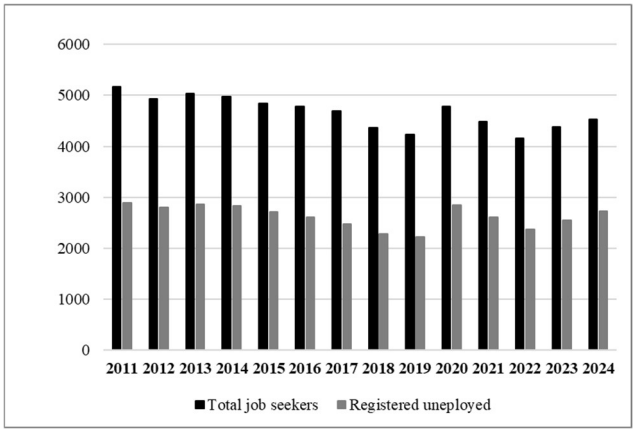
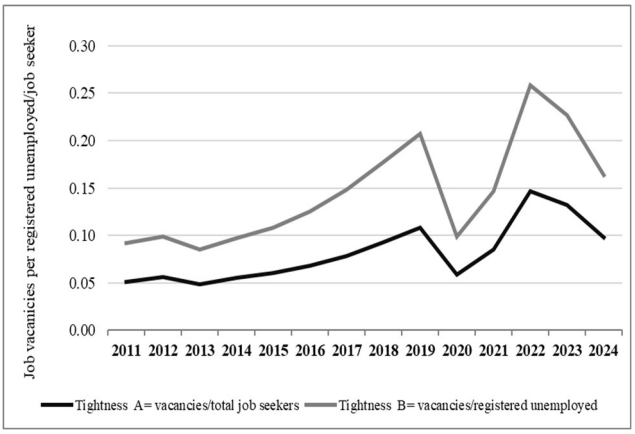


Figure 10: Labour market tightness, 2011-2024*



Notes:For the sake of methodological consistency and data comparability, this analysis adopts June as the reference month for all labour market tightness calculations. This approachaligns with established statistical conventions and the publication cycles of the Federal Employment Agency/BA(2025c) and the Institute for Employment Research/IAB(2025a),which release harmonised and methodologically validated data on job vacancies and jobseeker categories in June each year[12].The June jobseeker statistics include both registered unemployed individuals and other active jobseekers (e.g. those experiencing underemployment or participating in temporary labour market measures), providing a comprehensive approximation of labour supply.Such a practice is rooted in the IAB's established method of assessing labour market tightness over time (see Bossler & Popp, 2023) and complies with official statistical standards.
Source: The author's calculations and graphical representations based on data provided byFederal Employment Agency/BA (2025d) and Institute for Employment Research/IAB (2025c).

The low levels of labour market tightness observed in the early years of the analysed period (2011-2013) might initially suggest an oversupply of labour. However, this interpretation calls for nuance; a very low tightness ratio does not necessarily signal a healthy labour market, but may instead reflect structural mismatches, long-term unemployment, or forms of underemployment(Bossler & Popp, 2023b; OECD, 2024). The ideal is not an absence of tension, but rather a functional level of strain, high enough to indicate active demand and efficient labour mobility, yet not so high as to point to systemic shortages or recruitment bottlenecks.

As shown in Figure 10/Box 5, both labour market tightness indicators display a clear upward trend throughout the 2011-2024 period, albeit with different trajectories and intensities. *Tightness A* remained relatively low and stable during the initial years[13], reflecting a labour market with an ample supply and modest demand-side pressure. From the mid-2010s onwards, however, the indicator began to rise steadily, marking a visible shift towards a more constrained labour environment. Although the pandemic temporarily interrupted this trend, recovery was swift, and tightness levels soon surpassed pre-crisis values and have persisted at an elevated plateau in recent years.

[12]Using this mid-year benchmark provides a stable, seasonally neutral basis for interannual comparisons and avoids the distortions caused by spring transitions, year-end effects, and policy-related reporting fluctuations. Unlike the aggregation of monthly data across the full calendar year, which captures the cumulative flow of labour, using June figures provides a representative snapshot of the structural relationship between labour demand and supply at a consistent point in time.
[13]A low tightness ratio (e.g. 0.05, as registered in 2011) indicates a relaxed market, with many candidates available per vacancy, which is often associated with higher unemployment. Conversely, a high tightness ratio (e.g. above 0.10) suggests recruitment difficulties and a possible mismatch between job requirements and available profiles. A moderate level (e.g. 0.06-0.08, as observed in Germany pre-pandemic) is generally seen as functionally balanced, indicating a dynamic and well-aligned labour market.

Tightness B mirrors this general evolution, but with sharper fluctuations. The post-2015 acceleration was more pronounced, reaching peaks that suggest acute recruitment pressure within the institutionalised segment of the labour force. Even after a slight easing in recent years, the indicator remains well above earlier levels, highlighting an ongoing imbalance between available jobs and officially unemployed candidates.

Altogether, these trends indicate a structurally tightened labour market. Consequently, despite recent signs of moderation, both indicators continue to signal a high level of labour market pressure, underpinned more by structural mismatches between skills supply and demand than by cyclical fluctuations(Dorville, Filippucci, & Marcolin, 2024).

Although aggregate indicators such as labour market tightness offer valuable macro-level insights, they fail to reflect the uneven intensity of labour shortages across economic sectors. Beneath this general imbalance, sector-specific data uncover marked disparities in the distribution of unfilled positions, pointing to structural bottlenecks that are distinctly industry-bound. Analysing these differentiated sectoral dynamics is therefore essential to fully grasp the nature and persistence of labour market tensions in Germany. In this sense, Table 1 below outlines the distribution of job vacancies across major economic sectors, highlighting both absolute volumes and relative shares of total labour demand[14] between 2011 and 2024.

Table 1: Sectoral distribution of job vacancies in Germany, 2011-2024

	Primary sector	Industry and construction	Commercial and logistic services	Professional and social services	Public administration and social security	Total
Number of job vacancies (thousands)						
2011	21.1	658.2	865.4	1833.0	42.5	3420.2
2012	27.2	659.5	731.7	1784.3	46.3	3249.0
2013	20.8	584.4	682.9	1840.3	53.7	3182.1
2014	26.4	657.2	834.7	1921.8	65.6	3505.7
2015	34.6	685.5	829.7	2107.4	75.0	3732.2
2016	34.9	787.0	834.0	2204.2	76.5	3936.6
2017	33.4	938.2	966.8	2429.0	77.0	4444.4
2018	42.5	1175.2	1100.3	2672.2	85.6	5075.8
2019	47.7	1166.3	1257.8	2929.0	98.9	5499.7
2020	45.2	933.9	950.6	2170.1	112.8	4212.6
2021	50.7	1258.6	1081.0	2871.8	126.0	5388.1
2022	57.9	1670.4	1591.2	3817.8	163.5	7300.8
2023	48.4	1529.5	1540.9	3735.1	136.8	6990.7
2024	40.1	1125.2	1318.2	2937.8	165.0	5586.3
Share of total vacancies (%)						
2011	0.6%	19.2%	25.3%	53.6%	1.2%	
2012	0.8%	20.3%	22.5%	54.9%	1.4%	
2013	0.7%	18.4%	21.5%	57.8%	1.7%	
2014	0.8%	18.7%	23.8%	54.8%	1.9%	
2015	0.9%	18.4%	22.2%	56.5%	2.0%	
2016	0.9%	20.0%	21.2%	56.0%	1.9%	
2017	0.8%	21.1%	21.8%	54.7%	1.7%	100.0%
2018	0.8%	23.2%	21.7%	52.6%	1.7%	
2019	0.9%	21.2%	22.9%	53.3%	1.8%	
2020	1.1%	22.2%	22.6%	51.5%	2.7%	
2021	0.9%	23.4%	20.1%	53.3%	2.3%	
2022	0.8%	22.9%	21.8%	52.3%	2.2%	
2023	0.7%	21.9%	22.0%	53.4%	2.0%	

[14]In this context, "labour demand" refers to the number of job vacancies reported by employers as unfilled. It is used here as a proxy for sectoral labour market pressure, reflecting unmet demand for labour.

	Primary sector	Industry and construction	Commercial and logistic services	Professional and social services	Public administration and social security	Total
2024	0.7%	20.1%	23.6%	52.6%	3.0%	

Note: Sectoral groupings are defined by the author based on IAB vacancy statistics, aiming to provide a more coherent and comprehensive view of labour market dynamics.
Source: The author's calculations based on data provided by the Institute for Employment Research/IAB (2025c).

As the data shows, between 2011 and 2024, Germany's labour shortages remained highly concentrated in professional and social services[15], which consistently accounted for more than half of all reported job vacancies. Meanwhile, industry, logistics and construction (grouped here ascolumns 2 and 3) recorded peak vacancy levels in 2022 (a surge likely linked to post-pandemic recovery dynamics), followed by a moderate decline in 2023 and a steeper correction in 2024. The growing share of vacancies in public administration further highlights the mounting strain on institutional capacity.

This sectoral distribution also reveals several enduring significant patterns. The persistently marginal role of the primary sector highlights its declining importance in terms of Germany's labour absorption. Conversely, stable demand in professional and social services suggests deep-rooted structural needs rather than temporary imbalances. Sectors that are more volatile, such as industry and logistics, exhibit sharper fluctuations, which are likely to reflect their greater exposure to cyclical shocks and supply chain disruptions. Meanwhile, the steady increase observed in public sector vacancies indicates a gradual mounting pressure on administrative institutions, a trend with long-term implications for service delivery and institutional resilience.

This imbalance suggests that the current labour shortages in Germany are not merely quantitative but are instead rooted in the evolving mismatch between job requirements and the qualifications available. The qualification profile of job vacancies reveals a persistent structural demand for skilled vocational labour, as well as an increasing share of lower-skilled positions (Table 2). This signals distinct challenges for workforce development and training systems.

Table 2: Qualification profile of job vacancies in Germany: shares by education level in Q4[1], 2010-2023[2]

Data for the 4th quarter of the reporting year[1]	Without professional qualification/unskilled	Industrial, commercial or other training qualification incl. vocational school qualification	University of applied science degree/university degree
2010	21%	57%	22%
2011	17%	66%	17%
2012	19%	62%	19%
2013	20%	58%	22%
2014	18%	62%	20%
2015	20%	65%	16%
2016	20%	64%	16%
2017	22%	61%	17%
2018	23%	61%	16%
2019	20%	65%	15%
2020	19%	64%	18%
2021	24%	60%	16%
2022	23%	58%	19%
2023	24%	55%	21%

Notes:[1]The data refer to the fourth quarter of each year, as published by the IAB. This reference point is considered methodologically consistent and particularly suitable for capturing structural dynamics in qualification-specific labour

[15]According to IAB's data, this category includes business-related, personal, social and cultural activities.

demand, as it reflects the year's most stable and representative period, after summer-related seasonal fluctuations and before the January transition period; [2]The year 2023 marks the most recent data available at the time of writing.
Source:Data published by the Institute for Employment Research/IAB (2025c).

Although vocational training remains the main driver of labour demand, the growing number of job vacancies that do not require formal qualifications is raising concerns about shifting recruitment standards and the potential dilution of skills. The relatively modest but steady share of university-level positions reflects a structurally diverse, yet potentially fragmented, labour market. While current data do not directly capture recruitment difficulties, the evolving qualification profile suggests potential mismatches at both ends of the spectrum, namely from underqualified to overqualified candidates.

Since previous datasets lacked the occupational granularity needed for consistent tracking needed for direct comparison, the availability of 2024 figures provides a sharper lens into sector-specific hiring pressures across key sectors.To better understand how these frictions materialise in practice, Table 3 presents selected occupations with the longest average vacancy durations in 2024, a widely used proxy for recruitment difficulty. Ordered by severity, the list highlights critical bottlenecks, particularly in manual and technically skilled professions. These prolonged vacancy durations are not merely statistical indicators; they point to deeper structural frictions, qualification gaps, and sector-specific constraints that continue to shape the German labour market.

Tabel 3: Occupations with the highest recruitment difficulties in 2024 (based on average vacancy duration)

Occupation	Average vacancy duration by occupation (in days)
Insulation specialists	238
Plasterers/Stucco workers	225
Plumbing/HVAC technicians[16]	224
Elderly care workers	170
IT technicians – technical informatics	137
Truck drivers – freight transport	105
Software developers	88
IT – business informatics	66

Source: Author's synthesis based on statistical data published by Federal Employment Agency/BA (2025e).

These prolonged vacancy durations reveal more than just staffing difficulties; they reflect structural frictions and qualification mismatches that cannot be resolved by domestic labour alone. As Germany's economy evolves, so too must its strategies for aligning training systems, occupational standards, and real labour market needs, including the systematic integration of foreign workers in sectors where the local workforce is insufficient.

4.3 Skills and qualification mismatches: the silent engine of structural tightness

As shown in the previous section and confirmed by the Federal Employment Agency's Annual Labour Market Report 2024 (Federal Employment Agency/BA, 2025e), recruitment bottlenecks persist in sectors characterised by high qualification demands and limited domestic labour reserves, particularly in healthcare, construction and IT. Beyond the specific examples already highlighted, the chart below (Table 4) provides a broader categorisation of occupations currently facing high demand, grouped by qualification level, ranking from qualified professionals to highly specialised experts. This layered classification underlines the structural nature of recruitment shortages across the German labour market.

[16]According to the BA, HVAC technicians (Heating, Ventilation and Air Conditioning) are responsible for the installation, maintenance and repair of climate control systems in residential, commercial and industrial buildings. This professional category is among the technically skilled occupations facing persistent recruitment difficulties in Germany.

Table 4: Key occupations affected by labour shortages, by qualification level (2022-2024)

Qualified professionals	Specialists	Experts
- Professions in nursing; - Medical assistants (w/o specialisation); - Professions in automative engineering; - Medical assistants in dentistry;	- Professions in childcare and education; - Professions in physiotherapy; - Professions in specialist nursing; - Professions in ergotherapy;	- Professions in software development; - Physicians(w/o specialisation); - Teachers in secondary schools; - Professions in architecture; - Professions in construction project planning and supervision.
The category typically includes:		
→ individuals who have completed at least two years of vocational education and training or hold an equivalent non-academic qualification. They typically occupy hands-on technical or operational roles within their field;	→ workers with advanced vocational credentials such as master craftsperson titles, technician diplomas, or equivalent qualifications, including certain academic degrees. Their expertise often combines practical know-how with sector-specific depth;	→ highly educated professionals with at least a four-year university degree or equivalent academic training. They are commonly employed in roles that demand strategic, scientific, or planning capacities, often beyond the scope of traditional vocational routes.

Source: Adapted by the author based ondata published by Federal Employment Agency/BA (2024; 2025e) andThe Federal Government (2025).

Although Germany's dual vocational training system, which combines in-company apprenticeships with classroom-based instruction, remains a central pillar of workforce integration, thousands of apprenticeship positions continue to remain unfilled each year, particularly within small and medium-sized enterprises (SMEs).

Despite targeted efforts to modernise and internationalise the system, vocational training faces growing difficulties in attracting, retaining, and effectively matching trainees with real labour market opportunities. In 2024 alone, nearly 69,400 vocational training places remained vacant, surpassing the figure for 2022 (68,868) and almost doubling that for the 2014(37,101).

This persistent undersubscription, especially among SMEs, signals a widening gap between the supply of training and the expectations or availability of young labour market entrants. This resulting imbalance not only undermines the functioning of the vocational pathway, but also contributes to structural hiring frictions, as evidenced by prolonged vacancy durations and an increasing reliance on international recruitment.

Beyond the widely recognised training gaps, a recent report published under the auspices of the Federal Institute for Vocational Education and Training in early 2025(Langen & Dörsam, 2025) reveal a more subtle yet structurally embedded misalignment in the German labour market: the relationship between apprenticeship remuneration and occupational shortages. Between 2020 and 2023, average earnings in vocational training increased most notably in low-paying sectors with persistent shortages of applicants, leading to a partial convergence across regions and fields. While this trend of wage equalisation is encouraging at first glance, it also highlights a deeper systemic tension: even as remuneration improved in several key shortage areas, such as technical trades, hospitality, and care services, thousands of positions remained unfilled.

According to Langen and Dörsam (2025), who investigated the interplay between apprenticeship supply, remuneration levels and recruitment difficulties, the average monthly apprentice wage across all training years was EUR 966 in 2023. However, there were significant differences between sectors: while wages in banking and public administration exceeded EUR 1,200, those in manual trades or social care often remained below EUR 900. These discrepancies reflect economic stratification, as well as a divergence between vocational training offerings and the real preferences or expectations of younger generations.

Furthermore, the report emphasises the ongoing presence of regional and qualitative imbalances in training provision, as well as the limited adaptability of curricula to evolving workplace demands. Despite its undisputed importance for workforce formation, Germany's dual training system

development, demographic shifts, sectoral undervaluation and evolving aspirations among new labour market entrants are increasingly constraining its ability to deliver effective alignment between supply and demand.

To address the structural frictions hampering Germany's vocational training landscape, federal authorities have intensified their efforts in recent years to promote inclusive apprenticeship models, particularly targeting young migrants and refugees. According to the latest Annual Labour Market Report released by the Federal Employment Agency (2025e), approximately one in four applicants for vocational training positions in 2024 had a migration background, a proportion that has steadily increased over the past decade. Targeted support programmes, such as language training, preparatory bridging courses, and mentoring schemes, have facilitated access for non-German nationals, contributing to the stabilisation of training participation rates. While challenges persist, notably in matching migrant applicants with suitable enterprises, the expanding involvement of refugees and immigrants has helped to partially revitalise local labour markets, particularly in sectors facing demographic challenges, such as crafts and care (Table 5).

Table 5: Participation of refugees and immigrants in training and employment, 2020-2024

	Participation in vocational and qualification training programmes		Participation in employment	
	Refugees	**Immigrants**	**Refugees**	**Immigrants**
2020	24,000	220,000	335,000	3,860,000
2021	24,000	225,000	357,000	3,960,000
2022	23,000	230,000	382,000	4,060,000
2023	24,000	230,000	405,000	4,110,000
2024	27,000	232,000	428,000	4,170,000

Source: Author's synthesis based on annual labour market reports (2020–2024) published by the Federal Employment Agency/BA.

These persistent inconsistencies between qualification profiles, occupational structures, and regional labour demand underscore the need for a more flexible and forward-looking policy response. As Germany faces a narrowing demographic window and increasing structural rigidity, the adequacy of existing measures must be reassessed. The following section examines recent policy interventions, evaluating both their achievements and their limitations in addressing the evolving contours of labour market tightness.

5. Policy responses to labour market tightness and their systemic limits

Over the past decade, German policymakers have responded to labour market imbalances by implementing a complex mix of activation strategies, training incentives and support measures aimed at increasing workforce participation. These interventions have increasingly targeted structurally underrepresented groups, including older workers, women and, more recently, refugees and immigrants, while also seeking to enhance the adaptability of firms and training institutions. A series of tools has been deployed to strengthen vocational alignment and reduce recruitment bottlenecks, from the expansion of language and pre-apprenticeship programmes to the financial support for SMEs and the digitalisation of counselling services.

5.1. Measures to activate and upskill the workforce

In the face of mounting recruitment pressures and a shrinking domestic labour pool, German policymakers have broadened their focus to include activating untapped segments of the population and enhancing the qualifications of the existing workforce. These efforts have increasingly targeted groups that are structurally underrepresented, such as older workers, women returning to work, refugees and

immigrants (more recently), as well as young adults who are facing difficulties transitioning from school to work. Germany's implementation of the *Youth Guarantee*, for example, has offered tailored support in the form of counselling, training and employment services, paying special attention to those from disadvantaged backgrounds or remote areas(European Union, 2025). The active involvement of these underrepresented segments has become vital in addressing occupational shortages.

Central to these initiatives has been the expansion of language support, bridging courses, and vocational orientation schemes tailored for non-German nationals. Between 2020 and 2024, participation in qualification programmes among immigrants steadily increased, supported by mentoring initiatives and enhanced access to preparatory apprenticeships. At the same time, targeted subsidies for SMEs, the digitalisation of counselling services, and regional training alliances have sought to improve matching processes and reduce dropout rates (Federal Employment Agency/BA, 2024, 2025e).

Despite these measures, significant gaps remain in aligning training pathways with real labour market needs. Structural mismatches, sectoral undervaluation, and the limited responsiveness of vocational curricula continue to constrain the full impact of activation strategies. Nonetheless, the evolving policy mix reflects a growing recognition of the need to better integrate vulnerable groups and enhance the long-term adaptability of Germany's workforce.

5.2. Supporting reintegration through counselling and mutual commitments

In Germany, the Federal Employment Agency plays a central role in supporting the reintegration of jobseekers into the labour market, beyond its traditional role as administrator of unemployment benefits. Its core services include job placement, personalised counselling and developing individualised activation plans tailored to each applicant's profile (BA, 2024).

Every registered jobseeker undergoes an initial skills and barriers assessment, after which they conclude an Integration Agreement (*Eingliederungsvereinbarung, in German*) setting out reciprocal obligations. In return for financial support and advisory services, clients commit to actively searching for a job and participating in assigned activities. Counsellors monitor compliance and may impose sanctions depending on the type of benefit and the severity of non-compliance.

Although this logic of conditionality is intended to strengthen accountability and accelerate labour market reintegration, it has its limitations. Standardised agreements often leave limited room for adaptation to complex life realities, especially for vulnerable groups. As recent analyses have highlighted(Bossler & Popp, 2023a), an overly rigid approach may risk undermining motivation and trust. More flexible, tailored support strategies that respond to diverse personal circumstances are increasingly recognised as vital for sustaining engagement and long-term success.

Yet, beyond their procedural role, integration agreements remain controversial instruments. Although they are intended to embody the ''support and challenge'' principle enshrined in SGB II[17], studies have shown that they are often perceived as one-sided and overly formalistic. A series of analyses conducted by IAB (Bernhard & Senghaas, 2021)revealed that agreements tend to emphasise obligations and potential sanctions more than mutual support or flexible guidance. Furthermore, the complexity of these documents, coupled with asymmetrical power dynamics where subsistence security is at stake, can hinder the establishment of genuine joint goals. A significant proportion of jobseekers reported having limited opportunities for in-depth consultation or continuity with a dedicated counsellor, despite legal provisions for such personalised support. These findings suggest that, while integration agreements remain central to Germany's reintegration framework, their implementation in practice requires more empathy, clarity, and mutual accountability.

[17]SGB II refers to Social Code Book II (*Sozialgesetzbuch Zweites Buch*), which sets out the rules for providing basic income support to jobseekers in Germany. It establishes the legal framework for activation policies, integration agreements, counselling services and the conditions for receiving unemployment benefits.

5.3 Targeted qualification programmes for low-skilled and older workers

In response to long-standing skill gaps and accelerating structural change, Germany has developed targeted training schemes for low-skilled adults and older workers, who are often underrepresented in upskilling initiatives.

One of the most relevant instruments is WeGebAU[18] (*Further training for low-qualified and older employees within companies*), a programme designed to support continuing vocational training within companies, particularly in SMEs. It provides financial subsidies to cover training costs and lost wages during participation. The programme has been particularly effective for employees without formal qualifications and older workers whose skills no longer match market demands(CEDEFOP, 2020).

To complement this, the Initiative to Accompany Structural Transformation (*Initiative zur Flankierung des Strukturwandels* in German; IFlaS) was launched to address the regional impact of industrial transitions. It promotes longer retraining courses that lead to certified qualifications, with a focus on sectors that are most affected by technological change and climate policies. IFlaS works closely with local employers and chambers of commerce to ensure that qualification efforts directly respond to labour market needs(Cedefop&BIBB), 2023).

Both programmes emphasise certified vocational pathways to foster more stable reintegration outcomes. According to the sources cited above, participants in these schemes – especially those who were previously long-term unemployed or had fragmented employment histories – showed improved job prospects and increased participation in sectors facing acute labour shortages.

However, challenges remain in reaching the most disadvantaged groups, particularly those with limited digital or language skills. Furthermore, administrative complexity and low awareness among employers continue to hinder the realisation of the full potential of these tools. To scale their impact, especially in structurally weak regions, a more proactive outreach strategy and simpler funding procedures are needed.

5.4 Enhancing inclusion and addressing structural discrimination

In addition to traditional activation measures, German labour market policy has increasingly sought to foster social inclusion and address structural barriers affecting marginalised groups. A key part of this approach is the Social Labour Market (*Sozialer Arbeitsmarkt* in German, cf. Art. 16i SGB II), which provides long-term subsidised employment for people who have been unemployed for a long time and face significant barriers to finding a job(Institute for Employment Research/IAB, 2025d).

The programme targets individuals with multiple disadvantages, including health-related limitations, age-related challenges, and a lack of formal qualifications. Eligibility criteria are carefully defined to ensure that support reaches those furthest from the labour market. Participation is voluntary, and placements are designed to mirror regular employment relationships as closely as possible, offering stable contracts, defined working hours and a sense of purpose.

To maximise reintegration prospects, the model relies on personalised support, combining subsidised employment with medical, psychological, or socio-pedagogical counselling where necessary. This tailored approach helps build self-confidence and restore work capacity gradually. Studies have shown that commitment levels rise when placements reflect real work contexts and are accompanied by structured guidance.

Furthermore, policy efforts have begun to embrace an intersectional approach, recognising that people often experience multiple forms of exclusion based on factors such as gender, ethnicity, disability or age. Initiatives promoting diversity in recruitment, particularly in technical and male-dominated sectors, have expanded through targeted incentives, coaching and awareness campaigns.

[18]The acronymderives from the German title of the programme: *Weiterbildung Geringqualifizierter und Beschäftigter Älterer Arbeitnehmer in Unternehmen*).

Overall, the Social Labour Market represents a shift from passive support to empowered, socially embedded reactivation. However, its scalability is limited by funding constraints and the stigma surrounding subsidised work. For this model to meaningfully contribute to addressing labour market tightness, its value must be recognised as both a social instrument and a long-term economic investment in cohesion and human potential.

As the analysis has shown, recent efforts reflect an increasing awareness of deep-rooted structural challenges. However, the limited coherence, scope and impact of existing measures continue to hamper the development of a truly resilient German labour market, underscoring the need for a more integrated and forward-looking strategy.

6. Conclusion

As the analysis has shown, Germany's labour shortages are rooted in a long-term demographic transformation characterised by persistently low fertility rates and steadily increasing life expectancy. These shifts have accelerated population ageing, widened the generational imbalance and placed increasing pressure on the labour supply. Despite recent compensatory trends, such as net migration and isolated improvements in birth rates, these have not been sufficient to reverse the broader demographic trajectory.

At the same time, labour market tensions have deepened due to the structural mismatch between the rising number of job vacancies and the declining capacity of the labour market to absorb and match them, in both quantitative and qualitative terms. The persistent discrepancy between reported labour demand and jobseeker availability, coupled with ongoing recruitment challenges in critical sectors such as care, construction, logistics, and IT, indicates a systemic misalignment that cannot be resolved through cyclical recovery alone.

Sectoral analysis reveals that the shortages are widespread and unevenly distributed, with social and professional services absorbing most of the unfilled positions. Furthermore, vocational training is under strain as thousands of apprenticeships remain unfilled each year and there are persistent structural mismatches between training provision, wage incentives and the expectations of new labour market entrants.

Overall, the findings suggest that the labour market is tightening less due to a lack of people and more due to a disconnect between population dynamics, skill formation, and the evolving requirements of the economy. While these tensions have been developing for some time, they are now manifesting with increasing urgency, calling for more anticipatory, systemic and policy coherent responses.

While Germany has implemented a wide range of policy instruments to address labour market tightness, the effectiveness of these measures is limited by structural inertia and fragmented implementation. Despite notable efforts to expand vocational training, strengthen counselling and integration schemes, and promote inclusive employment through targeted programmes such as WeGebAU, IFlaS and the Social Labour Market, these initiatives often lack the necessary scale, coordination and adaptability to respond effectively to changing labour market dynamics.

The persistent mismatch between qualifications and real labour market needs, the bureaucratic rigidity of activation tools and the uneven accessibility for underrepresented groups highlight systemic barriers. Many interventions are reactive rather than forward-looking, narrowly focused rather than integrated, and insufficiently tailored to the complexity of long-term demographic and occupational shifts.

As such, while recent policy developments reflect an increasing awareness of the structural fragilities of the labour market, the current framework still lacks the strategic coherence and anticipatory depth required to ensure sustainable workforce resilience.

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